Highlights from Lepton Photon 2009

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http://lp09.desy.de/

Overview

- **XXIV International Symposium on Lepton Photon Interactions at High Energies, August 17-22, Hamburg**
- **Very nice and very well organized conference**
- **387 participants**
- **18 sessions with 54 plenary talks**
- **1 poster session, 74 posters**

Session Summary

- LHC
- QCD
- Electroweak and Top Physics
- Searches
- Flavor Physics
- Neutrino Physics
- Heavy Ion Collisions
- Future Projects
- Gravitation and Cosmology
- Dark Matter and Dark Energy
- Astroparticles

Agenda with links to slides and videos:
http://indico.desy.de/conferenceOtherViews.py?view=standard&confId=1761

In this RPM

- **LHC and collider physics**
  - Juerg Beringer
- **Astrophysics, cosmology, dark matter, gravitation**
  - William Carithers
- **Neutrinos and non-accelerator physics**
  - Cheng-Ju Lin

Apologies if your favorite talk or topic is not covered in our summary

LHC and Collider Physics

H. Burkhardt

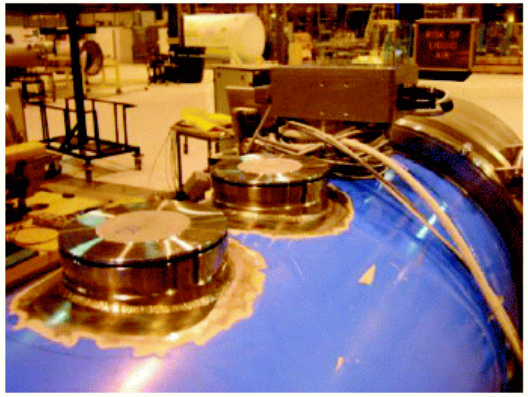
LHC Status – August 2009

damage repair

- **39 dipoles and 14 quadrupoles removed - and re-installed. Last magnet back in tunnel on 30/04/2009, electrical connections finished 2nd June**

avoid reoccurrence

- **Improved diagnostics, measurements of magnet interconnects - splice resistance**
- **> 50 % of machine (sectors, 1-2, 3-4, 5-6, 6-7, all standalone magnets) with fast pressure release valves**
- **Improved anchoring on vacuum barriers around the ring**
- **Enhanced Quench Protection System**
  - aperture symmetric quenches and joints in magnets
  - 2 × faster discharge



- **Remaining risks minimized by keeping maximum beam energy limited to 3.5 - 5 TeV for the first run**

Major amount of work - much of the hardware work is finished

Time also used to further improve crucial systems like BLM, complete collimator installation ..

Restart LHC with beam by mid-November 2009

H. Burkhardt

Strategy for the first LHC physics run

Main strategy in commissioning :
establish circulating beams and good lifetime at the injection energy. ✔ Sept. 2008

Chamonix 2/2009 baseline
1 month commissioning
10 month proton physics
1 month lead ions

August '09 : Detailed discussion of the knowledge from the 5 sectors measured at warm and the 3 sectors measured at 80 K
All put together and discussed in special LMC meeting on 5 Aug. 2009.
Decision by management - 6 Aug. 2009.

Go in three steps

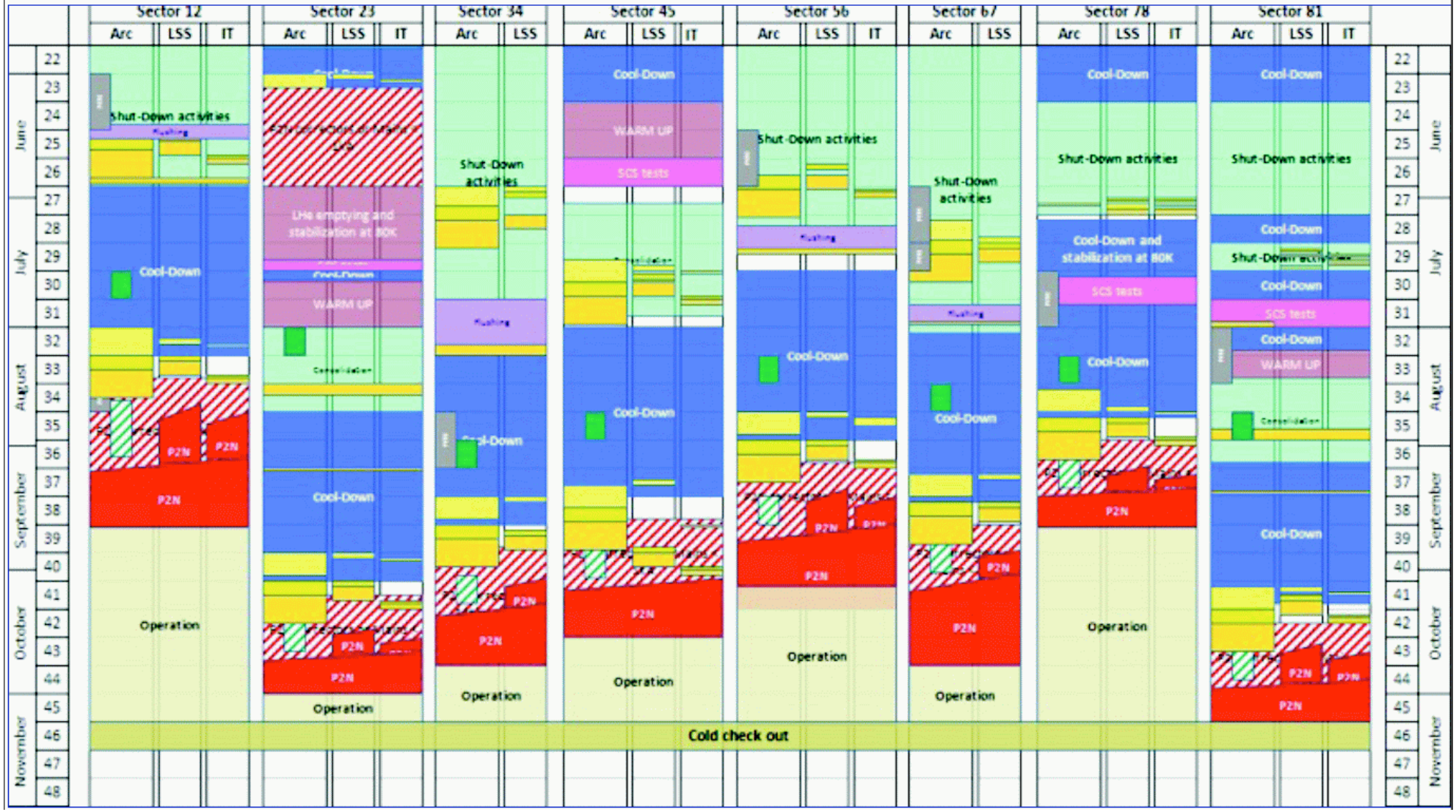
1. **collisions at injection energy 2 × 0.45 TeV = 0.9 TeV**
2. **physics run at 2 × 3.5 TeV = 7 TeV**
3. **physics run at increased energy, max. 2 × 5 TeV = 10 TeV**

Luminosity: Aiming at collecting ~200pb^{-1}

Towards the end of 2010 before the winter shutdown : 1st run with heavy ions, lead - lead.

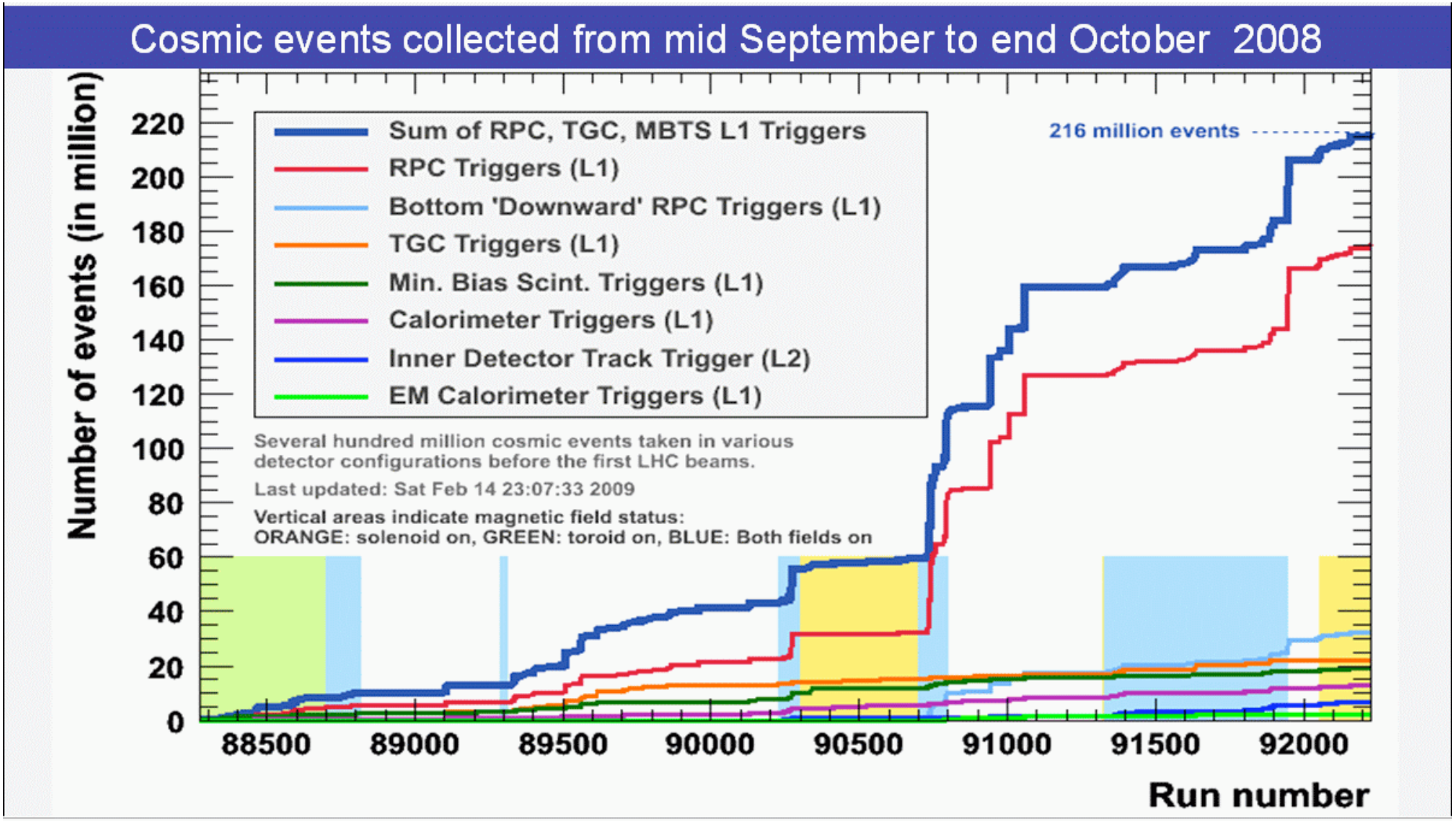
H. Burkhardt

Schedule July 22 (LMC23)



K. Jon-And

ATLAS: Cosmics Data Taking ...



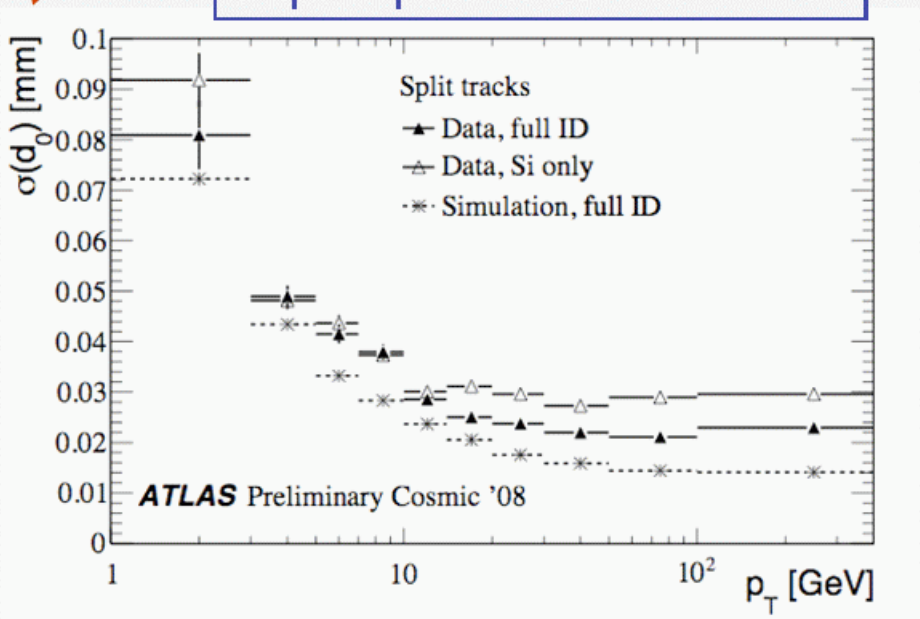
K. Jon-And

ATLAS: ... and Results

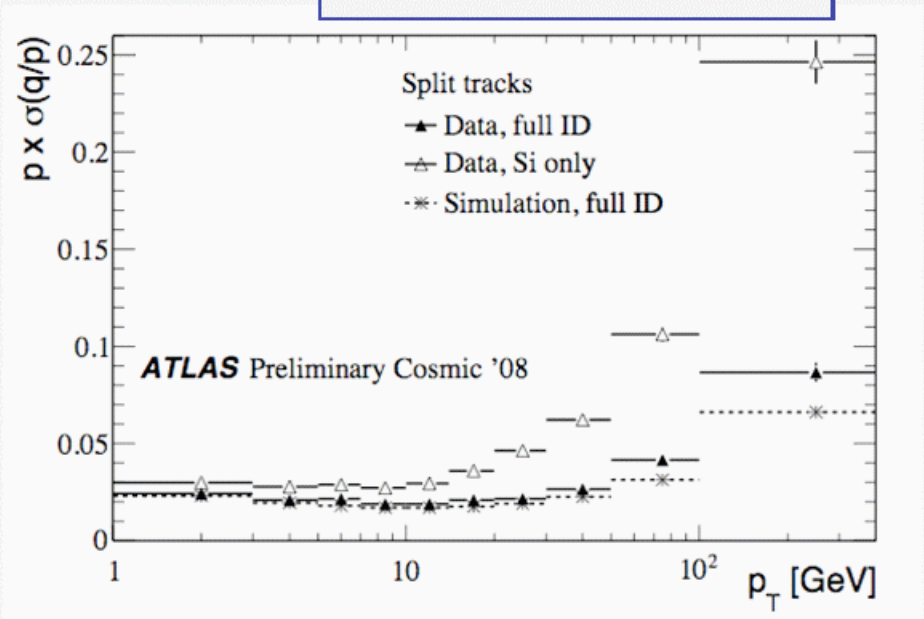
Cosmic tracks cross both the upper and lower hemisphere of the ID

Tracks are **split** in the center and refitted separately.
Direct measurement of the track parameter resolution possible!
Already close to ideal detector performance.

Impact parameter resolution



Momentum resolution



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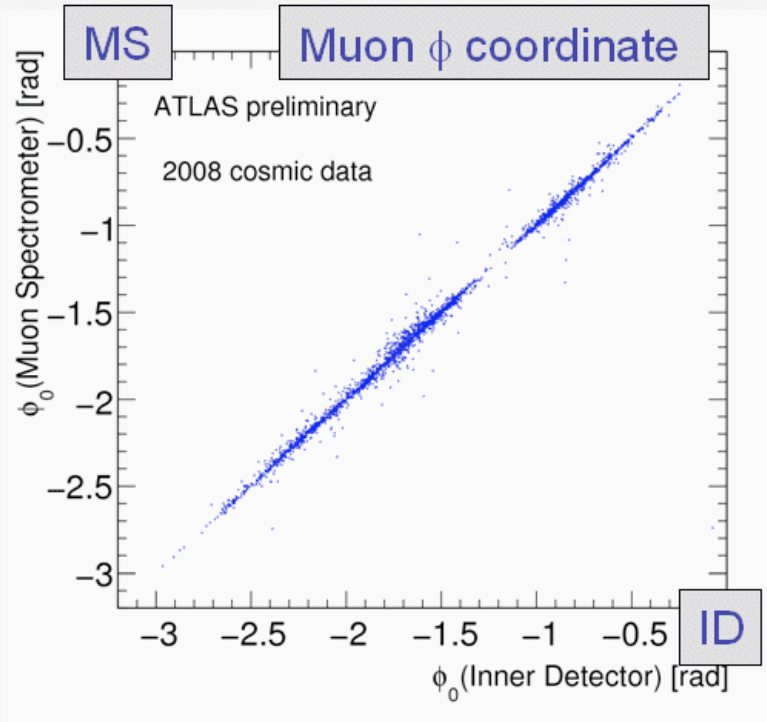
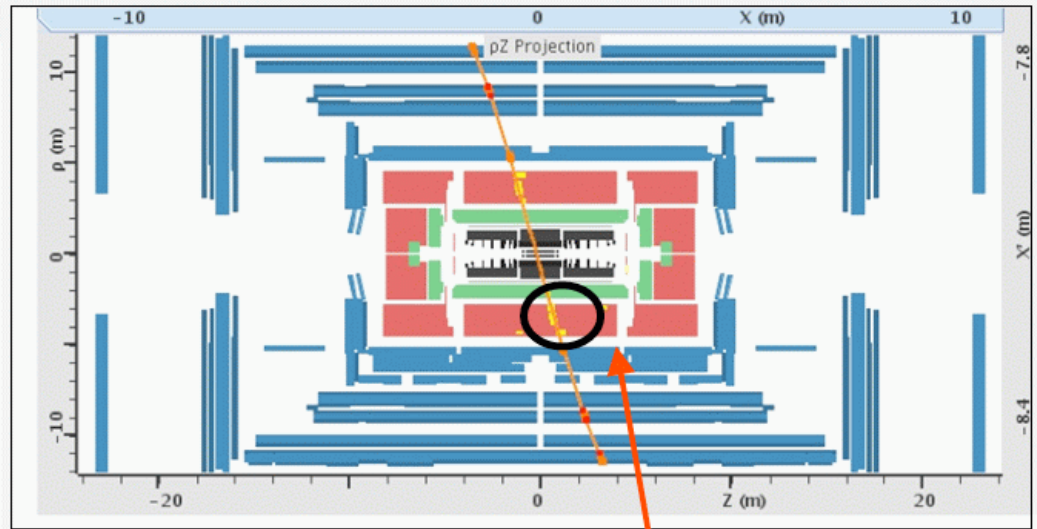
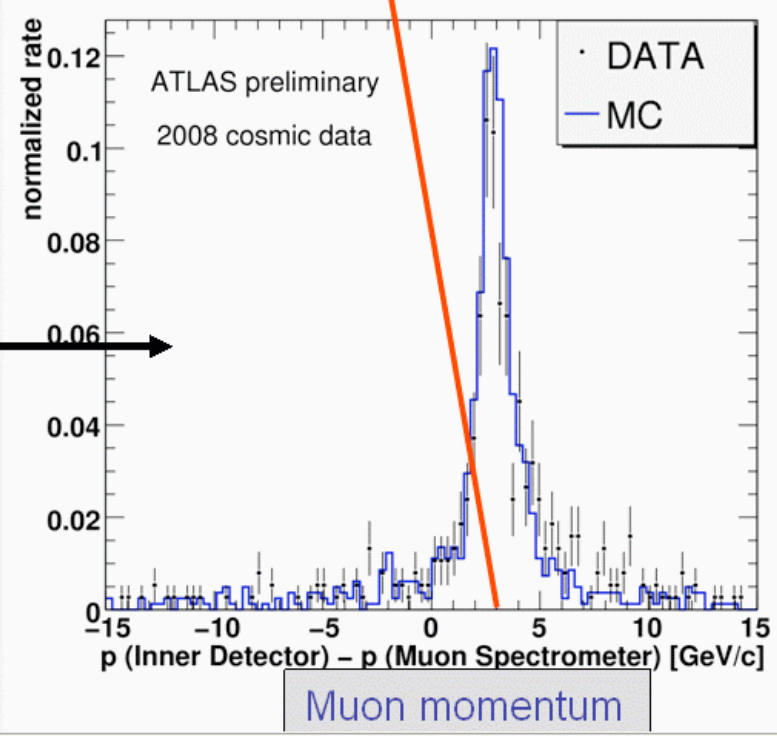
Correlation between the Inner Detector and Muon Spectrometer







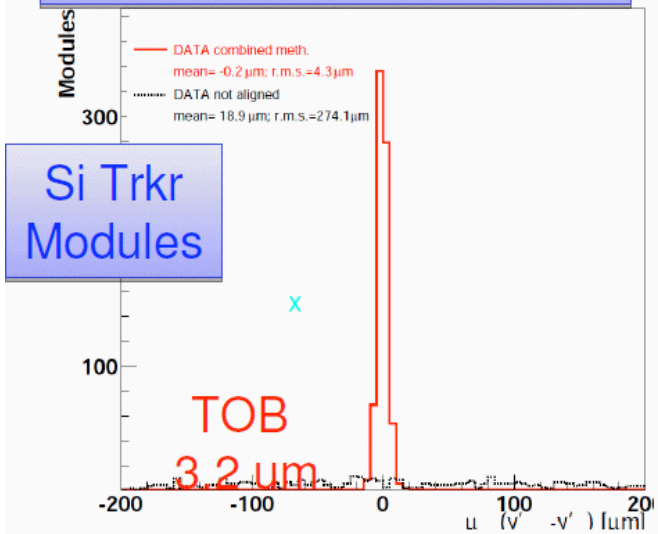
Difference between the muon momentum measured in the ID and in the MS for tracks in the bottom part of the detector (energy lost in the calorimeter: ~ 3 GeV as expected)

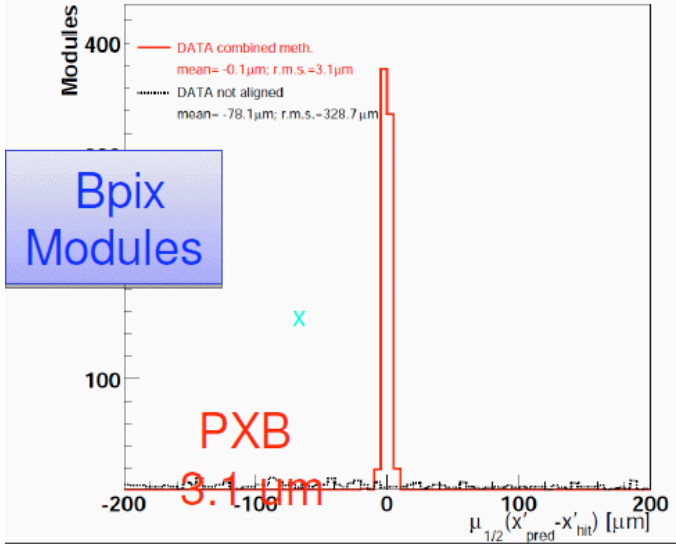
R. Cousins

CMS: Results from Cosmics

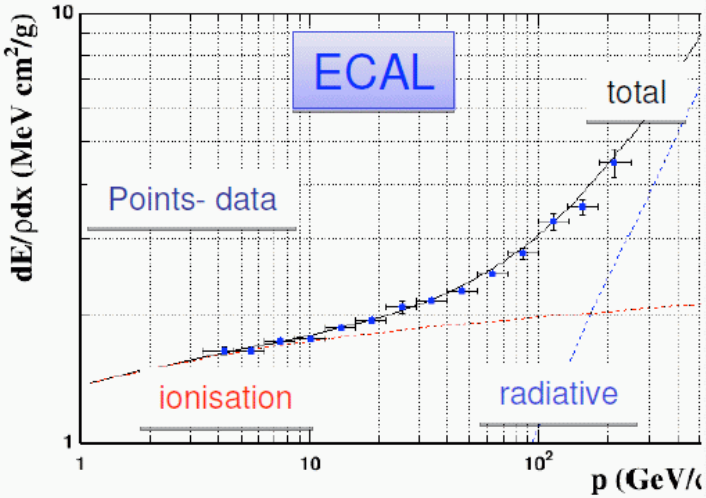
Alignment in Inner Tracker (Poster by J. Hauk)

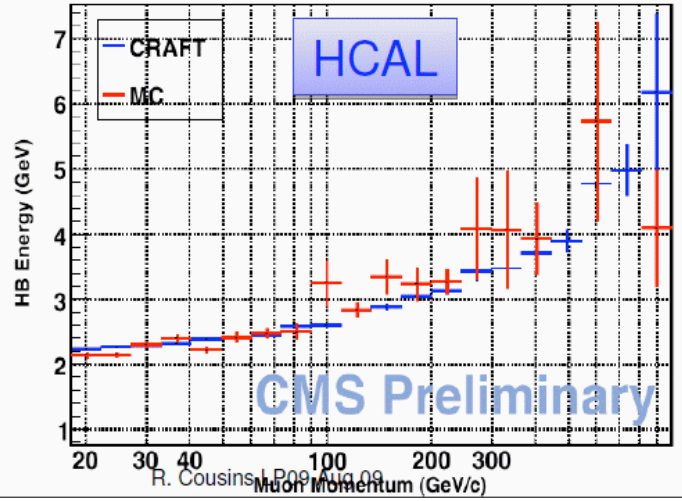
Distn of Mean Residuals



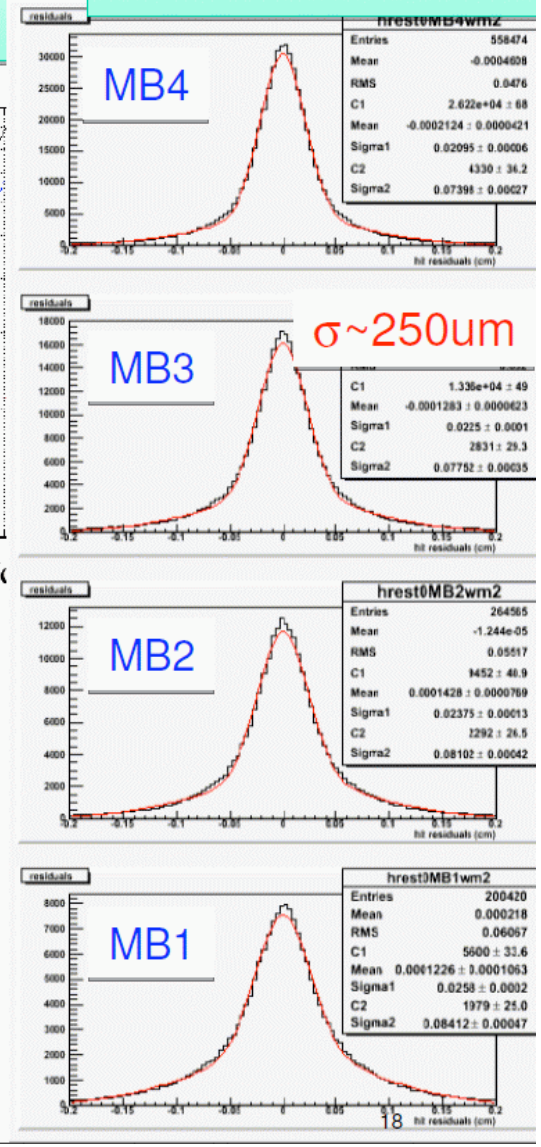


Energy deposited by muons



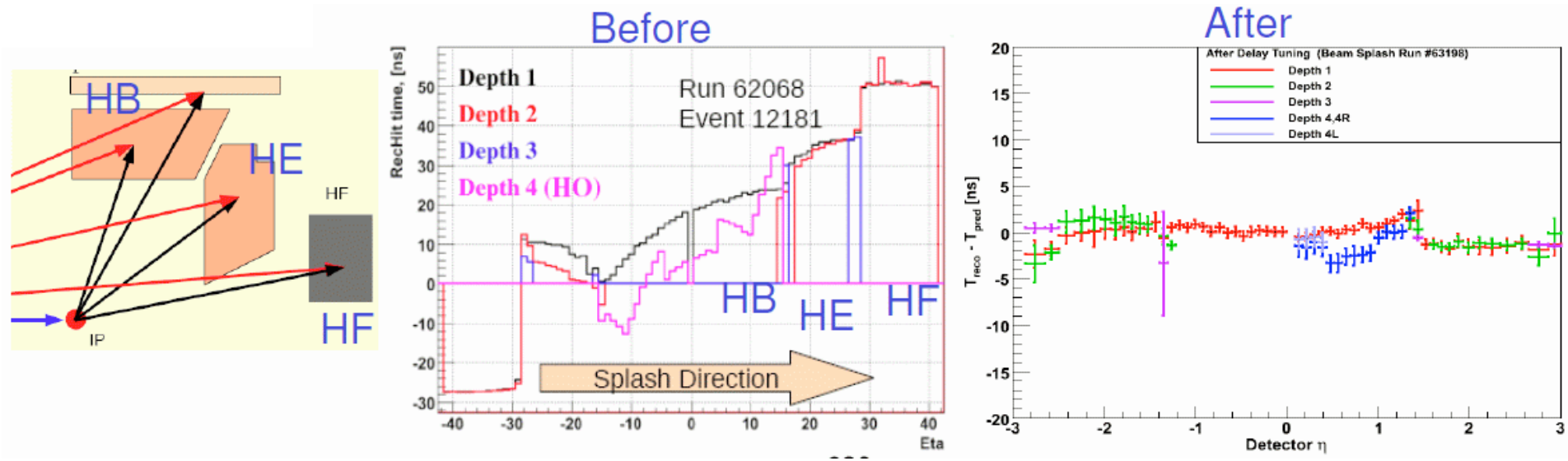


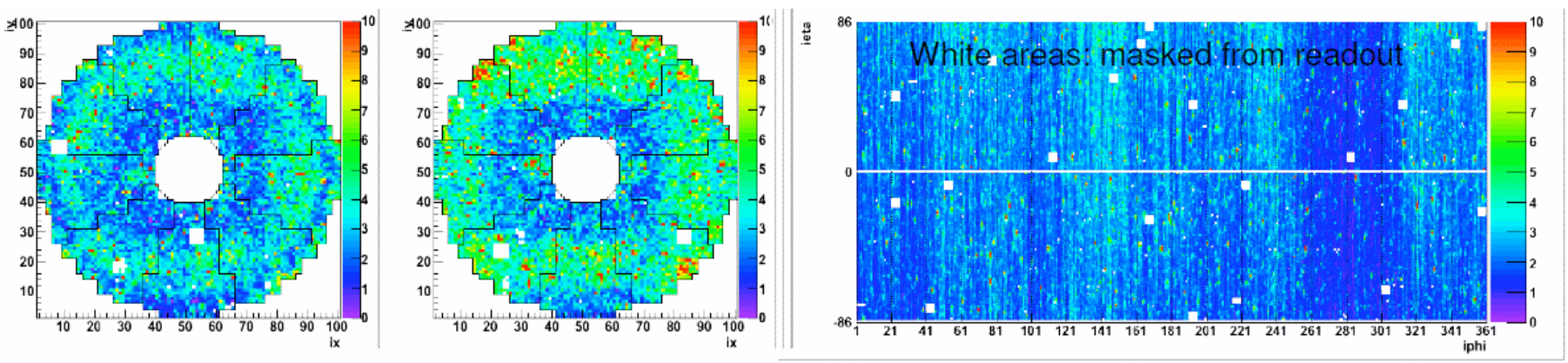
Muon Chambers Point Resolution



R. Cousins

CMS: Timing & Energy Deposit from Splash Evts





ECAL Endcaps (lhs), Barrel (rhs)

> 99% of ECAL channels alive, ~200 TeV energy deposited in EB+EE

Inter-crystals timing established (< 1ns), inter-crystal calibration EB (1.5-2.5% - test beam + cosmics), EE (~7% from splash events)

K. Jon-And

ATLAS (and CMS): Expected Data Samples

Expected data samples (examples) with 100 pb^{-1}

Note: expect up to 200 pb^{-1} after first physics run at high energy

Channels (examples)	Expected no of events in ATLAS after cuts $\sqrt{s}$ = 10 TeV, 100 pb^{-1}
$J/\psi \to \mu\mu$	$\sim 10^6$
$\Upsilon \to \mu\mu$	$\sim 5\ 10^4$
$W \to \mu\nu$	$\sim 3\ 10^5$
$Z \to \mu\mu$	$\sim 3\ 10^4$
$tt \to W\,b\,W\,b \to \mu\nu + X$	~ 800
QCD jets $p_T > 1$ TeV	~ 500
$\tilde{g}, \tilde{q}$ m ~ 1 TeV	~ 5

Goals in 2010:

1) Commission and calibrate the detector in situ using well-known physics samples
   e.g. - $Z \to ee, \mu\mu$ tracker, ECAL, Muon chamber calibration and alignment, etc.
   - $tt \to bl\nu\ bjj$ jet scale from $W \to jj$, b-tag performance, etc.

