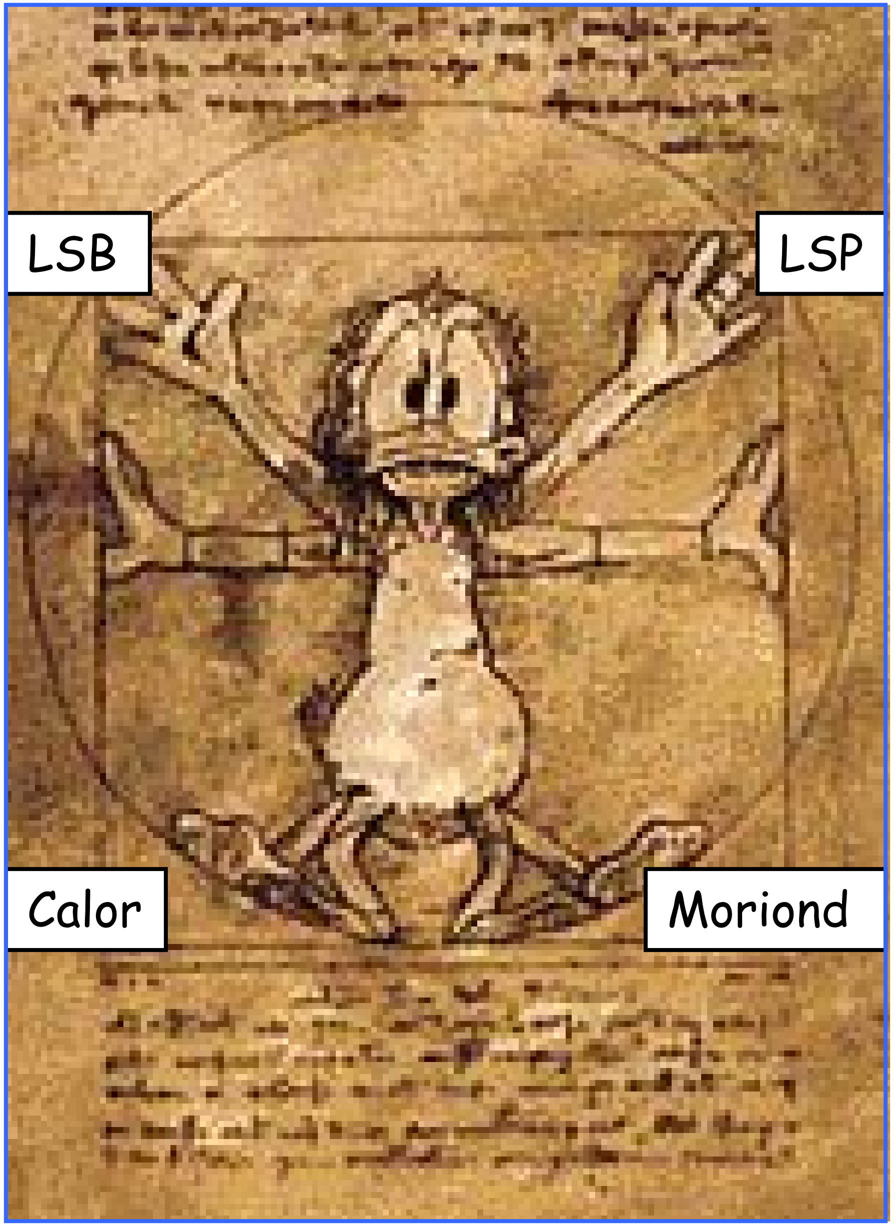


Ivo van Vulpen

Introduction:

Moriond (Electroweak)

Real ‘physics’ conference

Calorimetry 2004

Real ‘hardware’ conference.

Disclaimer:

Most of the sheets are taken directly from the talks given at Moriond.

- Small and very nice conference, but still: 90 talks !

Experiment:

EW results & precision measurements

B-physics

Searches and SUSY

Discovery of new particles

Dark matter

Neutrinos

Theory:

Large extra dimensions

top quark mass, g-2, s in$^2(\theta_w)$

Babar & Bell + frustrating sheet

Higgs at Tevatron

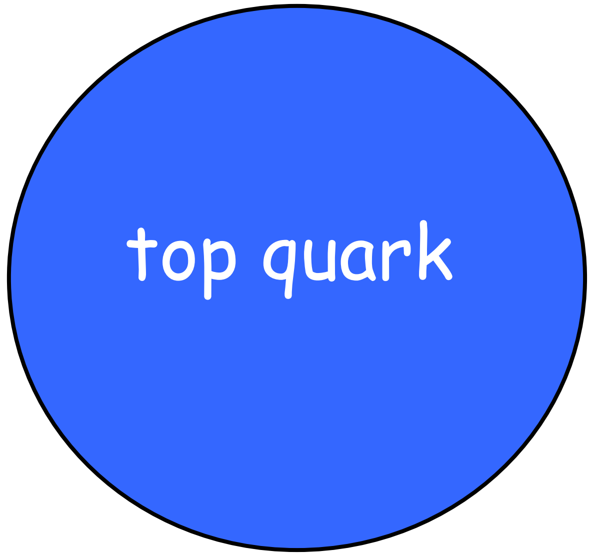
Penta-quarks

Discovery claim

What is happening

TALK

why and how can we seen it

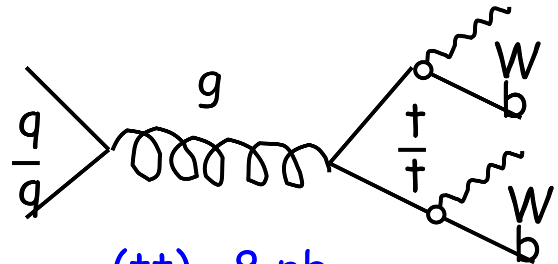


8 sheets

Top quark production

production

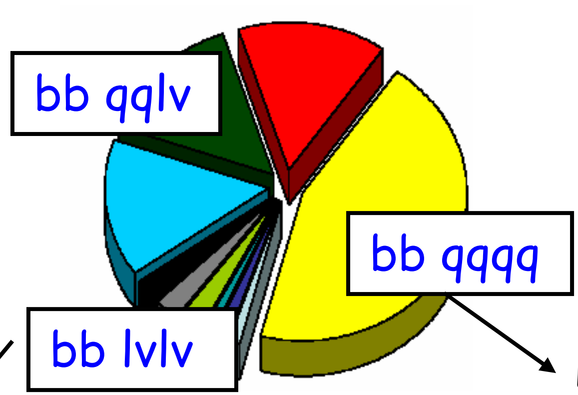
Final states



$\sigma(tt) \approx 8$ pb

WWbb

W->qq (2/3) and lν (1/3)



lepton + jets. Most sensitive

Large QCD background

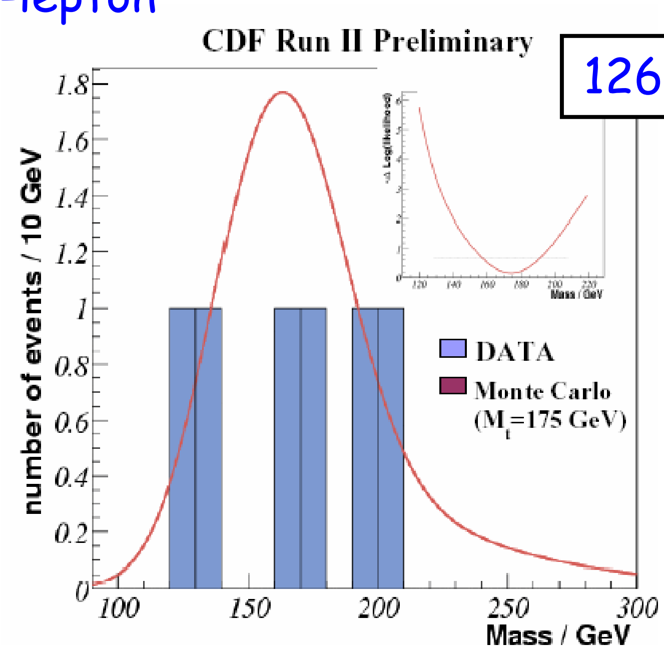
Di-lepton. small statistics

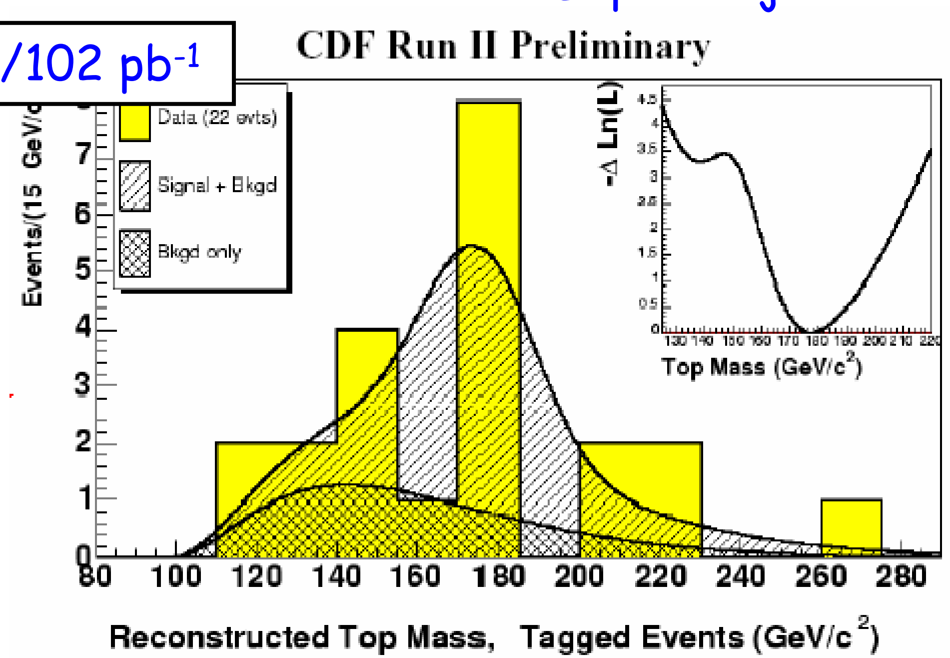
Tevatron run 2: CDF

di-lepton

Lepton + jets

126/102 pb^{-1}





6 events (0.5 background)

22 events (6 background)

Run II data, ~126 pb-1 m_t=175.0 $^{+17.4}_{-16.9}$ ± 8.4 (syst) GeV/c^2	Run II data, ~102 pb-1 m_t=177.5 $^{+12.7}_{-9.4}$ ± 7.1 (syst) GeV/c^2

Tevatron run 2: D0

"First we have something to say on our run 1 result."

Tevatron run 1: D0

New D0 analysis technique:

- Compute event-by-event probability

  Match measured 4-momenta to expectations for signal (m_{top} = 170,175,180 etc) and background.

New Approach is to calculate per event probability to be a tt event. Probability density

$$P(x, M_t) = \frac{1}{\sigma(x)} \int d\sigma(y, M_t)\, dq_1\, dq_2\, f(q_1)\, f(q_2)\, W(y, x)$$

Mass-dependent, reconstructed 4-vectors

Differential Xsec (LO Matrix element + phase space)

PDF's

Transfer function Relating partonic Variables to Measured quantities

Event Probability $P(x; c_1, c_2, M_t) = c_1 P_{t\bar{t}}(x; M_t) + c_2 P_{\text{bkgd}}(x)$

- Use only 4 jet (clean) events (22 events instead of 77 previously) & all combinations

Basically same as difference between:

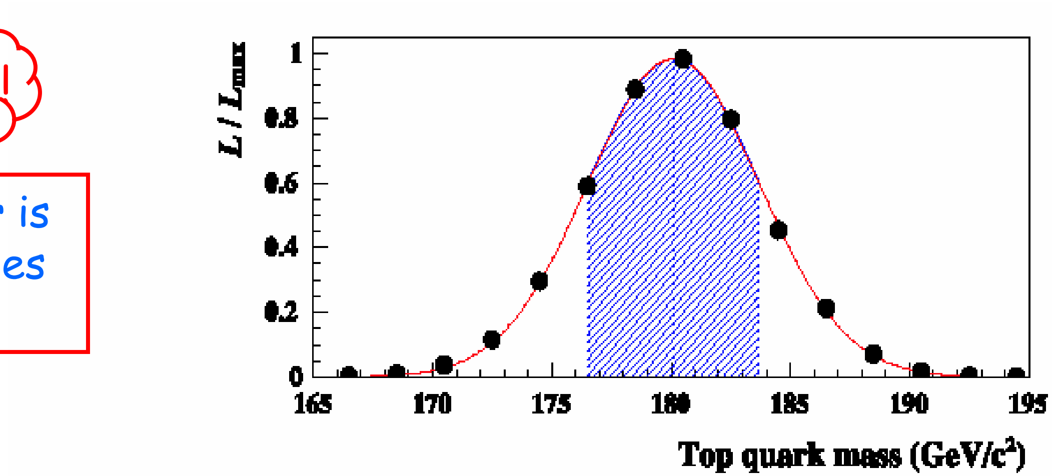
$$<\mathrm{m}> = \frac{\sum_i \left(\frac{1}{\sigma_i}\right)^2 m_i}{\sum_i \left(\frac{1}{\sigma_i}\right)^2} \quad \text{instead of} \quad <m> = \frac{1}{n} \sum_i m_i$$

Can it be so important ?? YES!!

