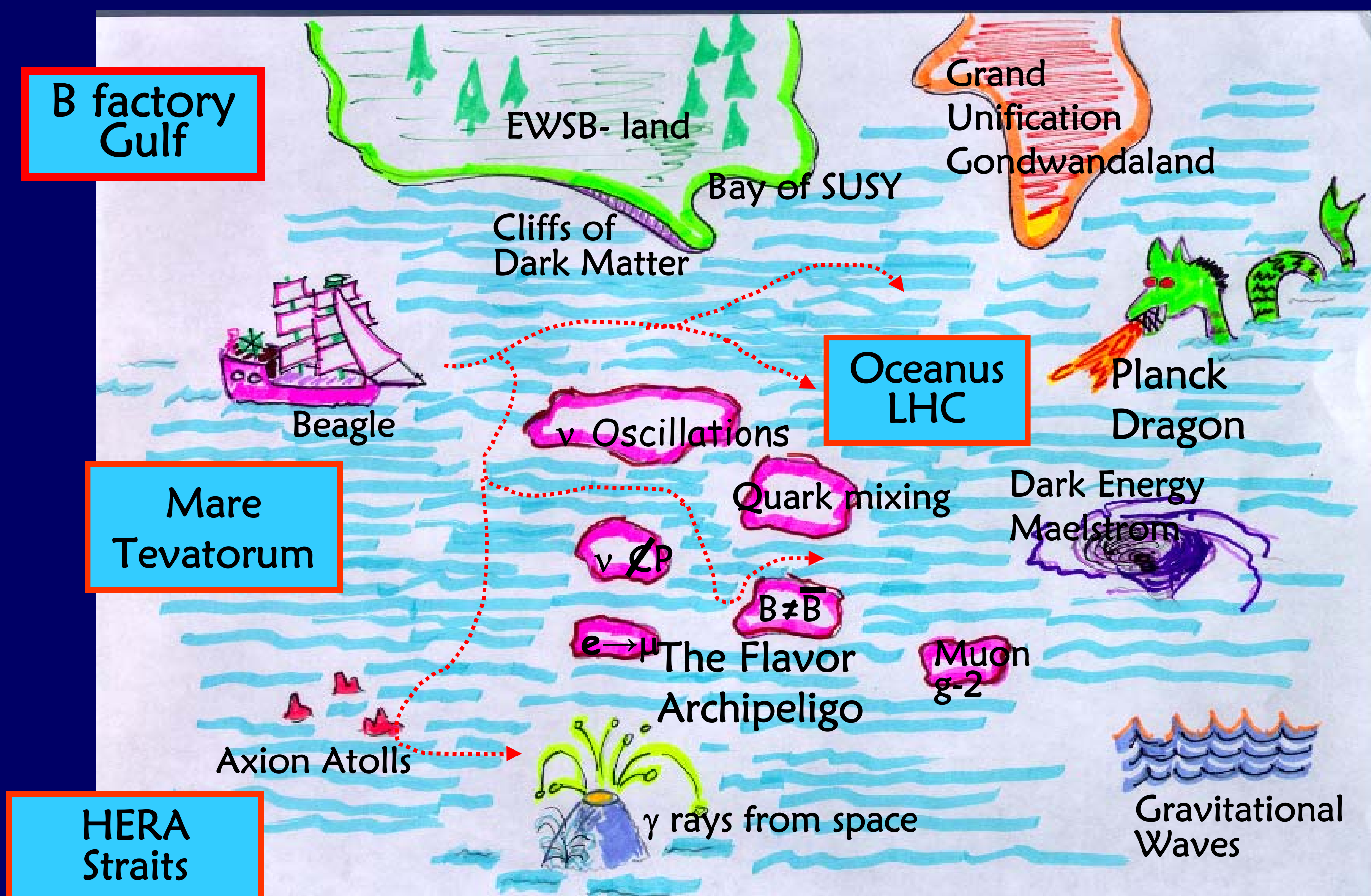
Rencontres de Moriond EW

Experimental Summary

Paul Grannis, March 13, 2010



Organization:

1. Quark and lepton flavors
2. Particles in the cosmos
3. The energy frontier

Most speakers started by thanking the organizers for inviting them to talk .
… I'm not so sure!

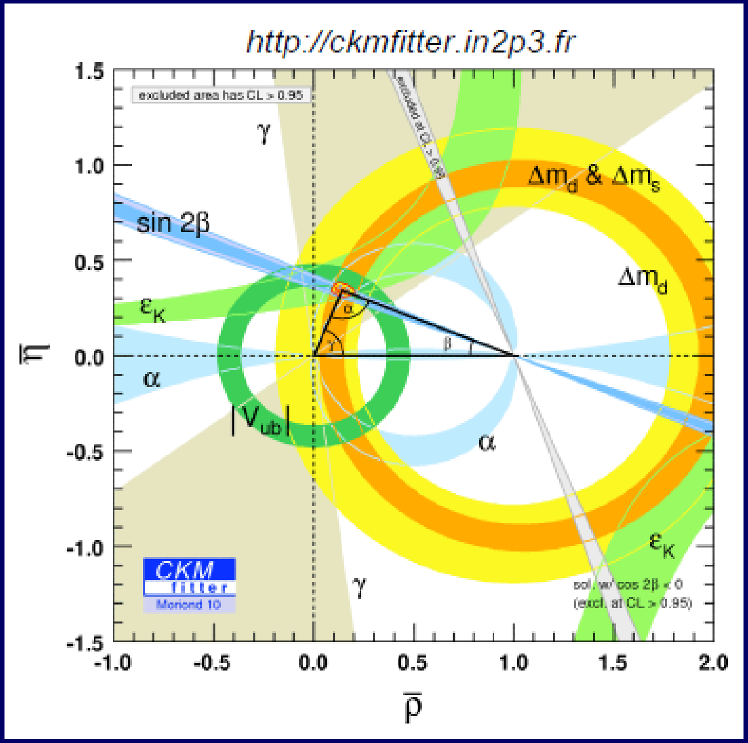
<u>The usual apologies</u>:

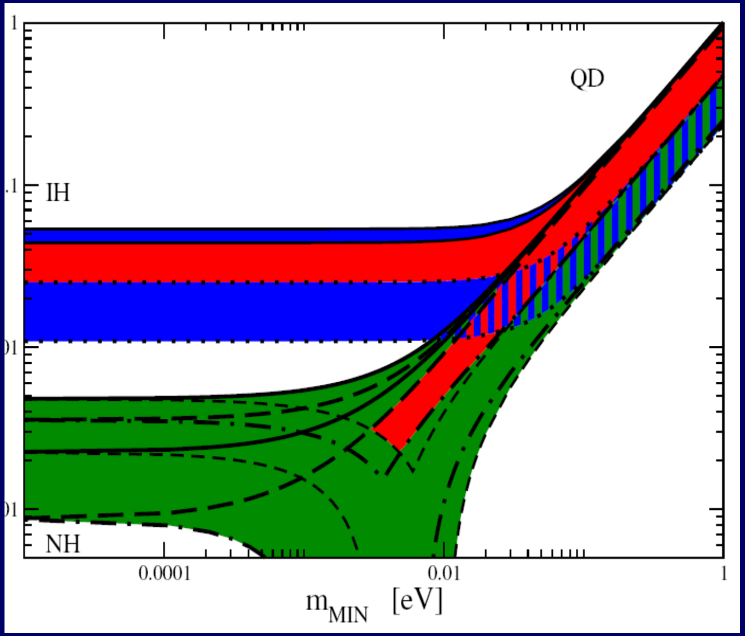
There were 75 excellent experimental talks (including YSF). I can only highlight a small fraction of the lovely results, so one should consult the individual talks and writeups! I started a talk on the important results from each presentation, but at 30 seconds/talk that seemed useless. So what I will present is a sampling of topics, chosen either because I felt they represent the important trends, or the results simply tickled my fancy.

And the disclaimer: I am not sure I am expert in <u>any</u> of the topics covered, but surely I am not expert in some. Apologies for any mangling of your arguments!

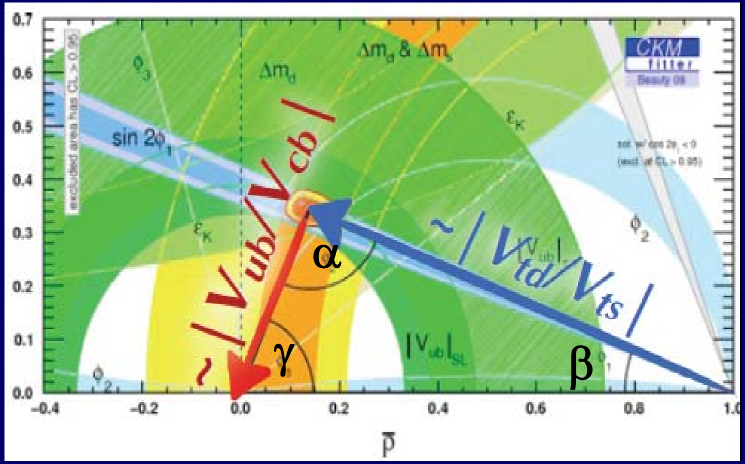
1. Quark and lepton flavors

Quark sector
Charged leptons
Neutrinos





1.1 Quark flavor: CKM parameters



We have had a decade of beautiful results from Belle and Babar that have refined our knowledge of the unitary triangle. Progressing from the golden mode and β determination, we are now, rather remarkably, closing in on the harder elements of the triangle.

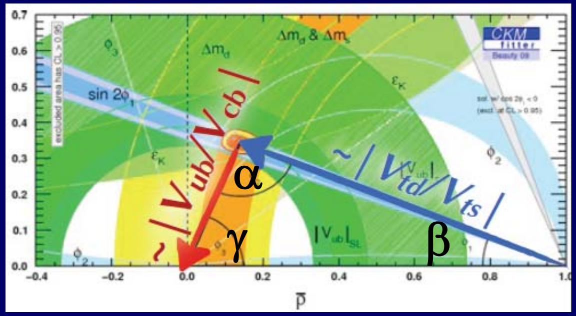
Our aim continues to be to overconstrain the triangle so as to sense contributions from new physics in loops.

The side |Vub/Vcb| is poorly measured. To fix it, BaBar and Belle measure b→q $\ell\nu$ (inclusive) or $B \rightarrow X_q \ell \nu$ (exclusive) with q=u,c. Inclusive is theoretically cleaner, but still need to get non-perturbative strong effects from data and correct for efficiency etc. Exclusive is experimentally cleaner but need form factors. The precision on |Vub/Vcb| is now ≤ 10%, but the exclusive and inclusive determinations differ somewhat.

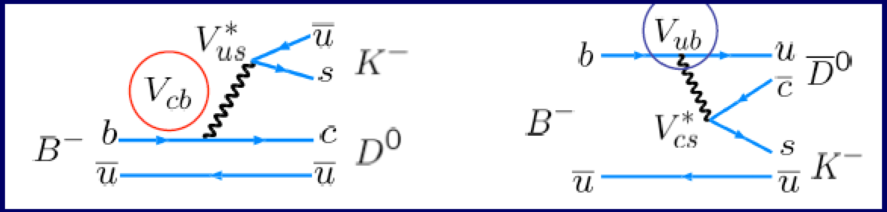
2010 Precision

	$\lvert V_{cb} \rvert$	$\lvert V_{ub} \rvert$
inclusive	1-2%	6-7%
exclusive	3%	10%
difference	~2σ	~1-2σ

1.1 Quark flavor: CKM parameters



The angle γ has been notoriously difficult to measure, and the efforts of BaBAR and Belle have been heroic. Can obtain γ from interference of 2 diagrams:



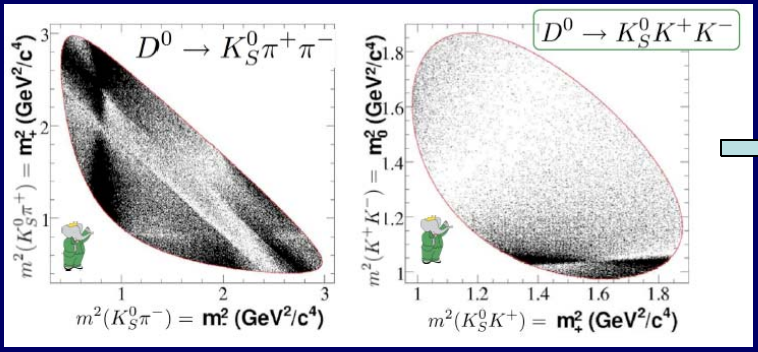
$B^{\pm} \to D K^{\pm}$

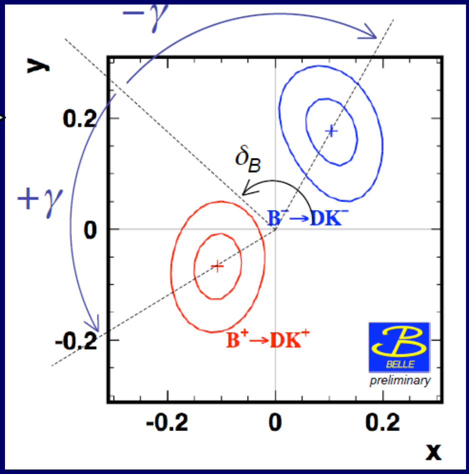
Use final states accessible from both D and $\bar{D}$ ($K_S \pi^+\pi^-$, $K_S K^+K^-$). Few 100 events from ~500M B's! Strong interaction amplitude ratio & phases measured in experiment.