2) "Rediscover" and measure Standard Model at $\sqrt{s}$ ~ 10 TeV: W, Z, tt, QCD jets ...
   (also because omnipresent backgrounds to New Physics)

3) Early discoveries ? Potentially accessible: Z', SUSY, ... surprises ?

few pb^{-1}
↓
50 pb^{-1}
↓
100 pb^{-1}
↓

A. Golutvin

LHCb: Physics Prospects for 2010

❑ *Analysis commissioning in hadronic modes*

Channel	Yield / 10 pb^{-1}
$B^0 \to K\pi$	340
$B \to D(K\pi)X$	31k
$B^+ \to D(K\pi)\pi^+$	1900
$B^+ \to D(K\pi)K^+$	160
$B_s \to D_s\pi^+$	320

Detailed studies of $D \to hh$ (rehearsal for $B \to hh$)
- *Separate $K\pi$, KK, $\pi\pi$ and DCS $K\pi$*
- *Vertex and mass resolutions*
- *Lifetimes*

Accumulate samples of $B \to D(K\pi)\pi$ ("ADS" control mode)
- *Study background environment*
- *Look for any evidence of B^+ / B^- asymmetries*

❑ *Charm physics: 20 pb^{-1} and upward*

(Exciting possibilities even with low luminosity)

An example: flavour tagged $D^0 \to KK$ events for measuring y_{CP}

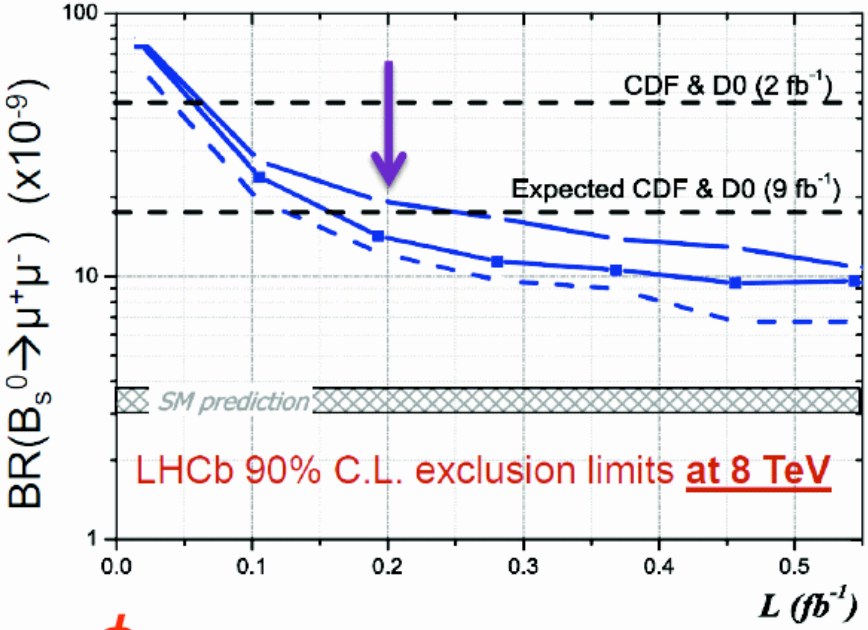
$$y = \tau(D^0 \to K\pi) / \tau(D^0 \to KK) - 1$$

and corresponding CP asymmetry

LHCb can collect ~ 10^5 flavour tagged KK events with 20 pb^{-1} (same statistics as BELLE with 540 fb^{-1}). Similar data sets for many related channels: $D^0 \to \pi\pi$, $KK\pi\pi$, $K_S\pi\pi$, K_SKK, $D^+ \to KK\pi$ …

Prospects for most competitive measurements in 2010

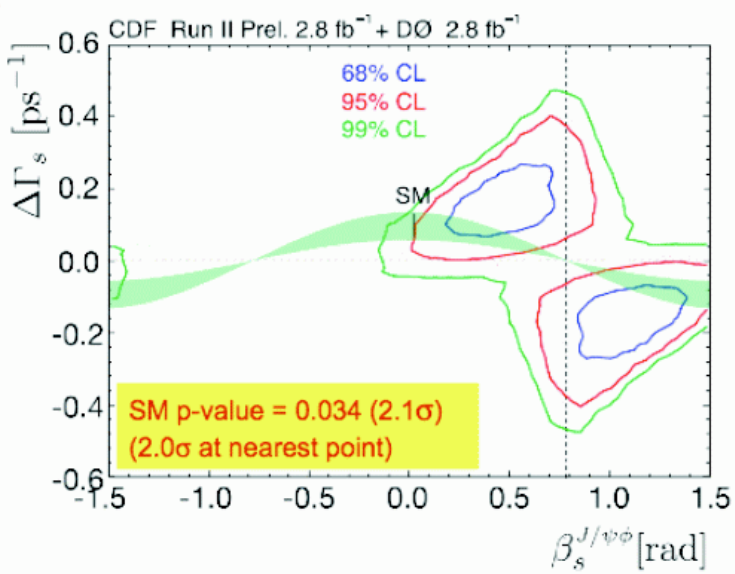
$B_s \rightarrow \mu\mu$

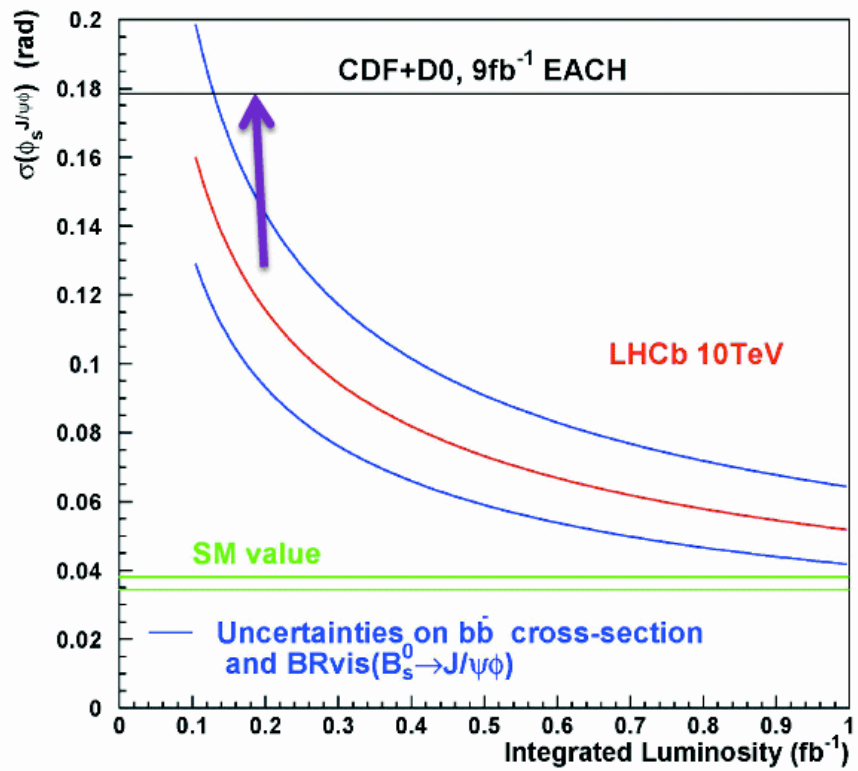


With data sample of ~200 pb^{-1} LHCb should be able to improve Tevatron sensitivity for $B_s \rightarrow \mu\mu$ and ϕ_s

(present 'central' value from Tevatron would be confirmed at 5σ level)

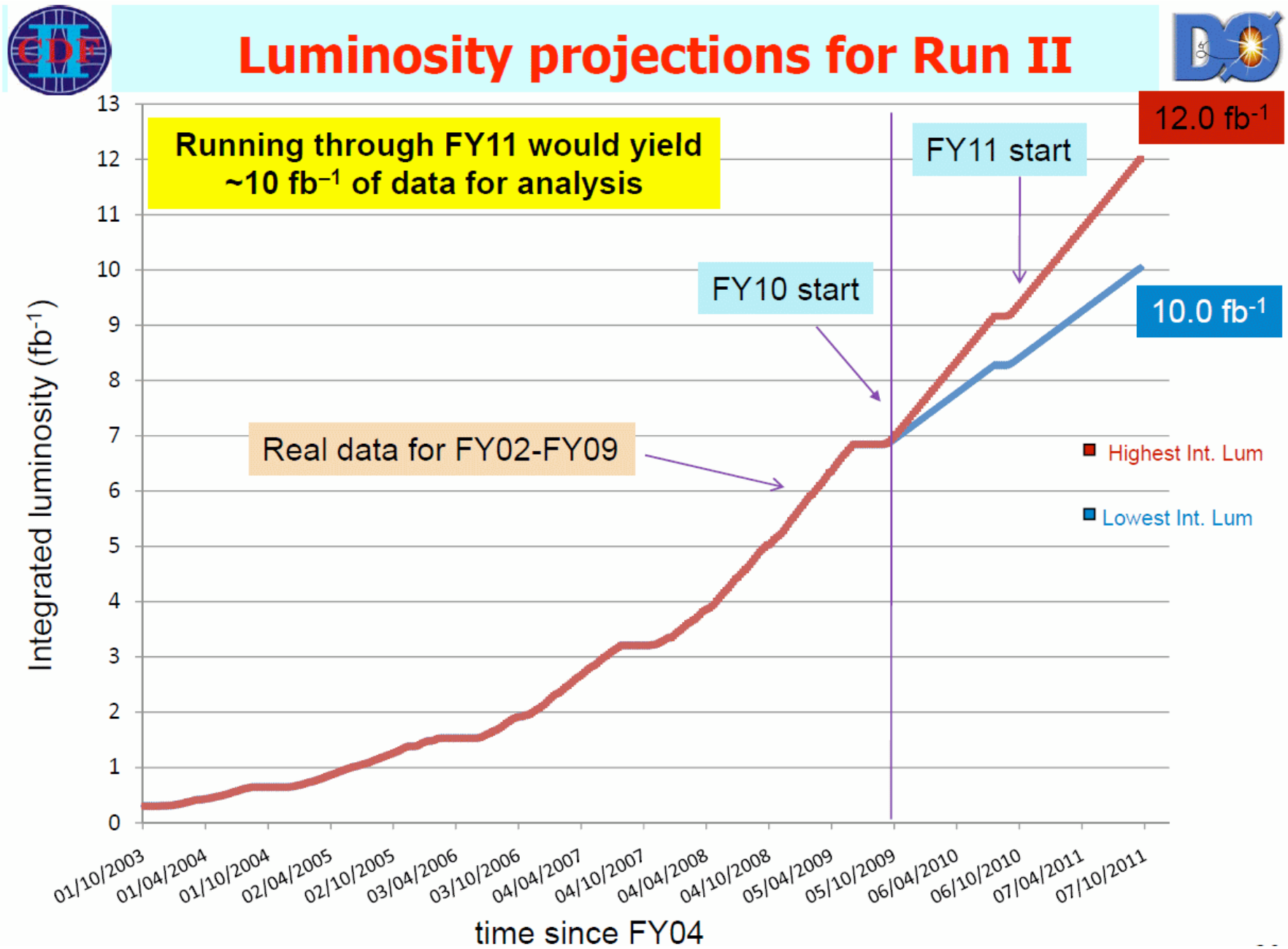
ϕ_s





G. Bernardi

Tevatron: CDF and D0



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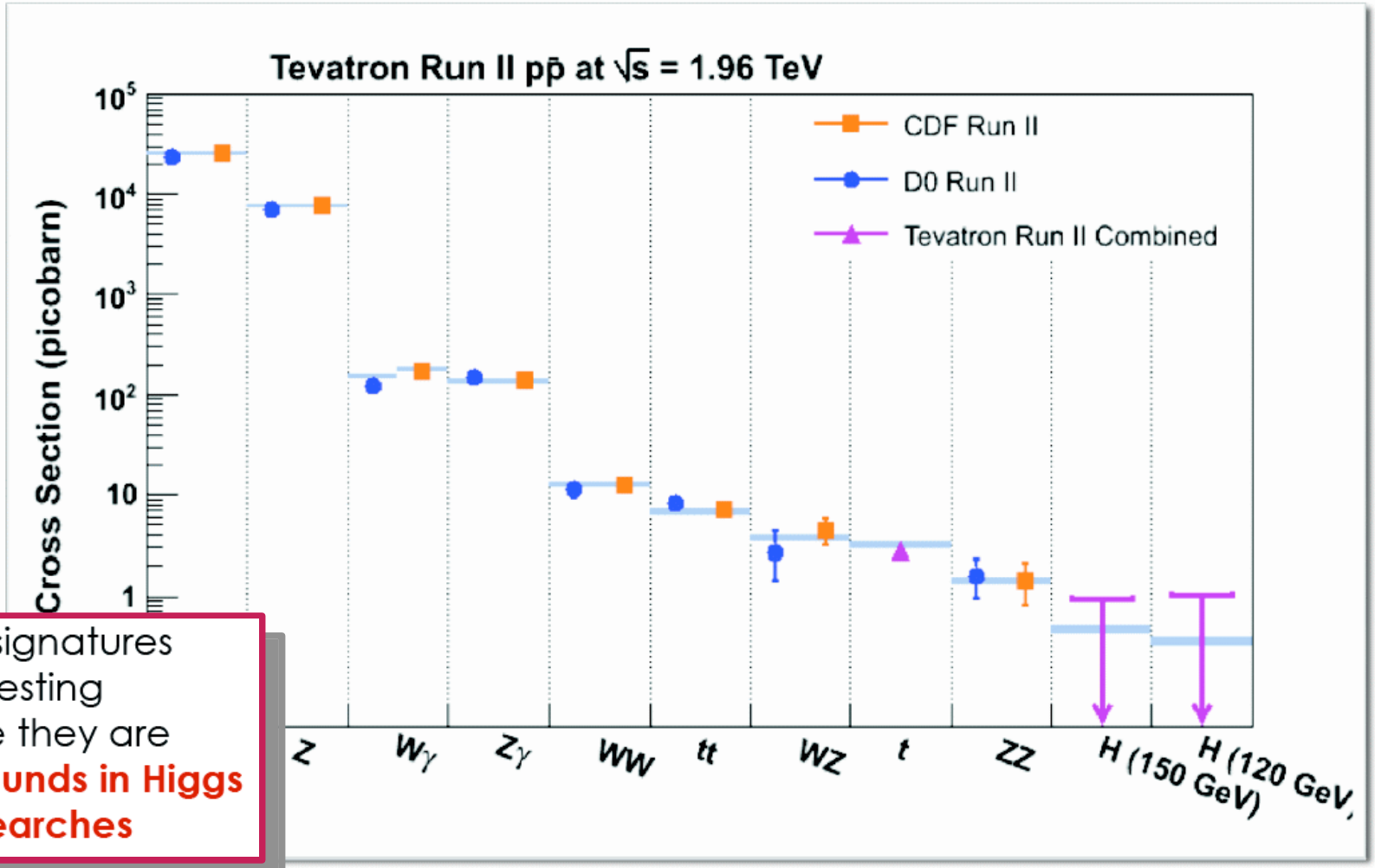
Electroweak and Top Samples

- Span over a wide range of cross sections



- Difficult signatures are interesting because they are **backgrounds in Higgs boson searches**

New this year: more data + the difficult channels, large backgrounds, no easy kinematic handles $Z\gamma \rightarrow \nu\nu\gamma$ $WW \rightarrow l\nu jj$ $WZ \rightarrow l\nu jj$ $ZZ \rightarrow \nu\nu jj$ Single top $\rightarrow l\nu jj$

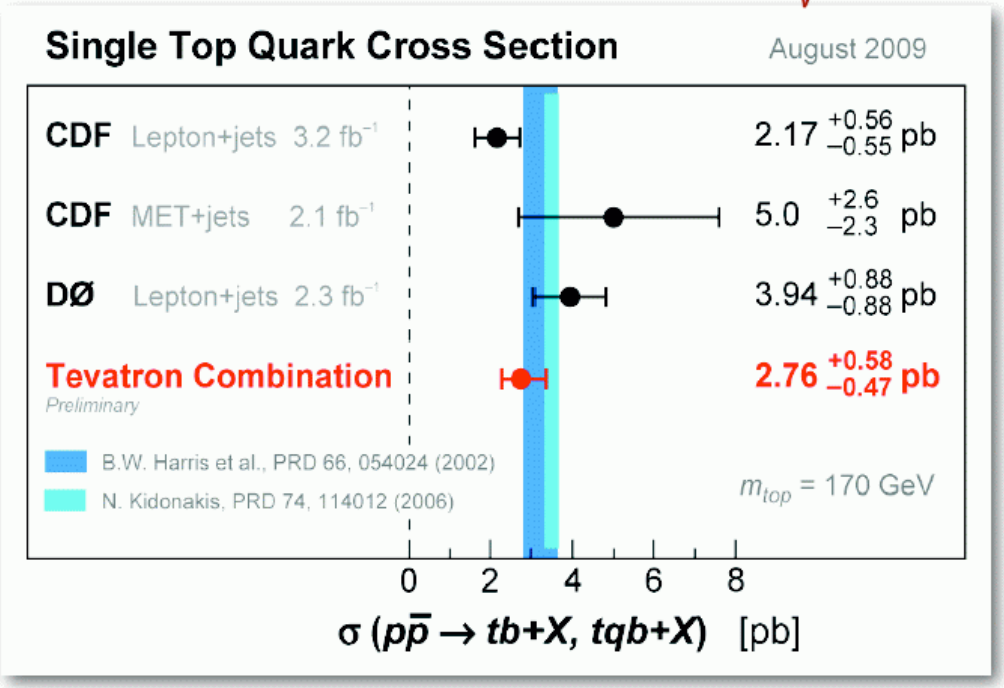
Single Top Quark: Tevatron Combination

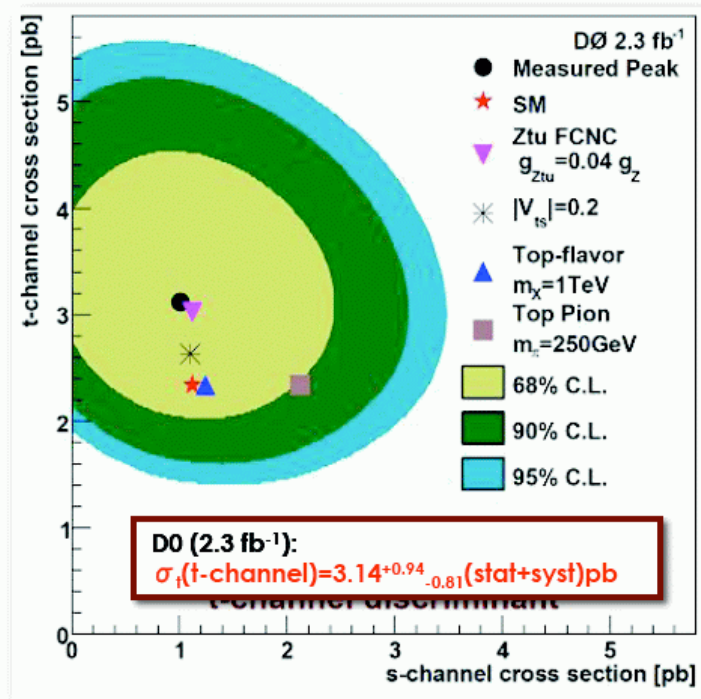
- In March 2009 the Tevatron experiments reported observation of with about **5 σ** significance (to be published in PRL this week)
- CDF and D0 combined their results using a Bayesian approach:

Tevatron (3.2 fb^{-1}):
$\sigma_t = 2.76^{+0.58}_{-0.47}$ (stat+syst) pb

LP09

Tevatron (3.2 fb^{-1}), PRD66 054024, 2002:
$|V_{tb}| = 0.91 \pm 0.08$ (stat+syst)





13% improvement

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Top Quark Properties Summary

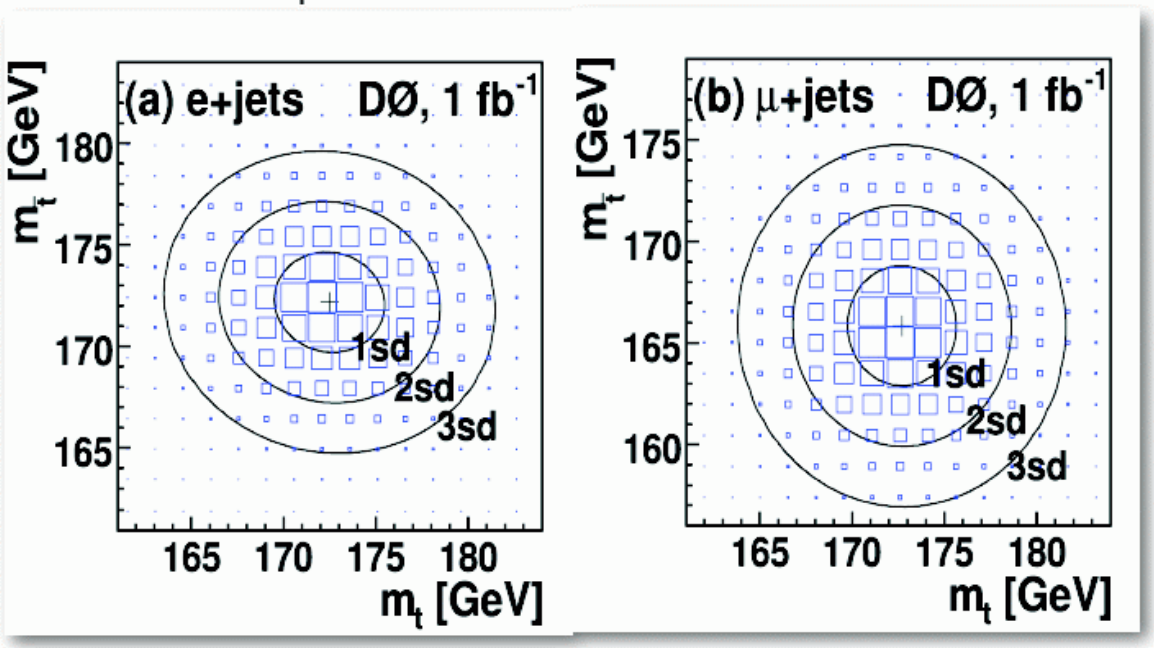
Property	Run II Measurement	SM prediction	Luminosity (fb^{-1})
m_t	CDF: 172.6 ± 0.9(stat) ± 1.2(syst) GeV D0: 174.2 ± 0.9(stat) ± 1.5(syst) GeV		4.3 3.6
σ_{ttbar} (@m_t=172.5 GeV) σ_{ttbar} (@m_t=170 GeV)	CDF: 7.50 ± 0.31 (stat) ± 0.34 (syst) ± 0.15 (lumi) pb D0: $7.84^{+0.46}_{-0.45}$ (stat)$^{+0.66}_{-0.54}$ (syst) $^{+0.54}_{-0.46}$ (lumi) pb	7.4 ± 0.6 pb 8.06 +0.6 pb	4.5 1
$\sigma_{singletop}$ (@m_t=170 GeV)	Tevatron: $2.76^{+0.58}_{-0.47}$ (stat+syst)	2.86±0.8 pb	3.2-2.3
$\|V_{tb}\|$	Tevatron: 0.91 ± 0.08 (stat+syst)	1	3.2-2.3
σ(gg->ttbar)/σ(qq->ttbar)	D0: 0.07+0.15-0.07(stat+sys)	0.18	1
m_t - m_{tbar}	D0: 3.8 ± 3.7 GeV	0	[illegible]
σ(tt→ll)/σ(tt→l+jets)	D0: $0.86^{+0.19}_{-0.17}$ (stat+syst)	1	
σ(tt→ τ l)/σ(tt→ll + l+jets)	D0: $0.97^{+0.32}_{-0.29}$ (stat+syst)		
$\sigma_{ttbar+jets}$ (@m_t=172.5 GeV)	CDF: 1.6 ± 0.2 (stat) ± 0.5 (syst)		[illegible]
CTtop	CDF: 52.5 μm @ 95%C.L.		0.3
T top	CDF: <13.1 GeV @ [illegible]	[illegible].5 GeV	1
BR(t->Wb)/BR(t->Wq)	CDF: [illegible]	1	0.2 0.9
F_0	[illegible] ±0.085 (syst)	0.7	2 2.7
F[illegible]	[illegible] ± 0.05 [illegible] 0.110 ±0.059 (stat) ±0.052 (syst)	0.0	2 2.7
Cl[illegible]	CDF: - 4/3 excluded with 87% C.L. D0: 4e/3 excluded at 92% C.L.	2/3	1.5 0.37
Spin correlations	CDF: κ = 0.32 + 0.55 - 0.78, -0.46 < K < 0.87 @ 68%C.L. D0: κ = $-0.17^{+0.65}_{-0.53}$ (stat + syst)	$0.78^{+0.027}_{-0.022}$	2.8 4.2
Charge asymmetry	CDF: 0.19 ± 0.07(stat) ± 0.02(syst) % D0: 12 ± 8 (stat) ± 1 (syst) %	0.05 +- 0.015	3.2 0.9

The best evidence so far it is the SM top quark comes from the agreement of σ_{tt} with theoretical expectations but a priori there is no guarantee that this is the SM top

F. Canelli

Search for CPT Violation

- Measure mass difference between t and tbar
- No violations ever observed, but this is the first CPT measurement in the quark sector
- Releasing constraint on $m_t = m_{tbar}$, measured in lepton + jets events using matrix element technique



D0 (1 fb^{-1}):
Δm_t=3.8 ± 3.7 GeV

Summer 09

- Consistent with SM expectations

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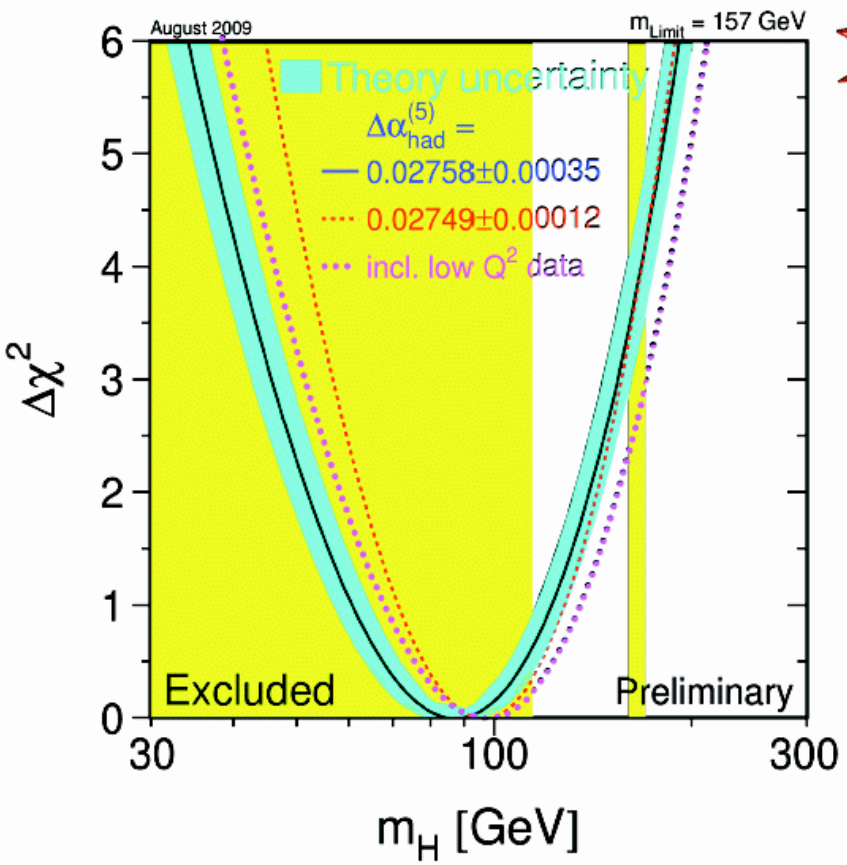
(In)direct Constraints on Higgs Mass