Tevatron run 1: D0

wow !!

- Improvement in statistical error is roughly 1.5 (comparable to 2.4 times more data)



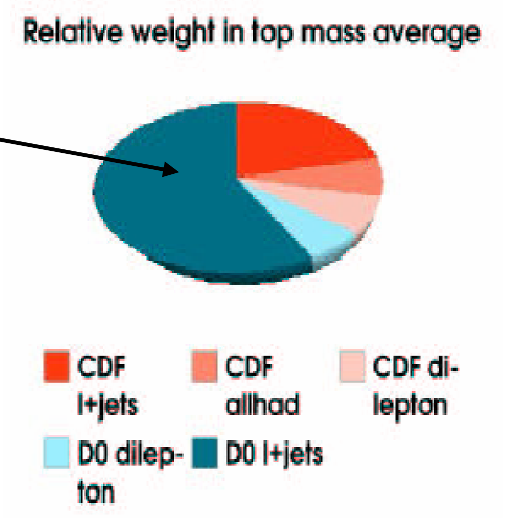
SAME DATA

D0 l+jets (old) $m_{top} = 173.3 \pm 5.6\,(stat) \pm 5.5\,(syst)\ \mathrm{GeV}$ 91 events

(new) $m_{top} = 180.1 \pm 3.6\,(stat) \pm 3.9\,(syst)\ \mathrm{GeV}$ 22 events

M_{top} moves up by ~7 GeV !!!

As if you had 2.4 times more data



D0 lepton + jets

Tevatron

New top quark mass averages

TEVATRON RUN1 (old) $m_{top} = 174.3 \pm 5.1\,\text{GeV}$

RUN1 (new) $m_{top} = 178.0 \pm 4.3\,\text{GeV}$

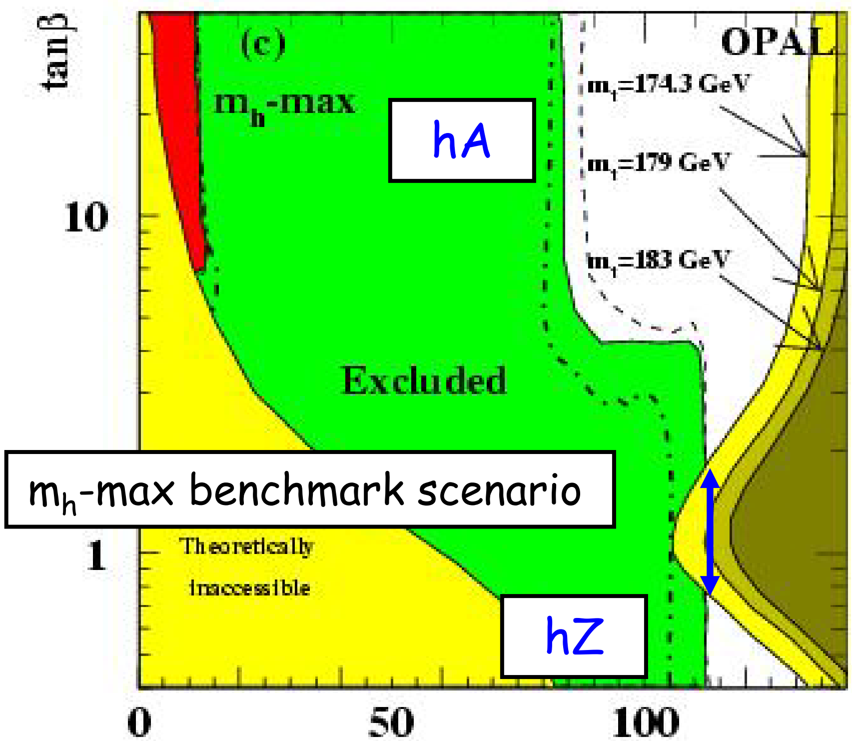
M_{top} moves up by +4.7 GeV

RUN2 (l+jets) $m_{top} = 177.8^{+4.5}_{-5.0} \pm 6.2\,\text{GeV}$

Influence on rest of EW physics results

Another example: Influence new top mass on tan(β) exclusion region from LEP:

In MSSM benchmarks: m_{top} = 175 GeV ⟶ Maximum m_h: in the MSSM < 135 GeV



- Computation of m_h-max:

  Loop corrections $\propto m^4_{top}$

  FeynHiggs:

  higher order corr. -> $\Delta m_h \approx 3$ GeV

  $\Delta m_{top} \approx 5$ GeV -> $\Delta m_h \approx 5$ GeV

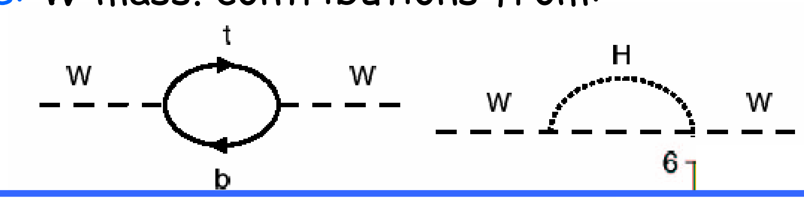
- LEP-excluded tan(β) region will shrink

LEP

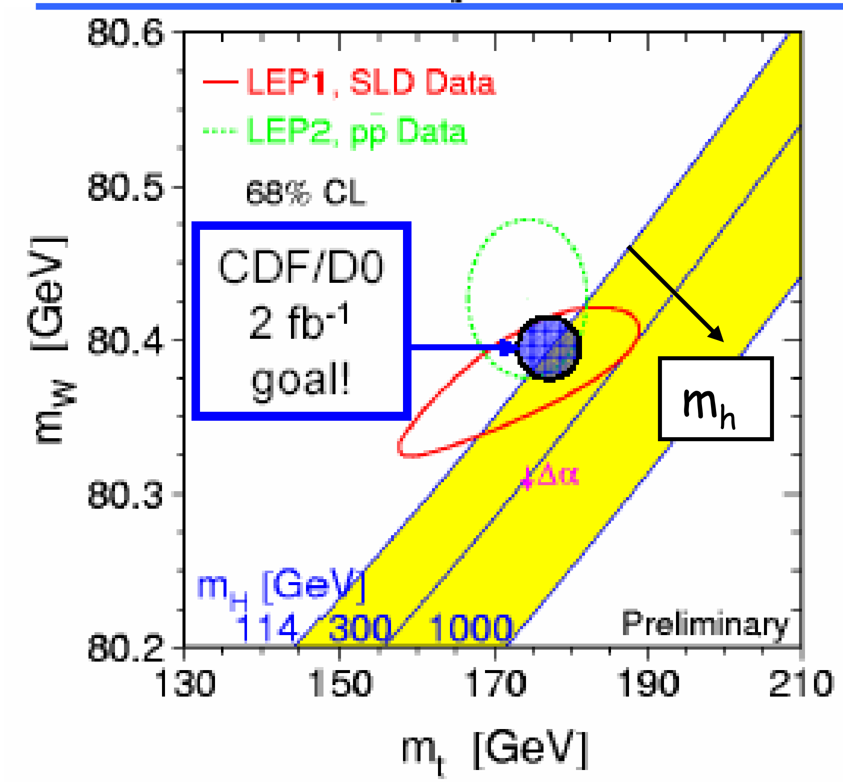
Scenario	m_h	m_A	Excluded tan(β)
M_h-max	>91.0	>91.9	0.5 < tan(β) < 2.4

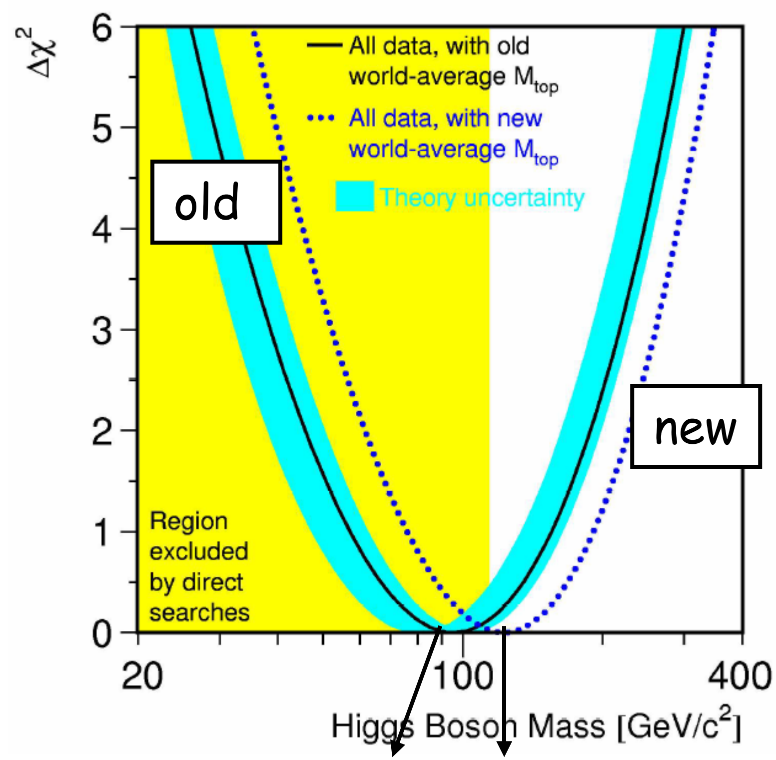
Impact new top mass on the electroweak fit

- Example: W mass. contributions from:



$$\delta_{M_W} \propto m_t^2 \ln(m_h)$$





Old (new): m_h = 96 (117) GeV

m_h < 219 (251) GeV @ 95% CL

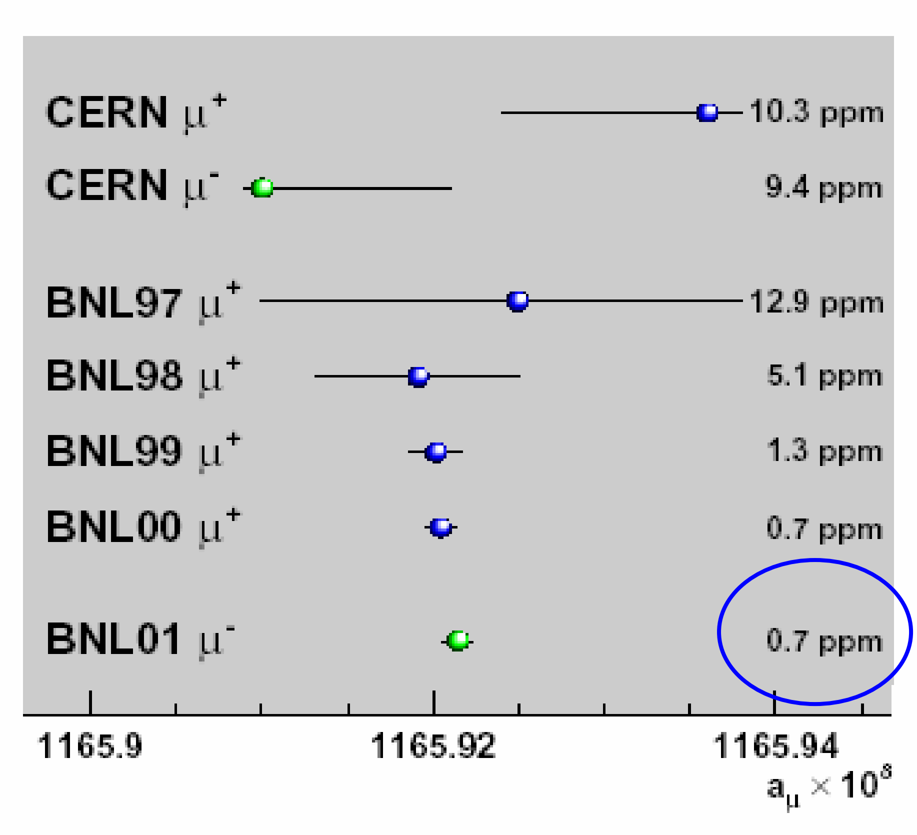
Electroweak

g-2

4 sheets

Anomalous magnetic moment of the muon

g-2 collaboration final results



"Compare to SM prediction: there is a 1.4/2.7 sigma deviation"

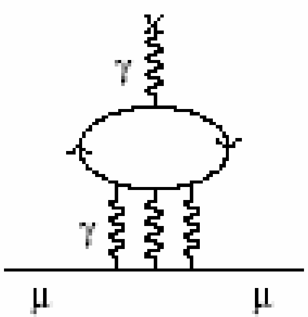
Depends on e+e- data or tau data

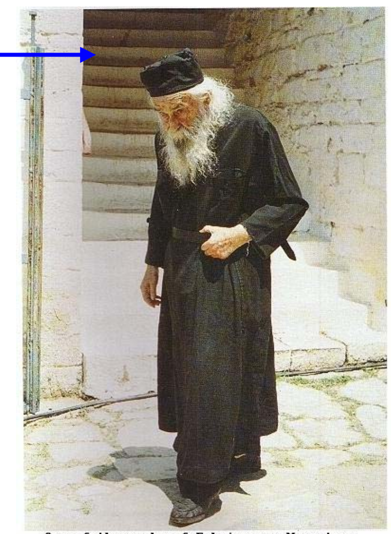
Theoretical computation of a_μ [(g-2)/2] part (1)

- a_μ^{SM} can be expressed in terms of its various contributions

$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{HLBL} + a_\mu^{HVP} + a_\mu^{HOHVP}$$

SM Term	$a_\mu \times 10^{-10}$	$\Delta a_\mu \times 10^{-10}$
a_μ^{QED}	11658471.94	0.18
a_μ^{EW}	15.1	0.4
a_μ^{HLBL}	12.0	3.5
$a_\mu^{HVP;e^+e^-}$	694.4	7.2
a_μ^{HOHVP}	-10.1	0.6





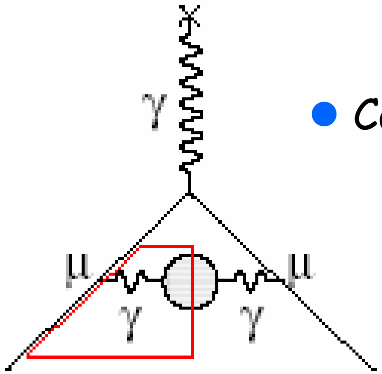
One of the monks of Eshpigmenou Monastery who is over 100 years old and also faces eviction, but has no other home.