Dalitz plot analysis gives values of

$(x,y) = f(V_{ub}/V_{cb},\ \gamma,\ \delta_{str})$

to give error ellipses for B^+ or B^- which depend on γ.

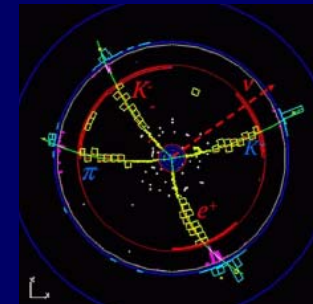




$\gamma = 69 \pm 20^{\circ}$ (frequentist) or $72 \pm 11^{\circ}$ (bayesian)

This represents improvement and is still statistics limited. However substantial further improvement awaits new measurements from LHCb (or SuperB)

1.1 Quark flavor: CKM parameters



Very clean kinematics at CLEO allow definitive study of D & $D_s^{(*)}$ mesons and allows measurement D, D_s decay constants for comparison with lattice:

$e^+ e^-$ collisions are clean; at charm threshold, they are really clean, plus with a definite initial quantum state!

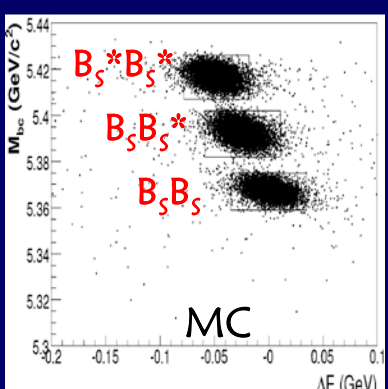
Accurate CLEO rates for $D_s \to \tau\nu$ and $D_s \to \mu\nu$, **and D decays,** determine D decay constants with accuracy better than lattice.

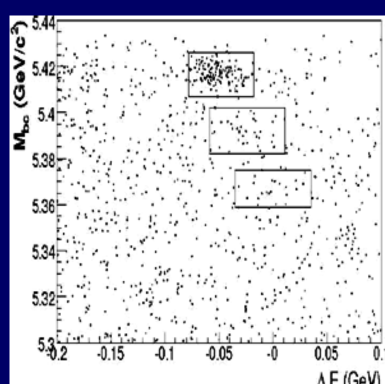
$$f_D = 205.8 \pm 8.5 \pm 2.5 \text{ MeV}$$
Lattice: $201 \pm 3 \pm 17$ MeV

$$f_{D_s} = 259.0 \pm 6.2 \pm 3.0 \text{ MeV}$$
Lattice: 241 ± 3 MeV

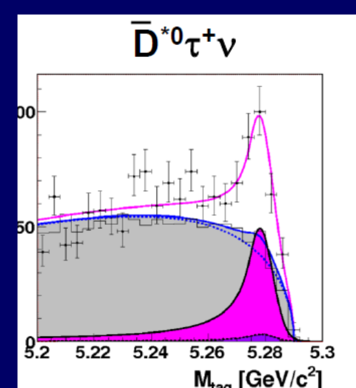
Measure strong phase in $D/\bar{D} \to$ hadrons for use in B factory CKM γ determination; reduce error from 8° to 2°. It will take LHCb some time to achieve these errors.

B_s studies from Belle at Υ(5S)

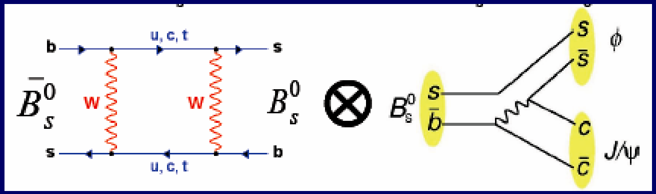




Exploration of $B_d \to \tau$ decays at Belle

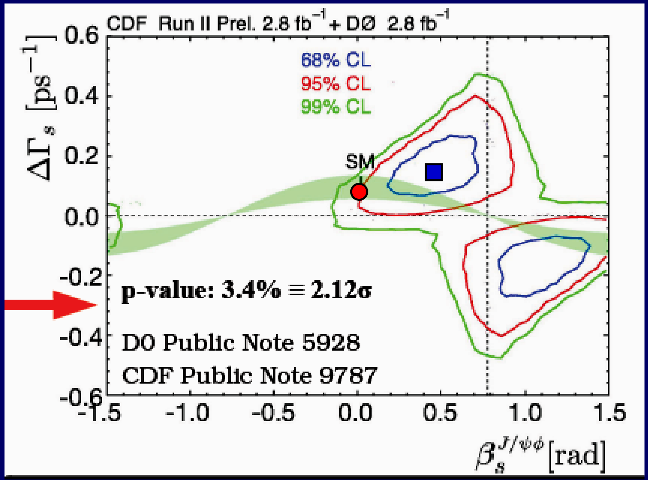


1.2 Quark flavor: CPV in B_s decays

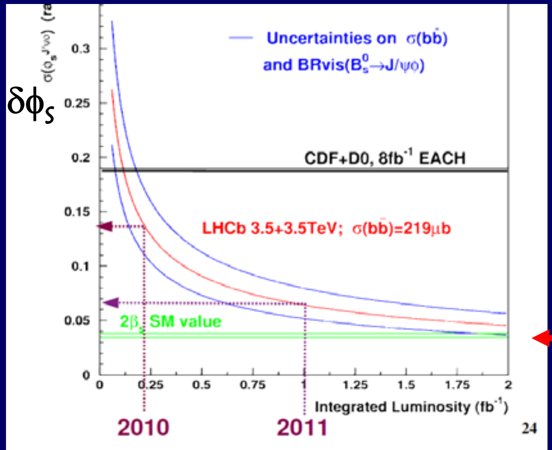


CPV in B_s system arises from interference between mixing & decay in $B_s \rightarrow J/\psi\ \phi$, where final state is mixture of CP eigenstates. The SM CPV phase ϕ_s is small (–0.04).

CDF and DØ measure differential rate as a function of decay angles& time. These involve amplitudes A_S (S= ⇈ ⇅ ⇊ combinations of J/ψ & ϕ polarizations), mass eigenstate parameters, initial flavor, known strong phases, 3 kinematic angles which can be determined event by event and the phase ϕ_s .



With 2.8 fb^{-1}, the CDF and DØ statistically dominated results agree. Results in $\Delta\Gamma_s$ vs. ϕ_s plane are 2.1σ away from SM. Additional data, analysis improvements, inclusion of semileptonic asymmetry, $D_s^{(*)}D_s^{(*)}$ modes, dimuon asymmetry will add further information.



This analysis illustrates that CKM physics using states like B_s in hadron colliders can add very important information not accessible at B factories.

The prospects for LHCb here are bright.

Some personal comments

As an outsider, I am impressed with the detailed and skilled analyses by the quark flavor collaborations. The methods and language remind me of my youth – Dalitz plots, spin-parity analyses, spectroscopy, the wonderful manifestation of Quantum Mechanics in meson mixing (but where are the Regge poles??)

There is truly a wealth of well-digested information whose relevance will continue to be important as we explore higher energies.

However, the current program is becoming asymptotic with most analyses now making only incremental improvements.

We should recognize the importance of precision tests for revealing new physics, but should also recognize that sensing that it is there and knowing what it is are different. Clearly one could do better at a super B factory, but it the main opportunity, for me, now is to go the next big step in energy to explore new physics directly.

1.3 Lepton flavor

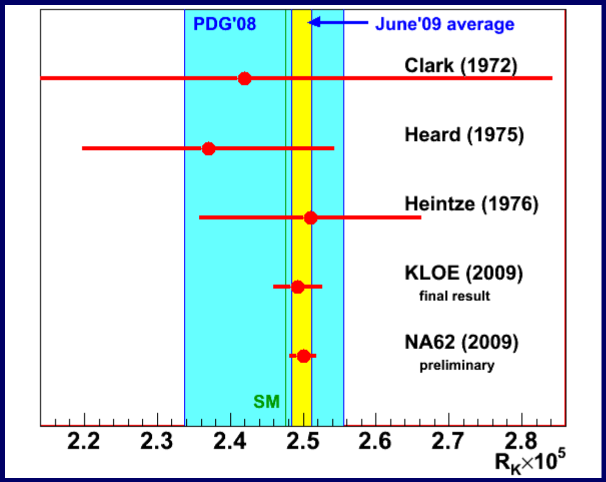
Lepton flavor violations

BaBar $\tau \to e/\mu\,\gamma$ limits ~ 3-4 x 10^{-8}

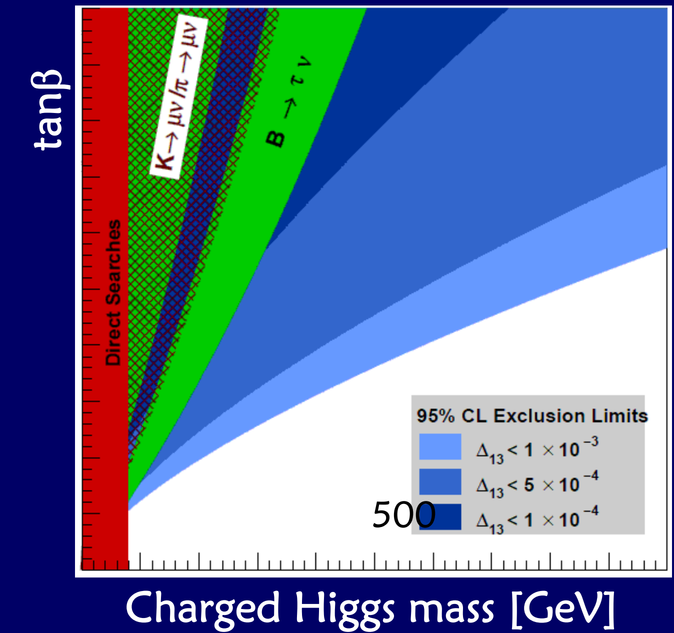
$\Upsilon(2S/3S) \to e/\mu\,\tau$ limits at ~3-4 x 10^{-6}

MEG First run for $\mu \to e\,\gamma$ has set a BR limit at 2.8×10^{-11}, approaching MEGA limit. Ultimate goal is 10^{-13}.

NA62, based on 40% of data set measures $R_K = B(K_{e2})/B(K_{\mu 2})$, in agreement with SM.



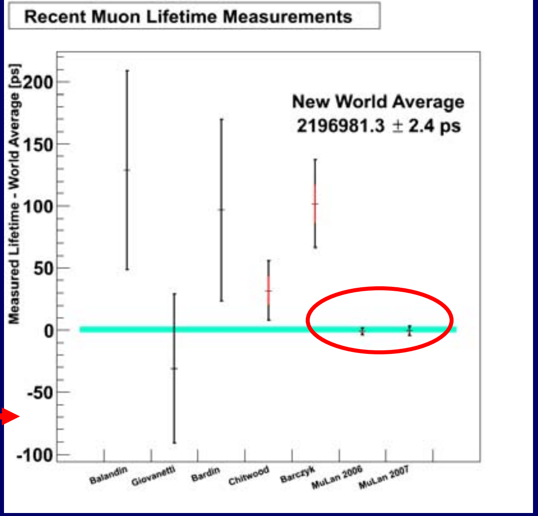
In models with slepton mixing Δ_{13} above 10^{-3}, these set very stringent bounds on charged Higgs.