- World top quark mass and W boson mass included, from LEP/TEVEWK working group:
  - m_H = 87+35-26 GeV
  - m_H < 157 GeV (95% CL)
  - m_H < 186 GeV (when LEP limit included)



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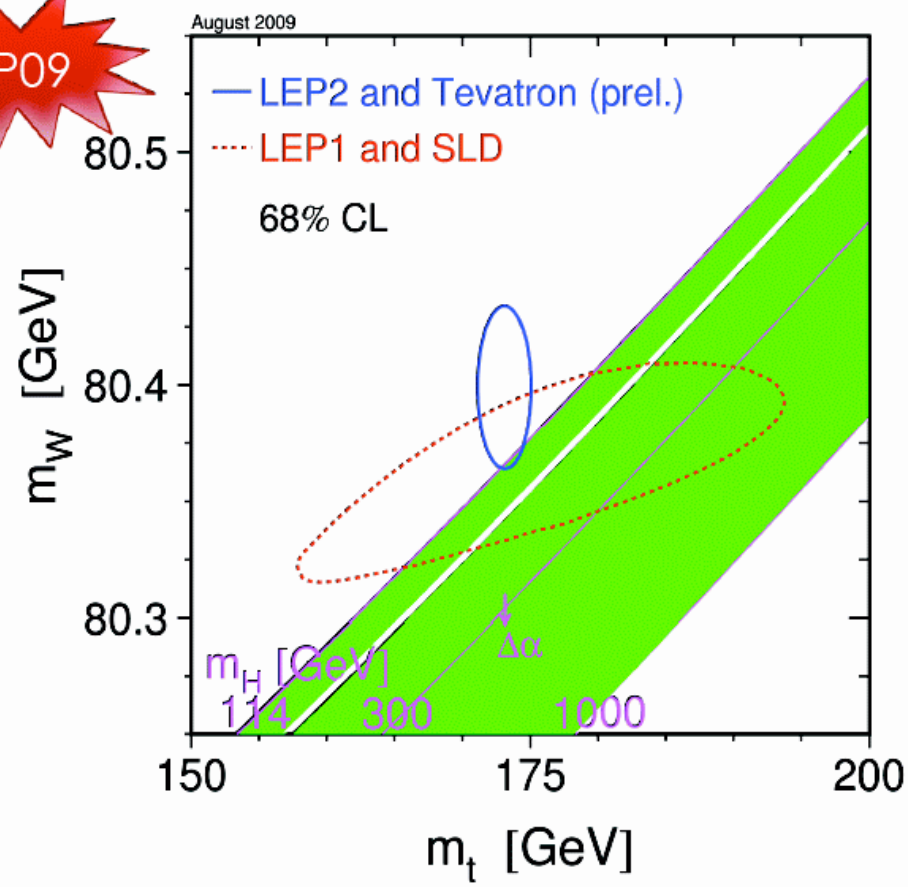
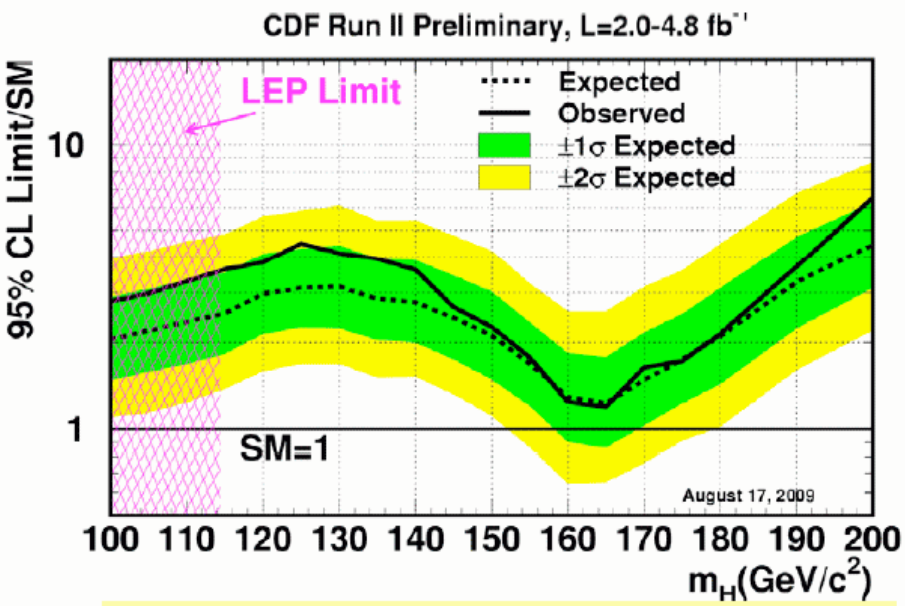
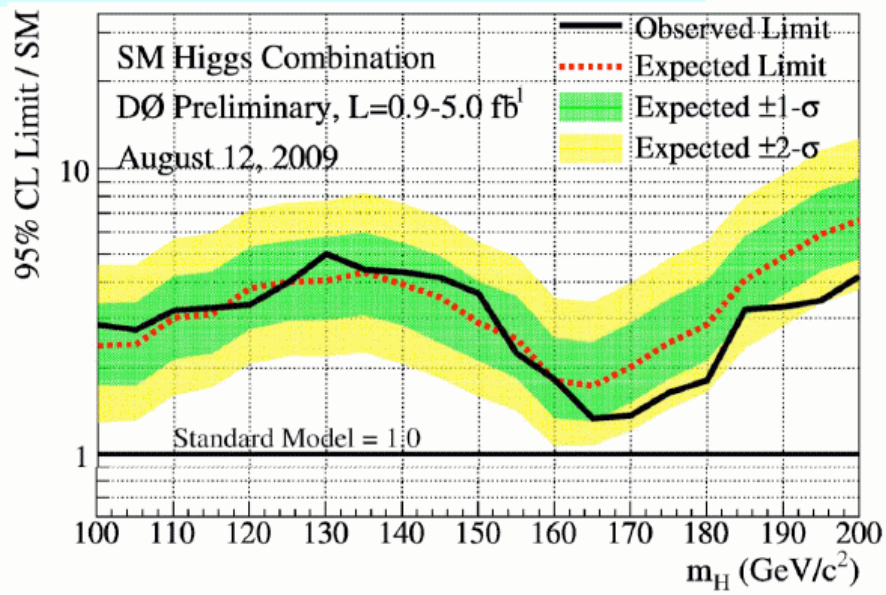


Higgs Searches

G. Bernardi

Lepton-Photon Combinations from CDF and DØ





CDF combination from Winter 2009 →Summer 2009

M_H=115 GeV

Expected limit 3.2 σ_{SM} → 2.5σ_{SM}

Observed limit 3.8 σ_{SM} → 3.6 σ_{SM}

M_H=165 GeV

Expected limit 1.7 σ_{SM} →1.2 σ_{SM}

Observed limit 1.6 σ_{SM} →1.2 σ_{SM}

DØ combination from Winter 2009 →Summer 2009

M_H=115 GeV

Expected limit 3.6 σ_{SM} → 3.1 σ_{SM}

Observed limit 3.7 σ_{SM} → 3.2 σ_{SM}

M_H=165 GeV

Expected limit 1.7 σ_{SM}

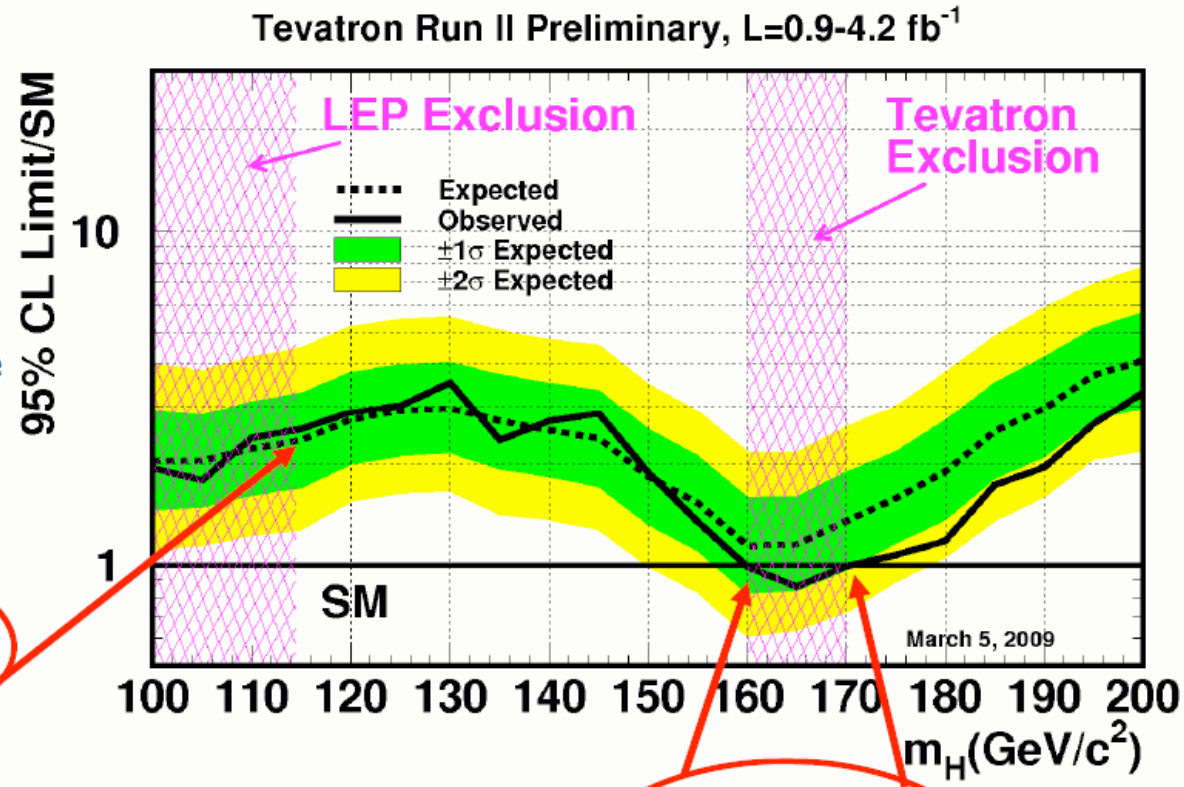
Observed limit 1.3 σ_{SM}

most CDF/DØ low mass updates finalized only last week, DØ still analyzing extended dataset at high mass (5.4 fb^{-1}) → all finalized analyses are included in the combinations above but NO update of Tevatron combination

Moriond '09 Tevatron Combination

Low Mass analyses:
L = 0.9 – 2.7fb^{-1}

(results with more luminosity as presented before are NOT yet included in this combination)



@ M_H=115
Observed →2.5xσ_{SM}
Expected →2.4xσ_{SM}

High Mass analyses:
Higgs cross sections use most recent theoretical inputs including MSTW 2008 NNLO PDF set

Bayesian	150	155	160	165	170	175	180	185
Expected	1.8	1.5	1.1	1.1	1.4	1.6	1.9	2.2
Observed	1.9	1.4	0.99	0.86	0.99	1.1	1.2	1.7

We exclude the SM Higgs from 160 to 170 GeV at 95% C.L.

These Moriond '09 CDF-DØ combined limits are obtained with an "effective" luminosity of 2.5/4.0 fb^{-1} at low/high mass

G. Bernardi

Conclusions

SM Higgs is excluded by Tevatron direct searches in the mass range

from 160 to 170 GeV @ 95% CL

More likely to be below 160 GeV (indirect constraints)

Tevatron progressing both in high and low mass Higgs searches

- **The machine continues to work very well with an expected delivered luminosity of 12 fb^{-1} with the 2011 run**
- **Sensitivity continues to improve faster than luminosity scaling**
- **Rapid incorporation of new data and analysis improvements**

> 40% probability to have a 3 sigma evidence for m_H =115 GeV Higgs with L=10 fb^{-1}

➔ Lookin ... ggs...

or directly exclude @ 95%CL the SM Higgs between 115 and 185 GeV

Good sensitivity also to MSSM Higgs and more exotics Higgs.
For MSSM, we will probe tanβ below 30

O. Gonzalez

Searches

- Searches for physics beyond the SM in colliders form a very active field covering a long list of topics.
- Here just a general summary...

Check the web pages of the experiments for the latest news!

- No success yet (but a lot of progress and limits significantly improved):

  ⇒ Direct searches are testing very hard the SM to the last corner and exploring regions far from those tested before.

  ⇒ Inclusive analysis are probing that our knowledge of the Collider Physics is very good and able to globally explain the data samples.

  ⇒ In both approaches discrepancies found, but nothing conclusive.

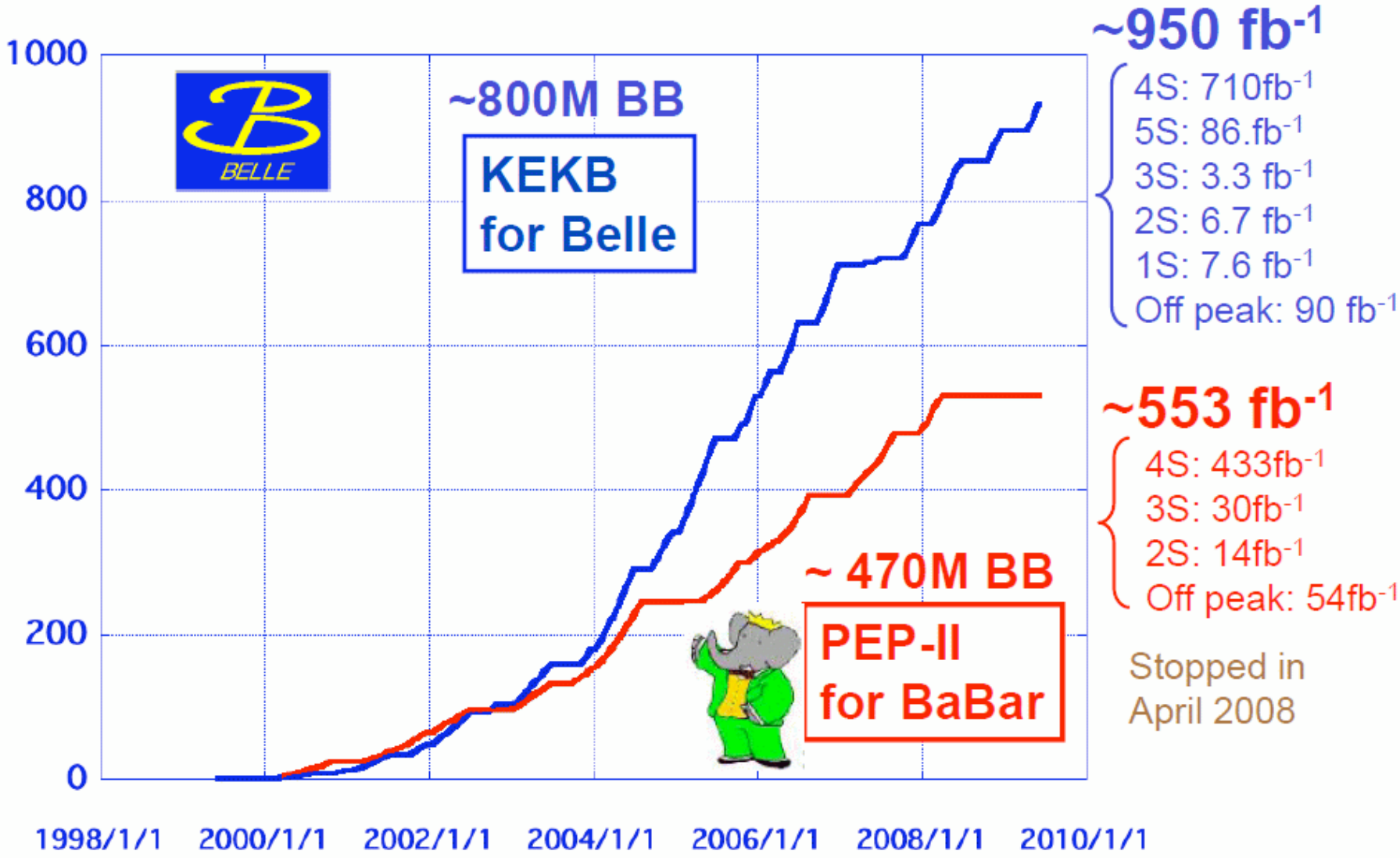
- Analyses of the full HERA dataset and the Tevatron data still to be analyzed (and collected) would provide more stringent tests of the SM, perhaps revealing hints of New Physics somewhere.

For now...the main conclusion is:

The Standard Model is still in good shape (even if we do not like that) **and getting stronger as we approach the LHC era!!!**

(but we won't give it a moment of peace)

Luminosity at the B-factories



J. Brodzicka

$c\bar{c}$-like states

neutral X and Y

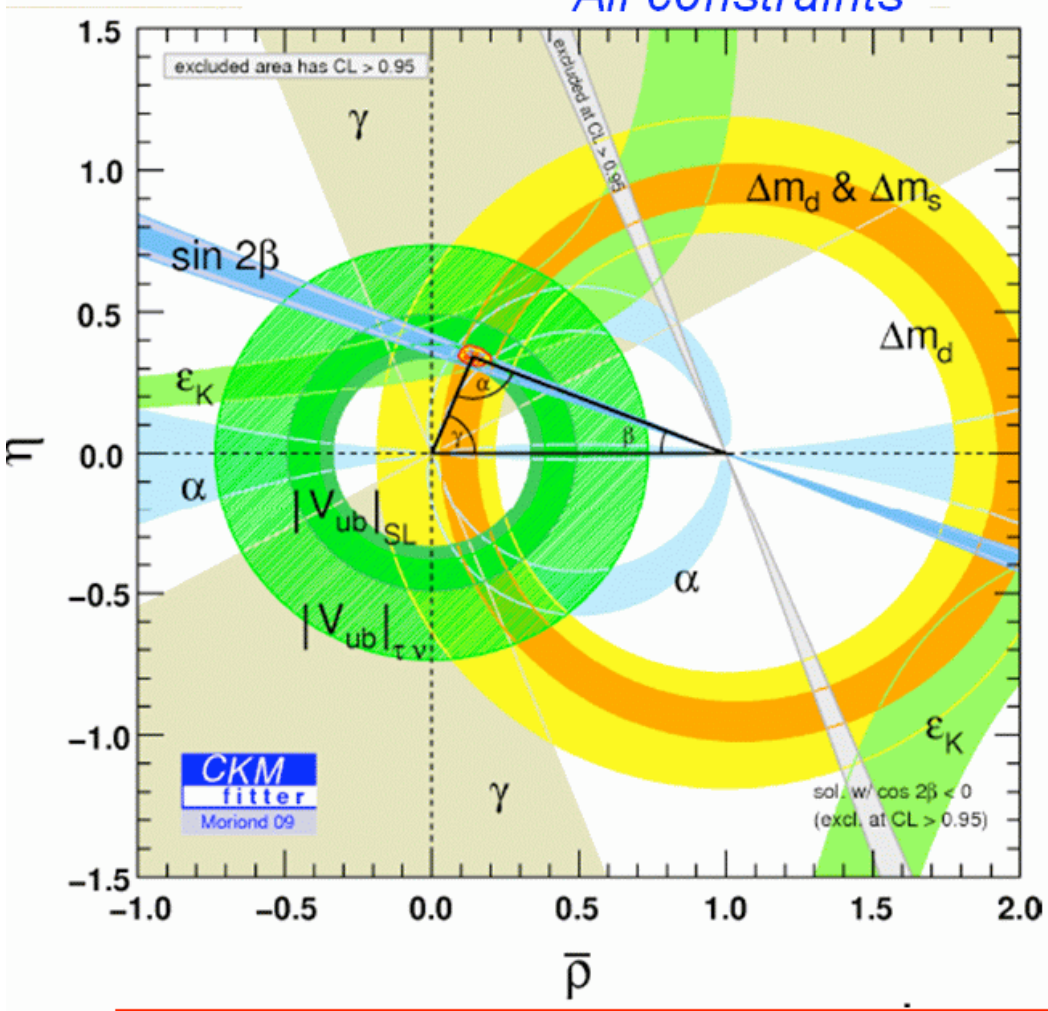
Name	J^{PC}	Γ (MeV)	Decay modes	Experiments	interpretation
X(3872)	1^{++}	<2.3	$\pi\pi J/\psi$; $\gamma J/\psi$; DD^*	Belle/CDF/D0/BaBar	DD^* molecule?
X(3940)	$0^{?+}$	~37	DD^* (not DD, $\omega J/\psi$)	Belle	$\eta_c''(?)$
Y(3940)	$?^{?+}$	~30	$\omega J/\psi$ (not DD^*)	Belle/BaBar	
X(4160)	$0^{?+}$	~140	D^*D^* (not DD, DD^*)	Belle	$\eta_c''(?)$
Y(4008)	1^-	~220	$\pi\pi J/\psi$	Belle (not Babar)	
Y(4260)	1^-	~80	$\pi\pi J/\psi$ (not $\pi\pi\psi'$)	BaBar/CLEO/Belle	$c\bar{c}g$ hybrid?
Y(4360)	1^-	~75	$\pi\pi\psi'$ (not $\pi\pi J/\psi$)	BaBar/Belle	
Y(4660)	1^-	~50	$\pi\pi\psi'$;$\Lambda_c\Lambda_c$ (?)	Belle	

charged Z

$Z^\pm(4430)$	$?^{??}$	~100	$\psi(2S)\pi^\pm$	Belle (not Babar)	4quark?
$Z^\pm(4050)$	$?^{??}$	~80	$\chi_{c1}\pi^\pm$	Belle	4quark?
$Z^\pm(4250)$	$?^{??}$	~180	$\chi_{c1}\pi^\pm$	Belle	4quark?

S. Prell

Global CKM Fit



- *Consistency of angles*

$$\alpha = \left(89.0^{+4.4}_{-4.2}\right)^{o}$$

$$\beta = \left(21.1 \pm 0.9\right)^{o}$$

$$\gamma = \left(75 \pm 12\right)^{o}$$

$$\boxed{\alpha + \beta + \gamma = \left(185 \pm 13\right)^{o}}$$

- *Consistency of angles and sides from global fit*
  - *Overall good fit (CKMFitter: global p-value 45%)*
  - *~2σ tension between sin2β and ε_K / V_{ub}*
    - *correction to ε_K will make it worse (Buras, Guadagnoli, PRD78, 033005 (2008))*

UTFit:	$\bar{\rho} = 0.154 \pm 0.022$	CKMFitter:	$\bar{\rho} = 0.139^{+0.025}_{-0.027}$
	$\bar{\eta} = 0.342 \pm 0.014$		$\bar{\eta} = 0.341^{+0.016}_{-0.015}$

$B \to \tau\nu$

Naïve world average

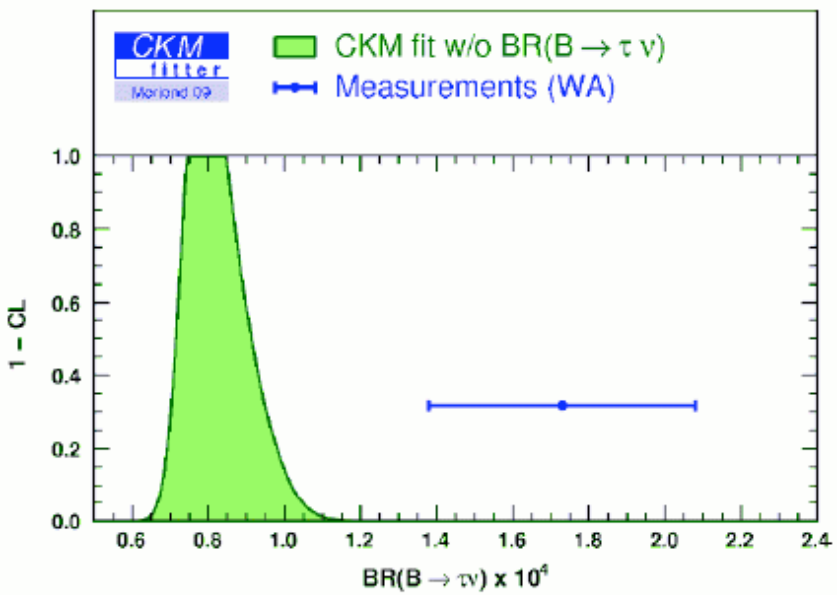
$$Br(\tau\nu) = [1.73 \pm 0.35] \times 10^{-4}$$

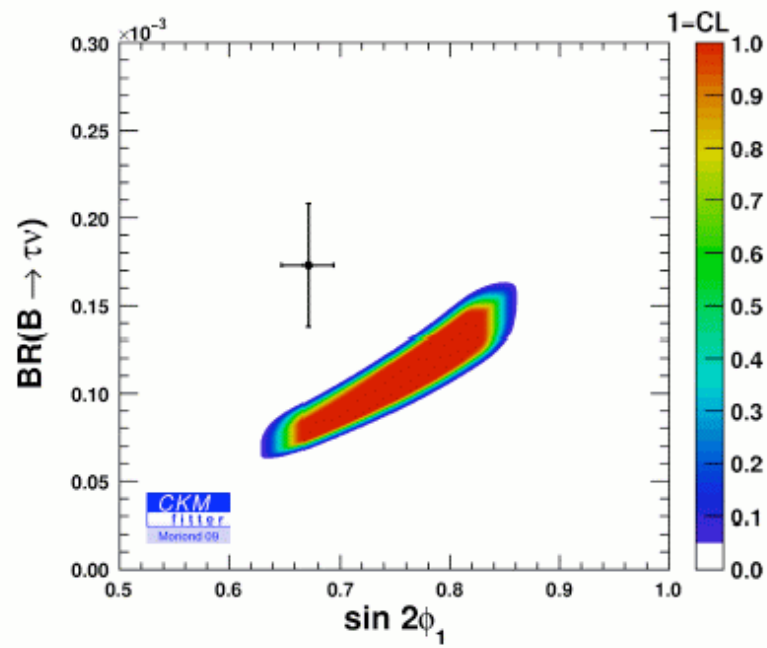
$$Br_{SM}(\tau\nu) = [1.20 \pm 0.25] \times 10^{-4}$$

Based on fB from HPQCD and $|V_{ub}|$ from HFAG (BLNP, ICHEP08)

$$Br(\tau\nu)_{CKM\ fit} = \left[0.786\ ^{+0.179}_{-0.083}\right] \times 10^{-4}$$

Output of a CKM fit without including $B \to \tau\nu$ in the fit (CKM fitter, ICHEP08)





The measured Br is 2.4 σ higher than the value predicted by the CKM fit.

CKM and Rare B Decays - Conclusions

S. Prell
T. Iijima

- *CKM mechanism proven to be dominant mechanism for quark mixing*
  - *describes all current experimental results in quark mixing and CP violation*
- *Some intrinsic discrepancies need to be resolved*
  - *V_{ud} (neutron lifetime), V_{us} (incl. vs. excl. strange τ decays), V_{cb} and V_{ub} (incl. vs excl. decays)*
- *A few interesting "tensions" at the 2-3 σ level should be monitored closely in the future*
  - *β ($J/\psi\ K^0$) vs ε_K and V_{ub}*
  - *β_s*
  - *$B \rightarrow \tau\nu$ (see Toru Iijima's talk)*
- *Expect significant impact from upcoming experiments (LHCb, Super B factories) and improved theory/lattice calculations mostly on improving γ, β_s, V_{ub}, V_{td}/V_{ts}*

ries has made it
h enough precision to
begin to probe NP ($B\rightarrow\tau\nu$, $D\tau\nu$, Kll distributions etc.) .

- There are some hints and puzzles.

Large $Br(B\rightarrow\tau\nu)$?	↔	tension between $\lvert V_{ub}\rvert$ - $\sin 2\phi_1$?
Large $A_{FB}(K^*ll)$?		Deviation of $A_l(K^*ll)$ in low q^2 ?
A_{CP} ($K\pi$) puzzle ?		Polarization puzzle in $B\rightarrow VV$?

- $B_s/B_d\rightarrow\mu\mu$ at Tevatron will be at critical corner in coming years.
- We need much more luminosity to clearly see the effects of new physics; O(0.1) correction to SM.

Summary (LHC and Collider Physics)

- **LHC experiments are ready and eagerly awaiting collisions**
  - Expect ~200pb^{-1} at up to 10 TeV next year; plus lead-ion run
- **Tevatron data taking and analysis en route to up to 12 fb^{-1}**
  - Chance of seeing 3σ peak or 2σ exclusion of SM Higgs
- **Standard Model continues to be broadly confirmed**
  - But no sign of the Higgs (yet)
  - CKM mechanism proven to be dominant mechanism for quark mixing
  - Some "interesting tensions" in results from B factories remain
  - Interpretation of a number of new charmonium-like states unclear
- **Future collider experiments**
  - sLHC, SuperB factories, ILC, CLIC, ...
  - "Any new large-scale project of HEP will have to await the successful start-up of LHC and the first physics harvest"

In conclusion

Is it possible that the LHC does not find the Higgs particle?

Yes, it is possible, but then must find something else

Is it possible that the LHC finds the Higgs particle but no other new physics (pure and simple SM)?