(1) light by light scattering: theory!

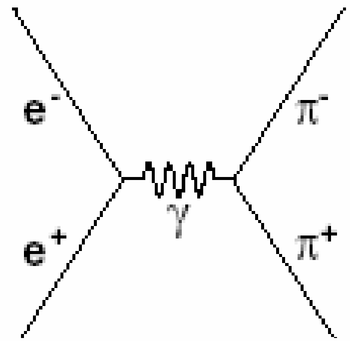
Tedious work. Done by 1 guy basically.

Sign flip found in 2002 (PhD student from Marseille ??)

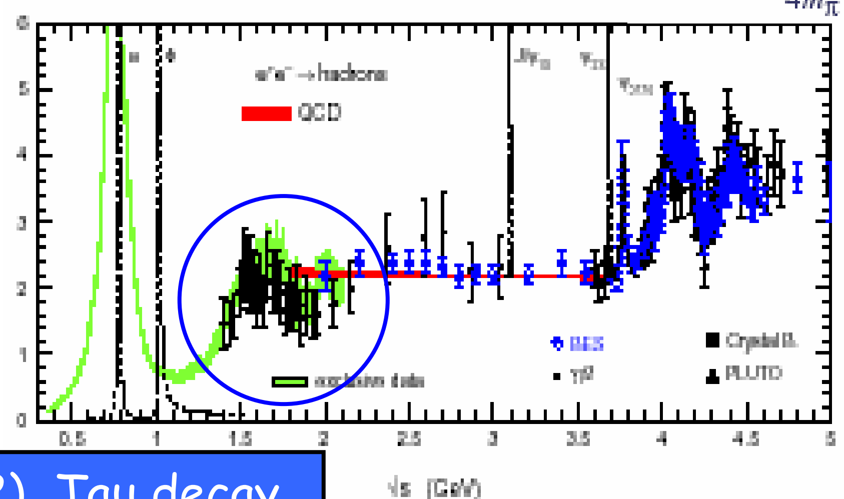
(2) Hadronic vacuum polarization: experiment (2 ways to extract it)



- Cannot be calculated



$$a_\mu^{HVP} \propto \int_{4m_\pi^2}^{\infty} \frac{R(s)}{s} K(s)ds, \text{ where } R(s) = \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}.$$



(1) CMD: e+e- results:

- Claim 0.6% uncertainty, but new rad corr shifted cross section by 3%
- Region < 1.8 GeV dominates
- They were alone (check needed)

Now confirmed by KLOE (radiative events). Maybe BaBar and Cleo can do something as well

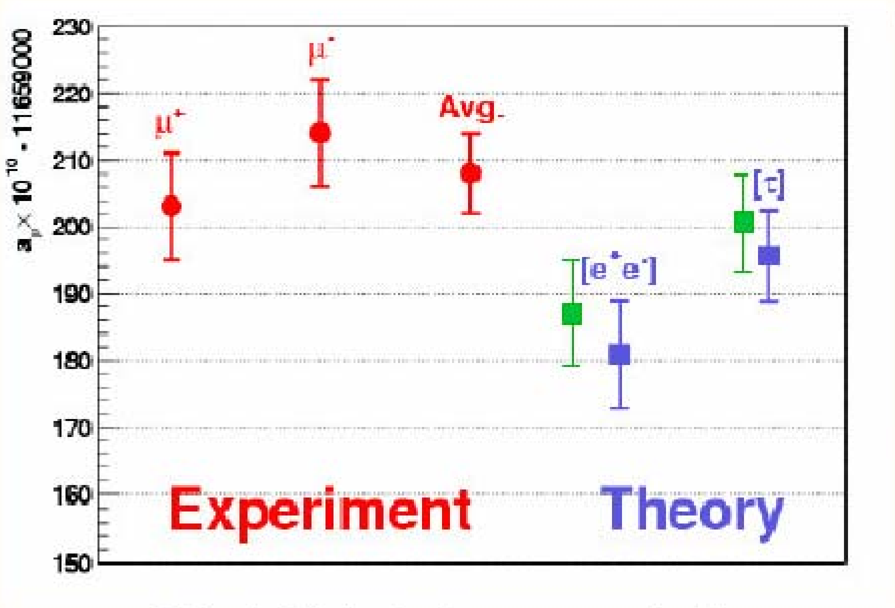
(2) Tau decay

- Gives different e+e- -> hadrons

FINAL

Muon g-2: new results

Brookhaven, January 2004: μ^- measurement.



Arkady Vainshtein: new analysis

$$a_\mu^{exp} - a_\mu^{SM} = 270 \pm 100 \cdot 10^{-11}$$

$$\rightarrow 2.7\sigma \text{ (again...)}$$

(based on Davier et al., 2003, e+e-)

$$a_\mu^{exp} - a_\mu^{SM} = 123 \pm 89 \cdot 10^{-11}$$

$$\rightarrow 1.4\sigma$$

(tau)

Electroweak

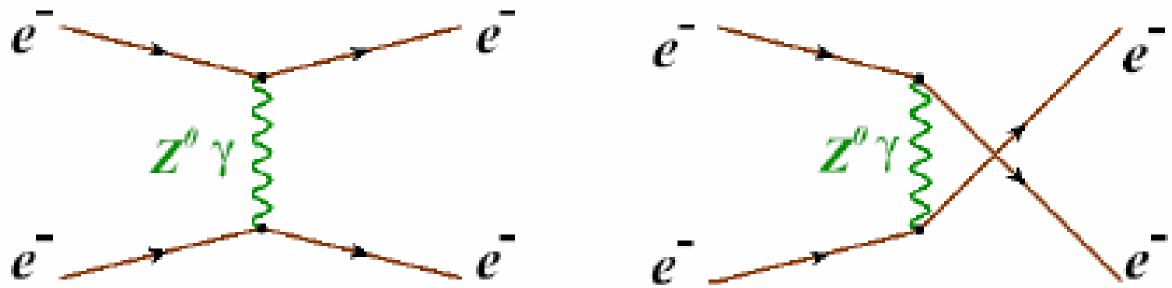
$\sin^2 \theta_w$

4 sheets

SLAC E-158

Measuring Parity Violation in Møller Scattering

E = 48 GeV, Q^2 = 0.03 GeV^2



For a polarized electron beam and an unpolarized electron target,

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$A_{PV} \propto (1 - 4\sin^2\theta_W)$$

tree level: $-3 \cdot 10^{-7}$

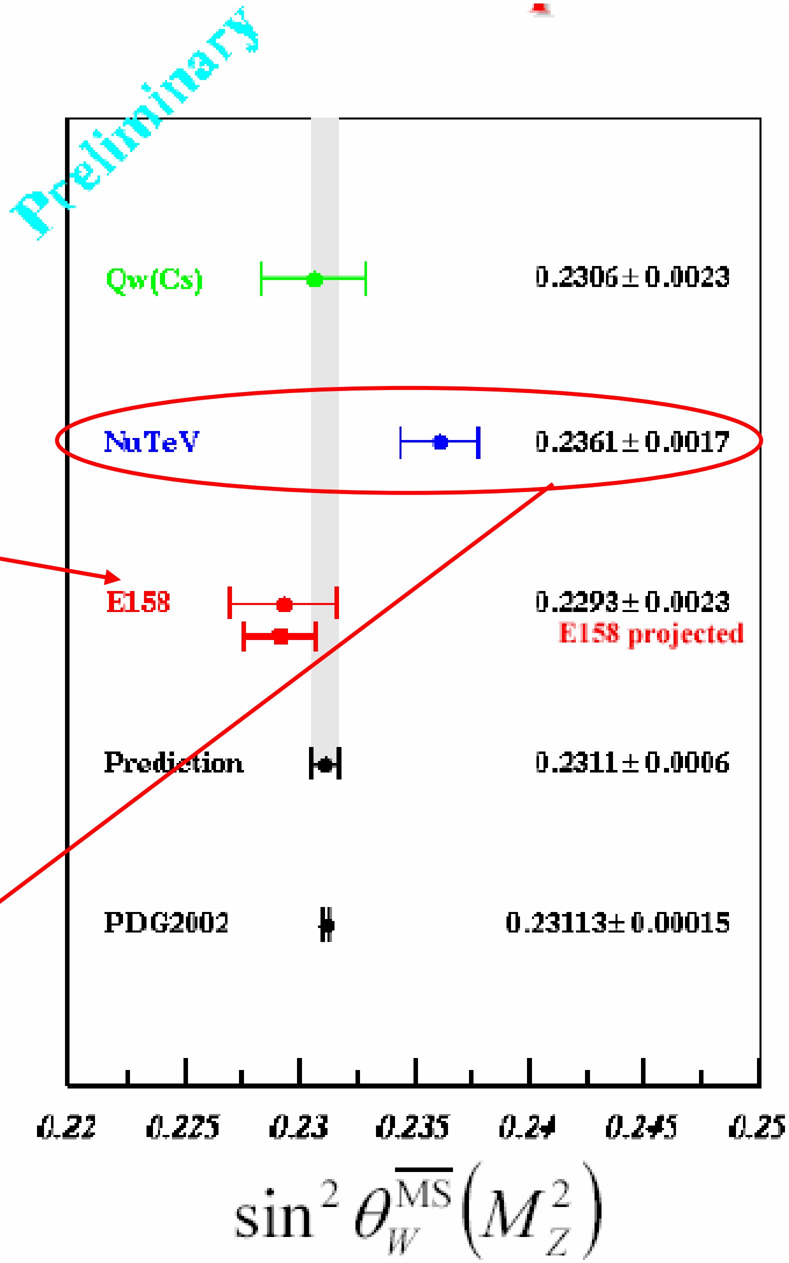
E158 Goal: $\delta\sin^2\theta_W$ = +/- 0.001

Best measurement of θ_W away from the Z-pole

- A_{PV} = -160 ± 21 ± 17

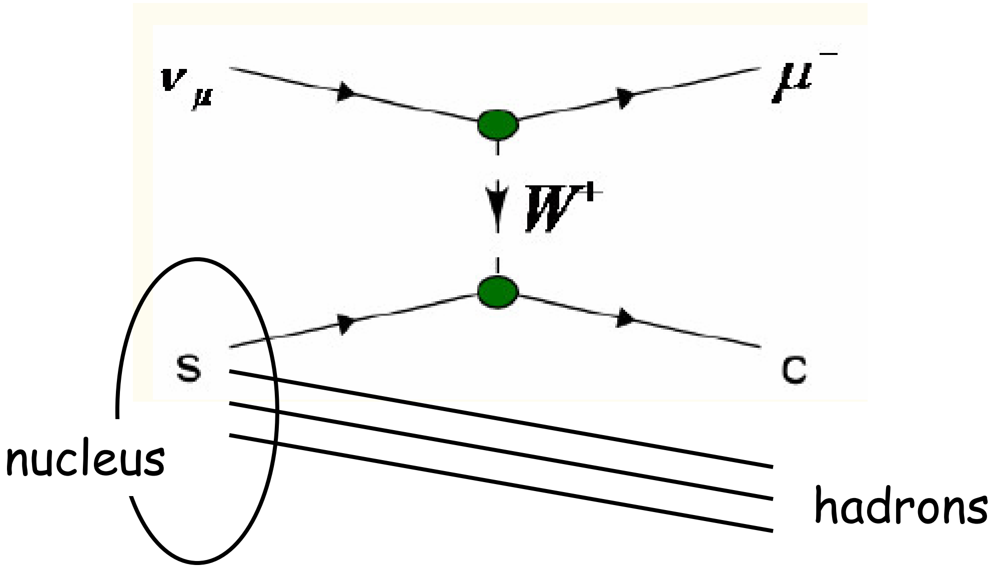
Significance of parity non-conservation is 6.3 sigma !!

Translate to $\sin^2(\theta_w)$



Still the old NuTeV 'discrepancy'

NuTeV: neutrino-nucleus deep inelastic scattering



probe strange sea

ν and anti-ν beam

clean events

Measure $\sin^2\theta_W$ through NC CC cross section ratio:

Paschos-Wolfenstein:

$$\frac{\sigma^{NC}(\nu N) - \sigma^{NC}(\bar{\nu} N)}{\sigma^{CC}(\nu N) - \sigma^{CC}(\bar{\nu} N)} = \frac{1}{2} - \sin^2\theta_W$$

For and against PWR

⊕ PWR is based on isospin symmetry
It is stable against α_s and HT corrections
PWR holds for both diff. and tot. x-sections.