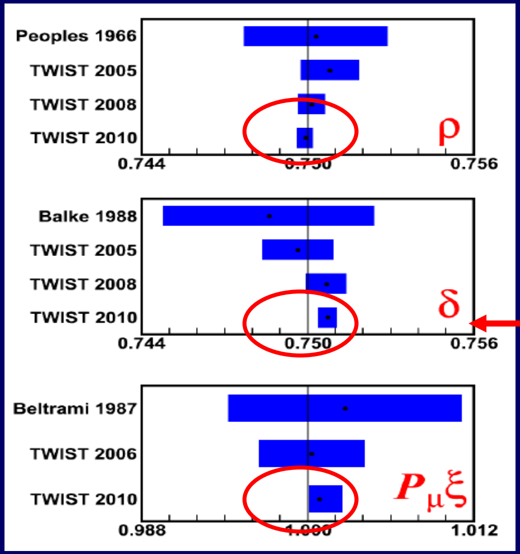
Studies of lepton universality violations are setting world class limits on new physics beyond the SM.

1.4 Lepton precision measurements

Hadron and lepton colliders may talk about "precision measurements", but …



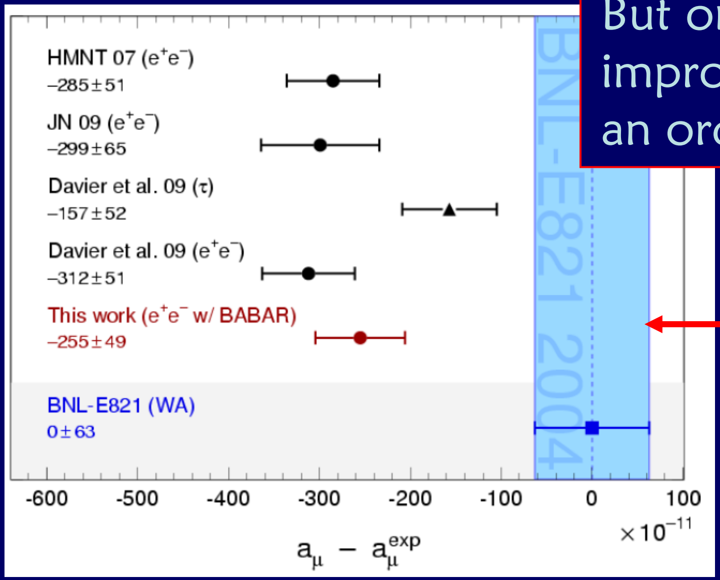
New measurement of τ_μ (G_F) by MuLan collaboration gets 1.3 ppm.



And new measurement of Michel parameters for muon decay by TWIST collaboration is at 10^{-4} level.

These measurements enable new searches for BSM phenomena.

But on a purely experimental basis, any time you can improve the precision of a fundamental measurement by an order of magnitude or more, you should go for it!



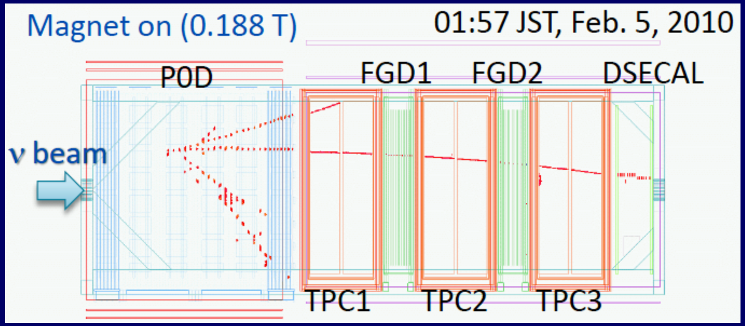
The truth of this axiom has been shown by the E821 (g_μ-2) measurement which has stimulated many models for BSM physics. New analyses shown here of the hadronic vacuum polarization corrections based on recent KLOE and BaBar data.

1.3 Neutrino MNS parameters

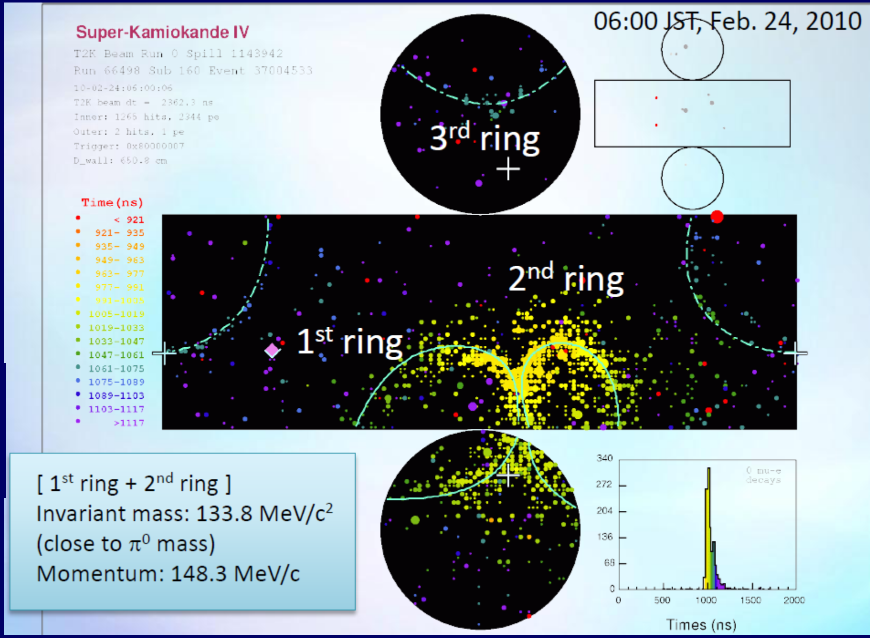
Congratulations!

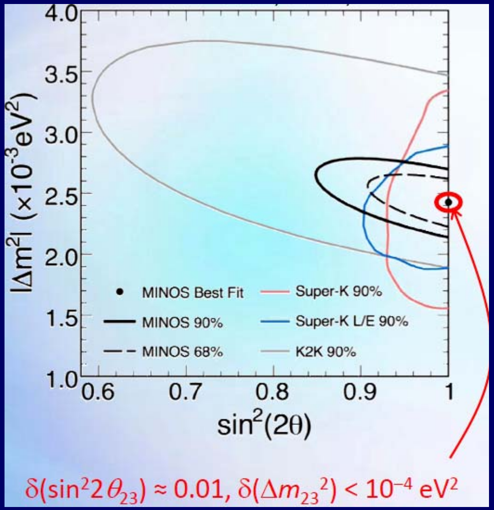
T2K is now online to seek ν_e appearance and ν_μ disappearance on 295 km baseline.

1st near detector event CC inelastic



1st far detector event in SuperK





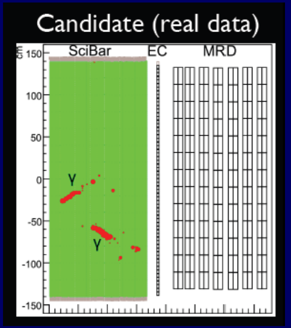
$\sin^2(2\theta_{13})$ expected limit is $\sim 10^{-2}$

Major bknd for ν_e appearance is NC π^0

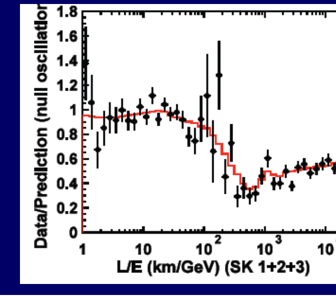
Major effort underway by SHINE group to measure secondary production spectra in the T2K target.

SciBoone designed to measure ν cross sections for T2K (particularly the NC 1 π^0).

Find $\sigma(NC\pi^0)/\sigma(CC)$ -- agrees w/ MC and higher energy data.



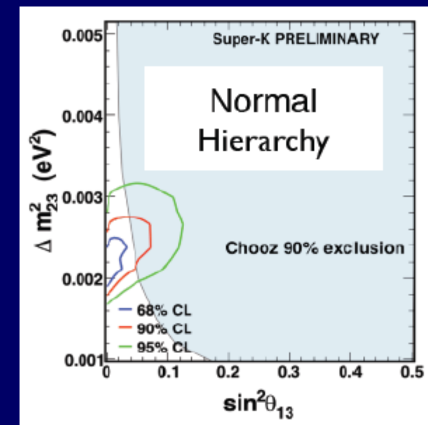
1.3 Neutrino MNS parameters

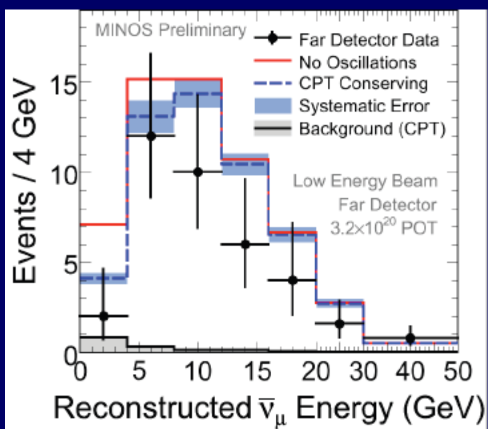


SuperK analysis complete through 2008 data. 2 flavor oscillation results updated. 3 flavor oscillation analysis gives 90% C.L. limits:

normal : $\sin^2\theta_{13} < 0.04$ ($\sin^2 2\theta_{13} < 0.015$)
inverted : $\sin^2\theta_{13} < 0.09$ ($\sin^2 2\theta_{13} < 0.033$)

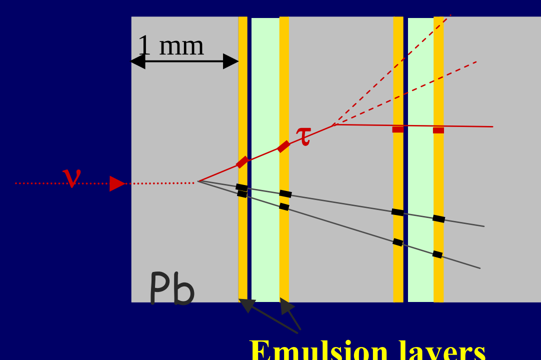
(Approaching Chooz limit)

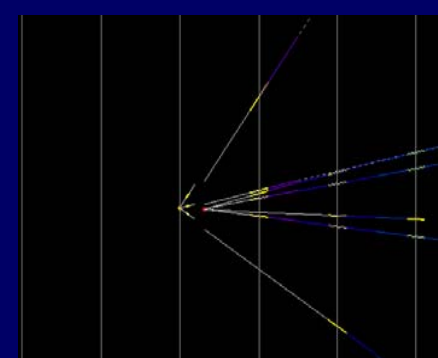




MINOS measurement using $\bar{\nu}_\mu$ in ν_μ beam sees an event deficit relative to ν_μ. Expect 58.3±8.4, see 42 (1.9σ) Recent run with $\bar{\nu}_\mu$ production mode to explore this.

OPERA in Gran Sasso beam from CERN using emulsion stacks in Pb sandwich has recorded ~1400 ν interactions. No ν_τ seen yet. Event display is D^0 4-prong.