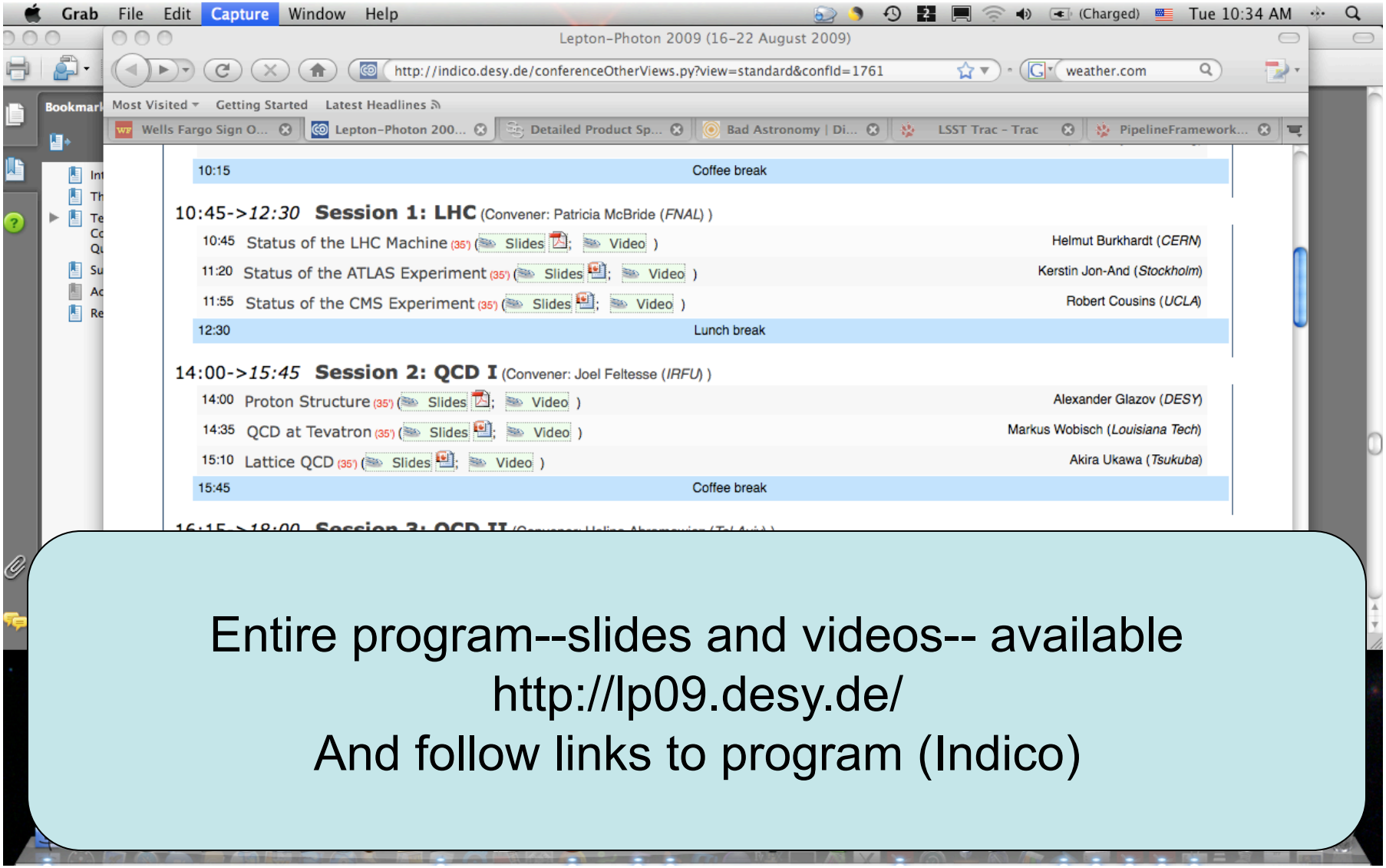
Yes, it is technically possible but it is not natural

Is it possible that the LHC finds neither the Higgs nor new physics?

⊕ No, it is "approximately impossible"

Astro-particle results from LP09

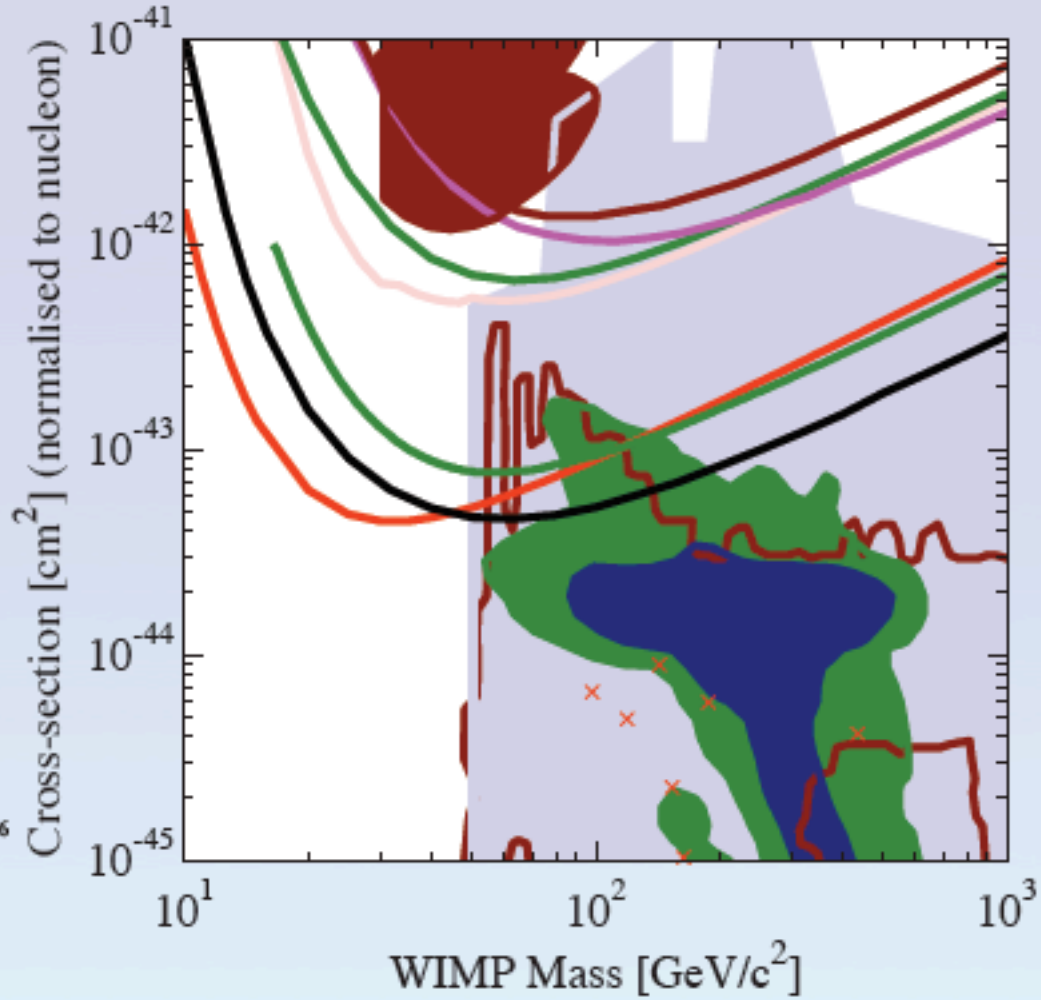
Bill Carithers



Entire program--slides and videos-- available
http://lp09.desy.de/
And follow links to program (Indico)

Where are we now?

- 'Canonical' halo model
  - Spin independent interaction
  - normalised to nucleon
- Different statistical methods adopted dependent on technique
- Work continues on
  - low energy calibration
  - control of backgrounds

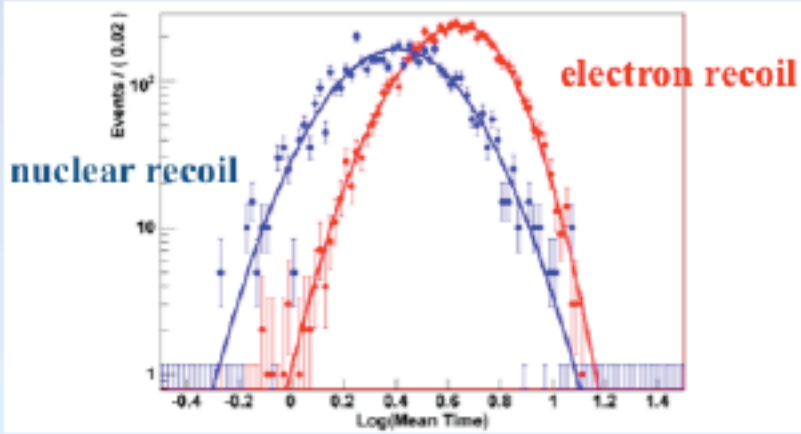


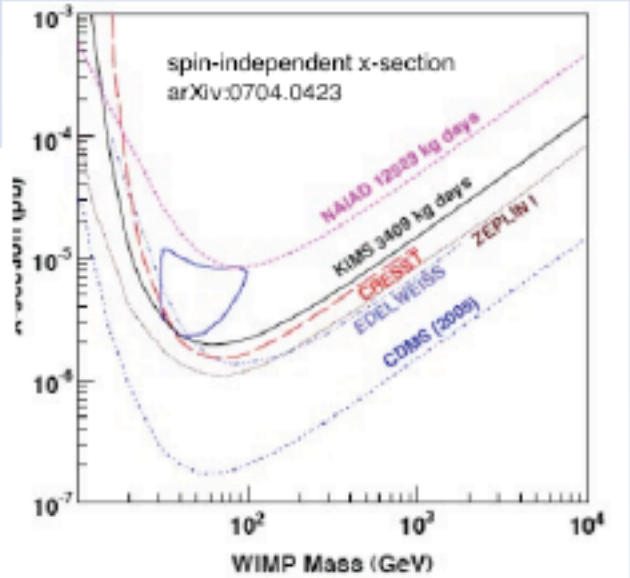
DATA listed top to bottom on plot
DAMA/LIBRA 2008 3sigma, no ion channeling
Edelweiss I final limit, 62 kg-days Ge 2000+2002+2003 limit
DAMA 2000 58k kg-days NaI Ann. Mod. 3sigma w/DAMA 1996
WARP 2.3L, 96.5 kg-days 55 keV threshold
ZEPLIN II (Jan 2007) result
CRESST 2007 60 kg-day CaWO4
ZEPLIN III (Dec 2008) result
CDMS: 2004+2005 (reanalysis) +2008 Ge
XENON10 2007 (Net 136 kg-d)
Trotta et al 2008, CMSSM Bayesian: 68% contour
Trotta et al 2008, CMSSM Bayesian: 95% contour
Ellis et. al Theory region post-LEP benchmark points
Baltz and Gondolo 2003
Baltz and Gondolo, 2004, Markov Chain Monte Carlos

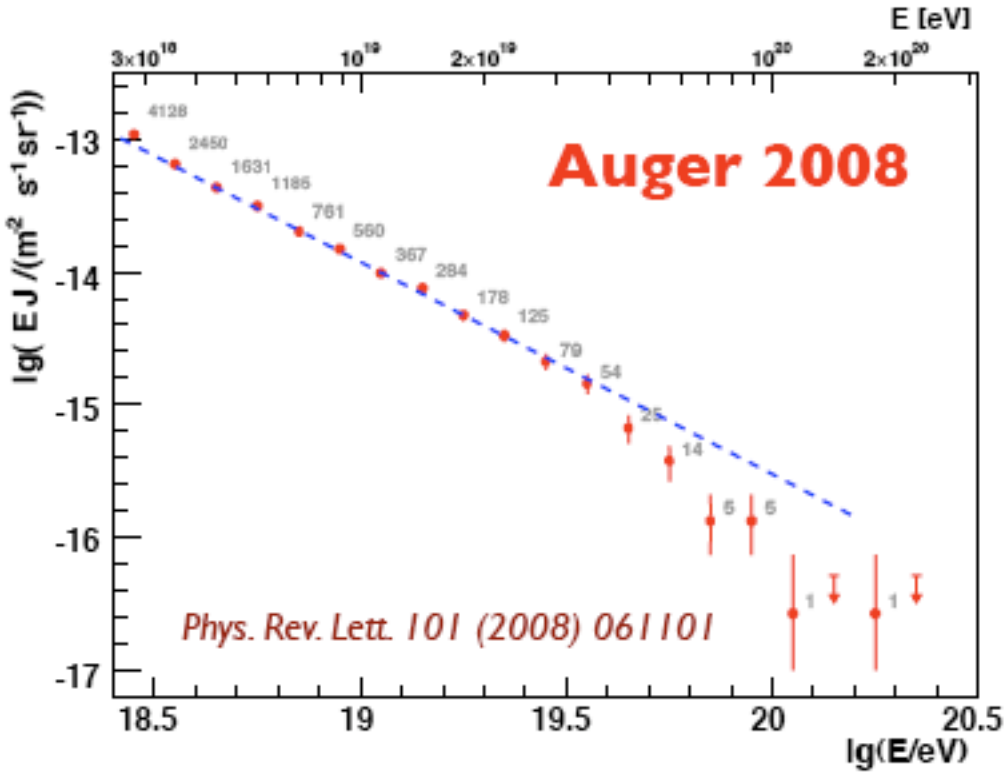
http://dmtools.berkeley.edu/limitplots/ Gaitskell/Mandic

KIMS

- CsI crystal array
  - 12 crystals, ~100kg
  - 60 photons/keV light yield
  - using PSD for background rejection
- Cs/I provide SI and SD interactions
- PSD limit at DAMA SI interpretation
- Aim for annual modulation study



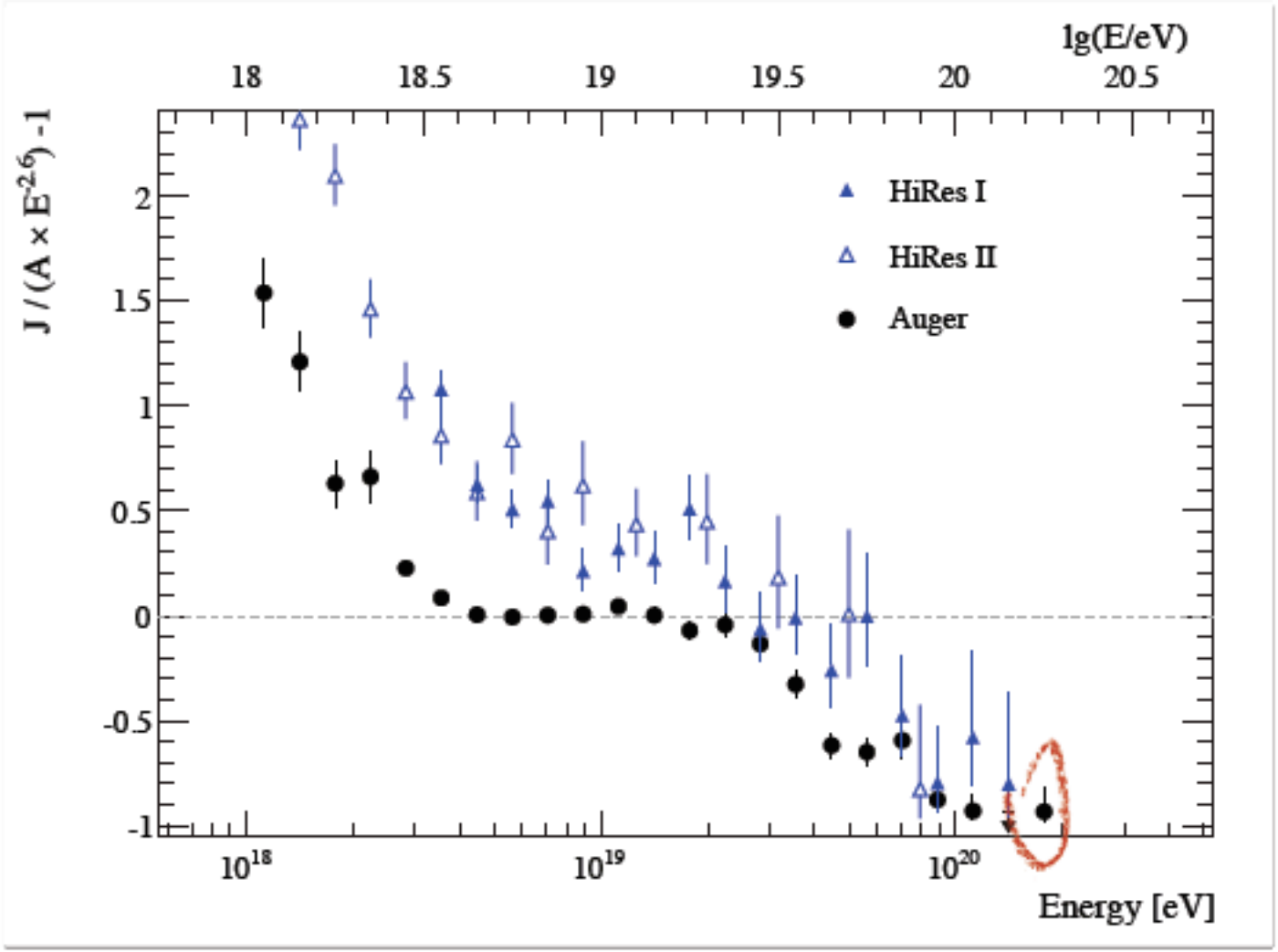




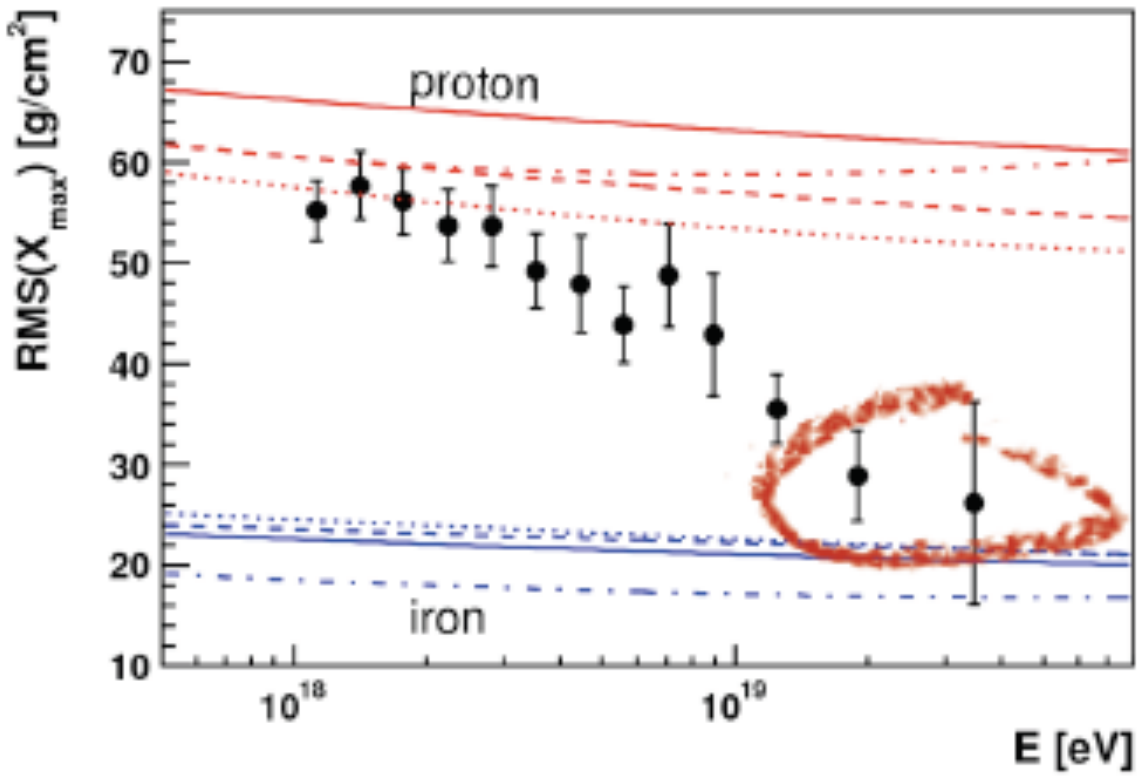
Model-independent measurement

18% stat. energy resolution

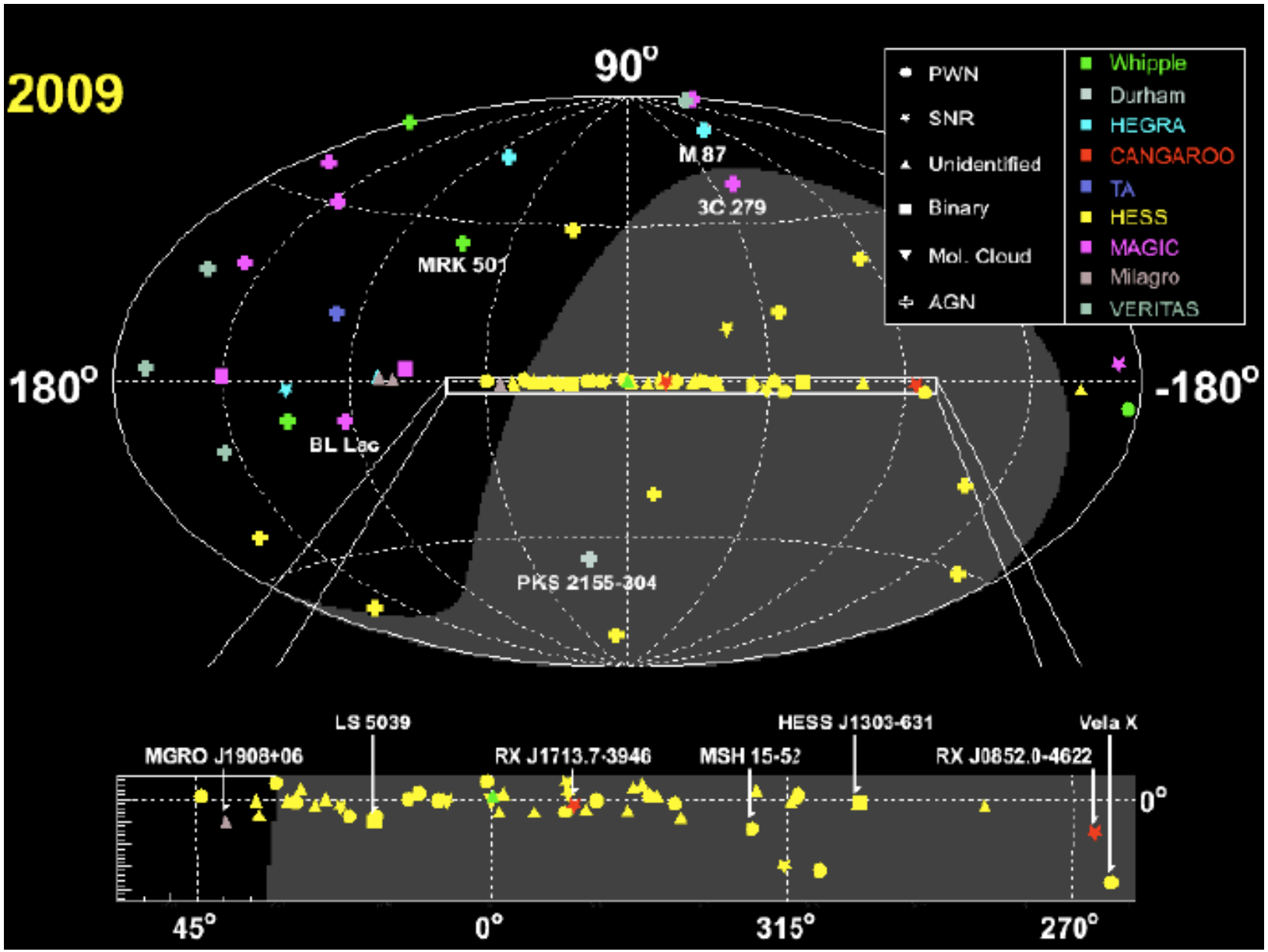
22% sys. energy uncertainty


lg(E/eV)
18
18.5
19
19.5
20
20.5
J / (A × E^2.6) -1
2
1.5
1
0.5
0
-0.5
-1
HiRes I
HiRes II
Auger
10^18
10^19
10^20
Energy [eV]

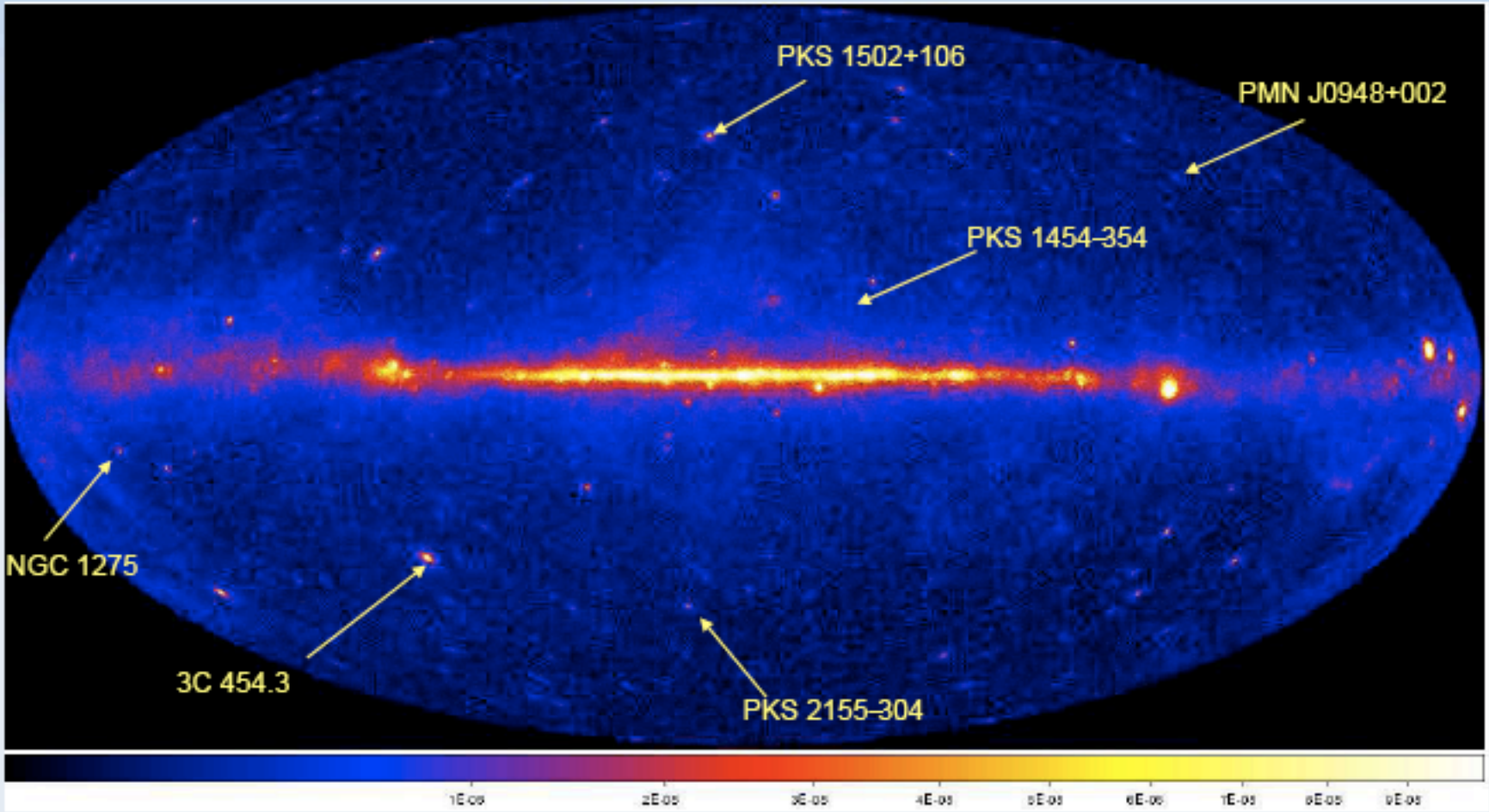
preliminary results - ICRC09



The Gamma-ray World


2009
90°
180°
-180°
PWN
SNR
Unidentified
Binary
Mol. Cloud
AGN
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
VERITAS
M 87
3C 279
MRK 501
BL Lac
PKS 2155-304
LS 5039
MGRO J1908+06
RX J1713.7-3946
MSH 15-52
HESS J1303-631
RX J0852.0-4622
Vela X
0°
45°
0°
315°
270°

Extragalactic HE catalogue



FermiLAT skymap: Some of the brightest AGNs are clearly visible

Overview of the Fermi Large Area Telescope (LAT)

- **Precision Si-strip Tracker (TKR)**

  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.

- **Hodoscopic CsI Calorimeter(CAL)**

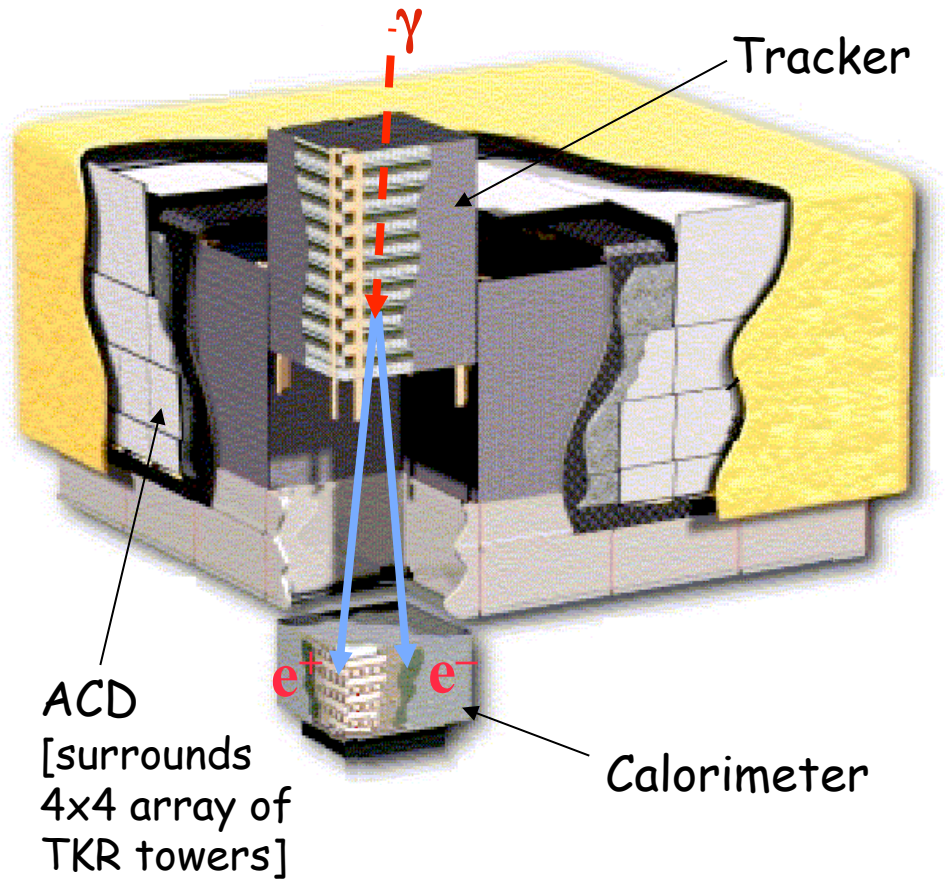
  Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.