⊖ PWR holds for an isoscalar target (e.g. D)
and must be corrected for non-isoscalarity eff.
in heavy nuclei. PWR is violated if $s \neq \bar{s}$.
PWR is violated if isospin symmetry is not exact.

Extracting $\sin^2(\theta_W)$ from DIS cross sections:

$$R = \frac{1}{2} - \sin^2\theta_w + \delta_R$$

Nuclear effects due to target corrections

More precise corrections:

(1) Z protons and N neutrons (10 x experimental error)

(2) QCD radiative corrections **new**

$\delta(\sin^2(\theta_W))$ = - 0.5 σ_{NuTeV} (towards SM value)

(3) Fermi-motion and nucleair binding effects from target **new**

$\delta(\sin^2(\theta_W))$ = - 0.5 σ_{NuTeV} (towards SM value)

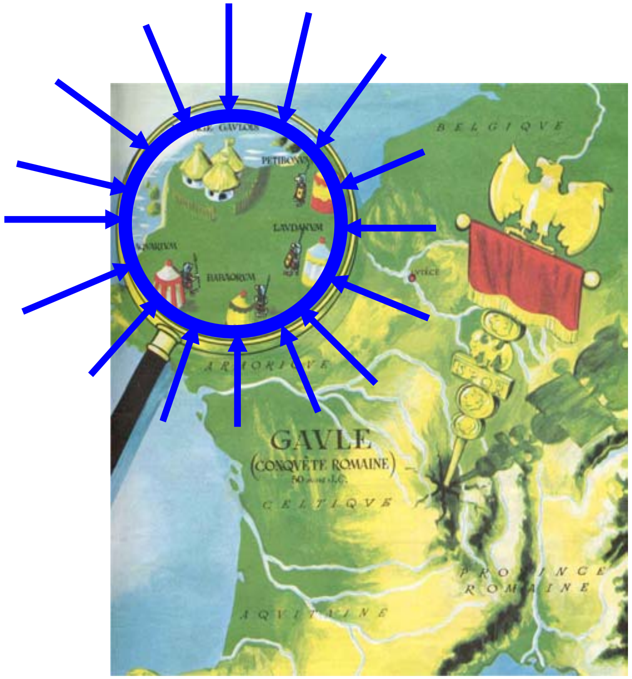
NuTeV shifts towards SM value (almost 1 sigma) !

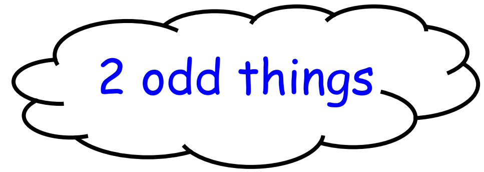
B-physics

Babar/Belle

4 sheets

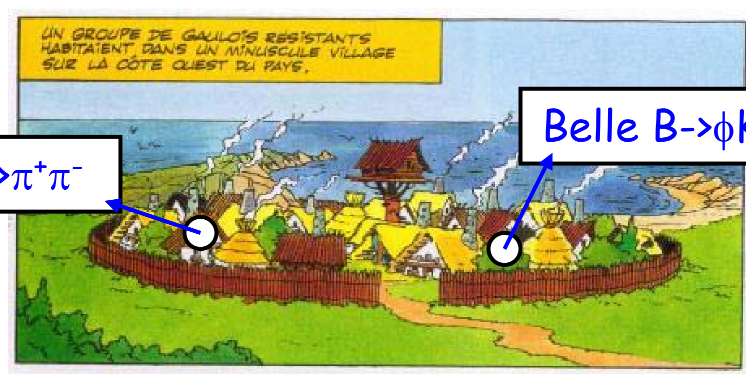
BABAR and Belle attacking the CKM matrix from all sides





Do they agree on everything ??

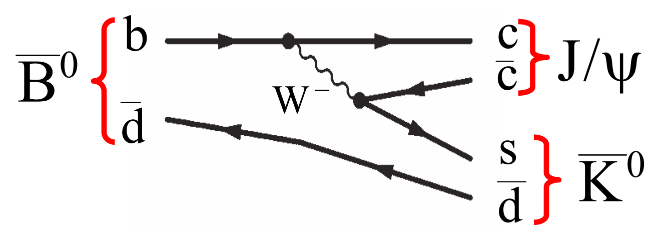
Are there anomalies left ??



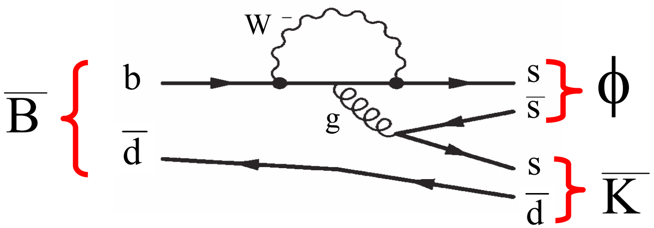
CP violation in $B^0 \to \pi^+\pi^-$

Belle $B \to \phi K_s$ 3.5 σ deviation from SM

Difference between $J/\psi K_s$ and ϕK_s



sin(2β)



sin(2β)

$B^0 \to \phi K_s \Rightarrow$ penguin diagram

NP contributions to $B^0 \to \phi K_s$ penguin can result in

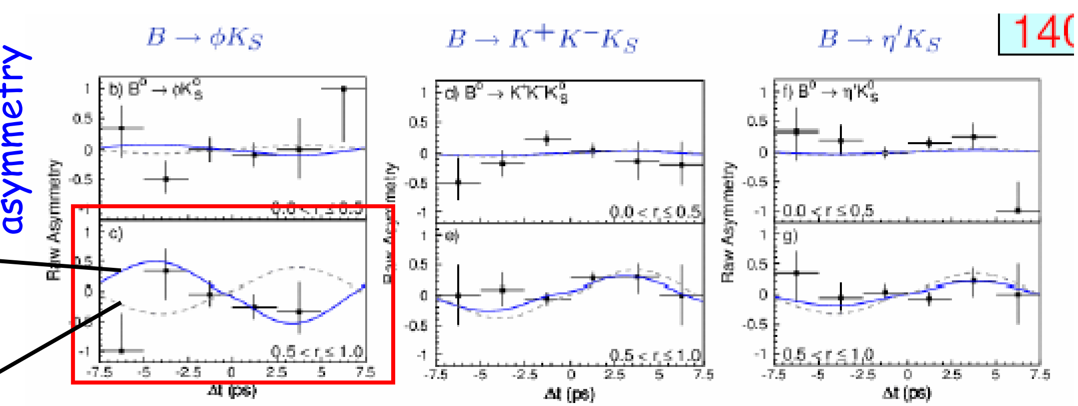
$\sin(2\beta)_{J/\psi Ks} \neq \sin(2\beta)_{\phi Ks}$

Old numbers

Babar	: $\sin(2\beta)_{J/\psi Ks}$=0.73±0.06
	: $\sin(2\beta)_{\phi Ks}$= 0.5±0.5
Belle	: $\sin(2\beta)_{\phi Ks}$=-1.0±0.6

Diff !

asymmetry



Measured

3.5 σ

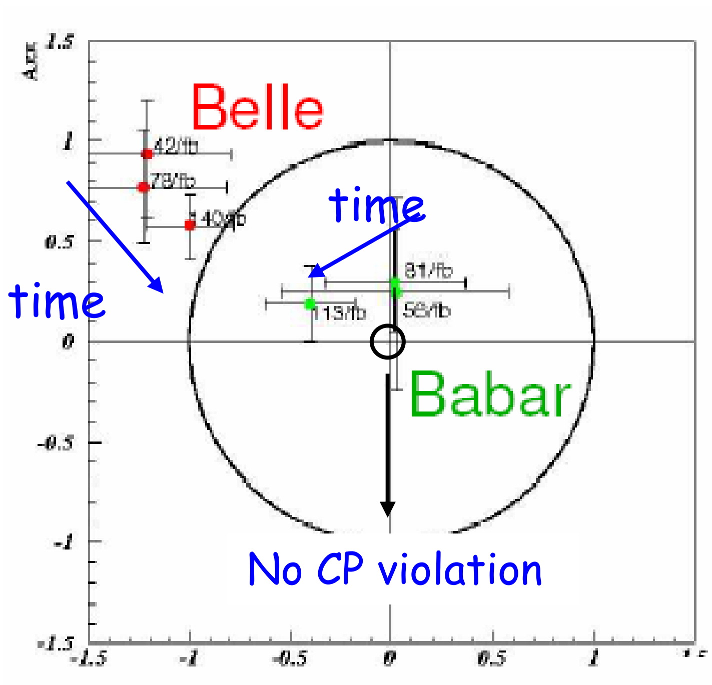
SM exp

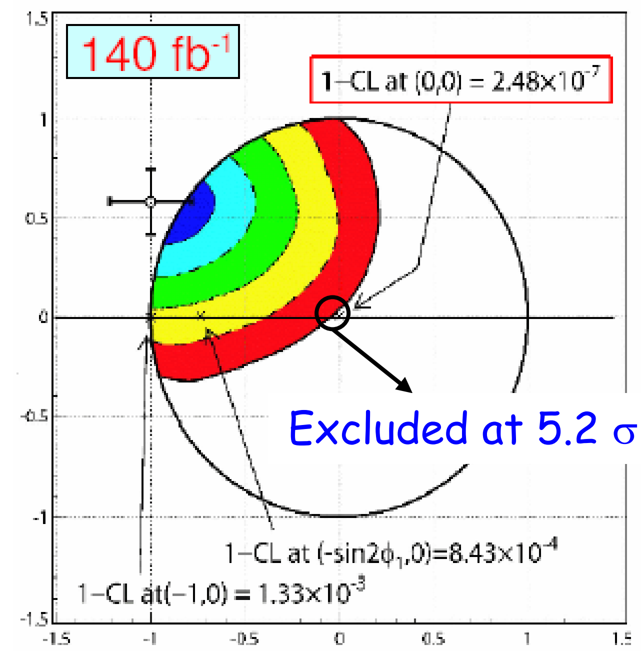
Δt decay time between tag-B and decay-B

CP violation in $B^0 \to \pi^+\pi^-$

Fit asymmetry to: $$A^{CP}_{\pi\pi}(t) = A_{\pi\pi}(t)\cos(\Delta m \Delta t) + S_{\pi\pi}(t)\sin(\Delta m \Delta t)$$

For no $B^\pm$, B^0 and $\overline{B^0}$ decays no CP-violation is observed (except Belle in $B^0 \to \pi^+\pi^-$)





SUMMARY (BABAR/Belle): doing well, some mysteries left.

Most frustrating slide in the conference !!

$B_s \to \mu^+ \mu^-$ is a promising window on possible physics beyond the SM.

In the SM, the expected branching ratio is small:

$$Br(B_s \to \mu^+ \mu^-) = (3.4 \pm 0.5) \cdot 10^{-9}$$

Quite a few talks on theoretical aspects of rare B decays as well.

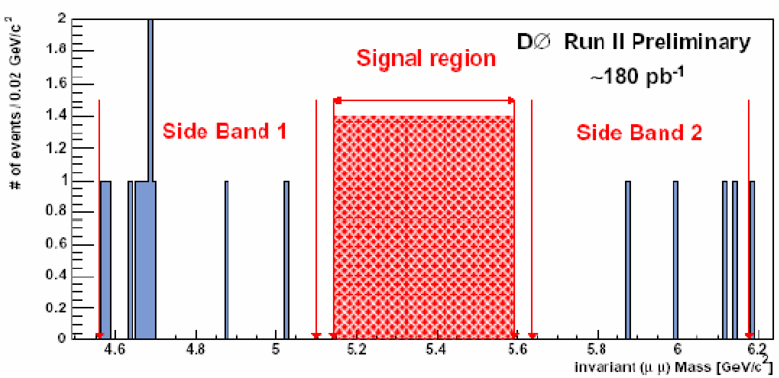
D0

$B_s \to \mu^+ \mu^-$ sensitivity study

Optimised cuts using Random Grid Search [Prosper, CHEP'95; Punzi, CSPP'03] based on the mass sidebands.

After optimisation:

expect 7.3 ± 1.8 background events in signal region



The analysis has not been *unblinded* yet (signal region still hidden).