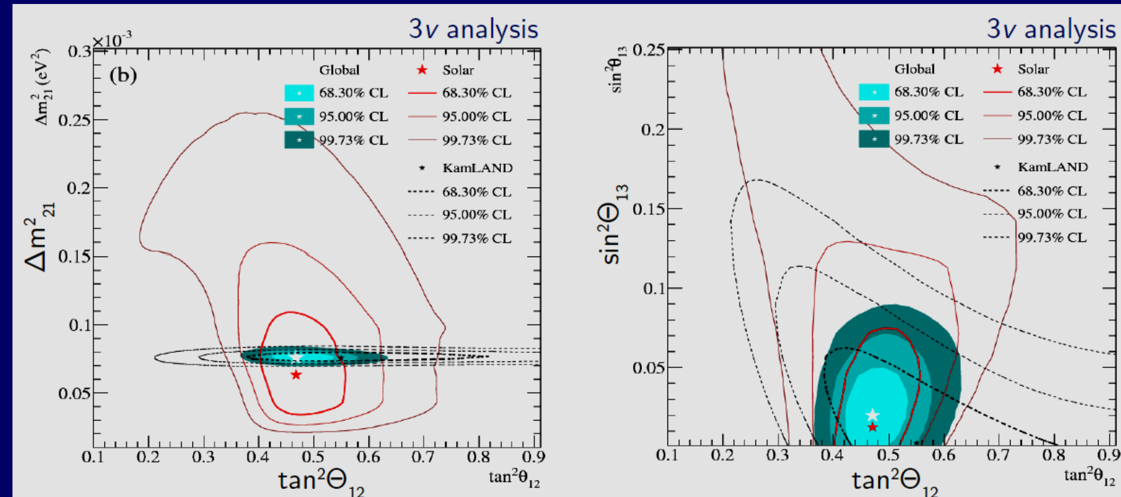




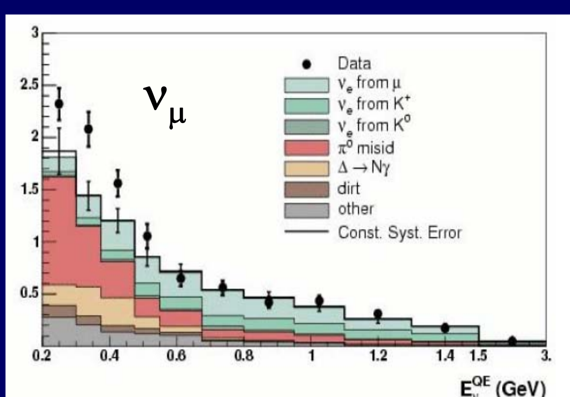
1.3 Neutrino MNS parameters

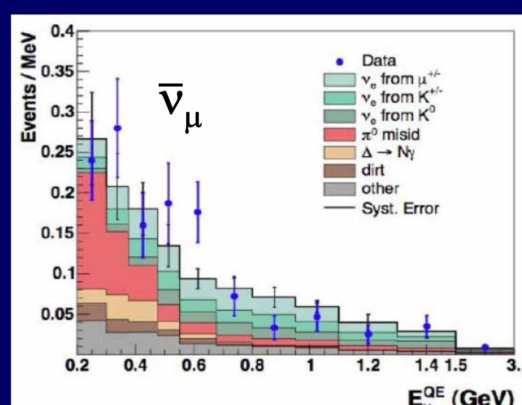
Combined fit of SNO, Kamland and other solar ν expts, allowing $\sin^2(2\theta_{13})$ to float. The good news is that the minimum in the fit is not at exactly zero!

$\sin^2(\theta_{13}) \approx (2\pm2)\times10^{-2}$ or <0.081 at 95% C.L. (n.b. θ, not 2θ)



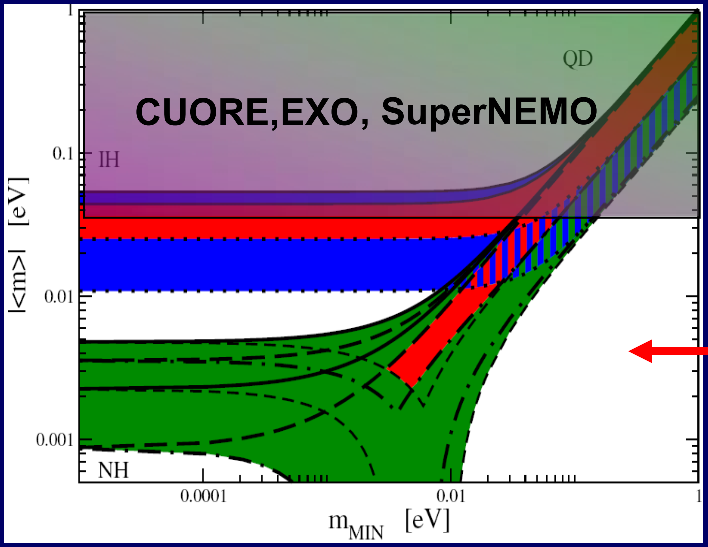
A new SuperK fit to solar mixing gives:
$\sin^2\theta_{12}=0.30$ and $\Delta m^2=6.0\times10^{-5}$ eV^2



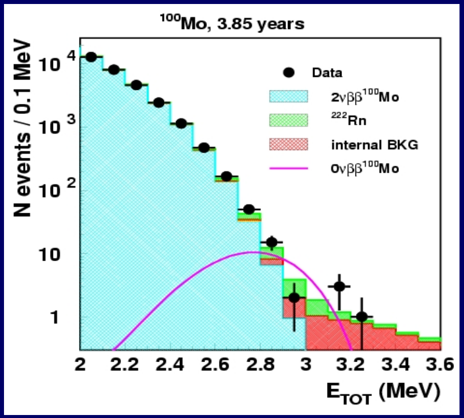


MiniBoone ruled out LSND eV^2 oscillations but found excess production for low energy ν_μ. Subsequent $\bar{\nu}_\mu$ study does not see such an excess. Continue running anti-neutrinos.

1.4 Double β decay



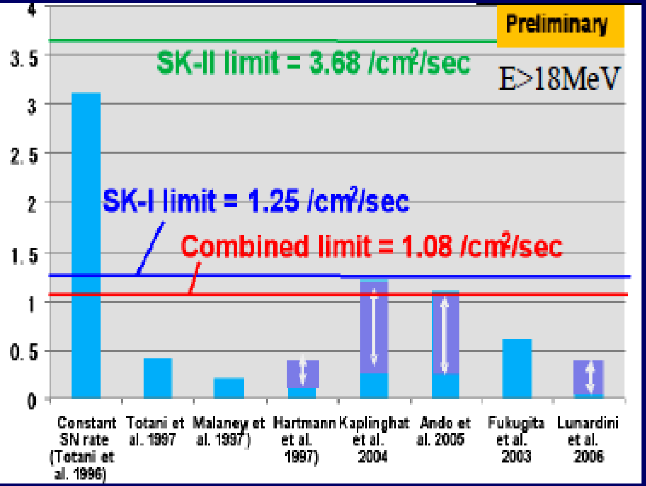
End point spectrum from NEMO-3 gives:
$\langle M_\nu \rangle < (0.45 - 0.93)$ eV



Next generation experiments (CUORE, SuperNEMO, EXO) aim at mass limits in range 40 – 100 meV, thus getting into the range of the inverted mass pattern.

1.5 Supernova relic neutrinos

Backgrounds in SuperK from reactors and atmospheric ν's give window to search for background ν's from galactic supernovas in 10 – 30 MeV region. Limits are now cutting into model space.



There are exciting prospects for observing ν's from nearby supernovae, giving opportunities to deduce neutrino properties and advance SN models.

Some personal comments

Neutrino physics is opening an era of great promise, with new facilities now underway or being planned. The big payoffs will come in finding whether neutrinos are Majorana or Dirac, measuring absolute neutrino masses, and in discovering CP violation in the neutrino matrix.

We will need to be a little patient however as there are steps on the way. While measuring the MNS matrix elements to higher precision is useful, in itself it is not worth heroic efforts. But for the near term this is critical as we need to know the value of θ_{13}. Combinations of running or near future experiments could achieve this. Only when that happens can future experiments be planned to address the really interesting portion of the program.

The coming of age of <u>precision</u> neutrino experiments makes particle physics a 'three legged stool' with each leg (hadron colliders, lepton colliders and neutrinos) essential to develop a coherent view of the microscopic world.

2. Particles in the cosmos

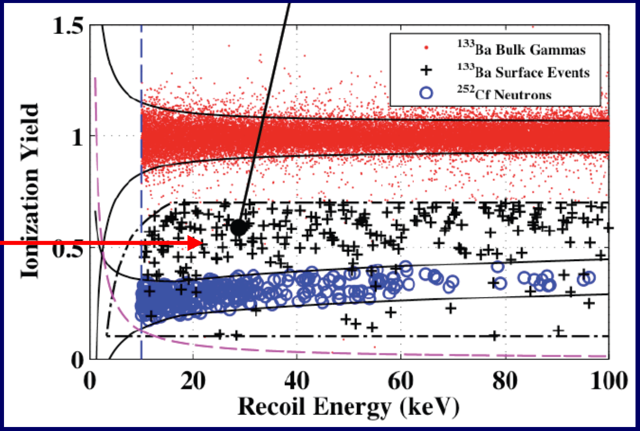
Dark matter

Astroparticles

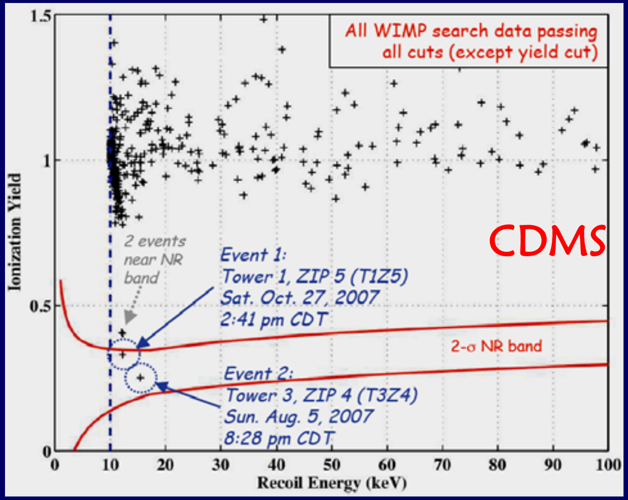
2.1 Dark matter searches

Cosmological observations indicate that DM is cold, thus due to heavy particles.

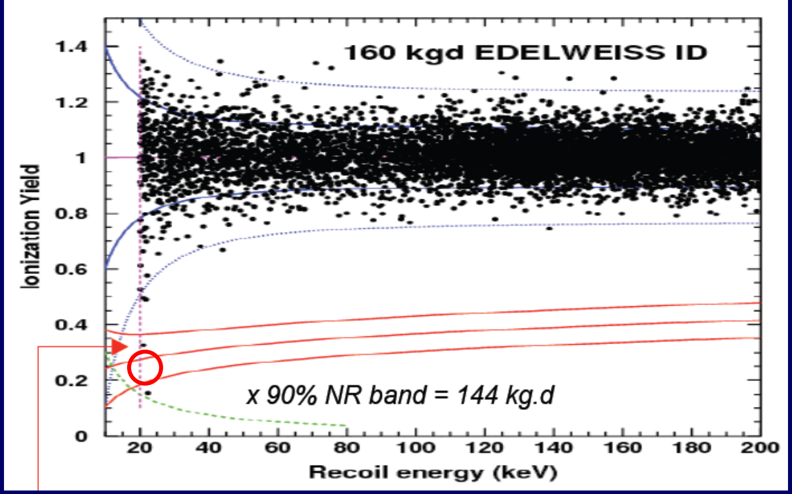
CDMS and Edelweiss II 5 kg Ge detectors reported here on 194 and 160 kg-day exposures. Both measure the phonon (heat) signal which is corrected to give the nuclear recoil energy E_R, and the ionization energy E_I. Discrimination against γ's is given by cuts on $\mathcal{Y}=(E_R/E_I)$; neutron background is reduced by shielding, event topology and material purity. γ's near surfaces in low response regions are the main backgrounds.



2 events; 23% prob for bknd



1 event; 0.23 exp. bknd

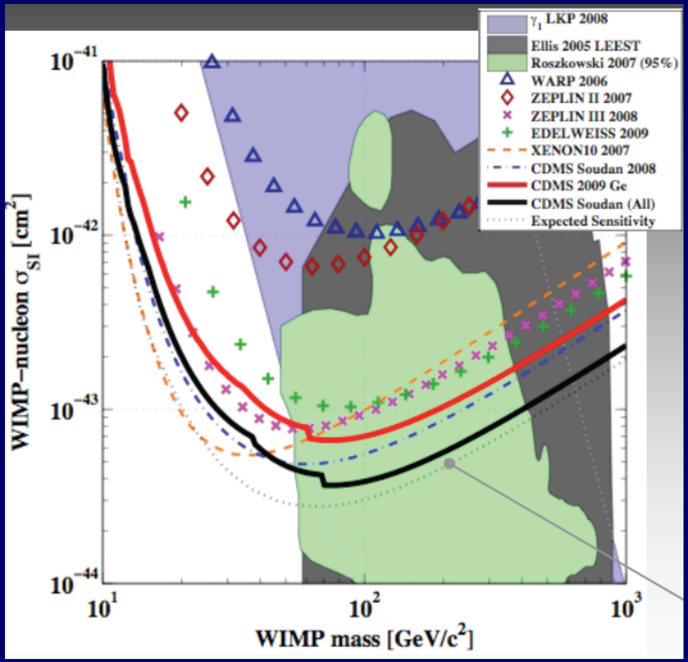


Recall that the E_R distribution is exponentially falling, so clustering at low E_R is ~OK.