- **Anticoincidence Detector (ACD)**

  89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation remove self-veto effects at high energy.

- **Electronics System**

  Includes flexible, robust hardware trigger and software filters.



Systems work together to identify and measure the flux of cosmic gamma rays AND (e^++e^-) with energy 20 MeV ➡ > 300 GeV.

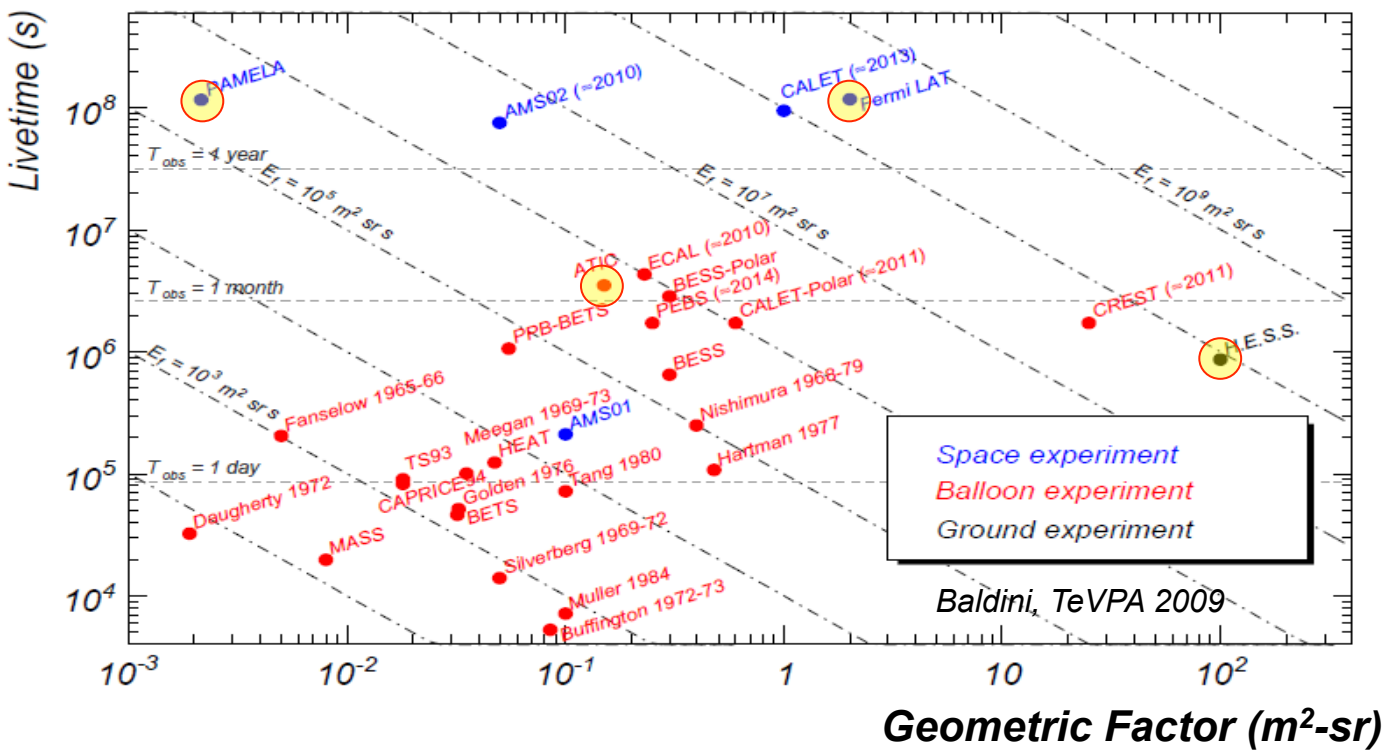
Cosmic-Ray Electron

Annihilations result in many different particle types: gamma rays, e^+,e^-, p, $\bar{p}$, etc.

Recently results on e^+, e^-, p and $\bar{p}$ could be interpreted as signaling DM decays or annihilations

Ground, balloon, and satellite experiments have published results

The Experiments



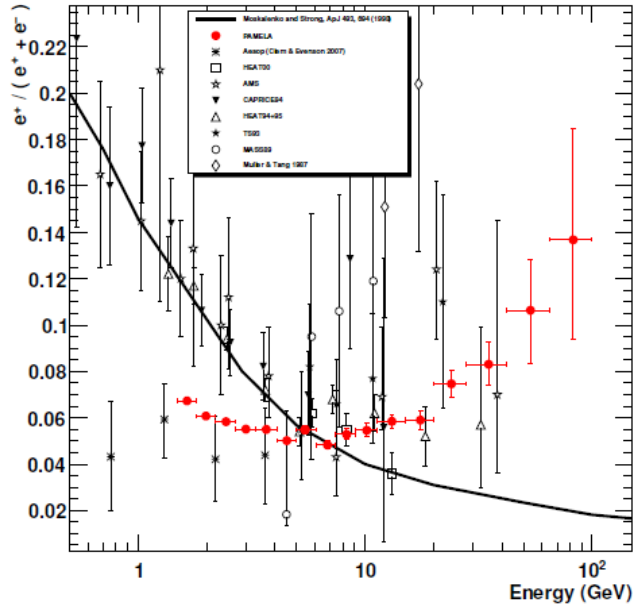
PAMELA Positron Fraction

Unexpected!

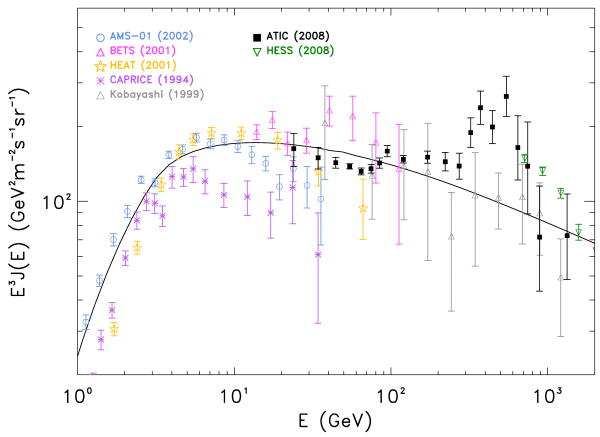
Positron fraction increases above 10 GeV!

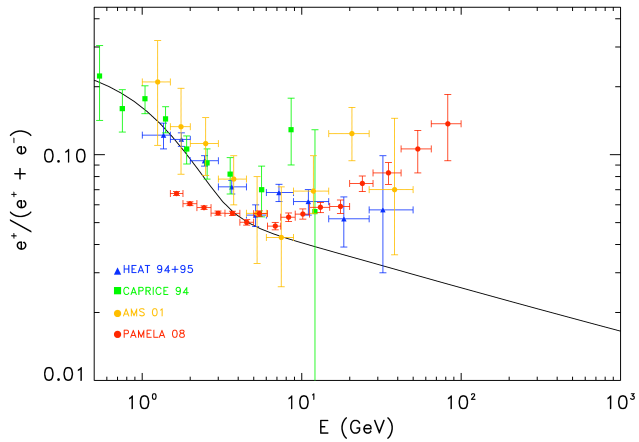
Note that Geomagnetic cut-off of primary cosmic rays is O(10 GeV)

Data below 10 GeV is dominated by trapped radiation and fluxes are sensitive to Solar Cycle



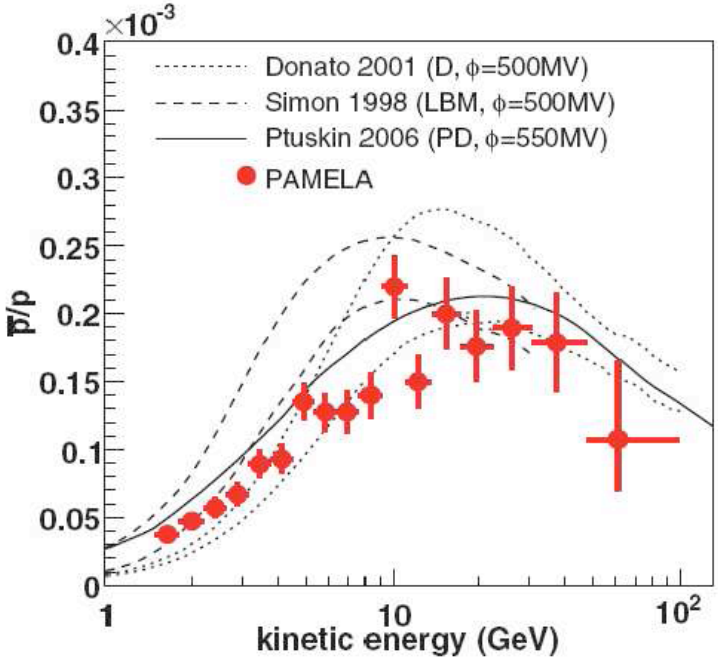
ATIC Electron Spectra & PAMELA e⁺ Fraction caused excitement in 2008!

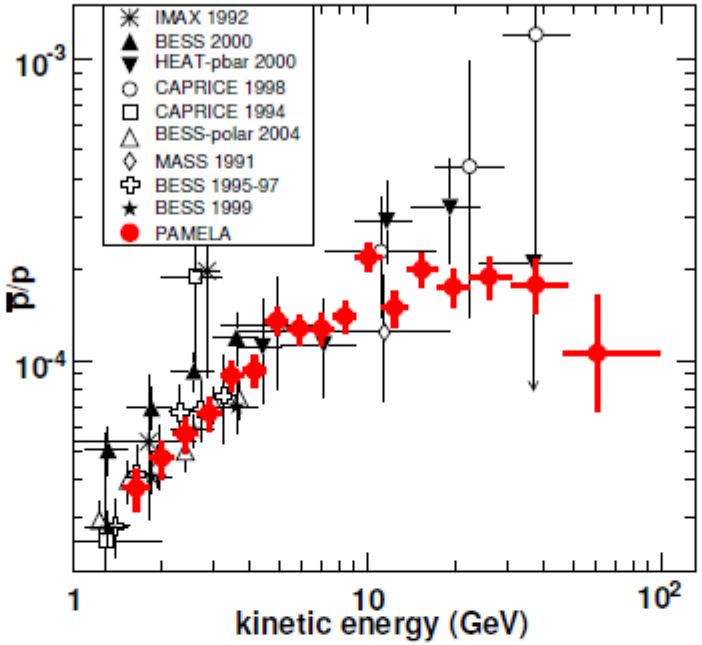




- **More than 200 papers in the last year**
- **Local source of electrons – Astrophysical? Dark Matter?**

Anti-Proton Fraction





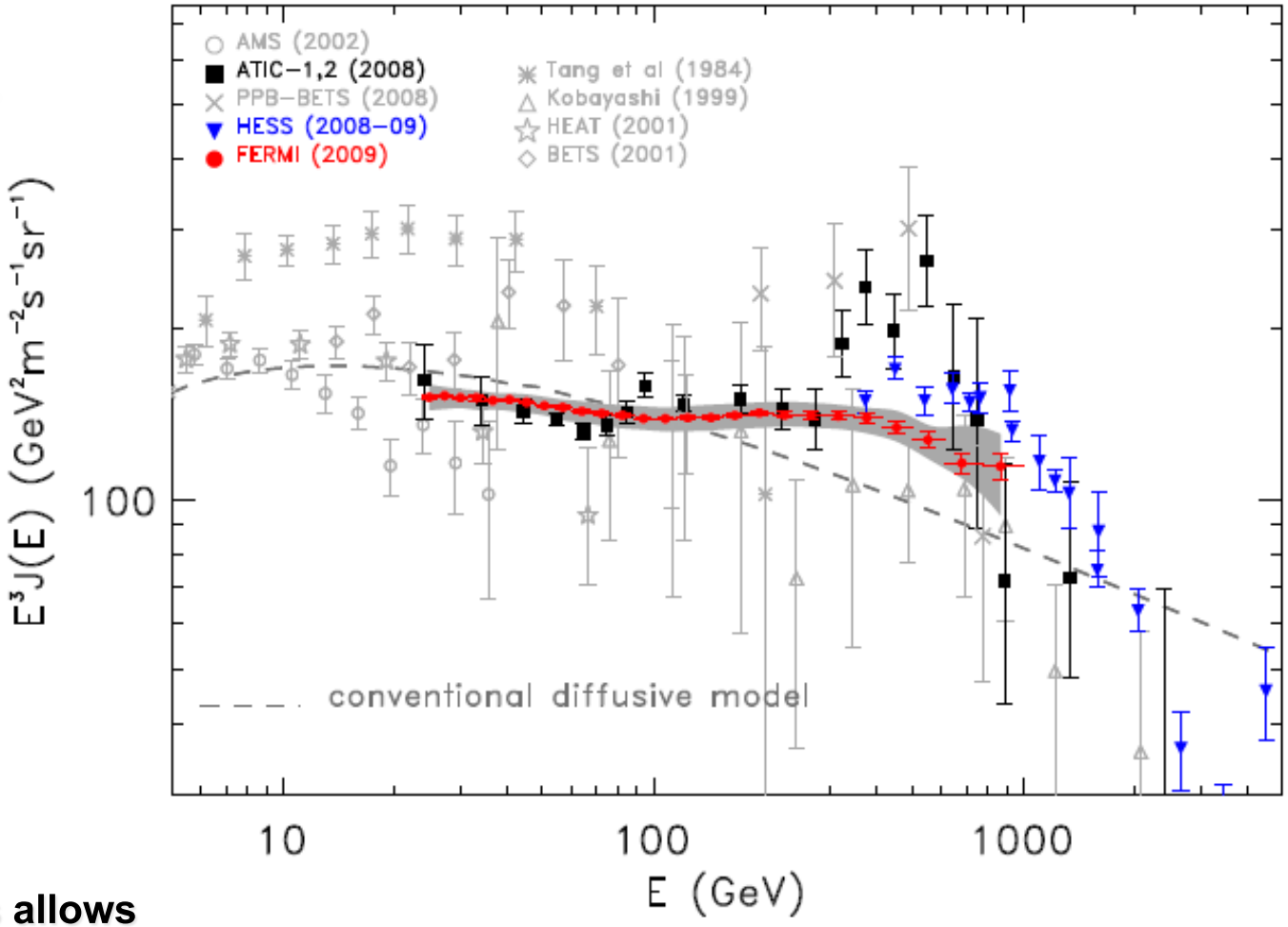
Nothing surprising seen in anti-proton / proton ratio

Anti-proton abundance consistent with expectations for secondary CR production off the Interstellar Medium

The Fermi-LAT e^++e^- Spectrum

Large number of events seen in the LAT

- 1500 electron events/ day above 100 GeV
- 1 LAT day ~ year for PAMELA
- 1 LAT day ~ ATIC Balloon Flights



Large number of events allows for detailed systematic studies

J. Chang et al., Nature **456**, 362 (2008)

F. Aharonian et al., Phys. Rev. Lett. **101**, 261104 (2008)

A. A. Abdo et al., Phys. Rev. Lett. **102**, 181101 (2009)

F. Aharonian et al., arXiv:0905.0105v1

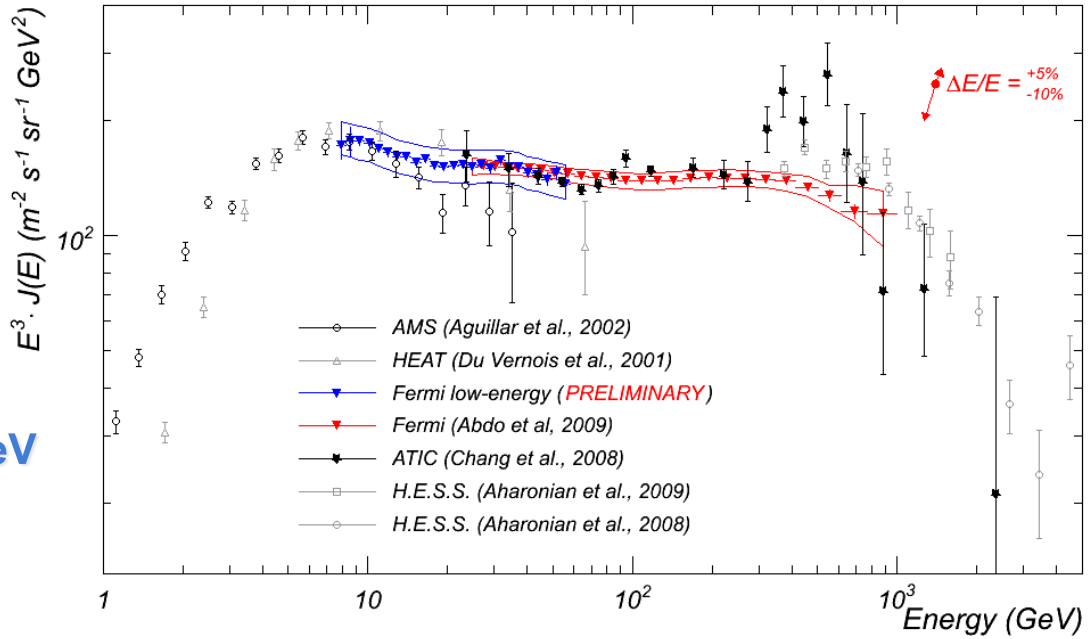
Update: Add the Low Energy Measurement

LAT has two Trigger Modes which can used to measure electrons:

- High Energy By-Pass Trigger
- Tracker 3-in-a-row Diagnostic Trigger

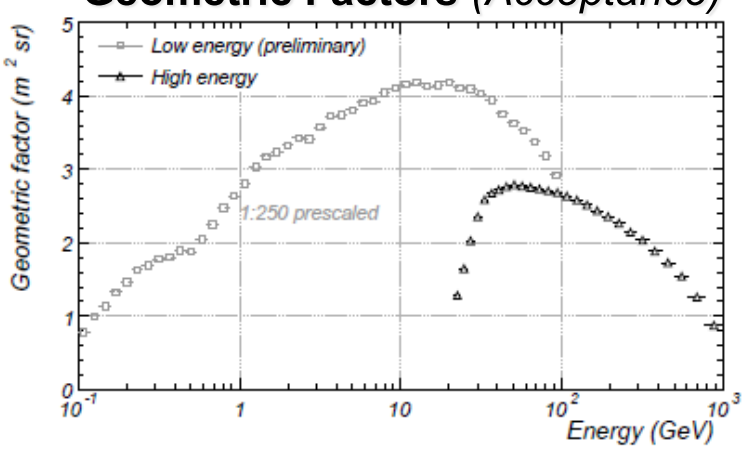
Two independent analyses start from these hardware triggers.

- **Low Energy: 100 MeV – 50 GeV**
- **High Energy: 20 GeV – 1 TeV**

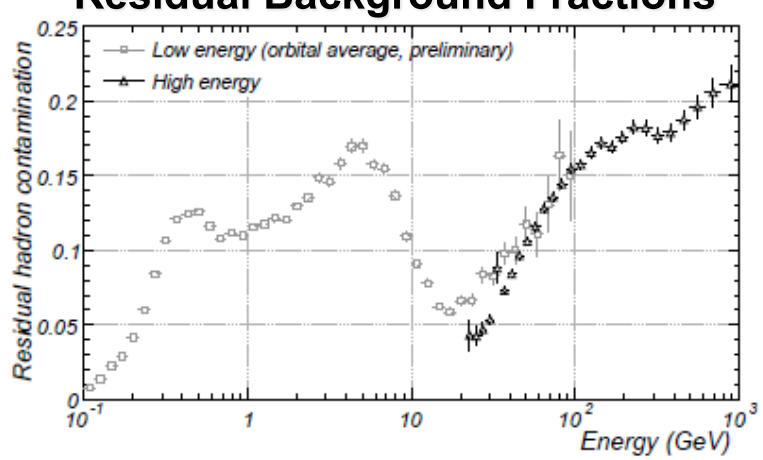


Both measurements agree within statistical errors!

Geometric Factors *(Acceptance)*

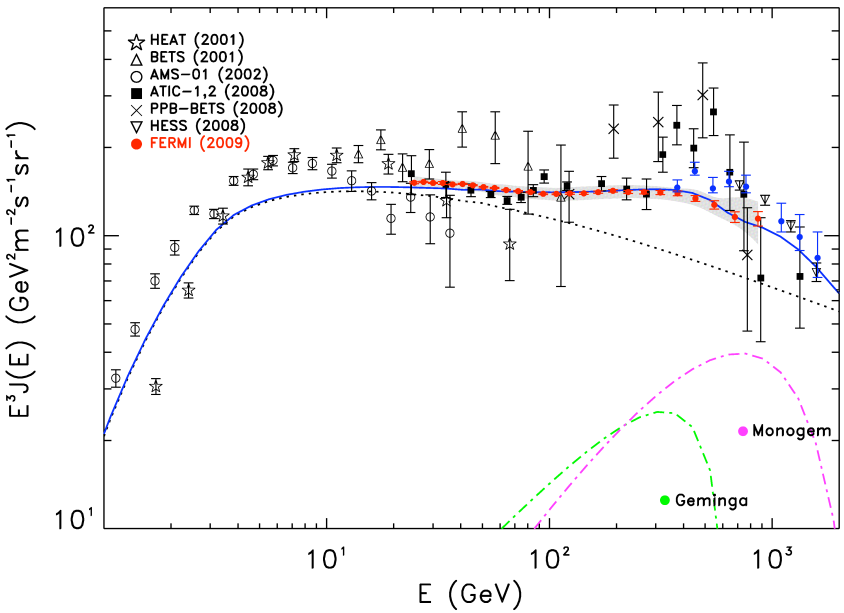


Residual Background Fractions



An Astrophysical Interpretation

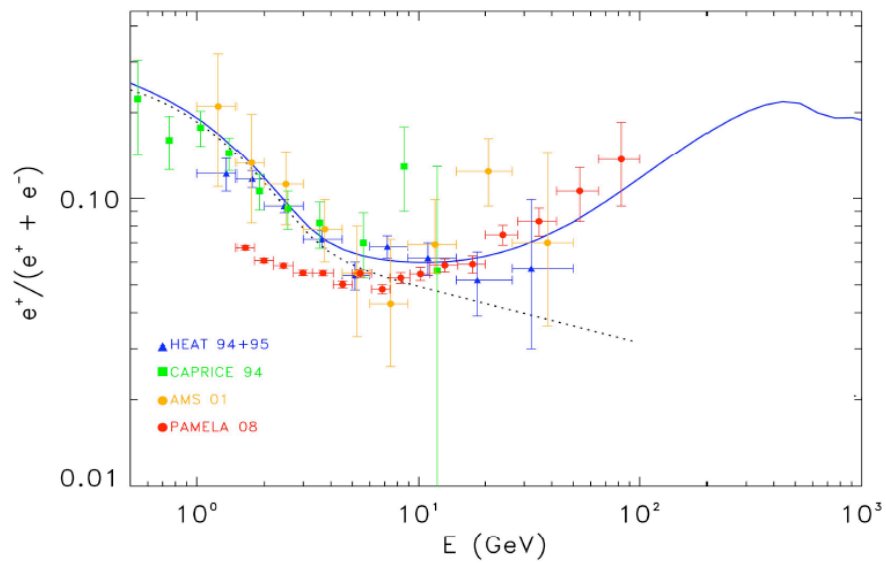
Add Pulsar(s) within 1Kpc



<u>Fermi-LAT data are nicely reproduced</u> assuming a 40% efficiency converting spin-down energy into electrons and positrons.

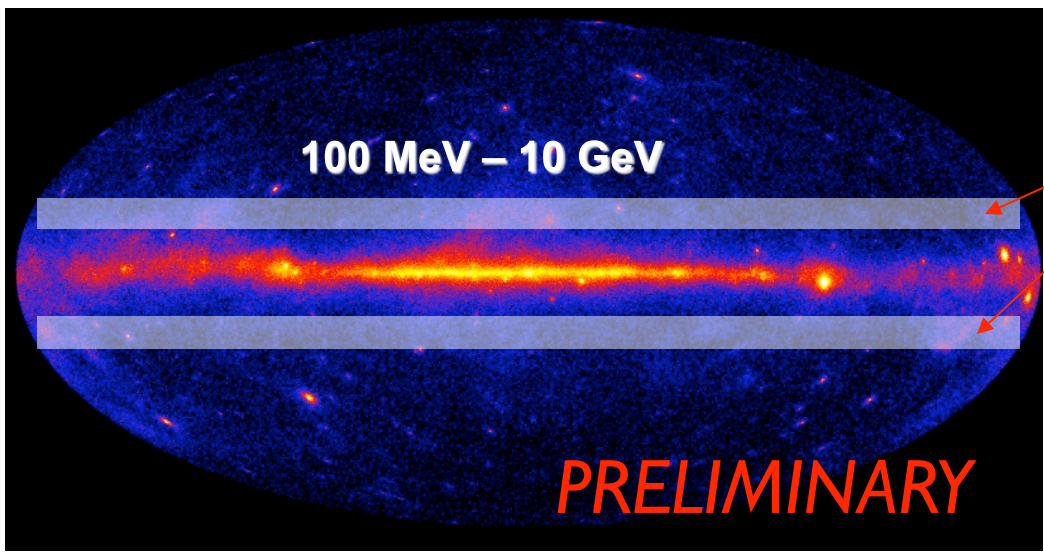
Pulsars are modeled as point-like sources with power-law injection spectra ($E^{-1.7}$) and expo. cutoff at 1 TeV

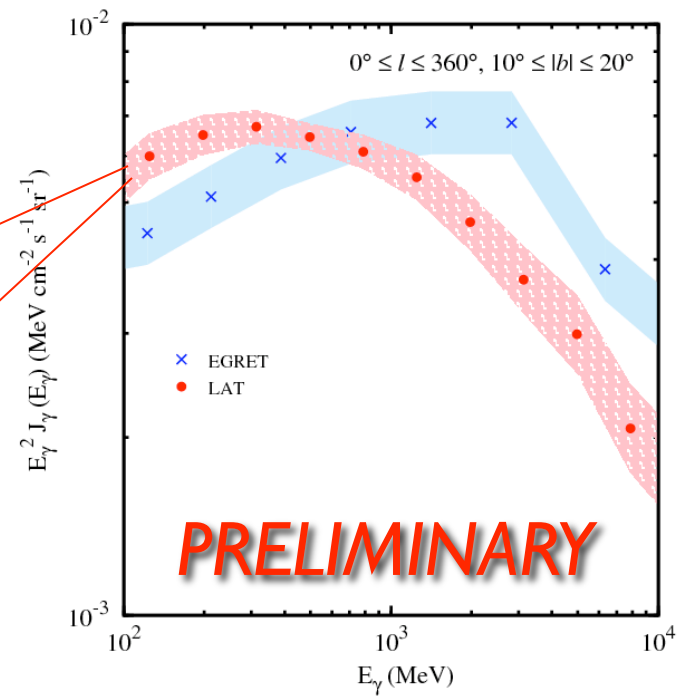
This explanation also works for the PAMELA results



Galactic Diffuse Emission: "The GeV Excess"

- EGRET observed an "all sky" excess in the GeV range compared to predictions from cosmic ray propagation and γ ray production models consistent with local cosmic-ray nuclei and electron spectra
- <u>The data collected by the LAT from mid-August to end of December do not confirm the excess at intermediate latitudes</u>
- Sources are not subtracted (minor component)
  LAT error is systematic dominated (~10%, preliminary)
- **Constrains DM interpretations – at least the crazy models!**





Gamma Ray Searches for Dark Matter

Galactic Center

Good Statistics but source confusion/diffuse background

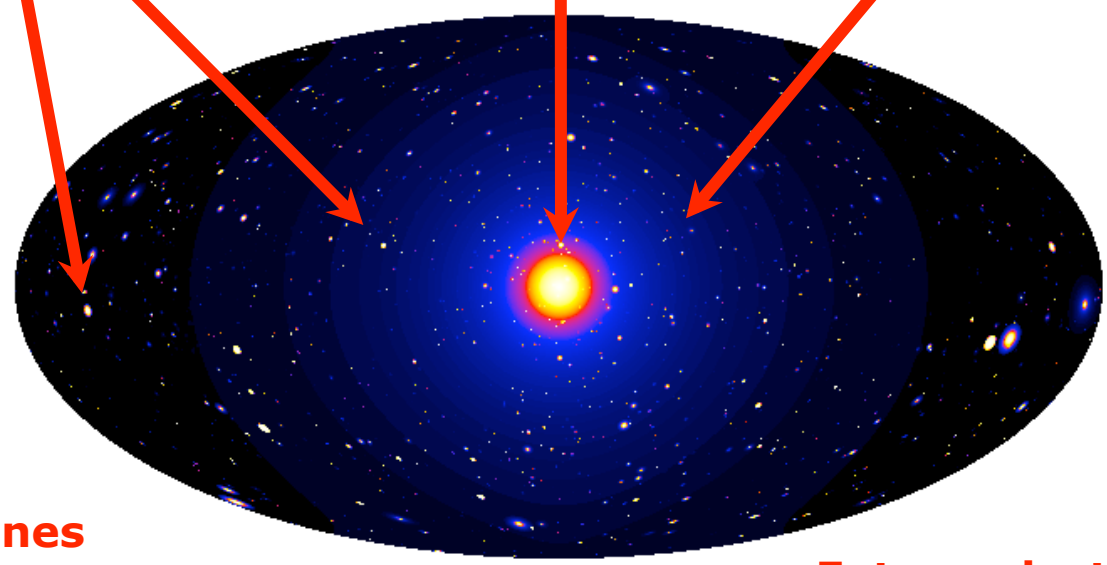
Satellites

Low background and good source id, but low statistics, astrophysical background

Milky Way Halo

Large statistics but diffuse background

All-sky map of simulated gamma ray signal from DM annihilation (Baltz 2006)



Spectral Lines

No astrophysical uncertainties, good source id, but low sensitivity because of expected small BR