Expected limit (Feldman/Cousins):

$Br(B_s \to \mu^+ \mu^-) < 9.1 \cdot 10^{-7}$ @ 95 % CL (stat only)

$Br(B_s \to \mu^+ \mu^-) < 1.0 \cdot 10^{-6}$ @ 95 % CL (stat + syst)

(expected signal has been normalised to $B^\pm \to J/\Psi\, K^\pm$)

Published CDF Run I result (98 pb^{-1}):

$Br(B_s \to \mu^+ \mu^-) < 2.6 \cdot 10^{-6}$ @ 95 % CL

Tevatron running

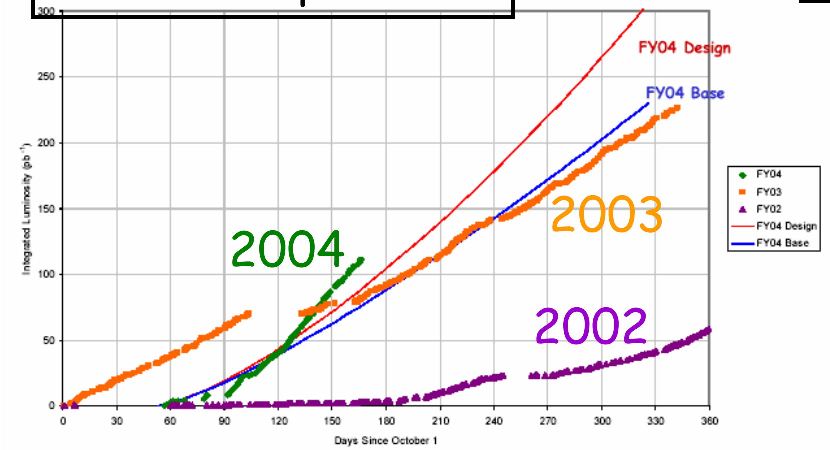
&

Higgs

1 sheet

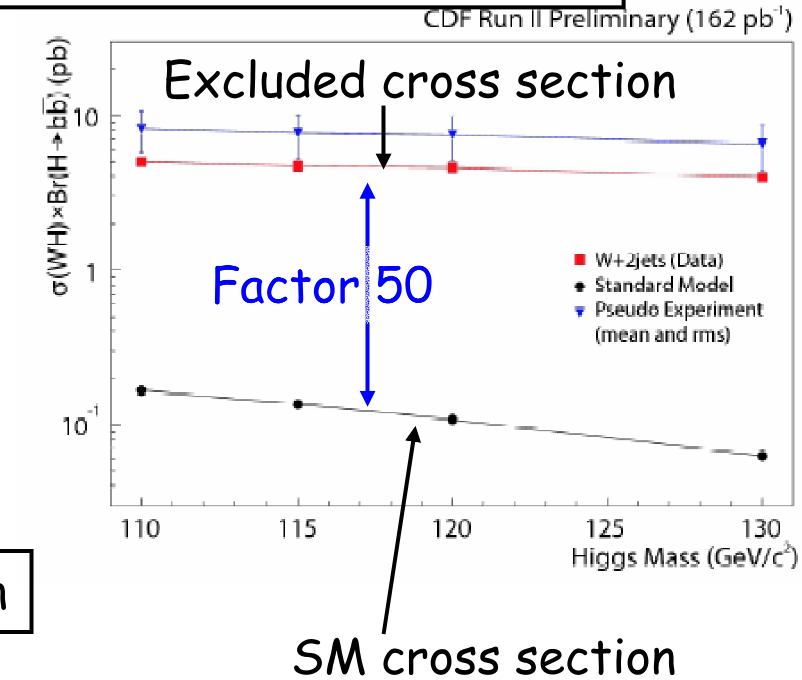
- Nothing new on the Higgs front & SUSY searches (updates from HERA, LEP, Tevatron)

Tevatron operation

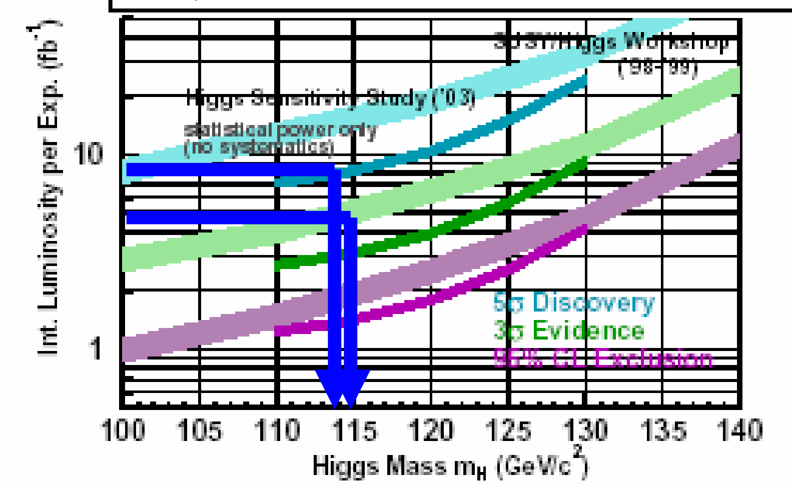


started bad, now ok

Higgs cross section exclusion



Expected Higgs boson mass exclusion



- Tevatron accelerator review:
  - 4.4 fb^{-1} at FY 09 feasible
  - 8.5 fb^{-1} at FY 09 very challenging

Penta-quarks

&

other new patricles

4 sheets

New particle

'New' particles are discovered all the time:

- two new extremely narrow mesons containing c and $\bar{s}$ quarks (BaBar, CLEO, BELLE)
- new very narrow resonance precisely at $D^{0*}D^0$ threshold (Belle, CDF)

- exotic 5-quark resonances: Θ^+ (KN), Ξ^{*--}

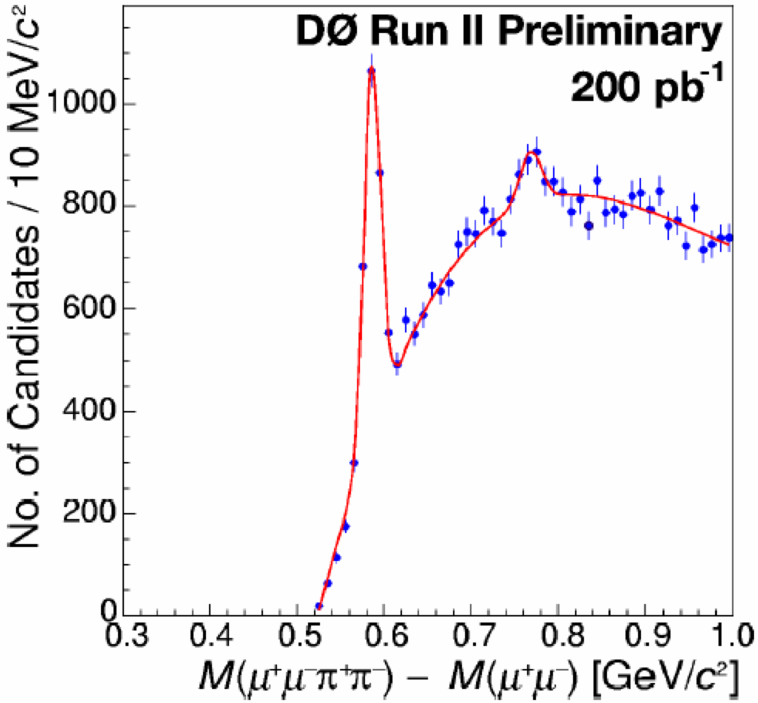
New particle

charmonium

X(3872) → J/Ψ $\pi^+ \pi^-$

Last summer, Belle announced a new particle at ≅ 3872 MeV/c^2, observed in B^+ decays:
$B^+ \rightarrow K^+ X(3872)$,
$X(3872) \rightarrow J/\Psi\ \pi^+ \pi^-$.

Belle's discovery has been confirmed by CDF and DØ.



DØ preliminary:

300 ± 61 events

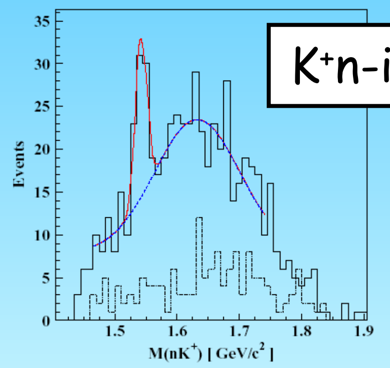
4.4σ effect

$\Delta M = 0.768 \pm 0.004\ (stat) \pm 0.004\ (syst)\ GeV/c^2$

Could have seen it in Run1 I guess. Now studying decay properties. Seems like charmonium state.

The discovery of Θ^+

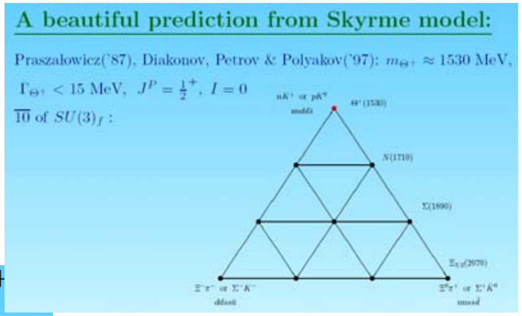
Pentaquarks: θ^+ and Ξ^{--}

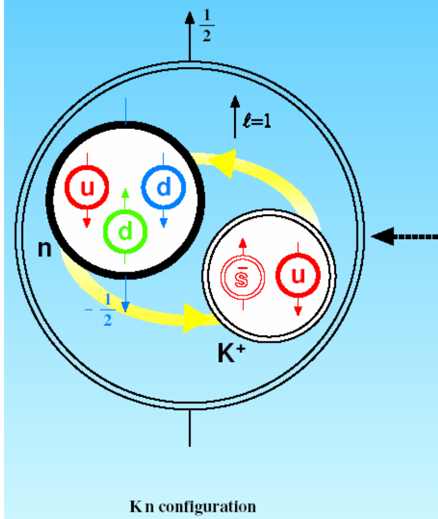


$m_{\Theta^+} = 1542 \pm 5$ MeV, $\Gamma_{\Theta^+} \leq 20$ MeV

New particle

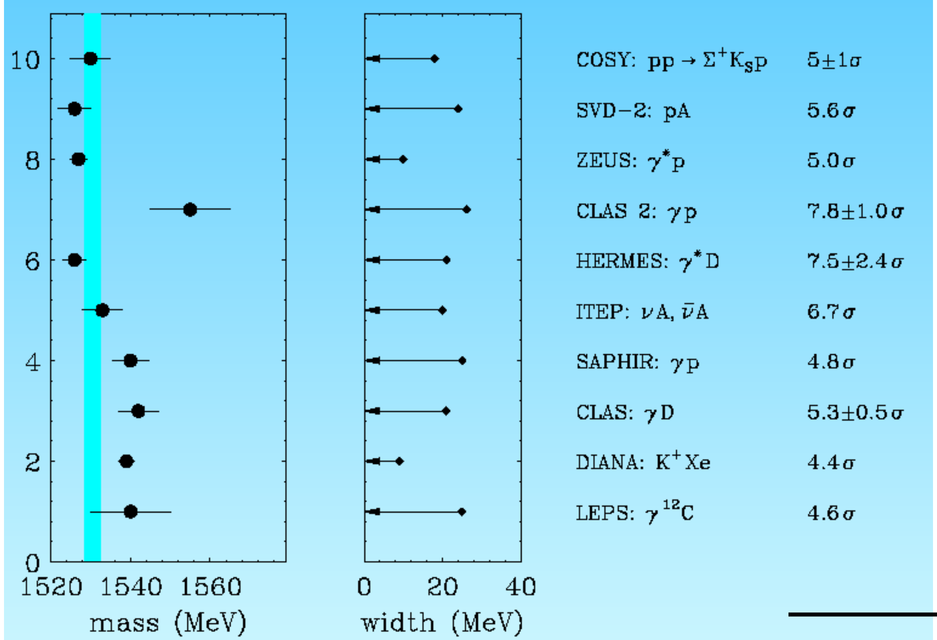
Penta-quark





P-wave diquark-triquark molecule.

mass and width measurements of Θ^+



World average: m=1530.5±2.0 MeV

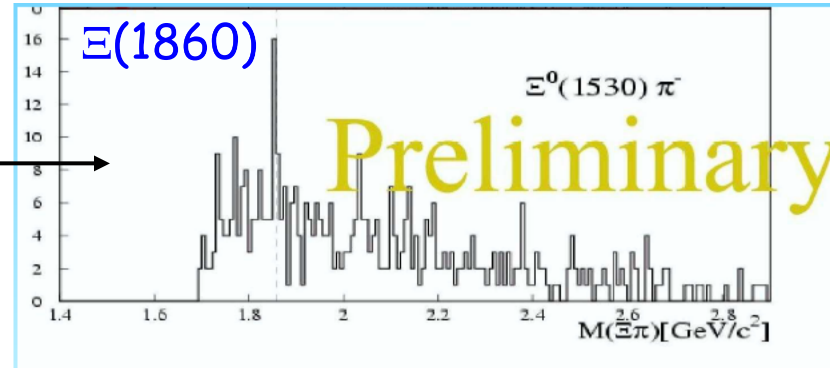
	Exp.	P-wave Theory (3+2)
$m_{\theta+}$	1542 ± 5	1592 ± 50
$m_{\Xi^{--}}$	1862 ± 5	1720 ± 50

→ Trying to understand the structure

New particle

Penta-quark

A 3rd penta-quark ??
(NA49)



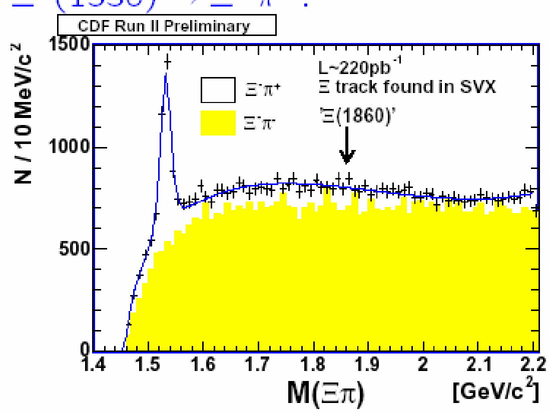
BUT

Not confirmed by CDF

Pentaquarks Looking for $\Xi(1860) \rightarrow \Xi^- \pi^\pm$

2^{nd} Step: Combine Ξ^- with $\pi^\pm$

Normalise by known $\Xi^0(1530) \rightarrow \Xi^- \pi^+$.