2.1 Dark matter searches

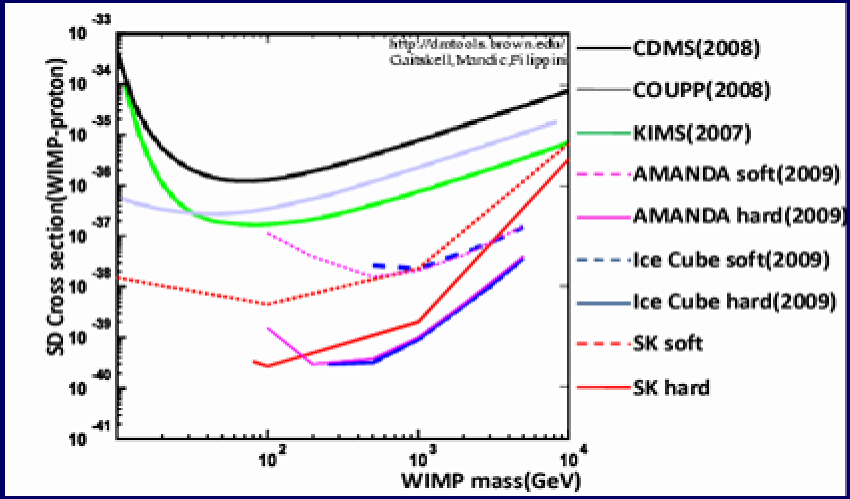
Mass-cross section contours show 90% limits vs. mass and XS, now well into the region of expected signals from Susy.

Next generation Ge detectors are being planned at the 15 kg scale.   Xe detectors have come to age, and we hope for larger ones.



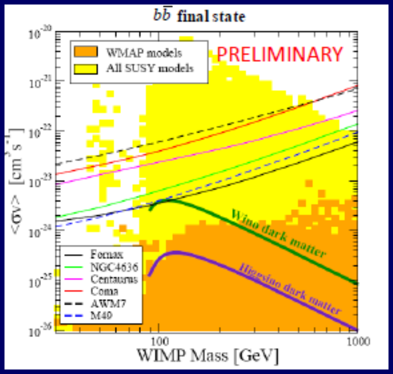
WIMPs can be trapped in the interior of the sun, and ultimately will annihilate:
'Hard' = $\chi\chi \rightarrow WW$ or 'Soft' = $\chi\chi \rightarrow bb$:

Neutrinos from the b's or W's can be observed in deep detectors on earth. SuperK and IceCube have set limits in complementary WIMP mass regions.



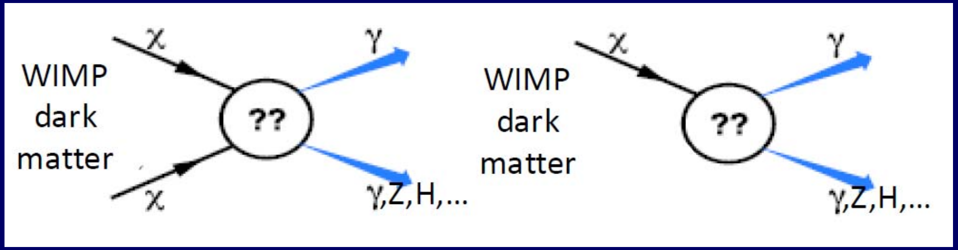
2.2 Cosmic γ probes for DM

Fermi LAT, using 11 months of data (expected lifetime of experiment is 10 years), has sought γ's from several potential astrophysical concentrations of DM, looking for DM annihilations to γ's. (Fermi spectrum is lower than Egret's in the 1 – 100 GeV range.)



- Selected 6 galactic clusters with high X-ray emission
- Galactic halos at all red shifts
- Low luminosity (high DM) dwarf galaxy companions to large galaxies

Fermi has searched for spectral lines from DM interactions or decay:

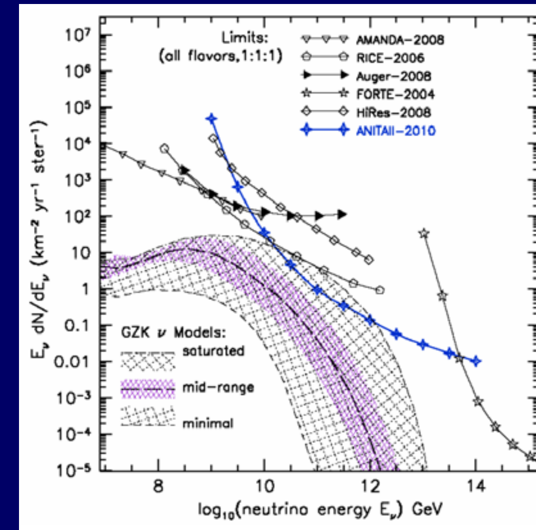


The current search limits typically fall well above most model predictions for DM induced γ's.

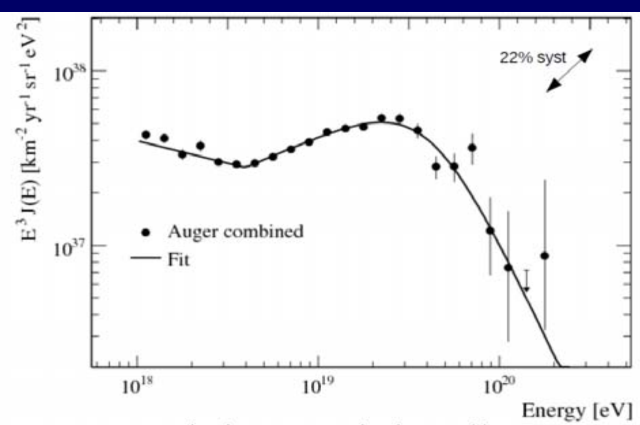
2.2 Cosmic SM particles

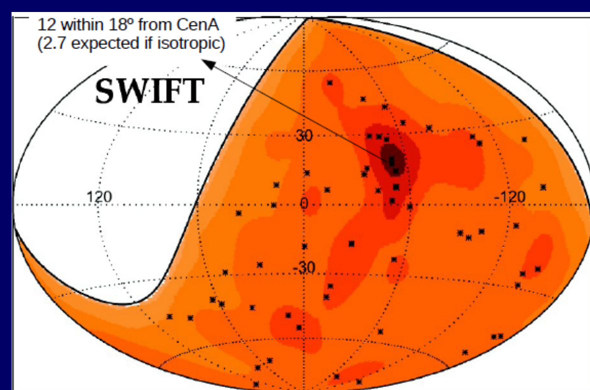
Anita seeks radio Cerenkov radiation from ν induced showers in ice.

Currently limits are just above expected from ν's due to CR interactions with CMB, above the GZK cutoff, followed by π→μ→ν.



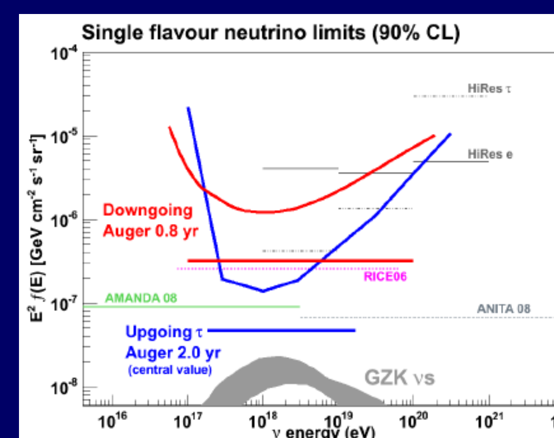
The Pierre Auger Observatory charged CR flux shows the GZK cutoff. Events in the cutoff region still have some correlation to AGNs (see 12 in a circle around CEN A, expect 2.7).





58 events with Swift-BAT AGN density x exposure map

Limits on showers for upward going ν_τ gives non-restrictive limits on GZK ν's



Some personal comments

There is no question that illuminating the dark particles is a high priority for the field. Beyond finding a positive signal in more than one detector, we need to measure the kinematics of WIMP scattering and find out how many types of DM there are. Deducing the velocity dependence of the DM candidates in our local environment is crucial, as the mass inference depends on it. The simple large scale velocity model could be modified significantly at the local scale.

We expect that progress will come through coordinated astrophysical and particle studies; masses from accelerators will allow much better interpretation of DM measurements which in turn will inform astrophysical modeling.

The detection of astrophysical hadrons, γ's and ν's is entering an exciting period. Limits are moderately close to model predictions in some cases. These measurements most directly probe astrophysical systems, but information on particle properties and interactions are also expected.

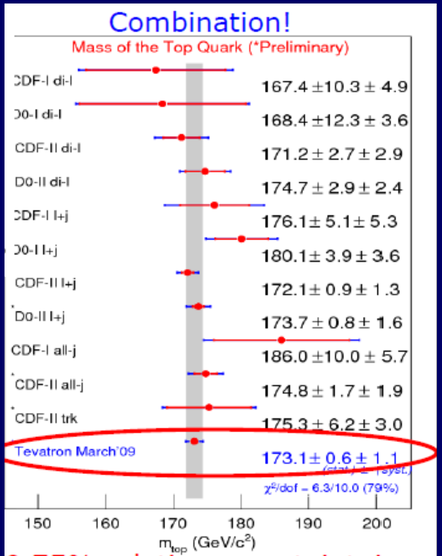
3. The energy frontier: from the Tevatron to LHC

Top quark
EW physics
Higgs searches
Beyond SM Searches
BSM from rare processes
LHC status and outlook

LHC size is 4 times the Tevatron, but is aiming at 7 times the energy. Therein lies a tortuous tale.

3.1 Top and W constraints on EWSB

Top mass: M_t=173.1 ± 1.3 GeV (March 2009; update soon). With 0.75% improvement, the most precise* quark mass.



0.75% relative uncertainty!
Exceeds Tevatron expectations!

Dominated by systematics now, particularly the jet energy scale corrections, so further improvements will be small. Measurements exist now for all leptons (e, μ, τ) in dilepton, ℓ + jets and 6 jets. Expect can reduce uncertainty to 1 GeV with 10 fb^{-1}.

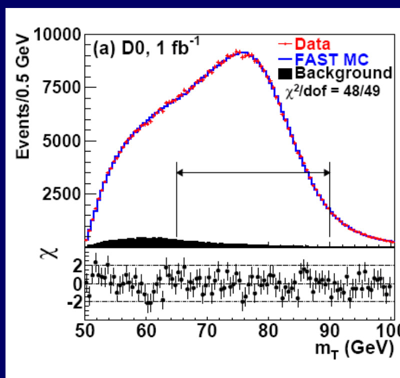
It will take some time for LHC to reach this precision.

* Most precise but do we know what it means? Theorists tell us that the pole mass differs from the running mass (by 10 GeV?). The experimental mass is probably closer to the pole mass. Can the experiments provide a translation, or provide measurements which do not use the top momentum? (Note that the experiments now do measure a mass by intersecting the measured cross section with the theory XS.

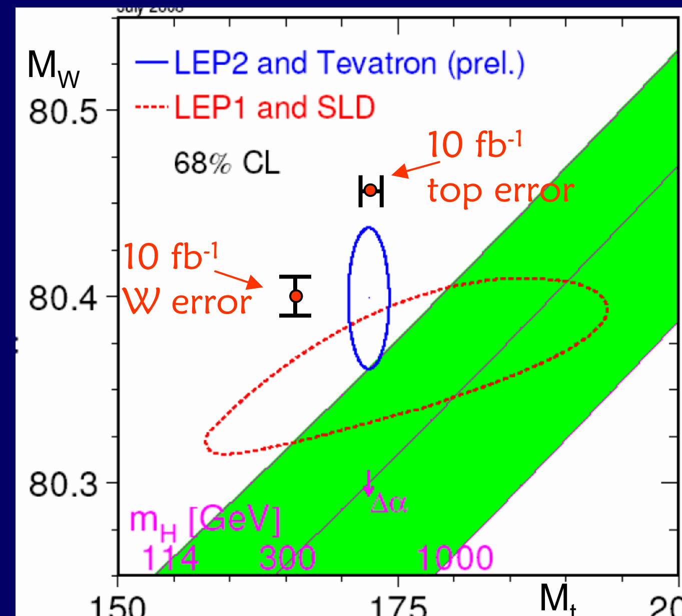
A measurement that amuses me: Top width (Γ_{SM}= 1.5 GeV in SM (5×10^{-25} s). CDF limits 0.4<Γ<1.4 GeV) at 68% CL (Γ<7.5 GeV at 95% CL.) We look forward to improvements on this soon.