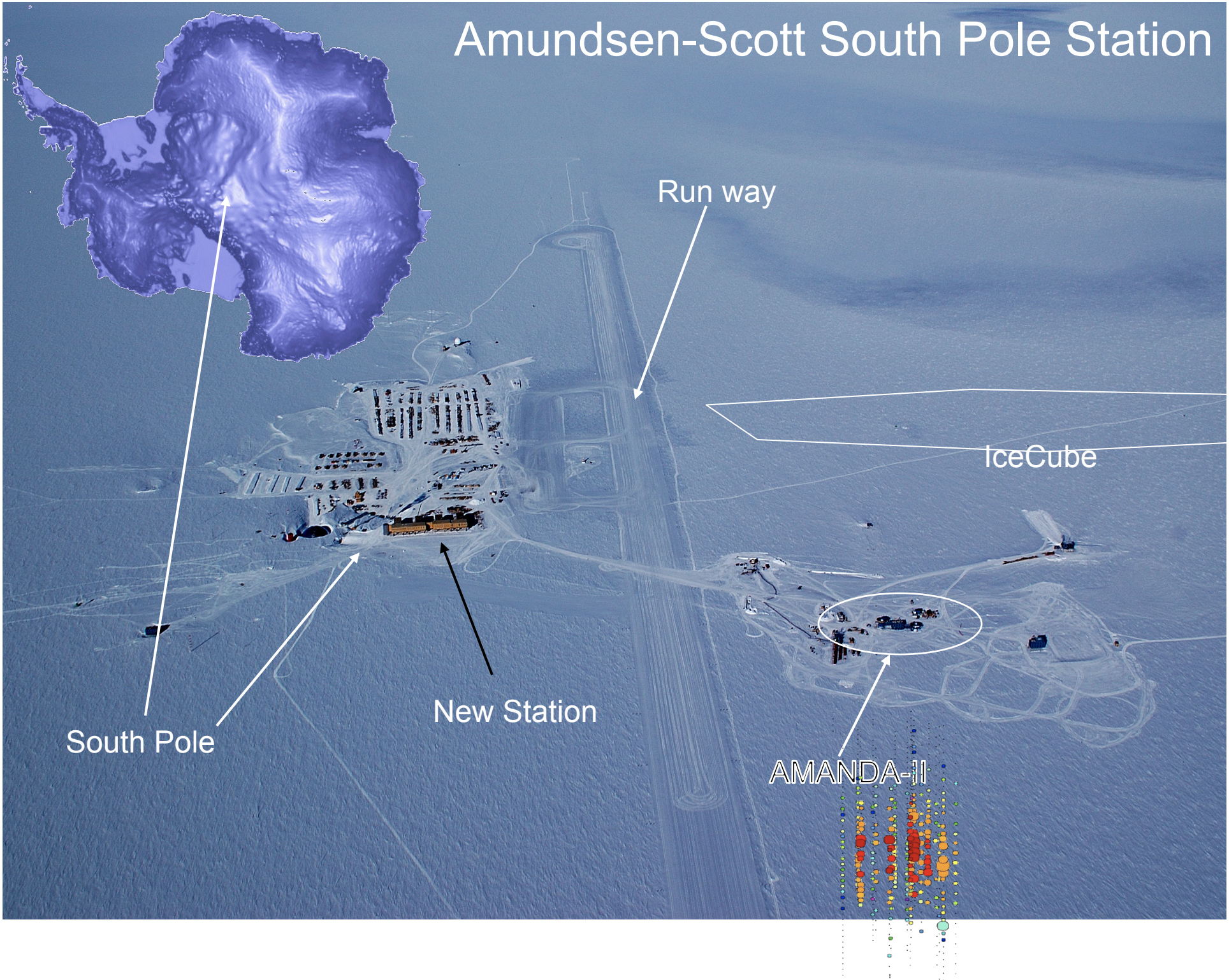
Extra-galactic

Large statistics, but astrophysics, galactic diffuse background

Pre-launch estimates of sensitivities published in Baltz et al., 2008, JCAP 0807:013 [astro-ph/0806.2911]

Recap of Gamma Ray and CR Electron Results

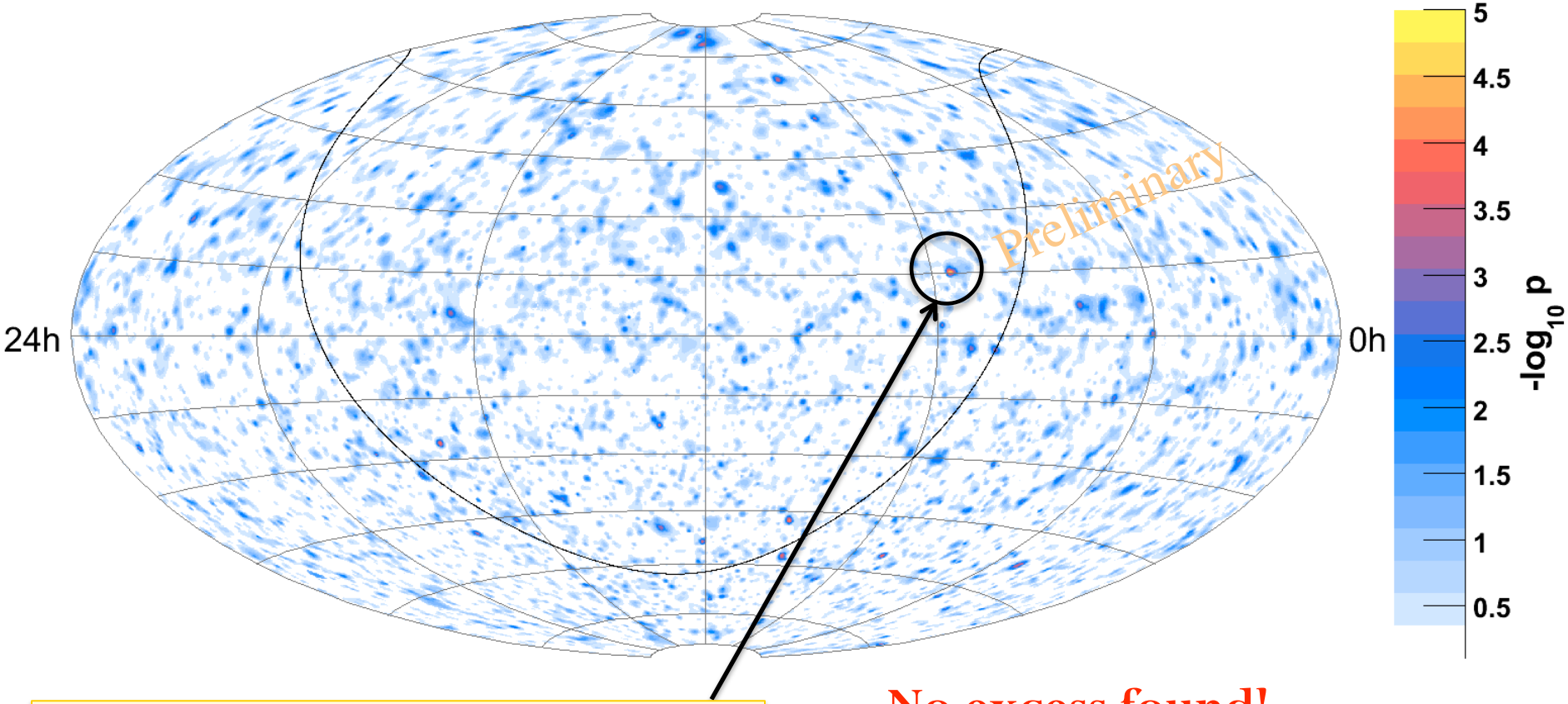
PAMELA Protons	No evidence of DM. Weakens expectations on b-b*bar* final states
PAMELA Positrons	Rise in fraction could indicate DM. More likely near-by pulsars.
ATIC CR Electrons	In conflict with Fermi-LAT results.
Fermi-LAT CR Electrons	Definite structure at high E, could indicate DM. More likely near-by pulsars
Fermi-LAT GeV Excess	Previous EGRET results not validated, consistent with CR expectations
Fermi-LAT Galactic Center	Weak limit, no spectral features seen
Fermi-LAT DM Lines	Not found, weak constraint on DM due to energy range and uncertainties on branching fraction
Fermi-LAT DM Satellites	Not found, starts to constrain Boost • $<\sigma v>$
Fermi-LAT dSph	Not found, starts to constrain Boost • $<\sigma v>$
Fermi-LAT Galaxy Clusters	Not found, starts to constrain Boost • $<\sigma v>$
Fermi-LAT EGD	Results similar to re-analyzed EGRET EGD, starts to constrain Boost • $<\sigma v>$


Amundsen-Scott South Pole Station
Run way
IceCube
New Station
South Pole
AMANDA-II

High Energy neutrino telescopes (optical)

Detector	Number of OMs	Enclosed mass (Megatons)	Depth (m.w.e)	Status
Baikal	230	10	1100-1310	Operating
AMANDA	677	15	1350-1850	2000-2009
ANTARES	900	10	2050-2400	Operating
IceCube (59 strings) IceCube (86 strings)	3540 5160	500 900	1350-2250 1350-2250	Operating 2009 Ready 2011
KM3Net (NEMO site) KM3Net (Nestor site) KM3Net (ANTARES site)	≈10,000 ≈10,000 ≈10,000	≈1000 ≈1000 ≈1000	2300-3300 2000-4000 1400-2400	Design study
GVD (Future Baikal)	≈1500	≈1000	800-1300	Design Study

Search for point sources - 40-string(6month) all-sky results

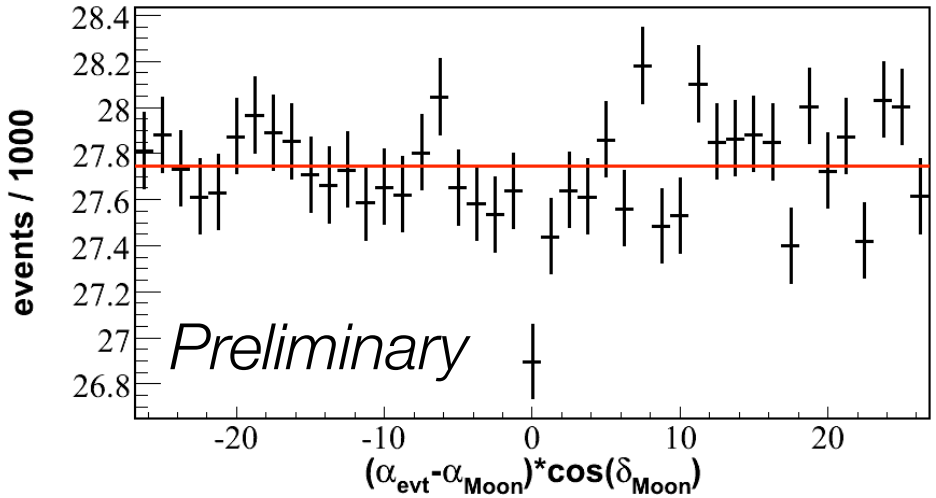


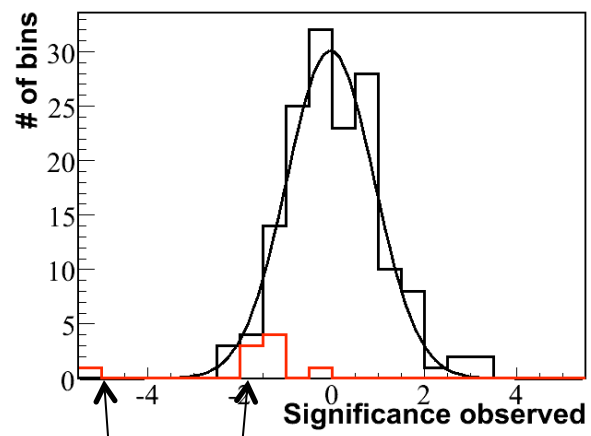
Hottest location in the all-sky search is:
r.a.=114.95°, dec.=15.35°

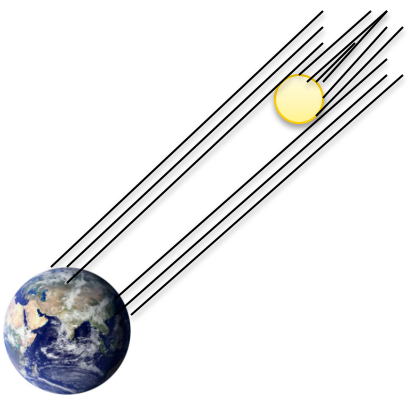
No excess found!
⇒all-sky p-value is 61%, not significant

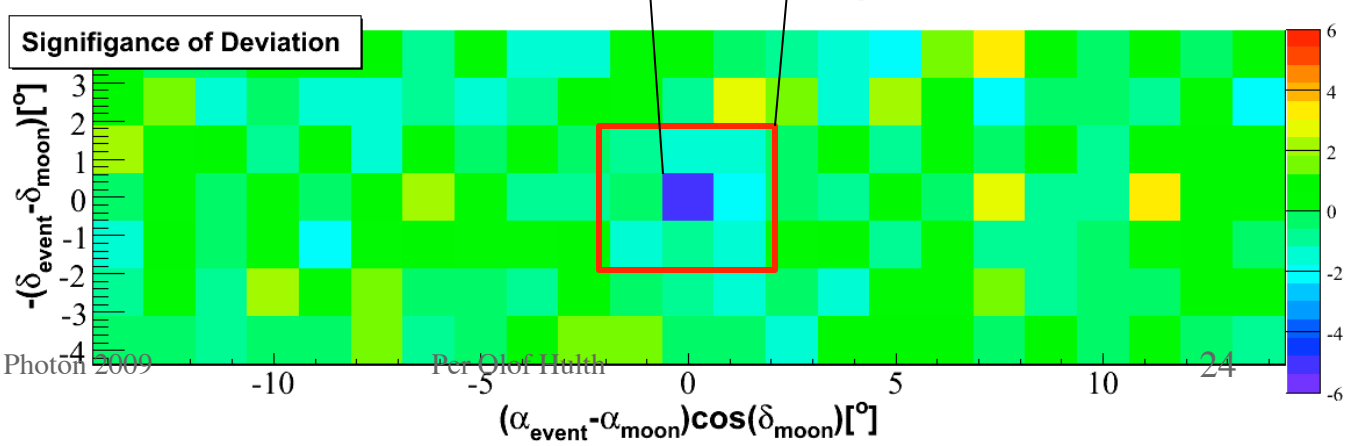
Moon shadow observed in muons

- Energy of parent air shower primary ~30TeV (median)
- Deficit: 5 σ (~900 events of ~28000) - consistent with expectation.
- **Important verification of angular resolution and absolute pointing.**









The end

DM Interpretation of PAMELA and Fermi-LAT Results

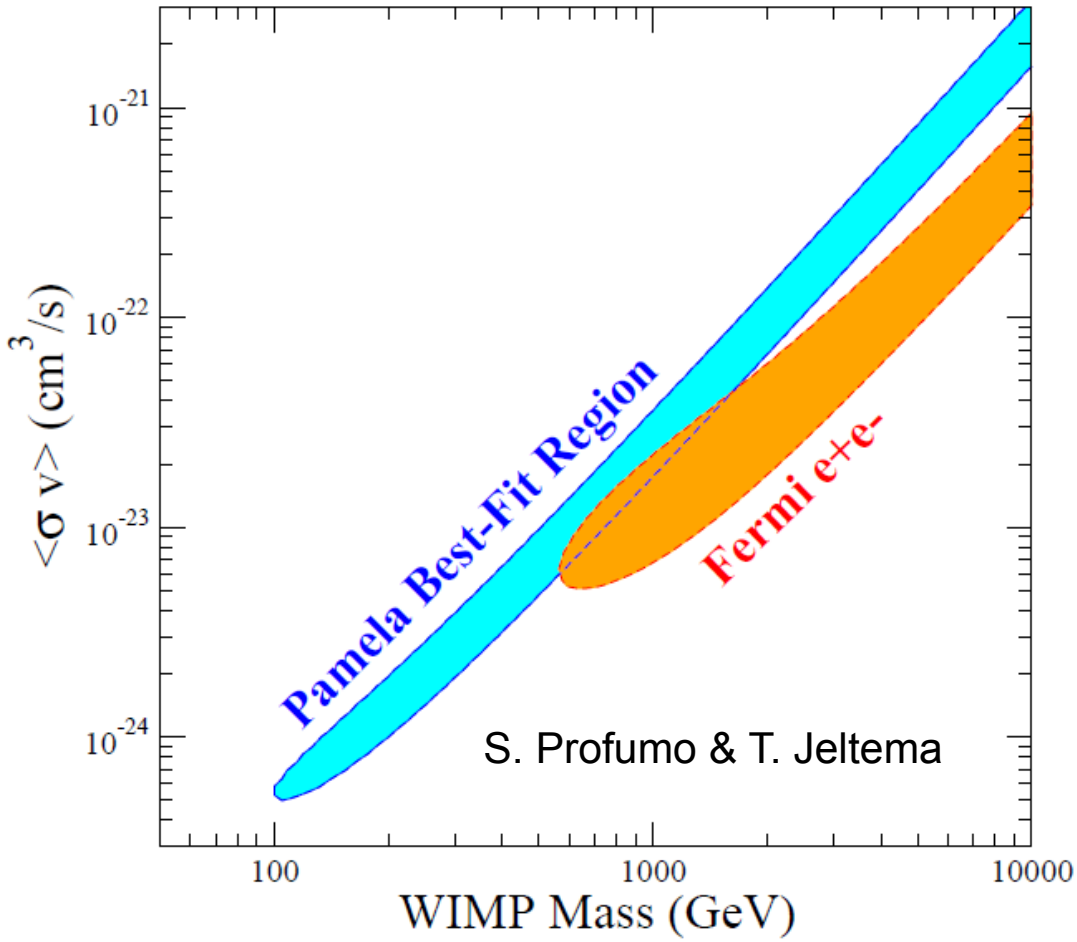
Basic Problem

Electron – Positron rates much larger then predicted by usual DM Models.

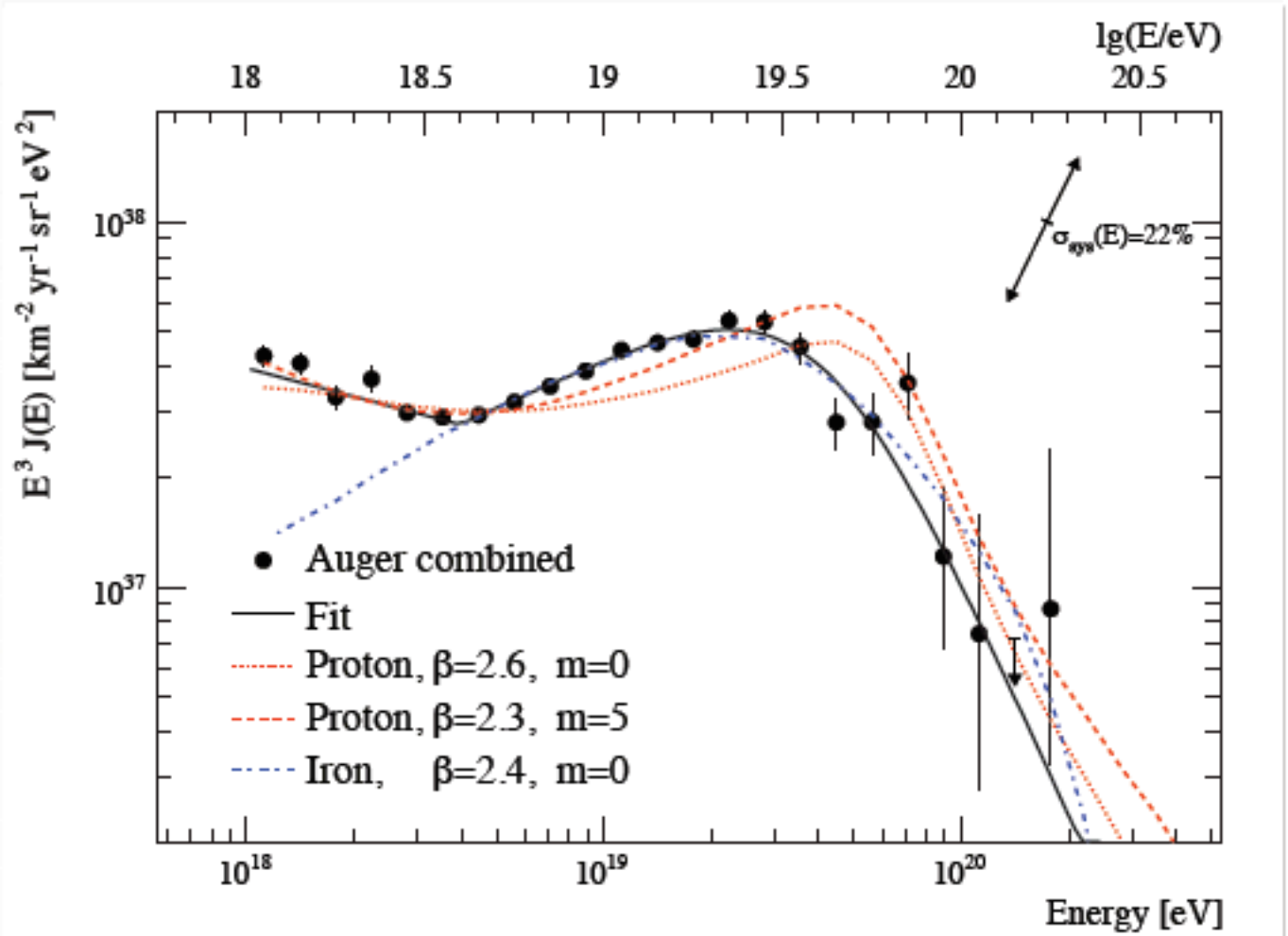
Requires special effects

- Large Boost factors from substructures
- Sommerfeld Enhancements
- Lepto-phylic Decay Modes

Example: Spectral results on electrons require DM models with large leptonic BRs. Of the three known leptons (e, μ, and τ), electron spectra from muon final states give the "best" fits but also suggests a high WIMP mass.



Overlap region requires a high WIMP mass <u>and</u> a very large rate


lg(E/eV)
18
18.5
19
19.5
20
20.5
$E^3 J(E)$ [$km^{-2} yr^{-1} sr^{-1} eV^2$]
10^{38}
10^{37}
$\sigma_{sys}(E)=22\%$
Auger combined
Fit
Proton, β=2.6, m=0
Proton, β=2.3, m=5
Iron, β=2.4, m=0
10^{18}
10^{19}
10^{20}
Energy [eV]

LEPTON-PHOTON 2009 Neutrino Summary

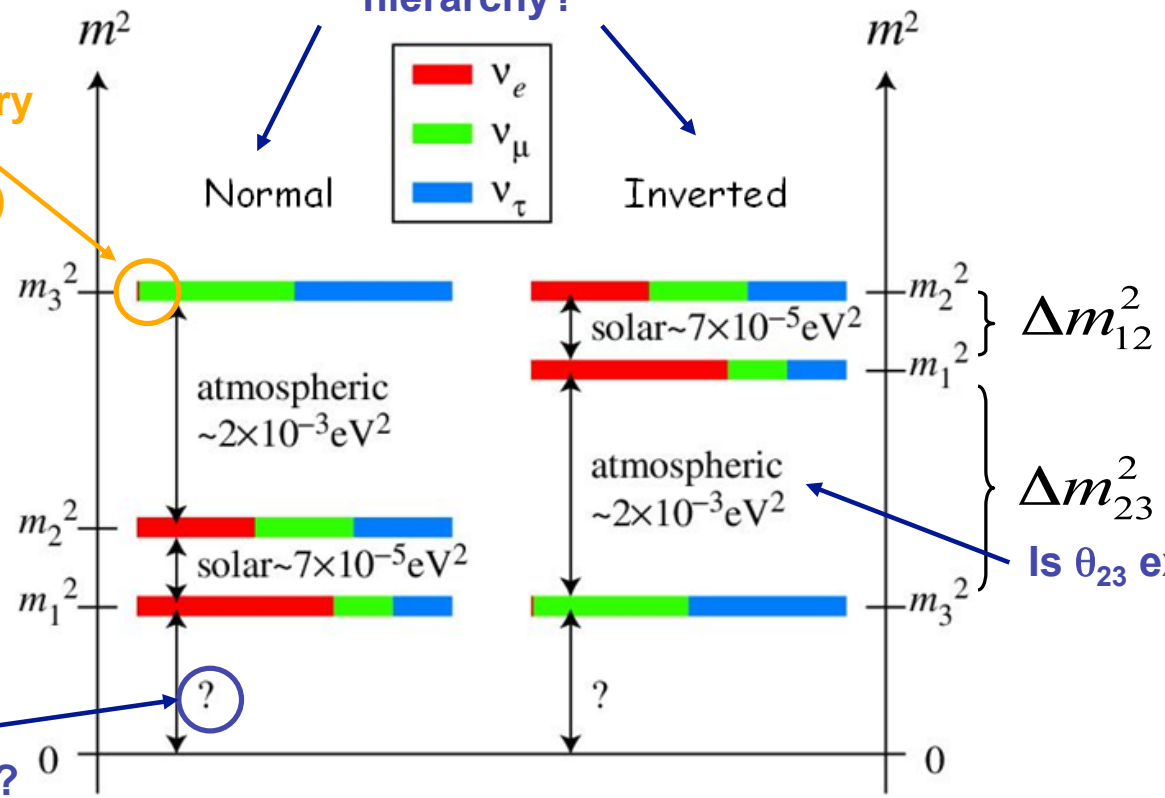
Cheng-Ju Lin

(Slides taken from various speakers)

Outstanding Questions in Neutrino Realm

What is the right mass hierarchy?

Is θ_{13}=0 or just very small?
(Topic of this talk)



Is θ_{23} exactly $\pi/4$?

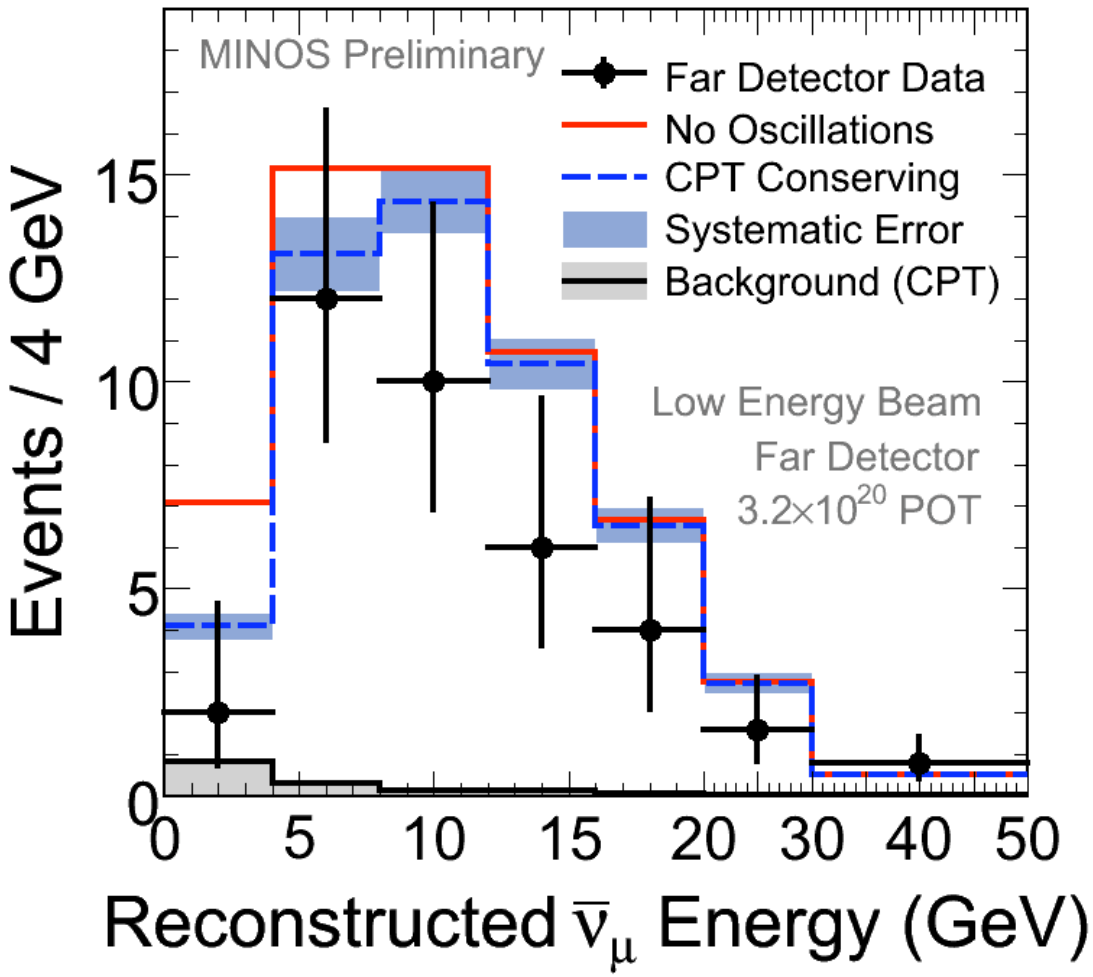
What is the rest mass of neutrinos?

And also:
- Are neutrinos their own antiparticles?
- Are there more than 3 neutrinos (sterile, heavier than Z)?
- Do neutrinos obey CP, CPT?

Search for ~~CPT~~ in Oscillations?

- Use 6% $\bar{\nu}_\mu$ in NuMI beam for separate oscillation search (1st time!)
- Observe **42 events** in the Far detector

- Predicted events with CPT conserving oscillations:
  - 58.3 ± 7.6 (stat.) ± 3.6 (syst.)
- Predicted events with null oscillations:
  - 64.6 ± 8.0 (stat.) ± 3.9 (syst.)