- Don't see any $\Xi(1860)$
- It's not statistics: (18× as many Ξ^- as NA49).
- Unknown bias due to Trigger? Re-check with Jet20 data (2× NA49). Still no $\Xi(1860)$

95% UL relativ to $\Xi(1530)$:

$\Xi^- \pi^+$ (search) / $\Xi(1530)$	0.07
$\Xi^- \pi^-$ (control) / $\Xi(1530)$	0.04

Extra
dimensions

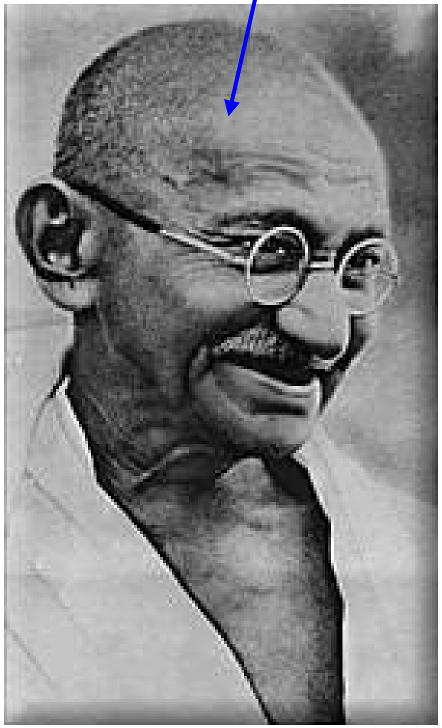
5 sheets

Many theory talks on this subject, a hot topic

e.g. Randall-Sundrum Models

prior

reality



Apparently I was not the only one who was surprised !

Why Consider Extra D?

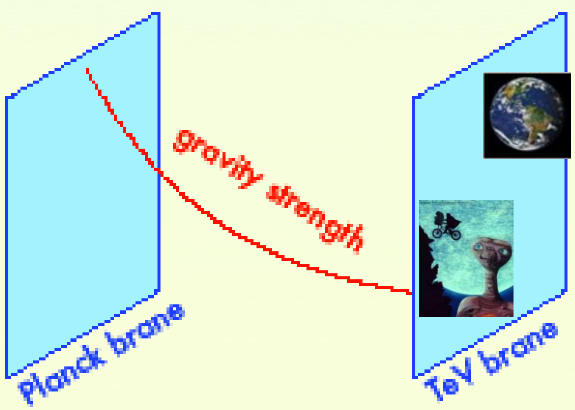
- String theory: at least six unseen dims
- General Relativity: why 4?
- New ways of approaching old problems
- Cosmology: still many unanswered questions
- Hierarchy, flavor, GUTs

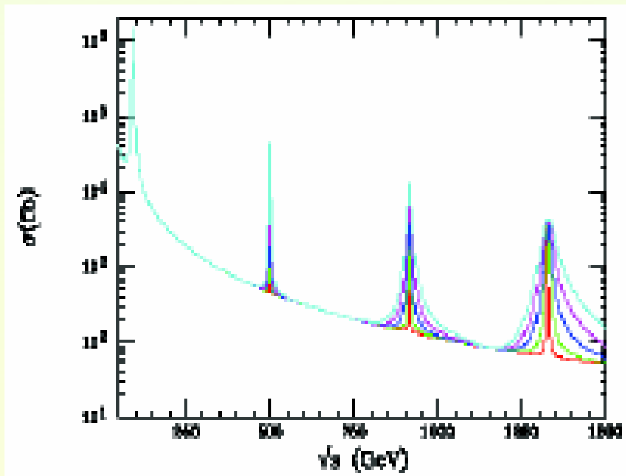
XD for EW Hierarchy

Randall

or why is gravity sooo small?

- ADD: all forces & particles localized on one brane, only gravity in large, flat XD ⇒
  - monojet+missing E_T (graviton KK modes)
- RS1: "warped" XD, with second (EW or TeV) brane, where gravity exp. suppressed
  - TeV resonances on EW brane ⇔ KK modes (also for gauge)





J. Orloff

Moriond EW04 Th Summary 5

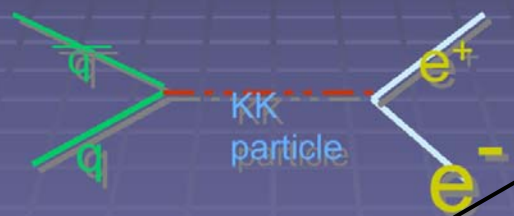
- You will see heavy partners of all particles
- Partners of the electron will be fermions
- Not bosons as in SUSY
- Partners should all have similar masses

Depend on size dimension

(like harmonic oscillator boundary conditions)

Experimental Signal

- Kaluza-Klein particles
- Definite mass spectrum and "spin"-2



Tevatron (direct) and LEP (indirect)

- Gravity strong near the EW scale

$$M_{pl}^2 \sim M_{eff}^{2+n} r^n$$

n extra (space) dimensions of radius r

- Virtual graviton exchange affects:

$$\frac{d}{d\cos(\theta)}\left[\sigma_{e^+e^- \to e^+e^-}\right]$$

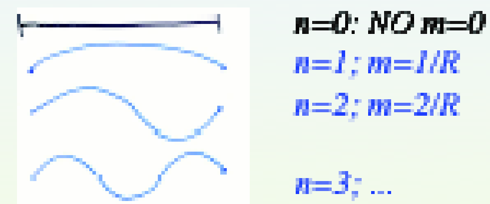
- We haven't seen additional charged particles up to m~TeV

SUMMARY:

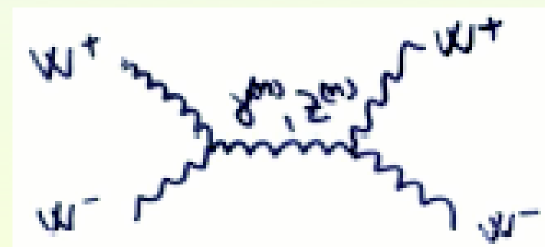
- No branes: 10^{-17} cm
- With branes, 0.2 cm
- With branes and curvature: infinite!

XD & EWSB: no Higgs

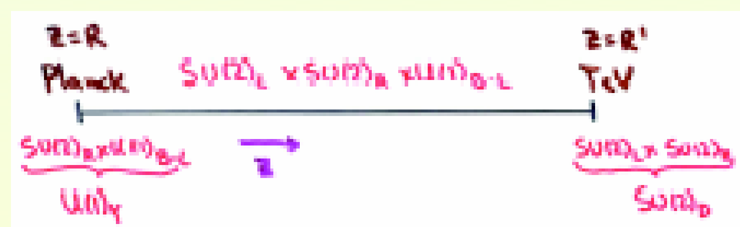
Csaki



- Boundary conditions can break 4D gauge symmetry (e.g. Dirichlet forbids $n=0$)



- Unitarity (without scalar) recovered iff all KK modes included, and 5d gauge invariant lagrangian; there are massive KK gauge bosons with m_{KK}<1.8 TeV



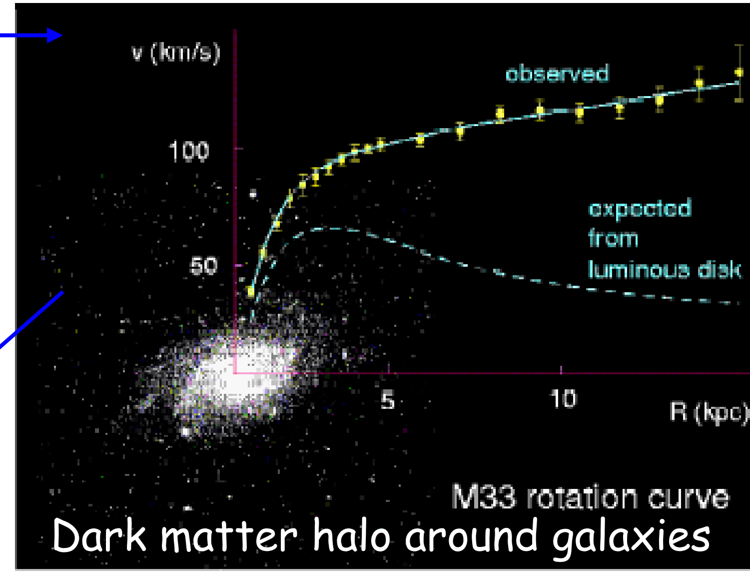
- Warped XD + more symmetries needed to suppress oblique corrections S,T,U
- Fermion masses: possible except for top

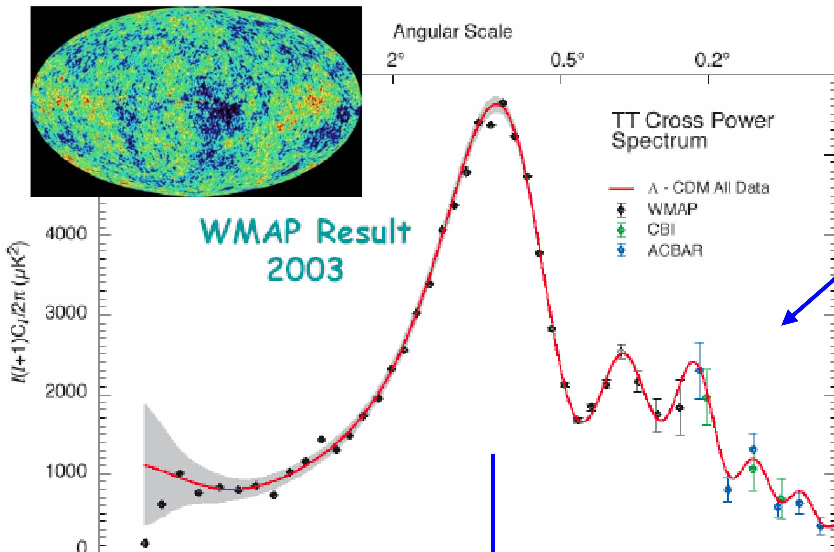
J. Orloff

Moriond EW04 Th Summary 7

11 sheets

Dark matter/energy





Baryon density	: $\Omega_b = 0.044 \pm 0.004$
Dark Matter	: $\Omega_m = 0.23 \pm 0.04$
Dark Energy	: $\Omega_\Lambda = 0.73 \pm 0.04$

$\Omega_{matter} > \Omega_{baryon}$ --> Non baryonic dark matter

$\Omega_{total} > \Omega_{matter}$ --> Dark Energy

What is dark matter ??

Axion

WIMP (SUSY stable LSP, χ_1^0)

Detecting WIMPS (1)

Assume WIMP = SUSY stable LSP

II. Direct detection of Neutralino WIMP

- Local Dark Matter density

$$\rho_{local} \approx 0.3 GeV / cm^3$$

- Maxwellian velocity distribution

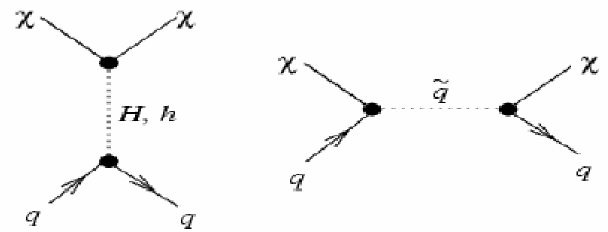
$$\bar{v} \approx 270 km / s$$

⇓

- Local Flux of Dark Matter

$$\Phi_{local} \approx \frac{100 GeV}{m_\chi} \cdot 10^5 cm^{-2} s^{-1}$$

Detecting WIMPS (2)