3.1 Top and W constraints on EWSB

W mass: Tevatron average: M_W=80.402±0.032 GeV (World Average δM_W=0.023). Hope to get to ~12 (10)MeV for Tevatron (WA) with the full data set. LHC will not approach this precision until ≥ 10 fb^{-1} with very well understood detectors.



with M_t

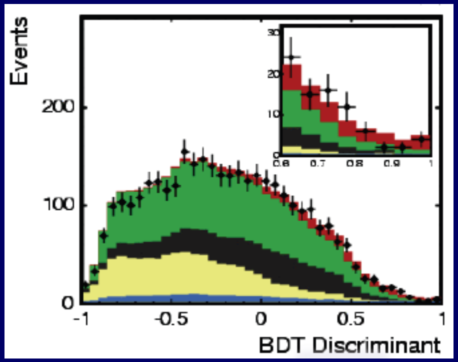


The blue error ellipse is the situation now. The error bars indicate the M_t M_W uncertainties expected with 10 fb^{-1}.

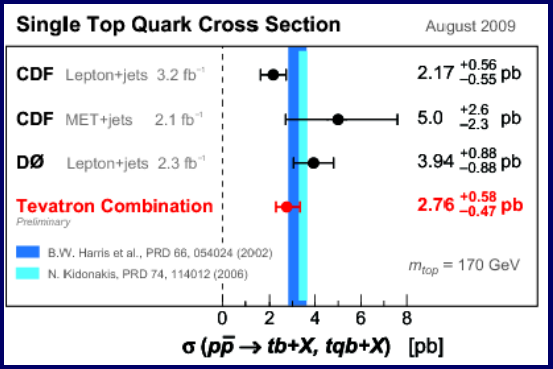
If the central value were to stay where it is, the green band of allowed Higgs masses would be excluded at 95% C.L. in the context of the SM.

This is another indication of the power of precision measurements sensitive to loops of unknown new objects.

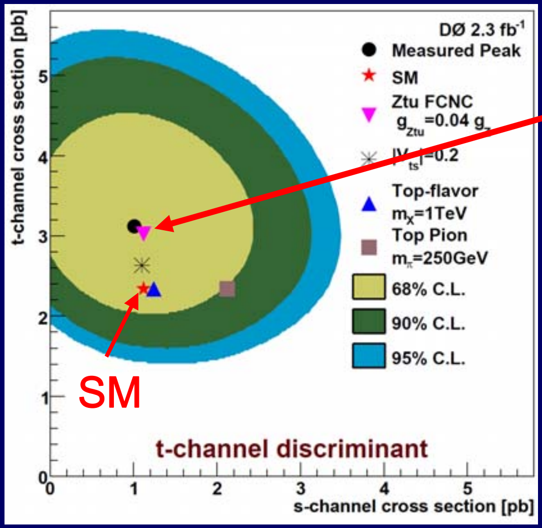
3.2 Single top production



Single top quark production has large backgrounds, so we need a complex multivariate analysis to dig out a signal. CDF and DØ use many well characterized input variables and several MV classifiers.



Single top production occurs via both s- and t-channel W exchanges. Both CDF and DØ observe a total single top XS consistent with SM.

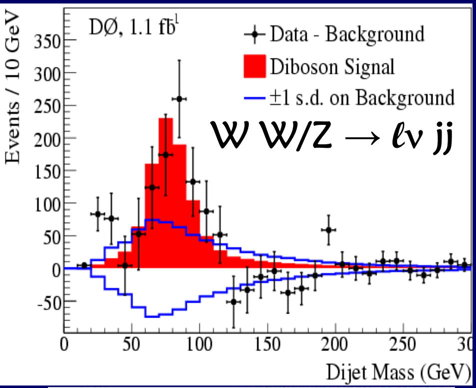


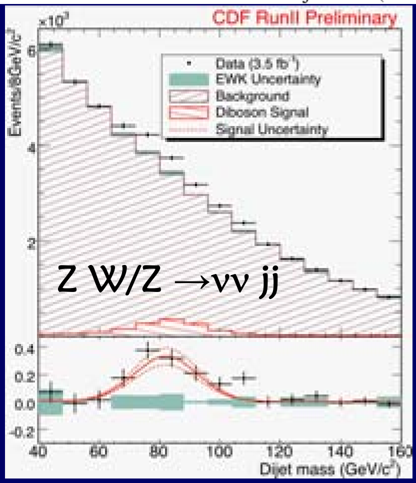
A recent DØ study disentangled the s- and t-channel processes; this can discriminate types of new physics.

Also measure V_{tb} = 0.911±0.08, independent of assumption of number of generations.

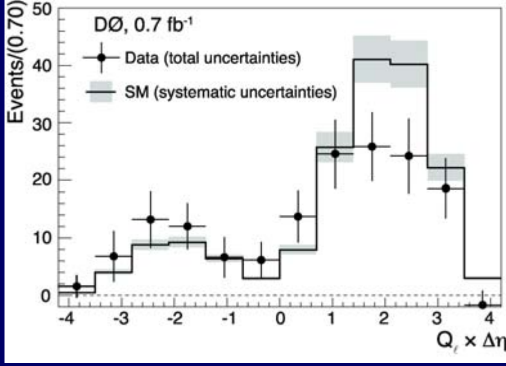
The single top sample can also used for measuring anomalous top couplings, searching for $H^{\pm} \rightarrow tb$, W' and top width.

3.3 Vector boson production





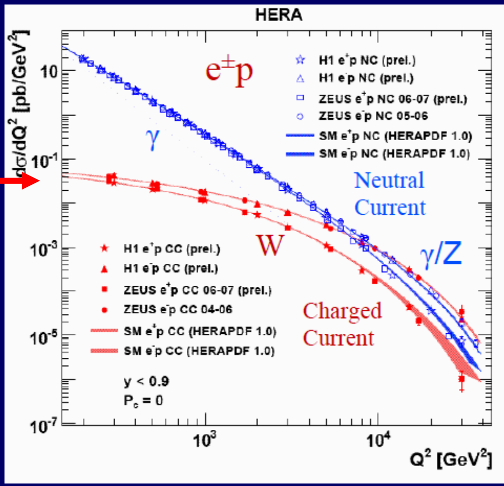
Observation of radiation amplitude zero in Wγ

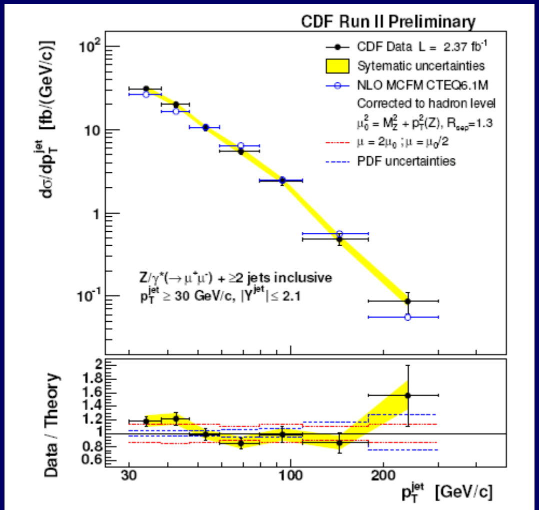


Previous diboson studies used all lepton final states.

Now diboson processes are observed with one boson hadronic decays, to lower precision than in all leptons. But the importance of these is the use of the MV techniques employed in Higgs/single top, verifying that these methods are robust.

A textbook demonstration of EW unification from HERA high Q^2 NC and CC cross sections





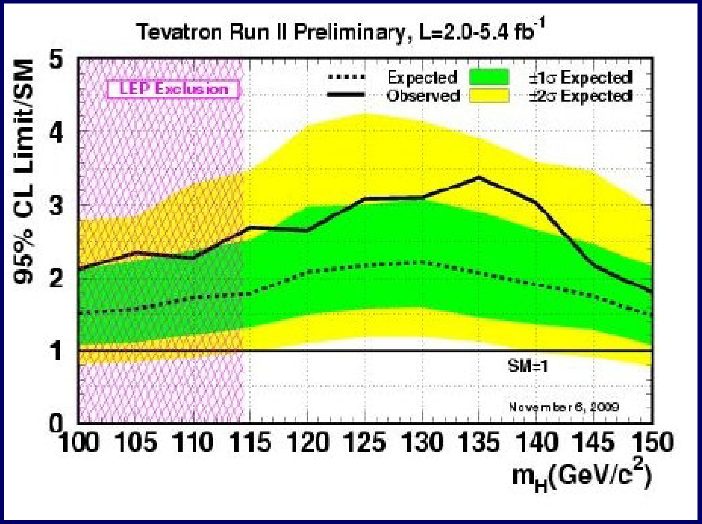
New Tevatron measurements of W/Z+n jets (n=1,2,3). Important for tuning MC generators to obtain backgrounds for Higgs. LHC will benefit from these.

3.4 Higgs searches

Tevatron Higgs searches make a crude distinction of low and high mass searches, with dividing line ≈135 GeV, to distinguish H→bb from H →WW,

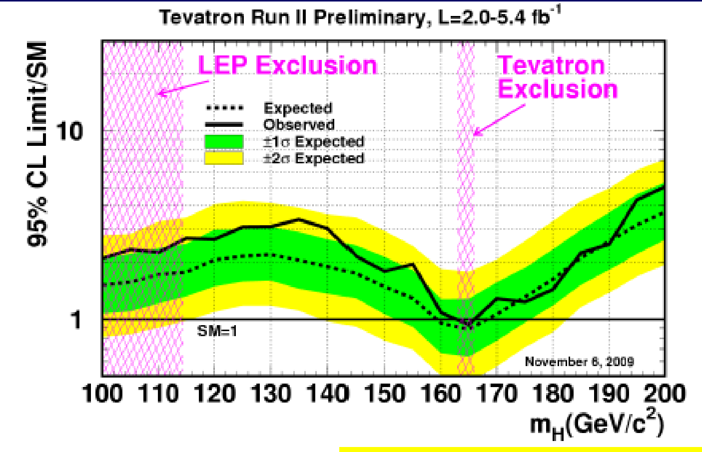
The highest sensitivity low mass searches are W(ℓν)H(bb) and Z(νν)H(bb) but many other channels contribute: Z(ℓℓ)H(bb), W/Z H(ττ), ttH(bb), etc. All add sensitivity.

High mass searches can use the higher XS gluon gluon fusion process with H→WW, and other lower yield channels.



Low mass combined CDF/DØ limit <ℒ>=4.4 fb^{-1}

At 115 GeV: ratio of limit to SM observed (expected) = 2.7 (1.8)



High mass combined limit excludes SM higgs 162< M_H<166 GeV.

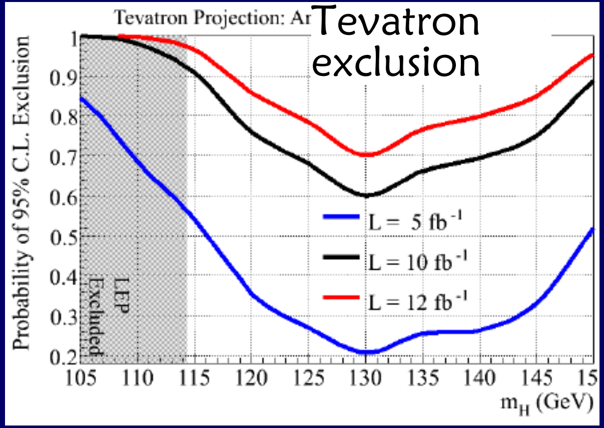
Discussion here questioned whether theory XS uncertainties are fully accounted for.

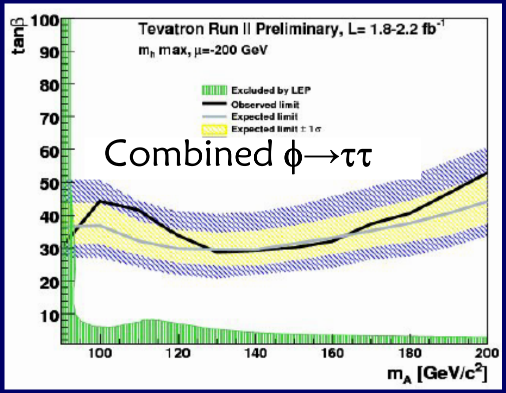
3.4 Higgs searches

In addition to the ≥2 fold increase in statistics, there will be new search channels and improvements in analysis techniques, improved b-tagging, dijet mass resolution, object algorithms, etc.