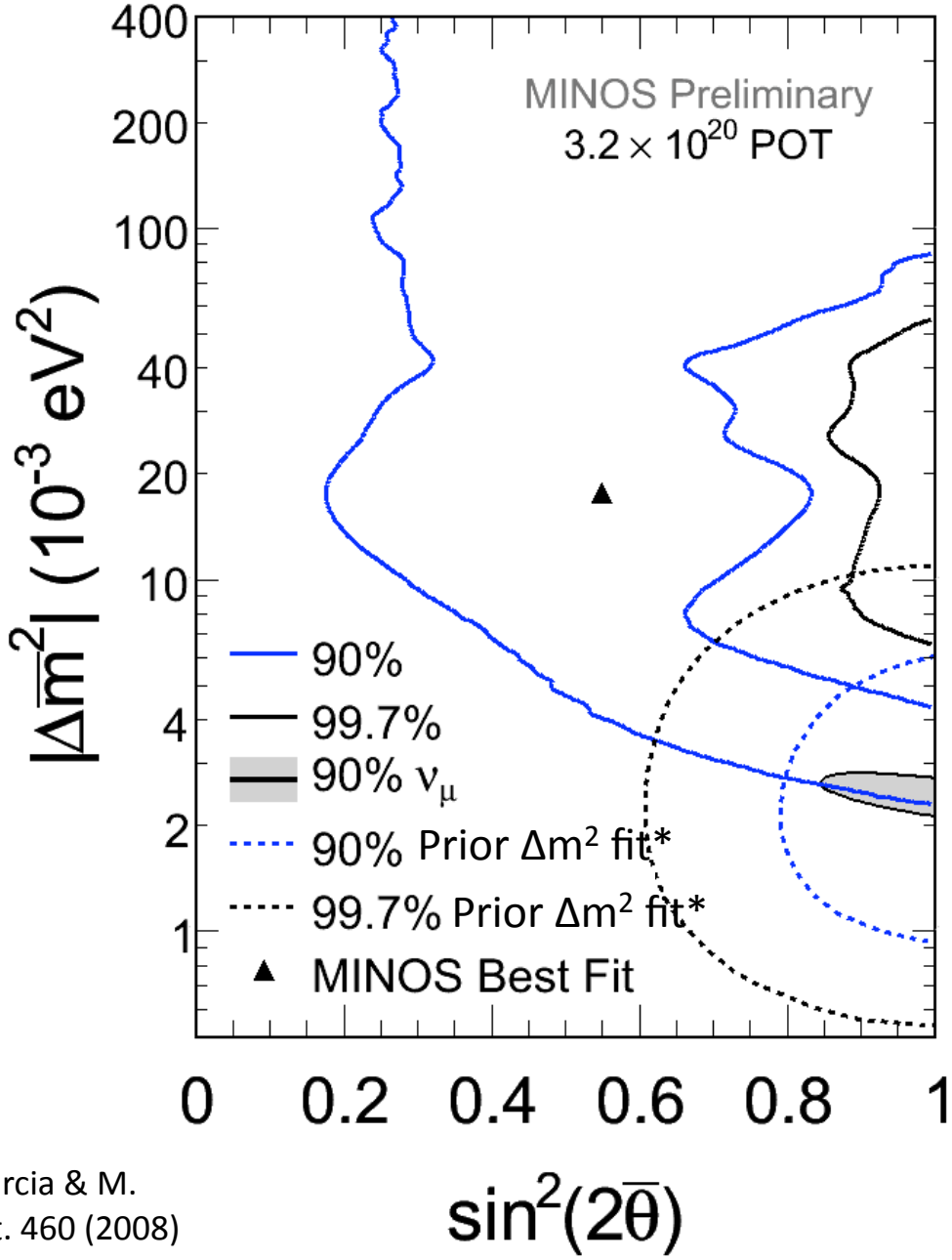


figures courtesy J. Hartnell (Sussex) Fermilab seminar

S. Kopp, Lepton-Photon 2009

Allowed Region

- Null oscillation hypothesis excluded at 99%
- $\bar{\nu}_\mu$ best fit is at high value, due to deficit at high energy
- $(5.0 < \Delta\bar{m}^2 < 81)\times10^{-3}$ eV^2 (90% C.L.)
- MINOS limits $P(\nu_\mu \rightarrow \bar{\nu}_\mu)<2\%$ at 90% C.L.
- MINOS plans to undertake a dedicated $\bar{\nu}_\mu$ run next year



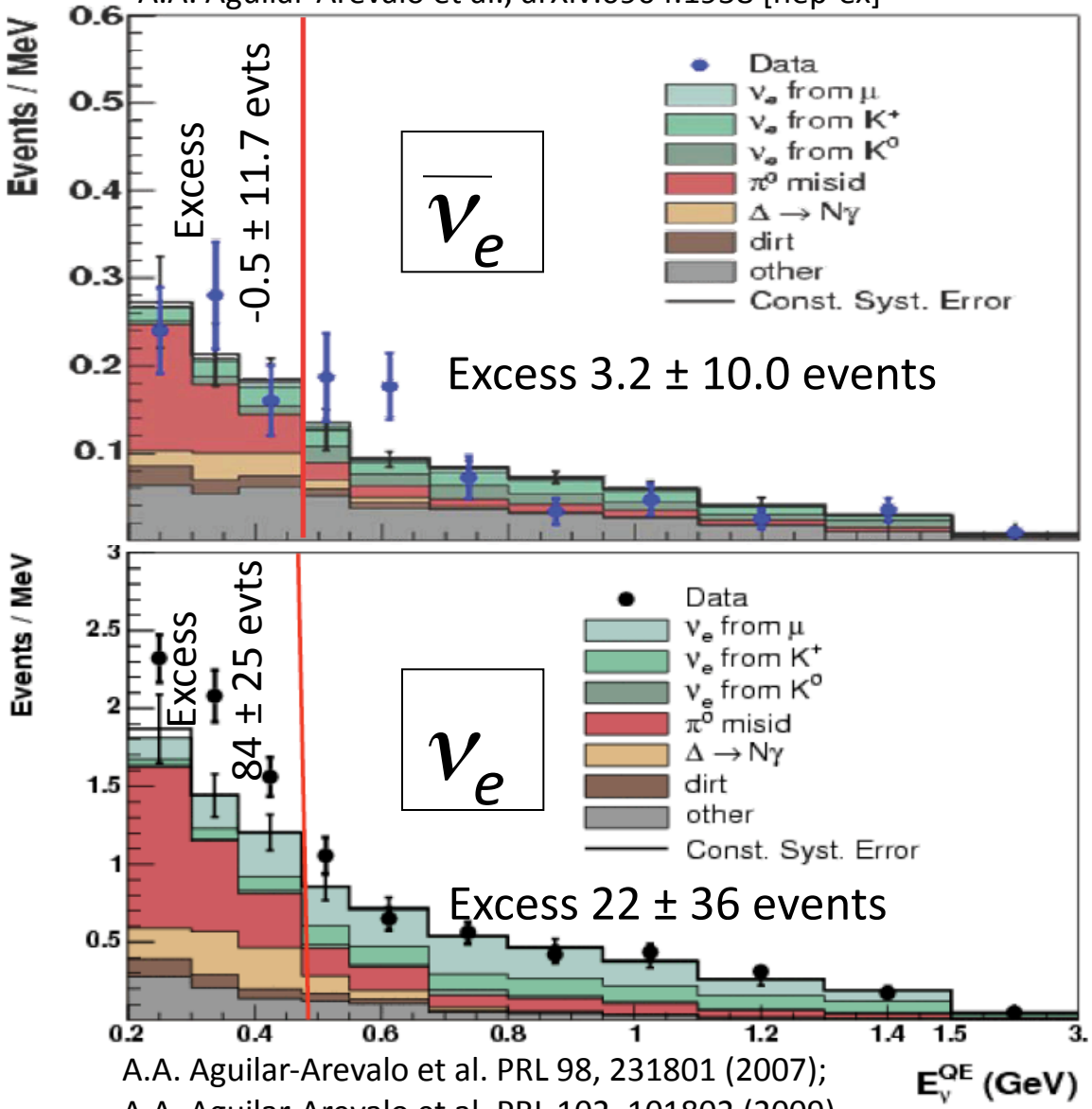
*M. C. Gonzalez-Garcia & M. Maltoni, Phys. Rept. 460 (2008)

figures J. Hartnell (Sussex) Lomonsov conference

S. Kopp, Lepton-Photon 2009

What About Sterile Neutrino?

A.A. Aguilar-Arevalo et al., arXiv:0904.1958 [hep-ex]



A.A. Aguilar-Arevalo et al. PRL 98, 231801 (2007);
A.A. Aguilar-Arevalo et al. PRL 102, 101802 (2009)

MiniBoone Results are inconsistent with LSND

Neither ν_e and $\overline{\nu}_e$ channels have excess of events in the LSND region

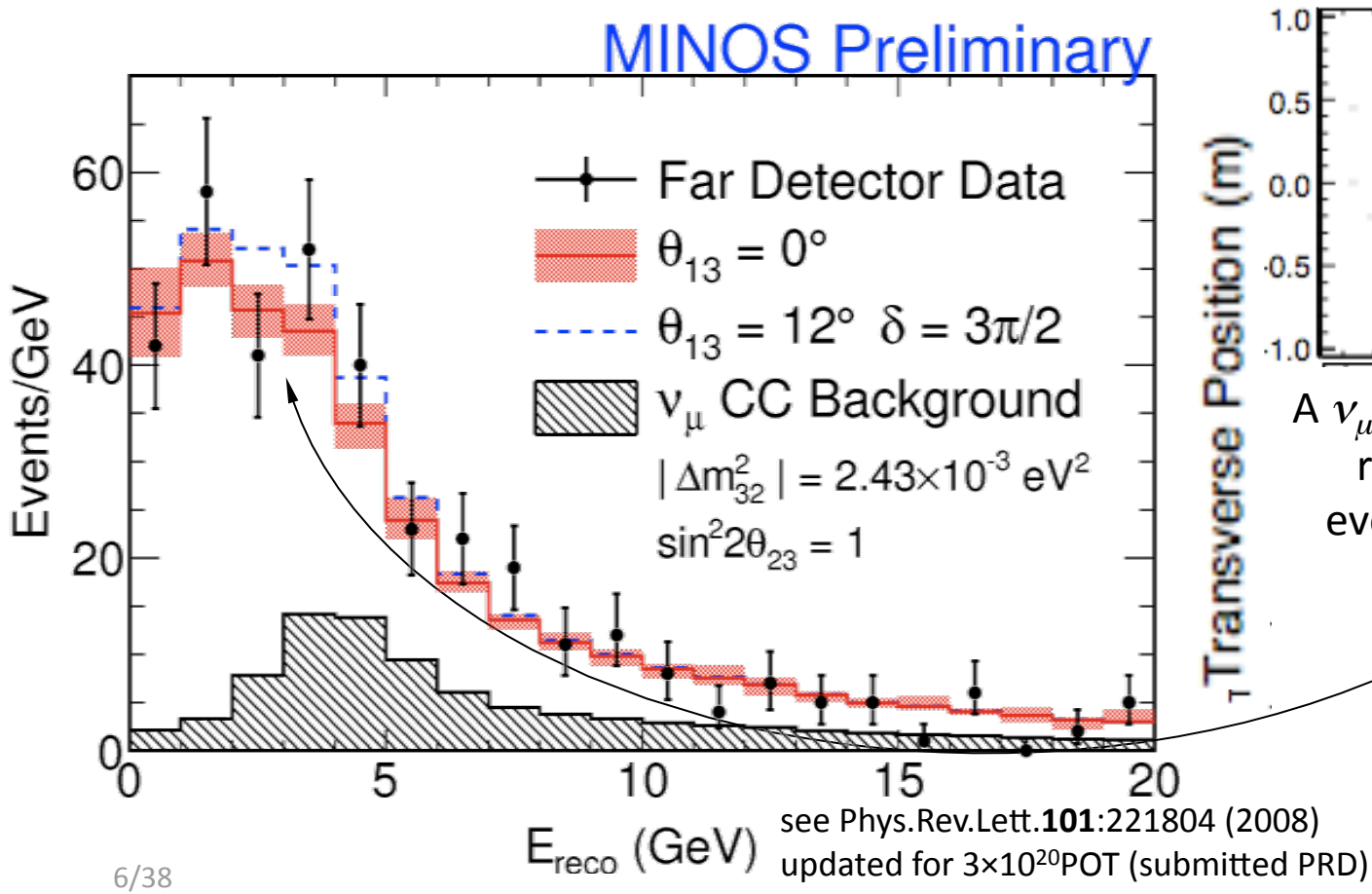
Low energy excess (<475MeV) is still not understood

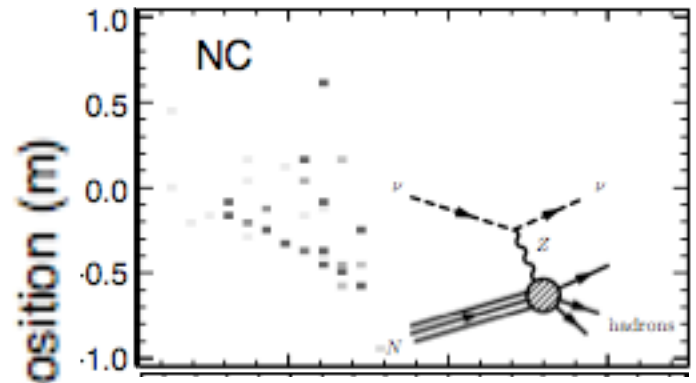
S. Kopp, Lepton-Photon 2009

figures courtesy M. Shaevitz, Columbia

MINOS Search for $\nu_\mu \rightarrow \nu_{\text{sterile}}$

- Charged current – identifies flavor of interacting ν_μ
- Neutral current – inclusive, all "active" ν flavors interact





A $\nu_\mu \rightarrow \nu_{\text{sterile}}$ oscillation would result in a deficit of NC events at the Far Detector

see Phys.Rev.Lett.**101**:221804 (2008)
updated for 3×10^{20}POT (submitted PRD)

S. Kopp, Lepton-Photon 2009

figures courtesy B. Rebel (FNAL), A. Sousa (RAL), Fermilab seminars

The CP-Violating Globe

WEDNESDAY, MAY 27, 2009

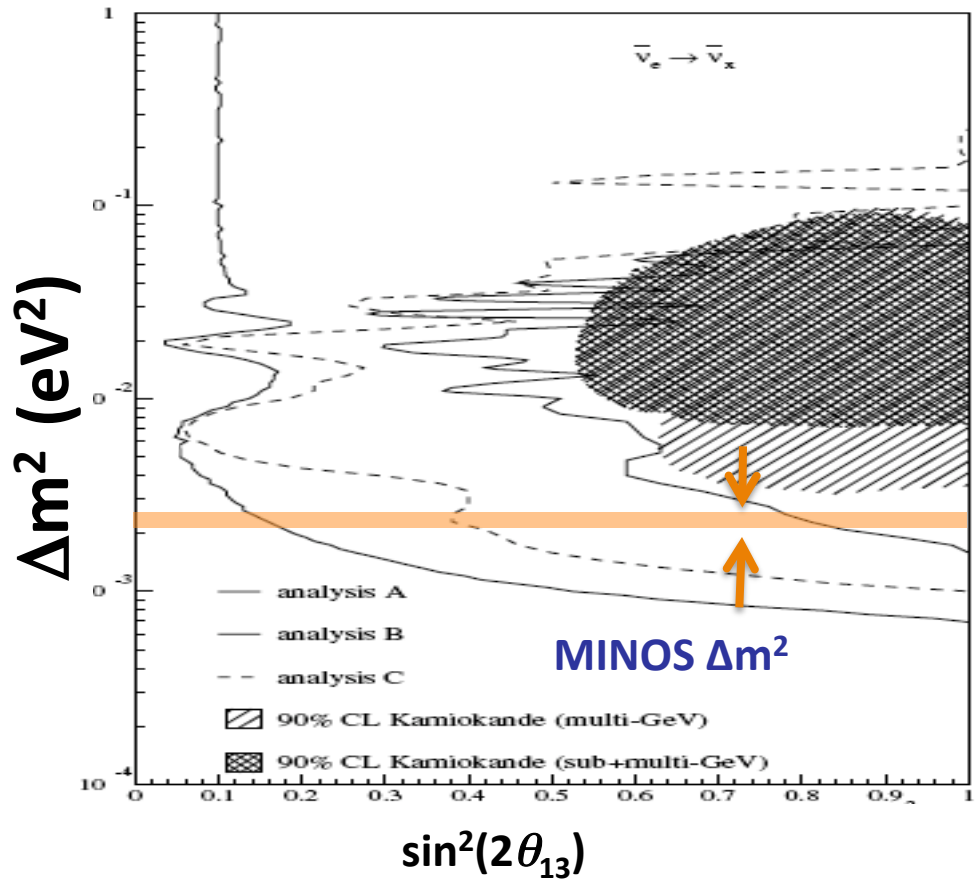
$\nu_\mu \rightarrow \nu_e$ Escapes Detection: Experiments Step Up The Search

Must find θ_{13}>0 to study CP

and Alan Wirzbicki
GLOBE CORRESPONDENT

WASHINGTON — Introducing Sonia Sotomayor yesterday as his first Supreme Court nominee, President Obama relished telling her up-from-poverty life story and highlighting her history-making ethnic roots. But he stressed that he picked her because of her intellect, judicial experience, and her determination "to approach decisions without any particular ideology or agenda."

CHOOZ limit $\sin^2(2\theta_{13})$<0.15
Eur.Phys.Journal C27:331-374, 2003



Search for θ_{13} via reactors (disappearance) or accelerators (appearance)

preme Court yesterday, selecting a woman who is a product of both New York City public housing and Ivy League universities, and who would become the first Hispanic and third female to serve on the high court.

Calling the 54-year-old Sotomayor "an inspiring woman," Obama praised her three-decade career as a corporate litigator, prosecutor, and federal appellate judge. But in his first chance to shape the closely divided high court, Obama also said her real-life experience filled his desire for a justice who has "a sense of compassion, an understanding of how the world works and how ordinary people live."

The president cited Sotomayor's humble upbringing, including her father's death when she was 9 years old, and the dia-

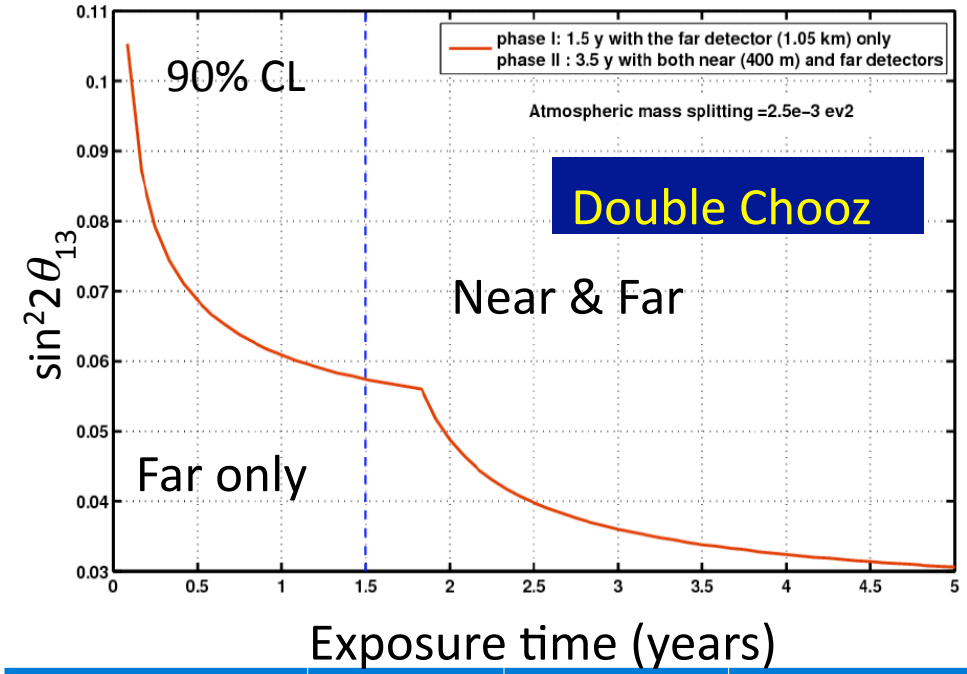
Experiments Under Construction

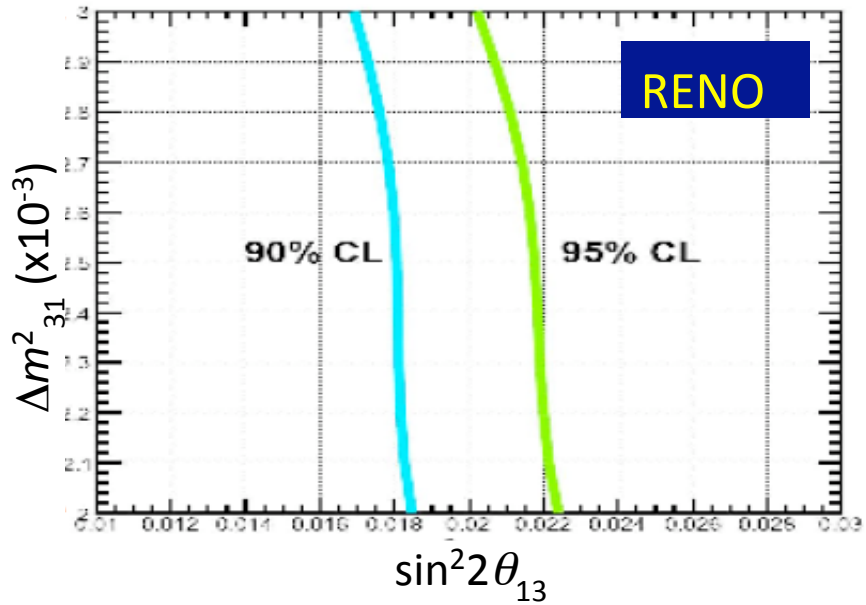
Exp't	Power (GWth)	Distance N/F (m)	Target N/F (t)
Double Chooz	8.6	400/1050	8.6/8.6
RENO	17.3	290/1380	16/16
Daya Bay	11.6 (17.4)	360(500)/ 1990(1620)	2x40/80

S. Kopp, Lepton-Photon 2009

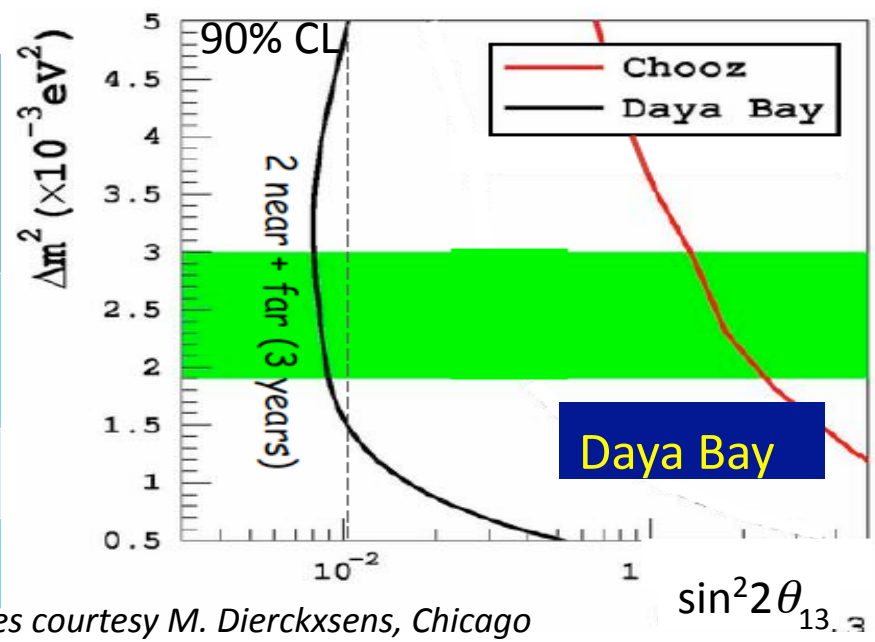
figures courtesy M. Dierckxsens, Chicago

Expected Sensitivities





Expt	σ_{stat} [%]	σ_{syst} rel. [%]	$\sin^2 2\theta_{13}$ > (90% CL)
Double Chooz	0.5	0.6	0.03
RENO	0.3	0.5	0.02
Daya Bay	0.2	0.4	0.01



S. Kopp, Lepton-Photon 2009

figures courtesy M. Dierckxsens, Chicago

ALL THE NU'S WITHOUT FEAR OF FLAVOR

The Japan Times

Samurai's Art: Original & Reproduced
Japan Sword

ISSN 8289-1956
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Tuesday, August 18, 2009

4TH EDITION ¥180

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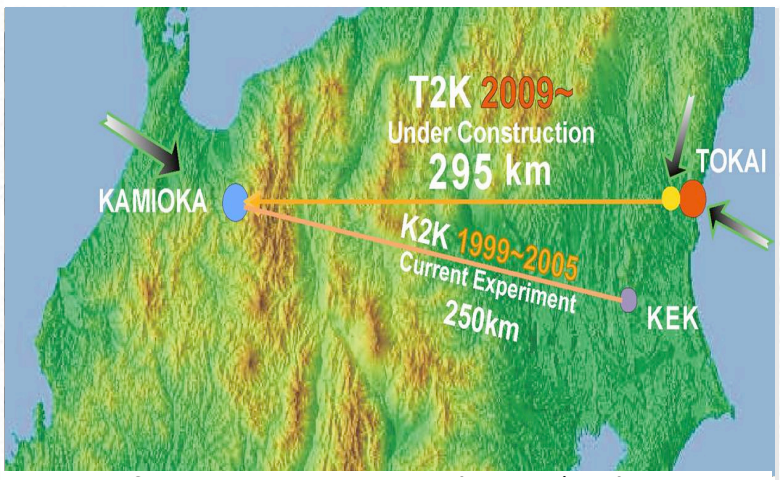
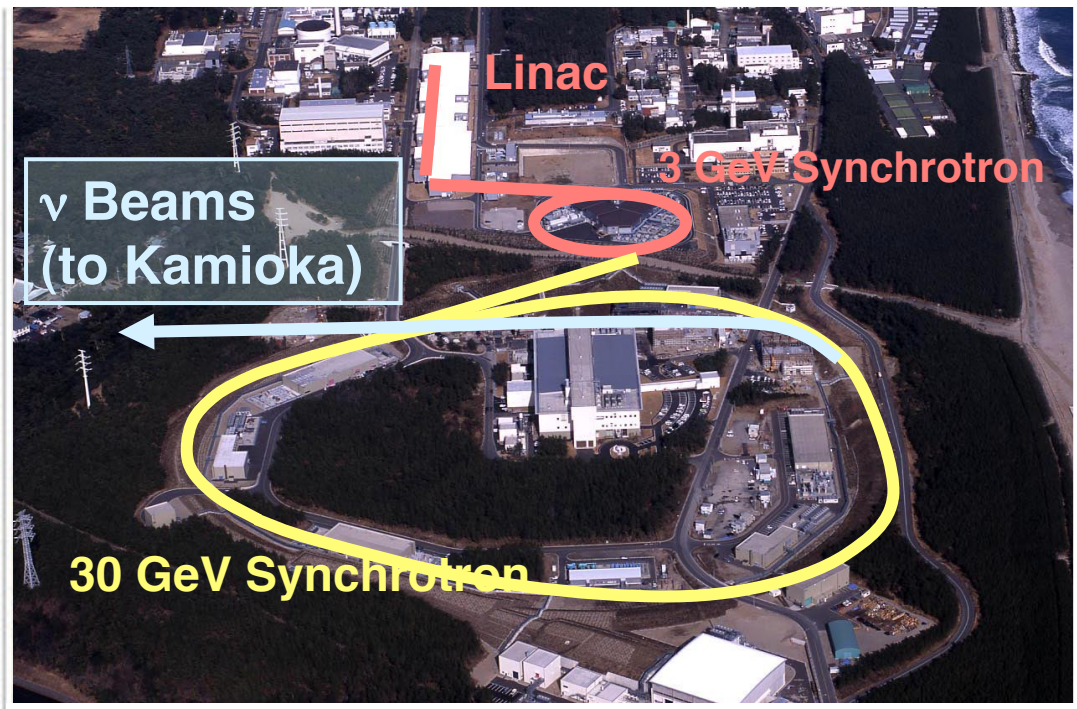
JPARC Launches $\nu_\mu \rightarrow \nu_e$ Search in 2009



100 kW in 2009-10, ramp to design of 700 kW operation in 2010 – 2011



figures courtesy T. Nakaya, Kyoto

Embattled Prime Minister Taro Aso, facing a national election this month, said Monday his policies helped the country out of recession after fresh data showed the economy logged its first growth in more than a year.

Aso, whose Liberal Democratic Party is trailing the Democratic Party of Japan in opinion polls ahead of the Aug. 30 election, vowed to strengthen the economic rebound to ensure that the public feels its benefits.

"Since I became prime min-

Earlier in the day, government data showed that the economy grew an annualized real 3.7 percent in the April-June quarter, meaning Japan officially emerged from recession, following Germany and France last week.

Aso's LDP-New Komeito government has launched a series of pump-priming packages to stimulate the economy and cushion the blow of unemployment, which hit 5.4 percent in June, close to its post-World War II high of 5.5 percent.

Aso said that despite the

ing cold water on consumer spending, which has just started to improve.

Overseas demand in April-June boosted GDP 1.6 percentage points, and domestic demand, including such components as consumer spending and capital investment, had a downward impact of 0.7 point.

Exports turned positive for the first time in five quarters, rising 6.3 percent and marking the fastest pace of growth since April-June 2002. Imports continued to fall, logging a 5.1 percent decline.

On the domestic front, ori-

KEK plan: long term upgrade to 1.66 MWatts

Democratic Party of Japan President Yukio Hatoyama displayed clear differences Monday in their parties' positions on whether to allow foreigners with permanent residency to vote in local races.

During an open debate hosted by the Japan National

mediately," Aso said, refusing to elaborate.

But Hatoyama said it is now time to consider granting foreigners voting rights at the local level.