- **Principles of WIMP detection**

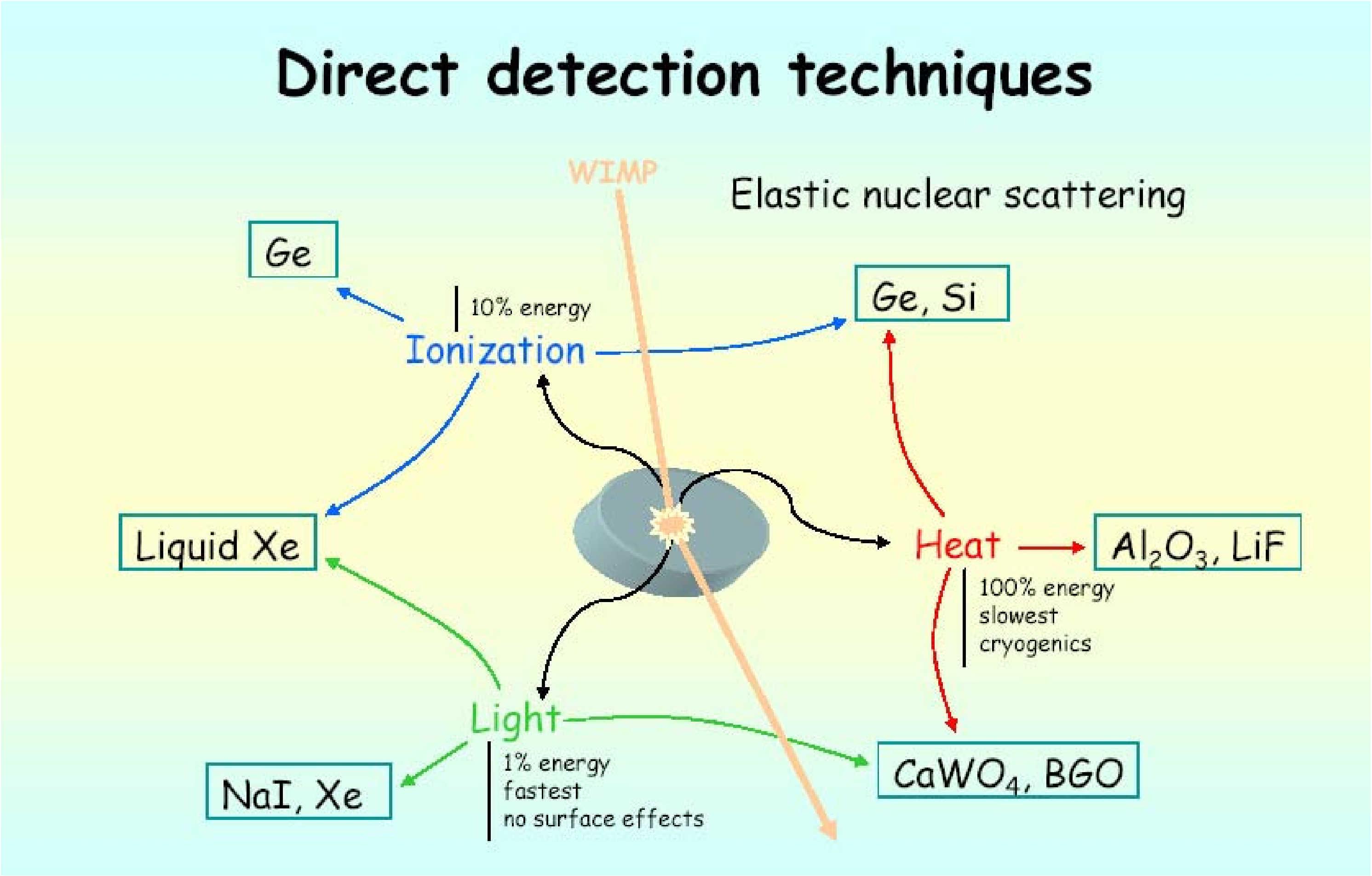
  - Elastic scattering of a WIMP on a nucleus inside a detector
  - The recoil energy of a nucleus with mass m_N

$$E_{recoil}(\max) = 2v_x^{\ 2} m_N \frac{m_\chi^{\ 2}}{(m_N + m_\chi)^2}$$

For $v_\chi \approx 10^{-3} c$ ⟹ $E_{recoil} \approx 10^{-6} m_N \approx 10 keV$

  - This recoil can be detected in some ways :
    - ✓ Electric charges released (ionization detector)
    - ✓ Flashes of light produced (scintillation detector)
    - ✓ Vibrations produced (phonon detector)

Sensitive underground detectors, but need large (mass * exposure time)



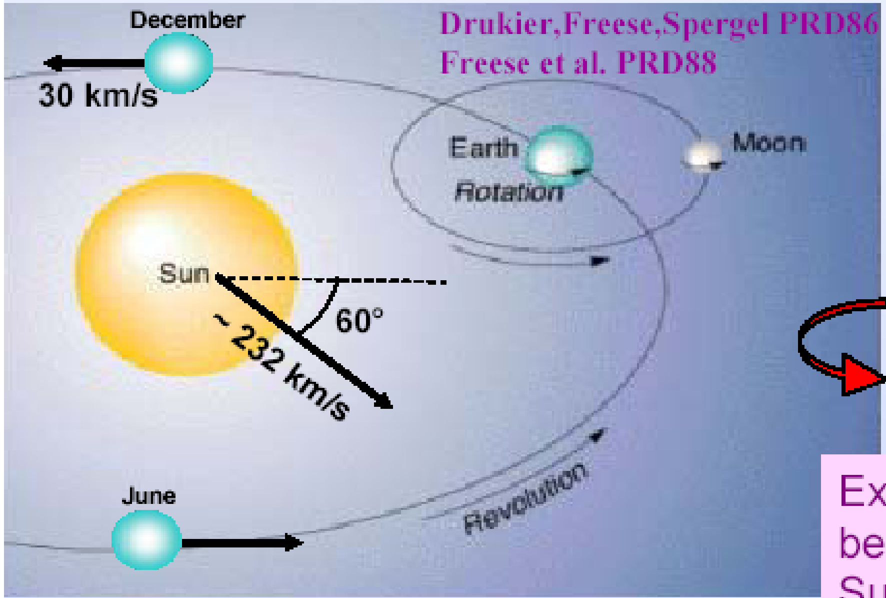
WIMPS

Discrim.	Name	Location	Technique	Material	Status
None	CUORICINO	Gran Sasso	Heat	41 kg TeO2	running
	GENIUS-TF	Gran Sasso	Ionization	42 kg Ge in N2	running
	HDMS	Gran Sasso	Ionization	0.2 kg Ge diodes	stopped
	IGEX	Canfranc	Ionization	2 kg Ge Diodes	stopped
Statistical	DAMA	Gran Sasso	Light	100 kg NaI	stopped
	LIBRA	Gran Sasso	Light	250 kg NaI	running
	NaIAD	Boulby mine	Light	65 kg NaI	running
	ZEPLIN-I	Boulby mine	Light	4 kg Liquid Xe	running
Event-by-event	CDMS-I	Stanford	Heat + Ionization	4 Kg Ge + Si	stopped
	CDMS-II	Soudan mine	Heat + Ionization	2 to 7 kg Ge + Si	running
	CRESST-I	Gran Sasso	Heat + Light	0.262 kg Al2O3	stopped
	CRESST-II	Gran Sasso	Heat + Light	0.6 to 9.9 kg CaWO4	running
	EDELWEISS-I	Modane	Heat + Ionization	1 kg Ge	running
	ROSEBUD	Canfranc	Heat + Light	1 kg BGO	running
	SIMPLE	Rustrel	Superheated droplets	Freon	stopped

→ DAMA & Edelweiss

DAMA at Moriond

Investigating the presence of a WIMP component in the galactic halo by the model independent WIMP annual modulation signature



Drukier,Freese,Spergel PRD86
Freese et al. PRD88

- v_{sun} ~ 232 km/s (Sun velocity in the halo)
- v_{orb} = 30 km/s (Earth velocity around the Sun)
- $\gamma = \pi/3$
- $\omega = 2\pi/T$ T = 1 year
- t_0 = 2nd June (when $v_\oplus$ is maximum)

$$v_\oplus(t) = v_{sun} + v_{orb} \cos\gamma \cos[\omega(t-t_0)]$$

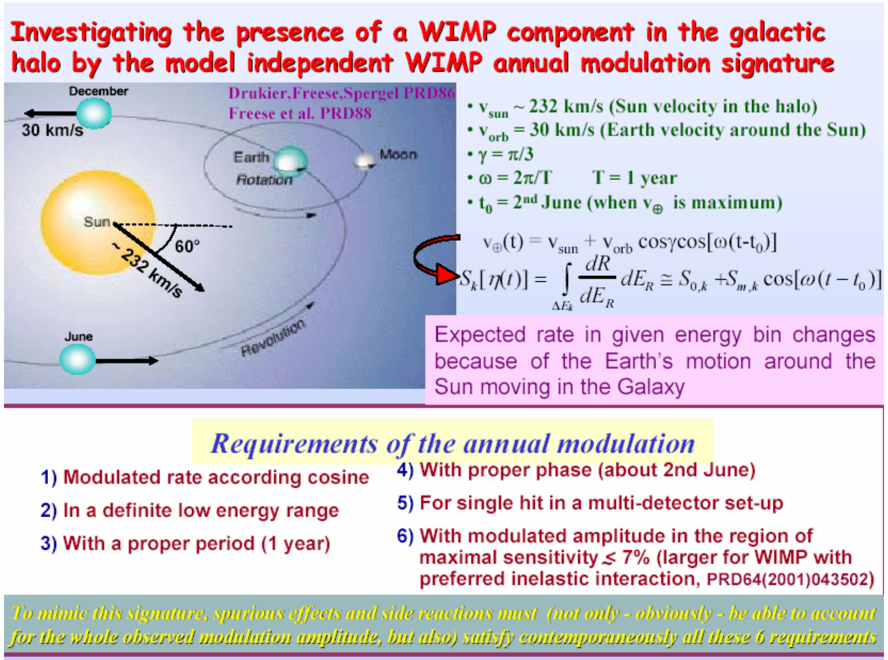
$$S_k[\eta(t)] = \int_{\Delta E_k} \frac{dR}{dE_R} dE_R \cong S_{0,k} + S_{m,k} \cos[\omega(t-t_0)]$$

Expected rate in given energy bin changes because of the Earth's motion around the Sun moving in the Galaxy

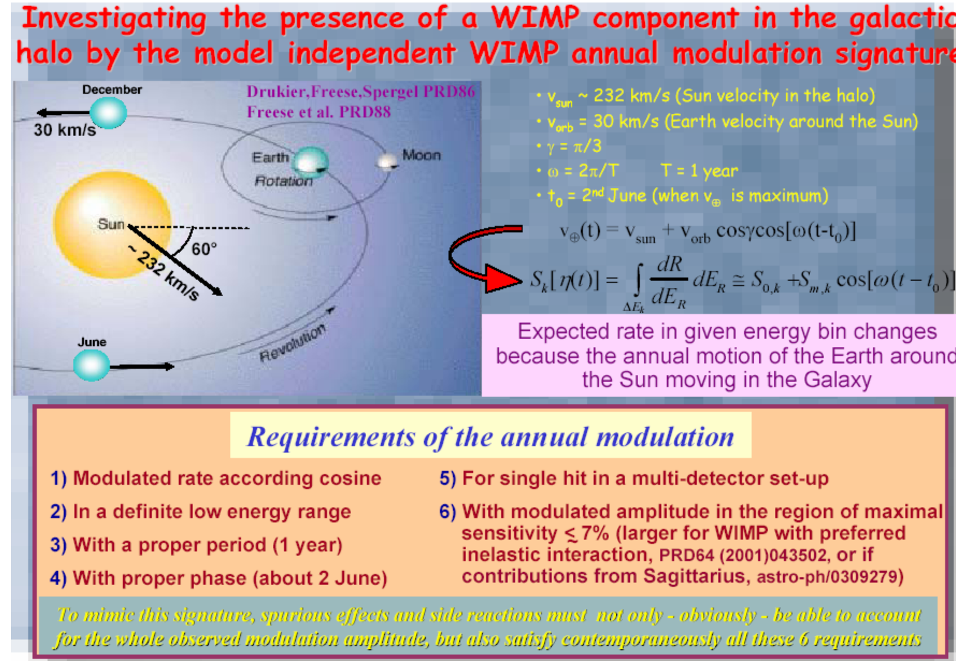
Requirements of the annual modulation

1) Modulated rate according cosine
2) In a definite low energy range
3) With a proper period (1 year)
4) With proper phase (about 2nd June)
5) For single hit in a multi-detector set-up
6) With modulated amplitude in the region of maximal sensitivity $\lesssim$ 7% (larger for WIMP with preferred inelastic interaction, PRD64(2001)043502)

To mimic this signature, spurious effects and side reactions must (not only - obviously - be able to account for the whole observed modulation amplitude, but also) satisfy contemporaneously all these 6 requirements



DAMA at Moriond



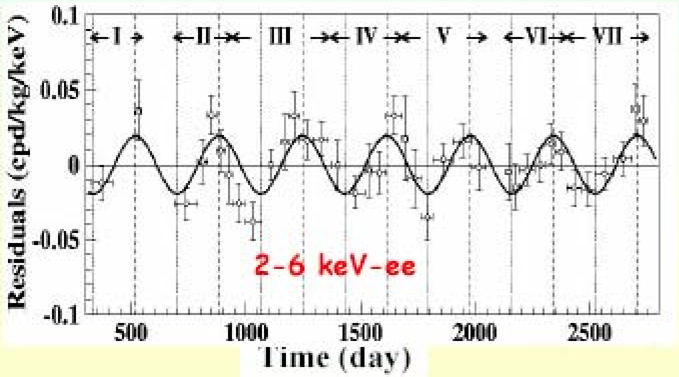
DAMA at CALOR

Talks from DAMA 95% the same:

They see something !!