There is better than an even chance for Tevatron to exclude a SM Higgs, wherever it does not exist, up to >180 GeV,

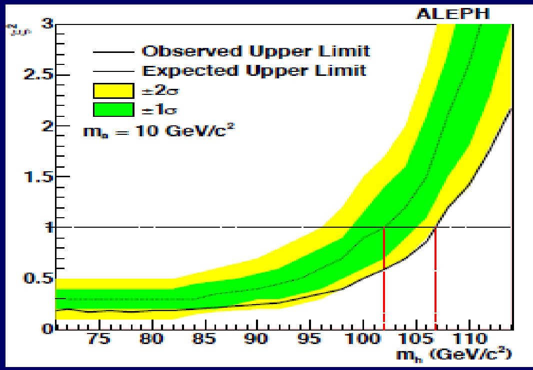
Prob. vs. M_H for exclusion





Tevatron Susy Higgs searches use $\phi\to\tau\tau$, $b\phi\to b\tau\tau$, $b\phi\to bbb$. These searches are now sensitive to the important region $\tan\beta \sim 30 \approx M_t/M_b$.

The NMSSM provides a new CP odd Higgs, **a**, whose mass could be light, allowing $H\to$**aa**. The **a** could decay to $\tau\tau$ if $M_a<2M_b$. In this case (or for other invisible decays), the LEP bounds are evaded.



Aleph' limits for BR H(aa)=1 and BR $a(\tau\tau)=1$.

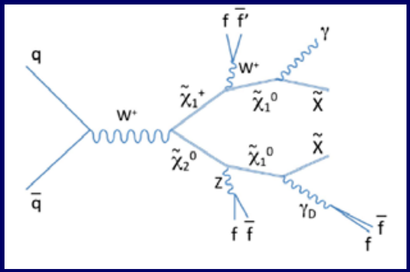
It has also been sought in Y(1S) decays and Y(3S) →**aa**.

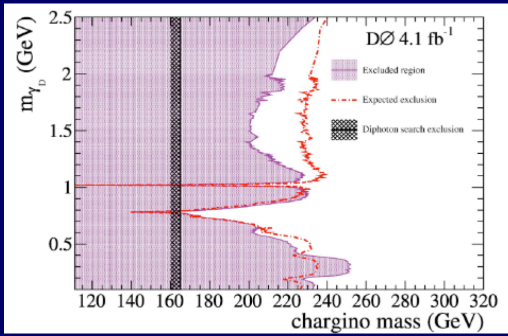
3.5 BSM searches

There have been many direct searches for evidence of phenomena at high mass beyond the SM. Some are within some model context, some are signature based. It is of course frustrating that no evidence for BSM has been found!

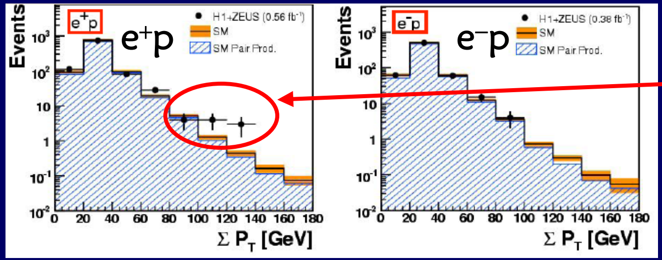
<u>Searches reported here:</u>

- Gaugino pairs (3 leptons)
- GMSB gauginos ($\gamma\gamma$ + MET)
- Squarks (τ +jets+ MET)
- Top squark (cc+MET; bb $\ell\ell$ + MET)
- Sbottom (jets + MET; bb MET)
- Z', W', KK gravitons ($\ell\ell$)
- RS gravitons ($\ell\ell/\gamma\gamma$)
- LQ3 ($bb\nu\nu$)
- WZ resonances
- 4th generation fermions
- Dark photons from gauginos
- Hidden valley higgs
- $B \to \mu\mu(X)$
- Multileptons in ep collisions
- Rare $b \to s X$ (e^+e^-)

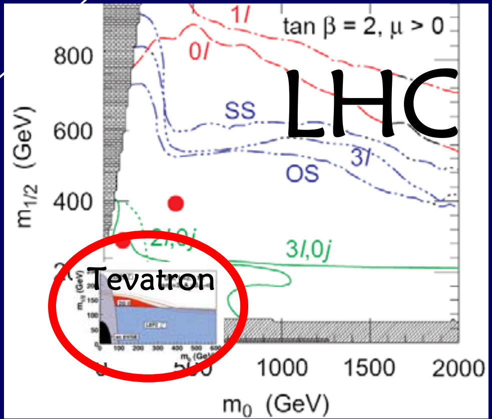




Hidden valley (dark) photons



Mostly H1 e^+p



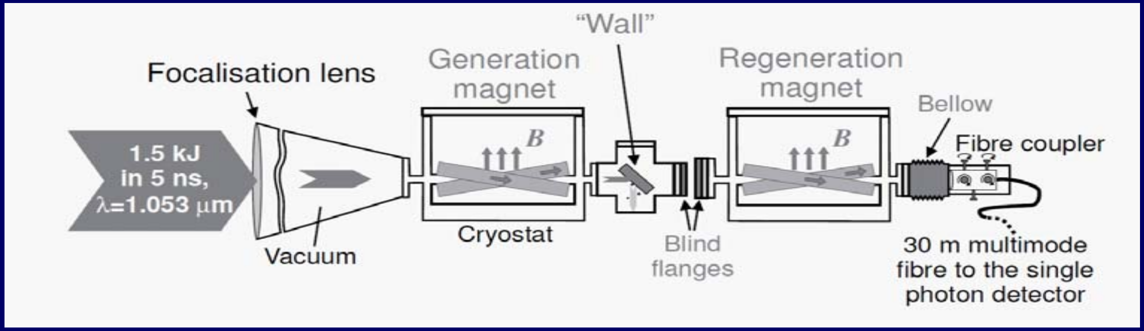
It is nice to see confrontation by experiment with new models …

but some perspective is in order: we are about to enter a new world.

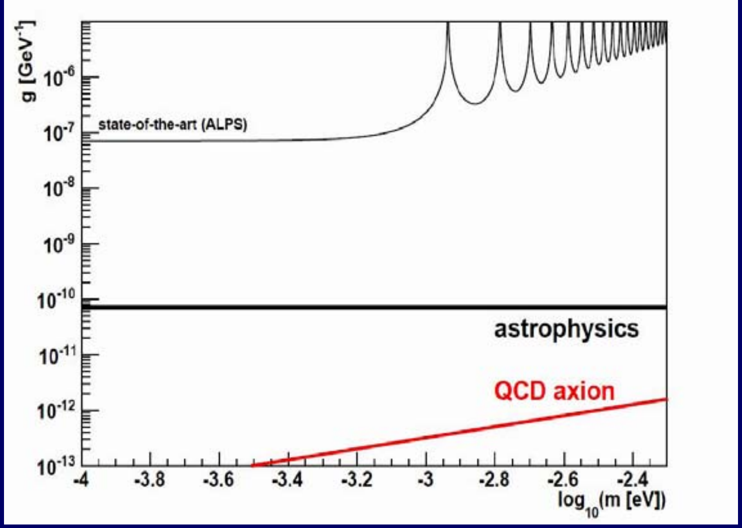
3.5 BSM searches

The forgotten parameter of the SM – the strong CP phase.

The solution to the strong CP problem motivated axions, and has spawned searches for axion-like particles. The signature is the transition of a photon in strong EM fields to the axion and regenerating it to a photon later – hence "shining light through walls"



The ALPS collaboration uses cavity enhanced laser in half a HERA magnet to stimulate axion production, followed by regeneration of the photon in the second magnet half.

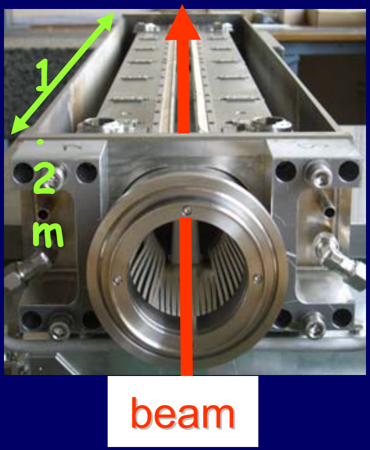


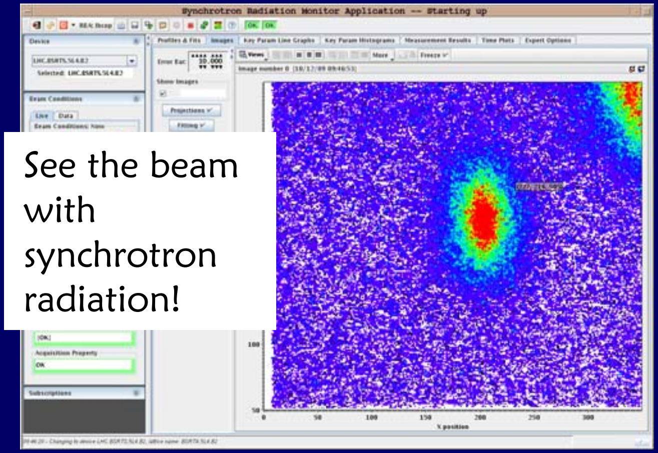
ALPS achieved the best terrestrial sensitivity so far, but is far from the limits set by regenerating axions from the sun, and even further from the QCD axion.

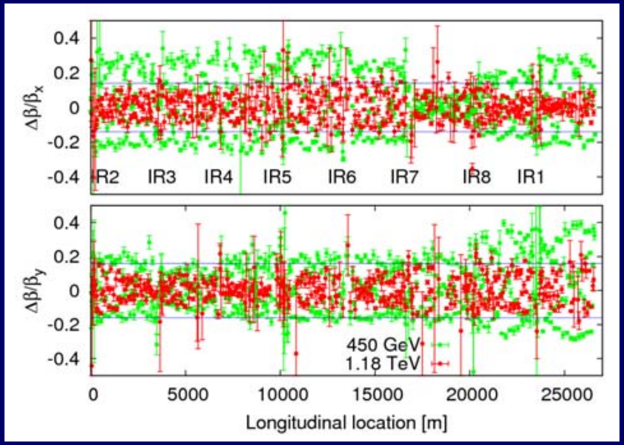
3.6 The LHC machine

The LHC is full of huge challenges. We know about those of the magnets & cryogenics only too well.

The collimators are unsung heros of the LHC in their role of protecting against wandering 350 MJ/beams.





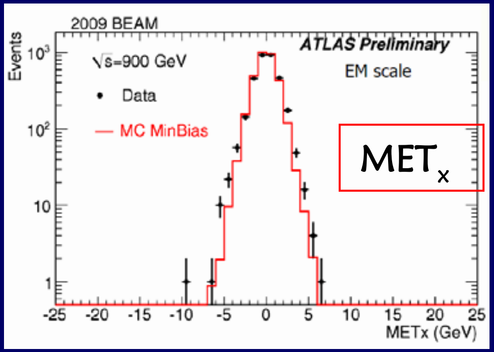


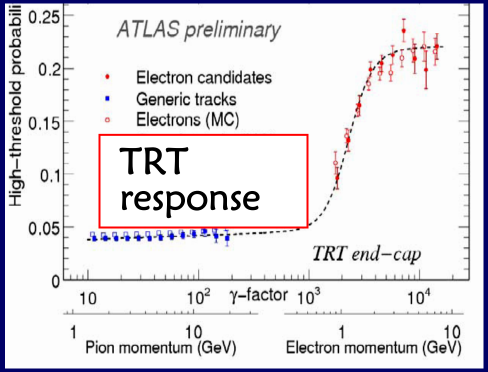
The alignment, RF capture, beam orbit stabilization have been great successes.

In retrospect, the most important news from Moriond 2010 will likely be the start of LHC operations!