"There are pros and cons and the DPJ is in the process of unifying its opinion right

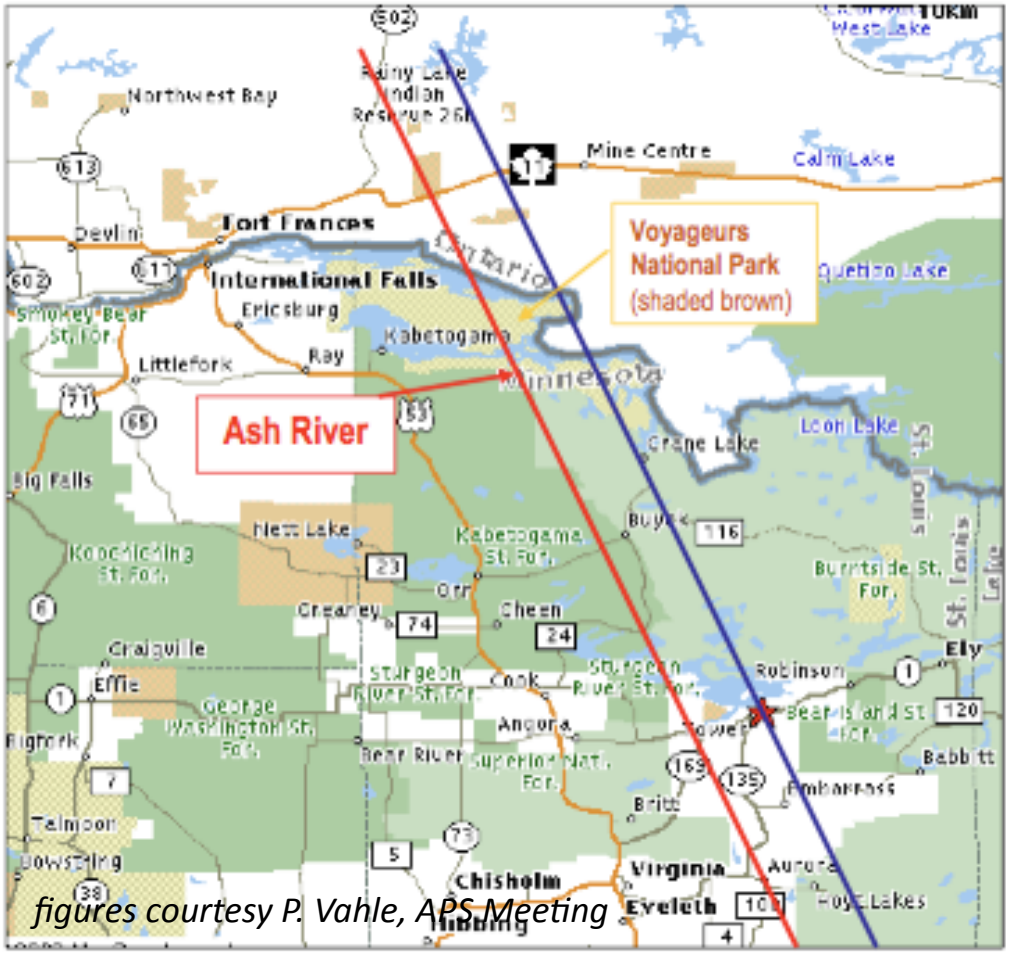
tious issue in the political world. While the conservative ranks of the LDP are strongly opposed, its coalition partner New Komeito is actively promoting this right.

Kokumin Shinto (People's New Party), which is expected to join hands with the DPJ if the main opposition party ousts the LDP-New Komeito coalition Aug. 30, has sided

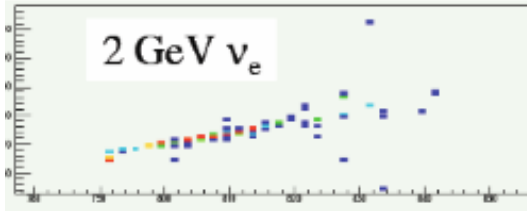
Shinto leader Tamisuke Watanuki, a veteran lawmaker who used to belong to the LDP.

Foreign nationals currently do not have the right to vote, and permanent foreign residents, especially Korean descendants of those who lived in Japan before and during the war and were forced to take Japanese citizenship at that time, have been fighting for local-level suffrage.

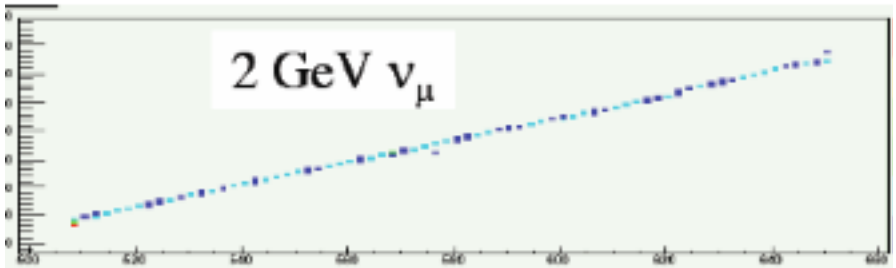
Off-Axis Beam from NuMI

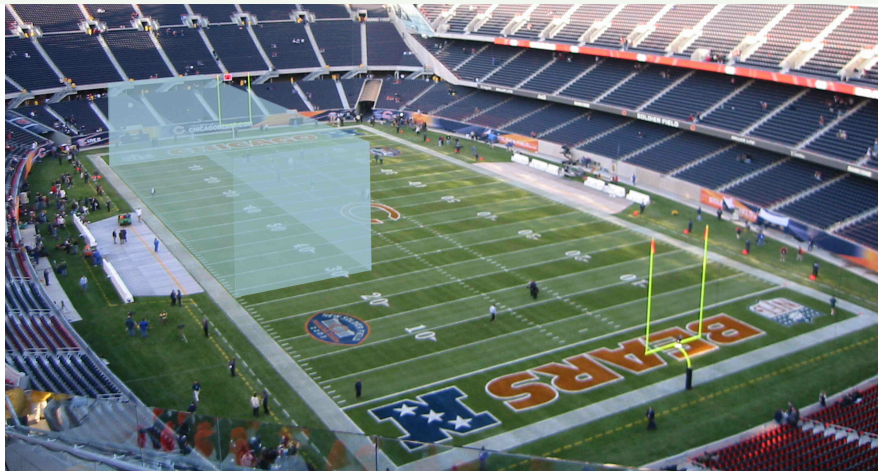


figures courtesy P. Vahle, APS Meeting



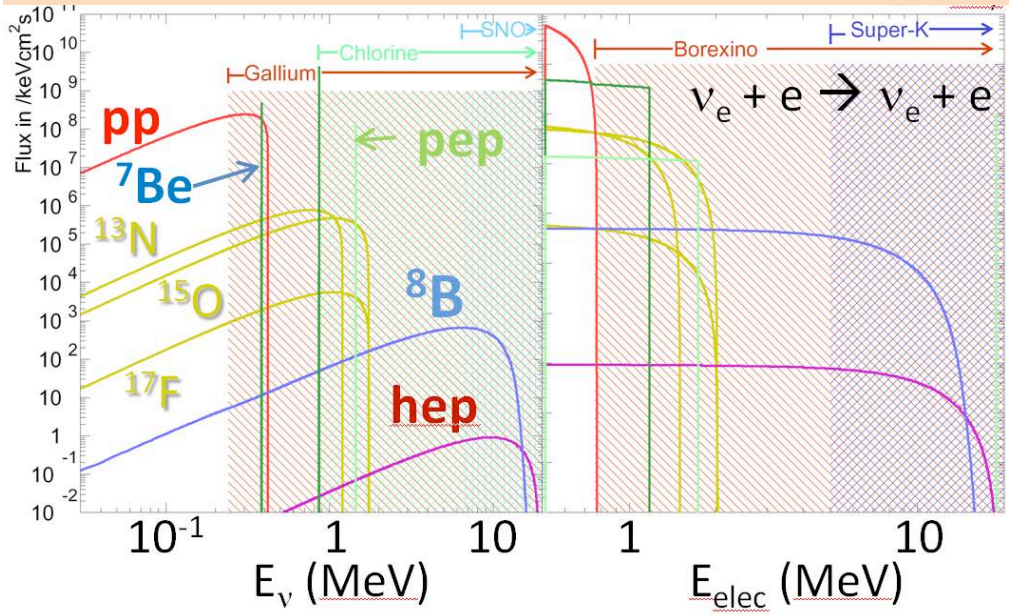
Events in the NOνA Detector





- NOνA civil construction start 6/2009! detector hall done 6/2010
- Far detector operational: 2.5kton (1/2012), 15kton (5/2013)

Neutrino Spectrum and Solar Neutrino Experiments



- **Radio-Chemical**
  - **Ga: SAGE, GALLEX/GNO (pp, ^{7}Be….)**

    $\nu_e + {}^{71}Ga \rightarrow e + {}^{71}Ge$: E_ν>235keV

    Meas: 66.1±3.1 SNU; R=0.52

    Pred: $127.9^{+8.1}_{-8.0}$ SNU$_{BPS08(GS)}$
  - **Cl: Homestake (^{8}B, ^{7}Be,..)**

    $\nu_e + {}^{37}Cl \rightarrow e + {}^{37}Cl$: E_ν > 816keV

    Meas: 2.56±0.16±0.16 SNU

    Pred: 2.46$^{+0.87}$ SNU

- **Real time Counter**
  - **H_2O: Kamiokande(ES) (^{8}B)**
  - **H_2O: Super-Kamiokande(ES) (^{8}B)**

    $\phi_{^8B}^{SK-I}$=2.35±0.02 ±0.08x10^{6}cm^2

    Pred: 5.94(1±0.11)x10^{6}cm^2$_{BPS08(GS)}$
  - **D_2O: SNO(CC, NC, ES) (^{8}B)**

    $\phi_{^8B}^{SNOIII(CC)}$=1.67$^{+0.05}_{-0.04}$$^{+0.07}_{-0.08}$x10^{6}cm^2

    $\phi_{^8B}^{SNOIII(NC)}$=5.54$^{+0.33}_{-0.31}$$^{+0.36}_{-0.34}$x10^{6}cm^2
  - **Scinti: Borexino (ES) (^{7}Be, ^{8}B)**

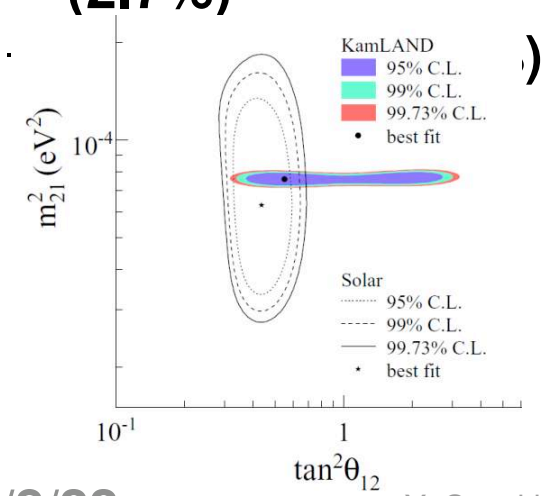
    ^{7}Be: Meas: 49±3$_{sta}$±4$_{sys}$ c/day/100ton

    ^{7}Be: Pred: 74±4 c/day/100ton$_{BPS08}$

KamLAND and Global Analysis (sol+KL)

KamLAND (KL)

- Reactor neutrino experiment
  - L ~ 180 km
  - E ~ a few MeV
- Good Δm^2 determination:
  - better knowledge of L/E
- KL only
  - **Δm^2 = 7.58 x 10^{-5} eV^2 (2.7%)**



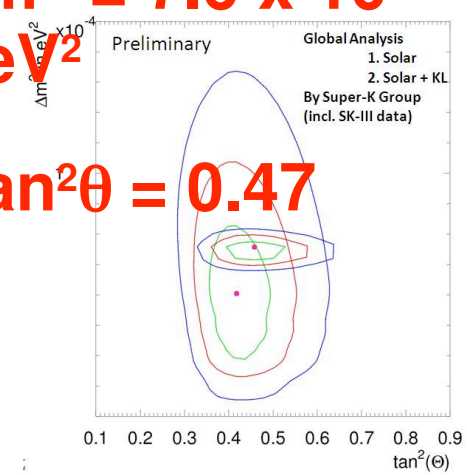
- **Solar+KL**

Global Analysis by SK-Group

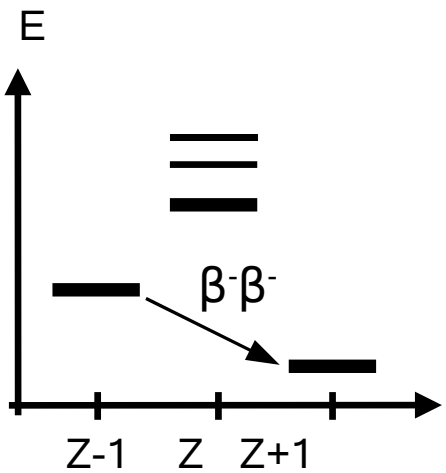
1) All solar, 2) All solar + KL including SK-III

m^2 = 7.6 x 10^{-5} eV^2

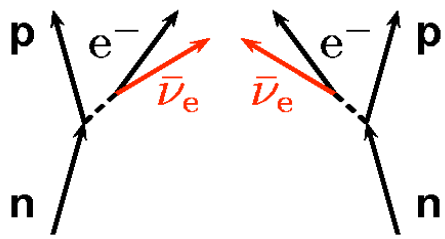
$an^2\theta$ = 0.47



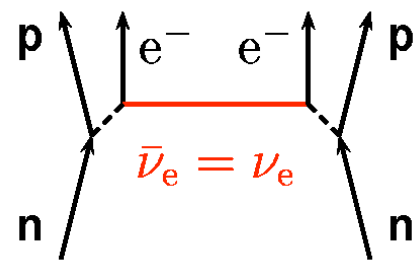
Double β decay



normal (2νββ)



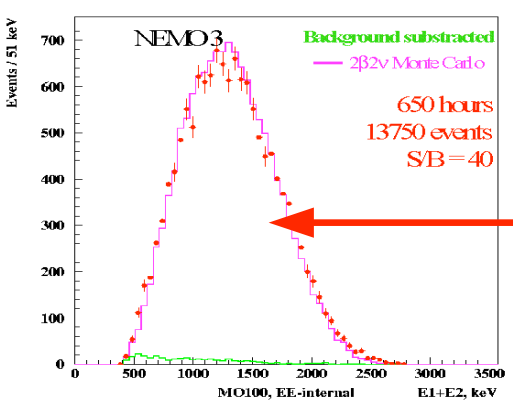
neutrinoless (0νββ)

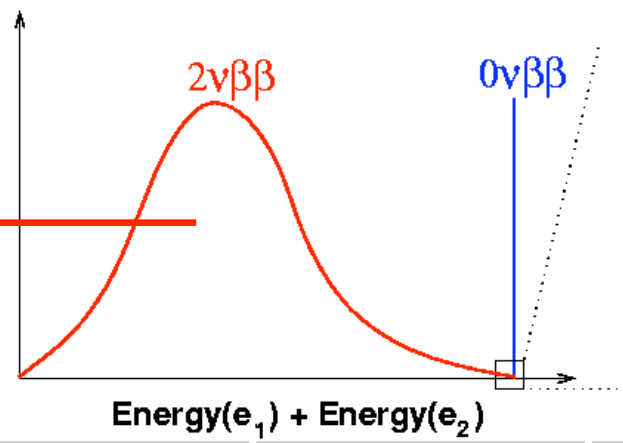


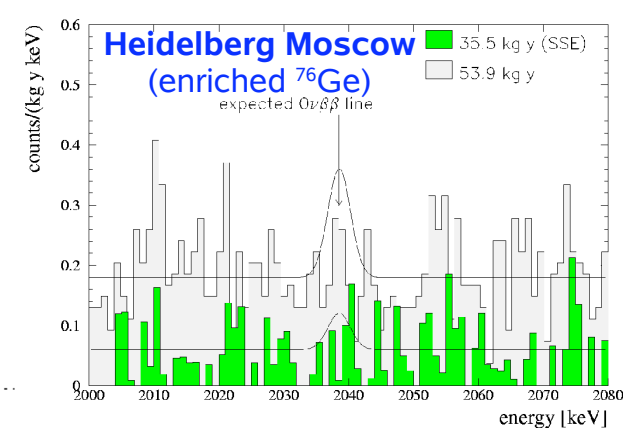
needed: a) $\bar{\nu} = \nu$ (Majorana)

b) helicity flip: $m(\nu) \neq 0$

or other new physics







Current and future double β decay experiments

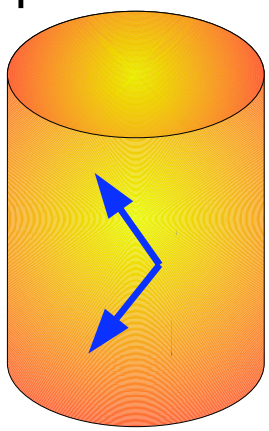
$m_{ee} \sim (1/\text{enrichment})^{1/2} \cdot (\Delta E \cdot bg/M \cdot t)^{1/4}$

⇒ mass → 1t, high enrichment, very low background *bg*

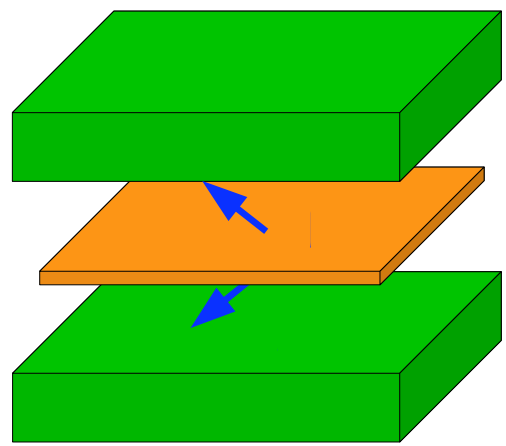
2 ways to measure both β-electrons:

semiconductor,
cryogenic bolometer
liquid scintillator

source
=
detector



tracking calorimeter



detector

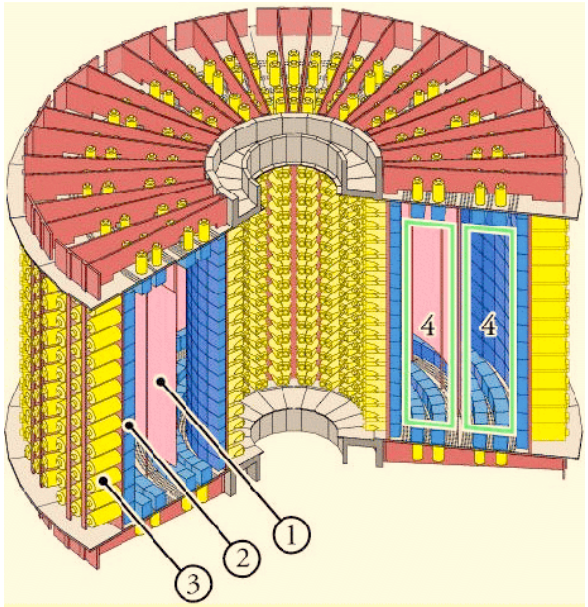
source

detector

running:	CUORICINO	running:	NEMO-3
setting up:	GERDA, CUORE, EXO-200	setting up:	SuperNEMO
planned:	Majorana, EXO, COBRA, SNO+ ..	planned:	MOON

Searching for 0νββ: NEMO3, CUORICINO

NEMO3: tracking calorimeter
(→ SuperNEMO with enr. ^{82}Se)

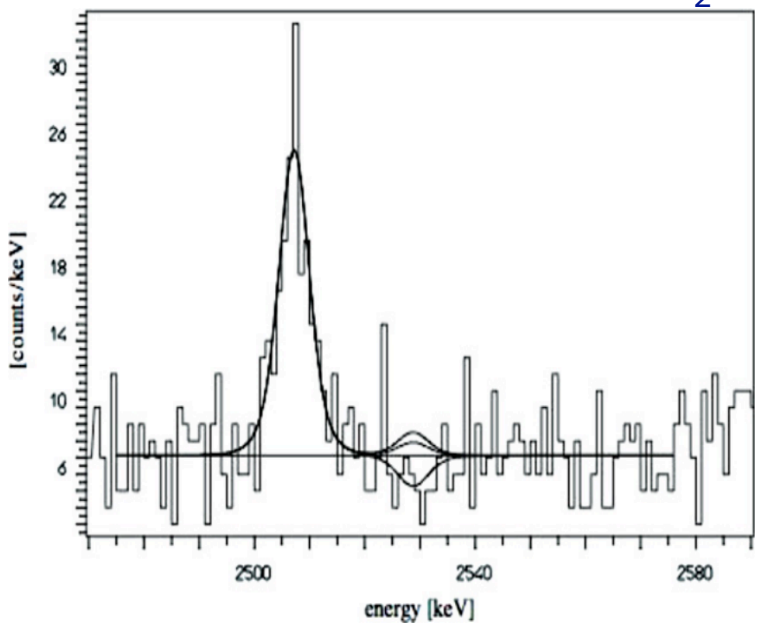


^{100}Mo: $T_{1/2}$ (0νββ) > 1.1 × 10^{24} y

⇒ m_{ee} < (0.45 – 0.93) eV

F Mauger, TAUP09

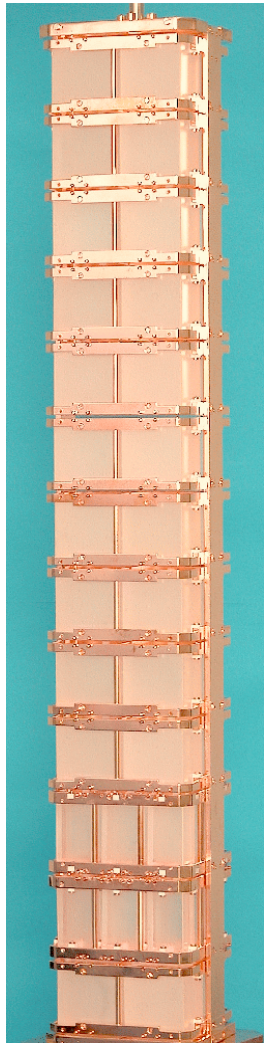
CUORICINO:
Te cryo bolometer)
(→ CUORE: 741 kg TeO_2)



^{130}Te: $T_{1/2}$ > 3 · 10^{24} y

⇒ m_{ee} < 0.19 – 0.68 eV

PRC 78 (2008) 35502



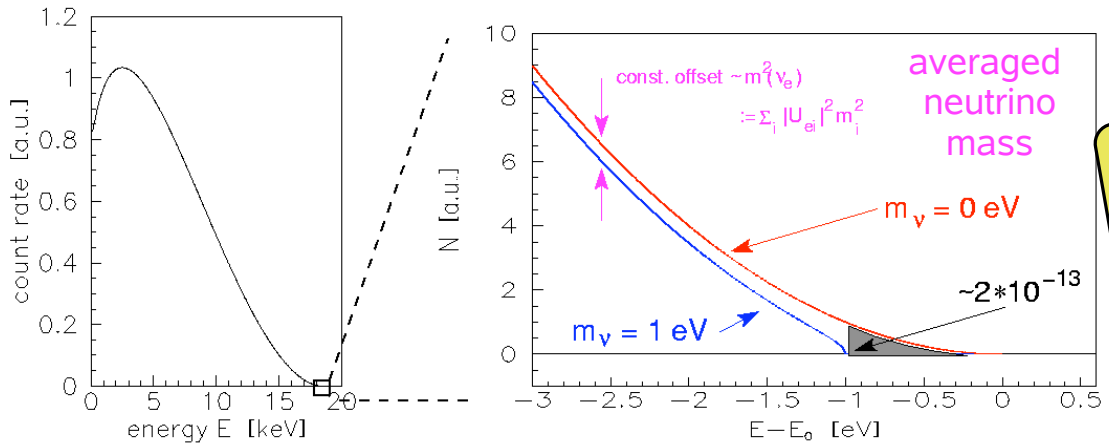
Direct determination of $m(\nu_e)$ from β decay

β decay: $(A,Z) \rightarrow (A,Z+1)^+ + e^- + \bar{\nu}_e$

β electron energy spectrum:

$$dN/dE = K\ F(E,Z)\ p\ E_{tot}\ (E_0-E_e)\ \Sigma\ |U_{ei}|^2\ \sqrt{(E_0-E_e)^2 - m(\nu_i)^2}$$

(modified by electronic final states, recoil corrections, radiative corrections)



E.W. Otten & C. Weinheimer Rep. Prog. Phys. 71 (2008) 086201

Need:
- low endpoint energy ⇒ Tritium ^3H, (^{187}Re)
- very high energy resolution &
- very high luminosity &
- very low background

} ⇒ MAC-E-Filter (or bolometer for ^{187}Re)

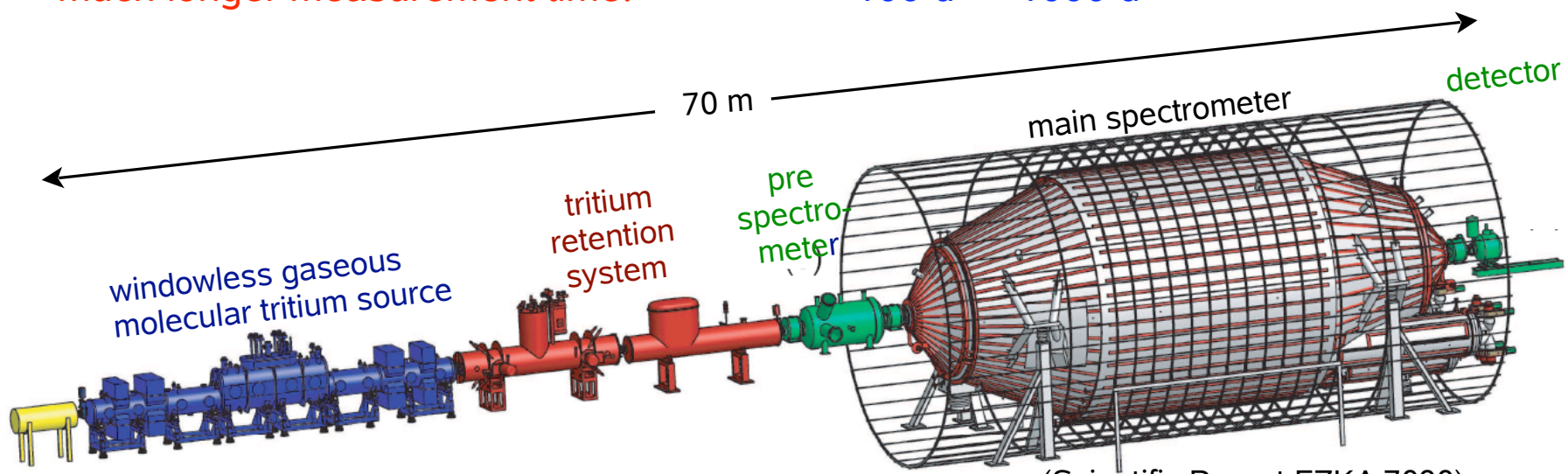
The Karlsruhe Tritium Neutrino experiment KATRIN

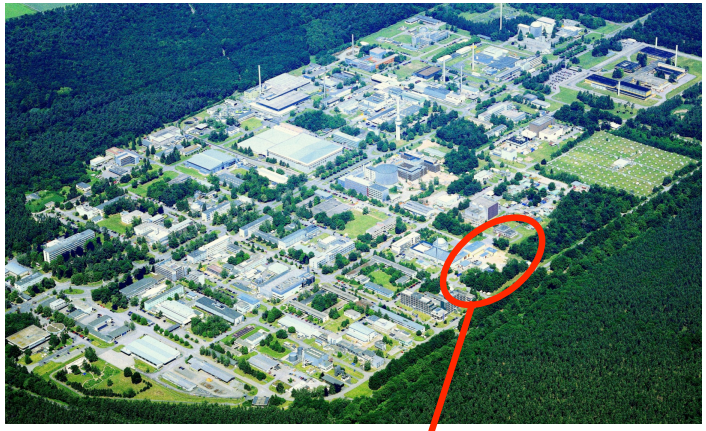
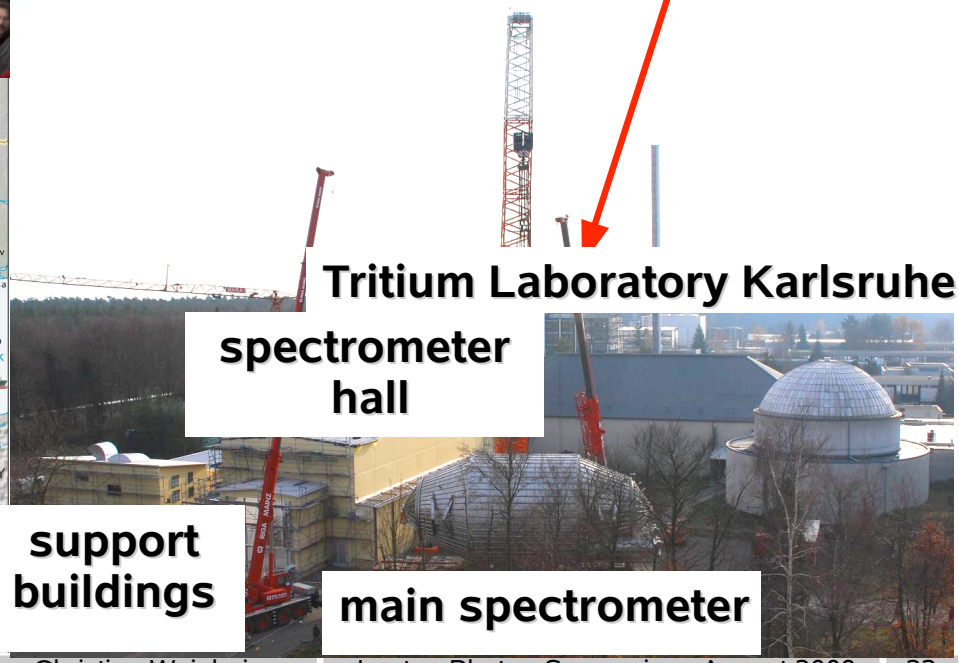
is being set up at the Forschungszentrum Karlsruhe

Physics Aim: $m(\nu_e)$ sensitivity of 0.2 eV (currently 2 eV)

- higher energy resolution: $\Delta E \approx 1$eV
  since $E/\Delta E \sim A_{spectrometer}$ ⇒ larger spectrometer
- relevant region below endpoint becomes smaller
  even less rate $dN/dt \sim A_{source} \sim A_{spectrometer}$ ⇒ larger spectrometer
- small systematics ⇒ windowless gaseous tritium source
- much longer measurement time: 100 d → 1000 d

} ⌀10m



(Scientific Report FZKA 7090)

Main Spectrometer – Transport to Forschungszentrum Karlsruhe