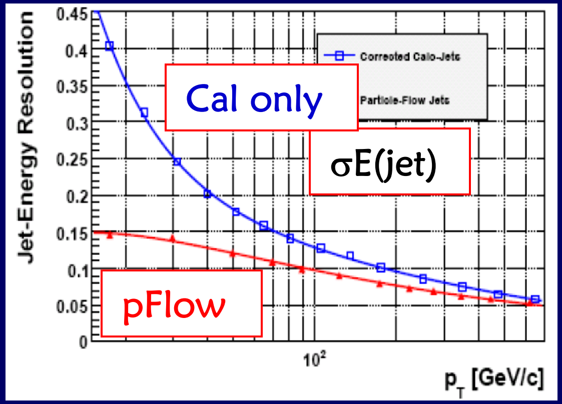
3.6 The LHC experiments

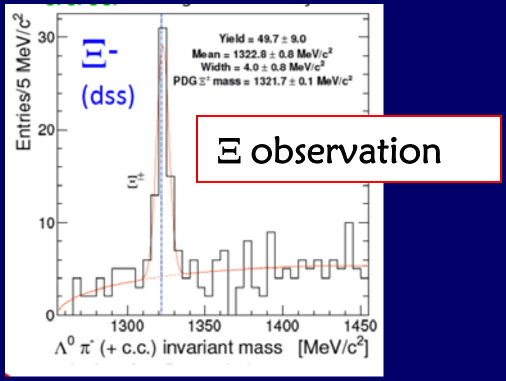
ATLAS, CMS and LHCb all showed very impressive performance plots from the first batch of collisions. The rapidity of the early data analyses and the good agreement with MC are striking (amazing).



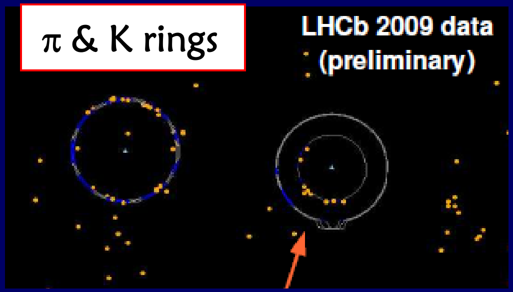


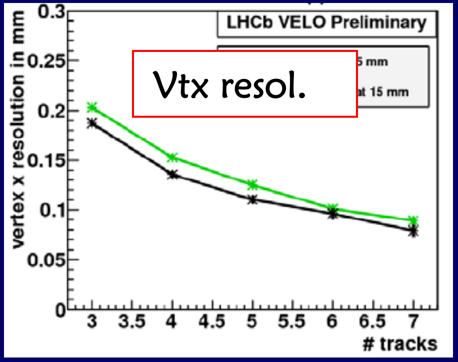
ATLAS





CMS





LHCb

3.6 LHC roadmap

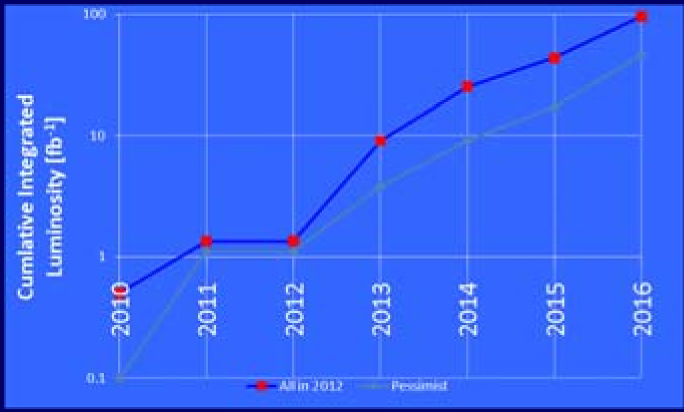
LHC plan and reading the tea leaves:

1 fb^{-1} at $\sqrt{s}$=7 TeV by end 2011

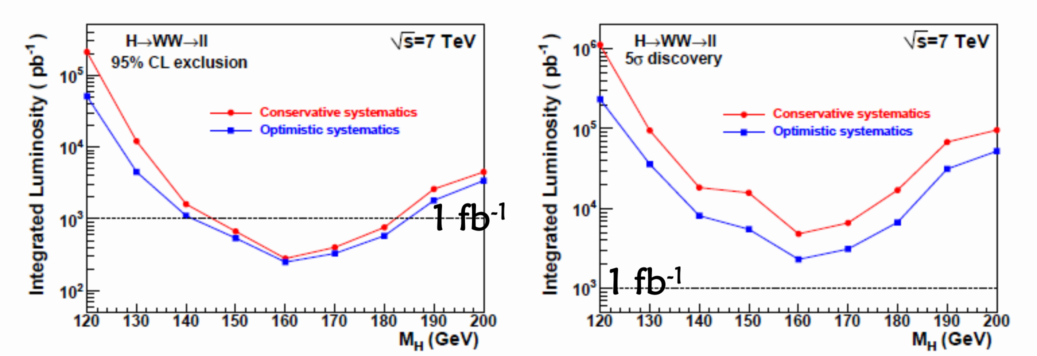
shutdown in 2012; fix magnets and splices; raise energy to ??

100 fb^{-1} by 2016

600fb^{-1} by 2020; 3000 fb^{-1} ~2030.



$\mathcal{L}$ vs. M for Higgs exclusion/ 5σ discovery at 7 TeV



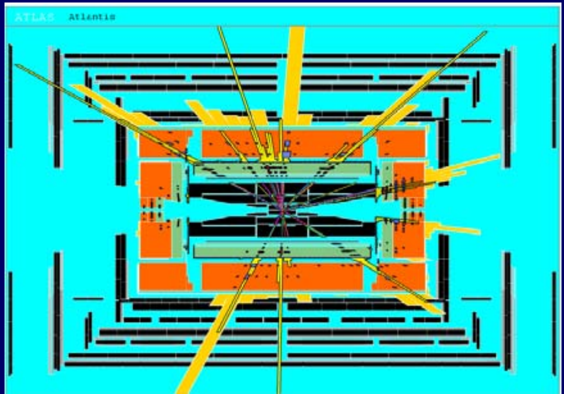
95% C.L. Exclusion   5σ Discovery

10 fb^{-1} to discover at low mass in H→γγ

And of course the higher energy opens many new windows to sense new physics:

From: Z' up to 1.5 TeV in 2011 (5 Tev ultimately)

To: Sighting mini-black holes, etc. ?



Some personal comments

The Tevatron has taken us far in understanding the SM. It has failed so far to see beyond the SM. The legacy of the Tevatron will be in its discovery and elucidation of the top quark, W & Z physics and perturbative QCD. It still has a critical role to play in the Higgs saga.

What strikes me about the Tevatron is the degree of sophistication of the object algorithms and analysis techniques and the tools developed to verify them. The Tevatron has also shown that the nearly impossible is actually possible – single top, sub part-per-mille W mass, identification of $Z(\nu\nu)\,\gamma$ come to mind. These advances will migrate to the LHC experiments.

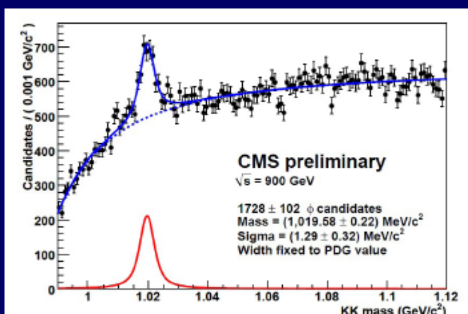
The LHC now takes the baton for answering questions that are now three decades old. For the sake of the field, we wish ATLAS & CMS well.

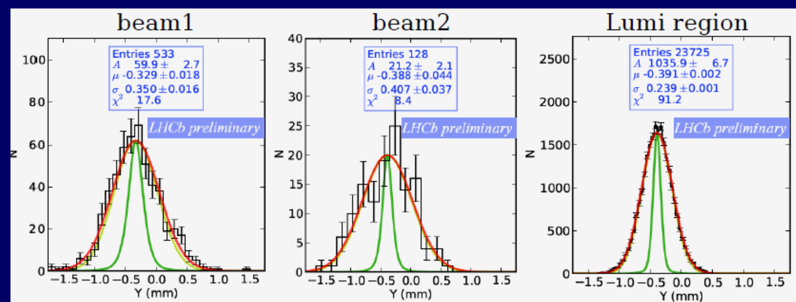
The slow start of the LHC is frustrating. We know that 7 TeV is likely not enough to teach us all that we want to know. But I am tremendously impressed with how well the machine has actually worked. All the challenging stuff (beam orbit control, instabilities etc.) works like a charm. We've foundered on the hard but 'prosaic' stuff. Other machines I have known have had teething problems, and I am willing to bet that the LHC will live up to its potential.

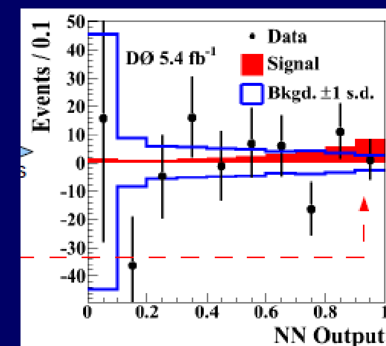
Young Scientist Forum

I enjoyed the YSM talks enormously. They were informative, to the point and well presented. The older speakers could learn something on technique and clarity. I hope the young physicists learned as well. Thank you!

A few slides that particularly struck my fancy were:



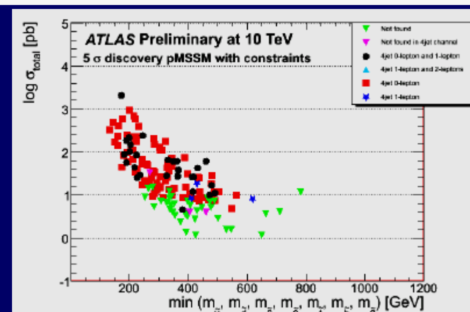


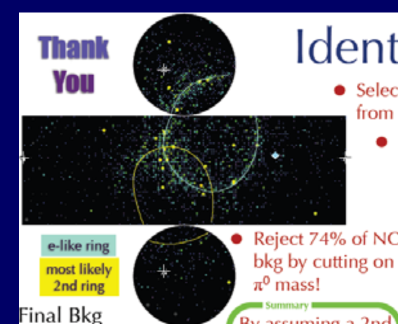


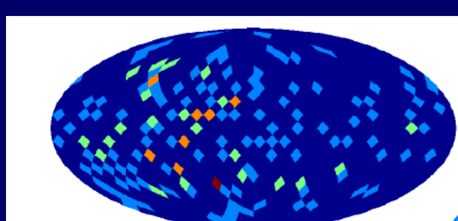
$$\mathcal{L}^{eff}_{\mu\to e\nu\bar{\nu}}(x) = \mathcal{L}^{eff,\,SM}_{\mu\to e\nu\bar{\nu}}(x) + \frac{v^2}{\Lambda^2}\mathcal{L}^{eff,\,bSM}_{\mu\to e\nu\bar{\nu}}(x)$$

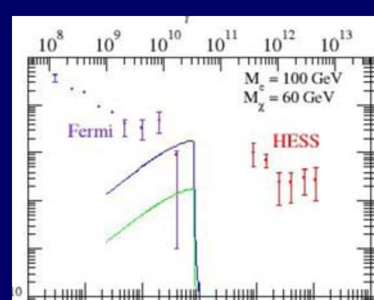
$$\mathcal{L}^{eff}_{d^j\to u^i l\bar{\nu}}(x) = \mathcal{L}^{eff,\,SM}_{d^j\to u^i l\bar{\nu}}(x) + \frac{v^2}{\Lambda^2}\mathcal{L}^{eff,\,bSM}_{d^j\to u^i l\bar{\nu}\nu}(x)$$

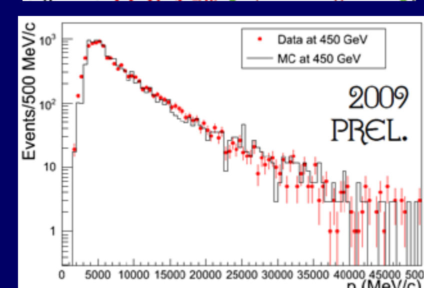
$\boxed{v \approx 174\ GeV}$











Conclusion

In this meeting, we have taken a few steps on our road to explore the *terra incognita*. I congratulate those who presented such beautiful data to help point the way, and wish those starting the new experimental voyages every success for new discoveries.

I now have second thoughts, and ask that you all join me in thanking the organizers of Moriond EW 2010 for a most productive, stimulating and enjoyable meeting.

And thanks to all the speakers for very informative new results and exceptionally clear presentations.