Latest results: DAMA

- Data taking completed in July 2002
- Total exposure of 107,731 kg.d
- See annual modulation at 6.3σ
- Claim model-independent evidence for WIMPs in the galactic halo



- WIMP candidate under standard halo parameters:
  $M_\chi = (52\ ^{+10}_{-8})$ GeV and $\sigma_{\chi-N} = (7.2\ ^{+0.4}_{-0.9})\ .10^{-6}$ pb

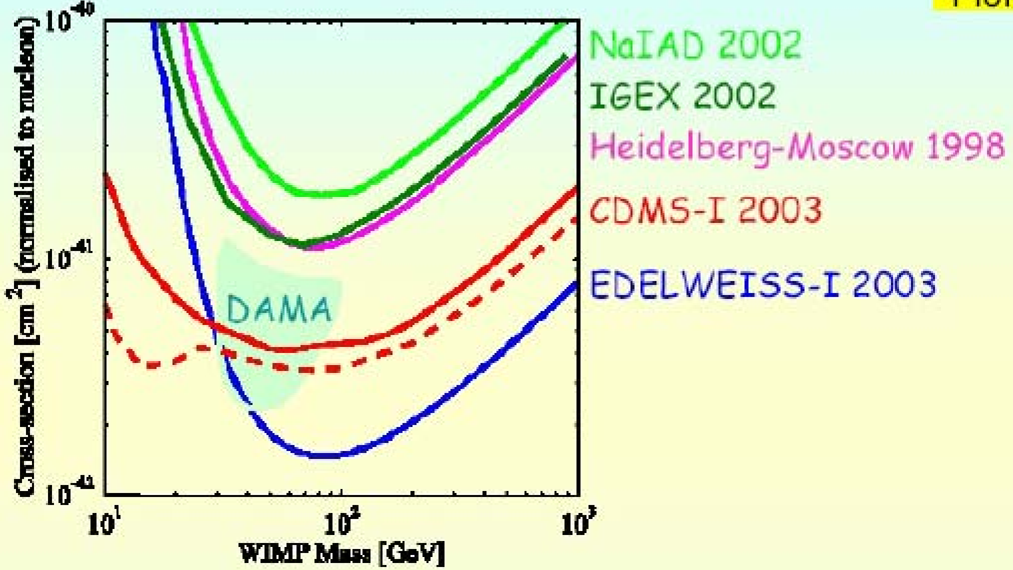
- Checking this result remains important

- 2nd phase 250 kg LIBRA running...
- NaIAD 65kg NaI in Boulby mine

EDELWEISS-I (Frejus, inonization-heat measurement, small)

Current exclusion limits

Fiorucci



- 99.8% CL incompatibility with DAMA modulation signal claimed by:
  - CDMS at low masses
  - EDELWEISS above 50 GeV
- Exclusion resists to a variation of halo parameters *

* Copi & Krauss, astro-ph/020810

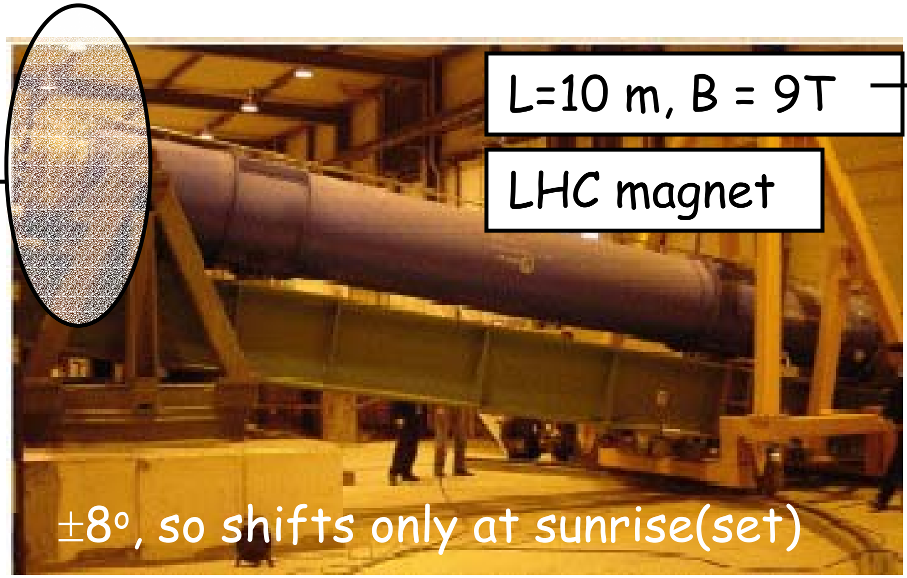
* Kurylov & Kamionkowski, hep-ph/0307185

Plans: 10^{-6} pb (now), 10^{-8} (soon), 10^{-10} (10 years)

However, DAMA claims that no model independent comparison is possible…

Axions can be produced in the sun.

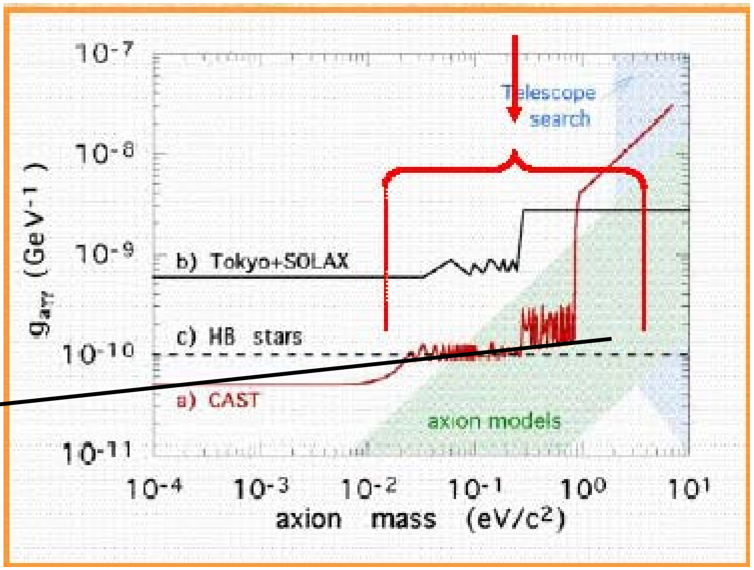
Interact with magnetic field ($\propto B^2L^2$) and produce X-rays ($a \rightarrow \gamma$)



→ 100 times more $a \rightarrow \gamma$ conversions than any other experiment

→ X ray telescope.

2005: Probe higher axion masses (fill magnet with helium)



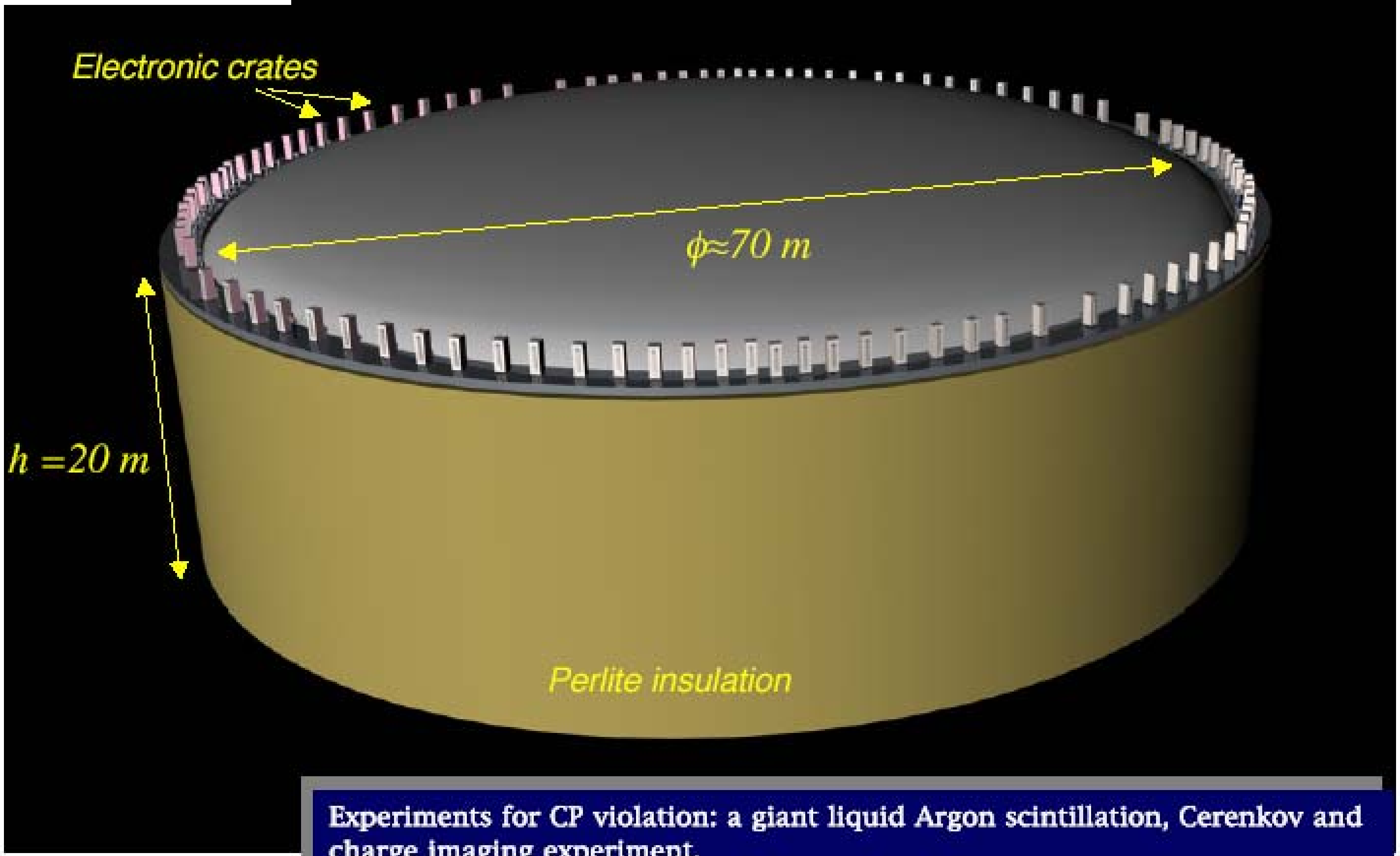
Other underground experiments: proton decay Explore lifetimes > 10^{35} years

Ambitious:

74 sheets in 30 minutes

100,000,000 kg liquid argon

Rubbia



Experiments for CP violation: a giant liquid Argon scintillation, Cerenkov and charge imaging experiment.

A.Rubbia, Proc. II Int. Workshop on Neutrinos in Venice, 2003, hep-ph/0402110

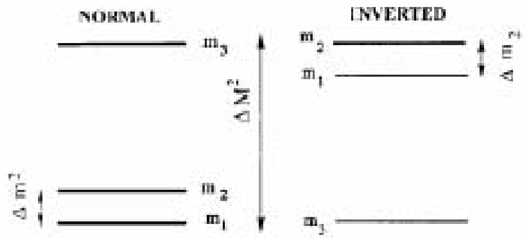
ndré Rubbia - April 2004

Neutrinos

7 sheet

Neutrino: mass and mixing parameters

- Puzzles and experimental tasks:
  - Do neutrinos really oscillate? ← OK, evidence from Super-K
  - Are there only 3 neutrino species? ← LSND / MiniBooNE NEW!
    Are there sterile neutrinos?
  - What is the mass hierarchy pattern? (Sgn Δm_{23}^2 ?)



  - What is absolute mass scale? ← Neutrinoless double beta-decay
  - Are neutrinos Dirac or Majorana? ← Neutrinoless double beta-decay
  - Measure θ_{13} and δ

How do we probe the neutrino sector of the SM:

Mass eigenstates are mixture of flavour eigenstates (a la CKM matrix)

$$|\nu_{flavour}\rangle = U_{PMNS} |\nu_{mass}\rangle \qquad |q_{flavour}\rangle = U_{CKM} |q_{mass}\rangle$$

2-3 mixing 1-3 mixing 1-2 mixing

$$U_{\alpha i} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \cdot \begin{pmatrix} c_{13} & 0 & s_{13}e^{+i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{-i\delta} & 0 & c_{13} \end{pmatrix} \cdot \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Atmospheric
Superkamiokande

Reactor (CHOOZ)
If $\theta_{13} \neq 0$ --> CP-violation

Solar (KAMLAND)

$\Delta(m_{23})^2$ = 2-3 eV^2
Θ_{23} = 45^o

$\Delta(m_{13})^2$ = ??

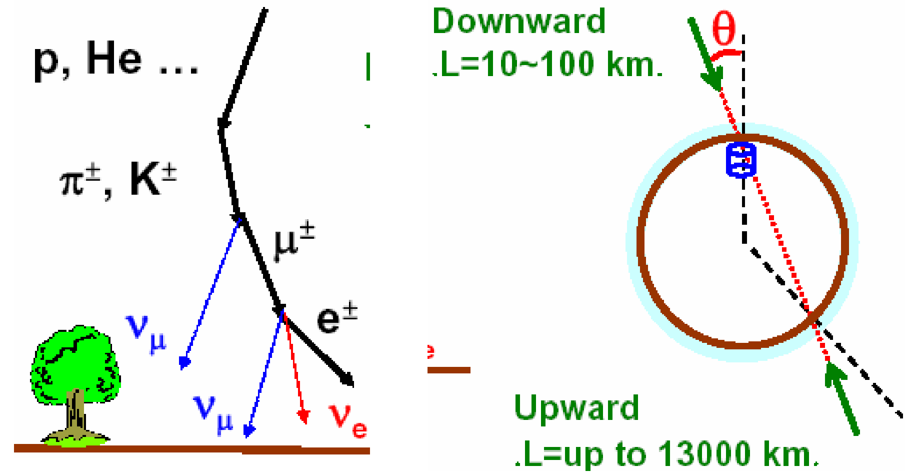
$\Delta(m_{12})^2$ = 5-7 eV^2

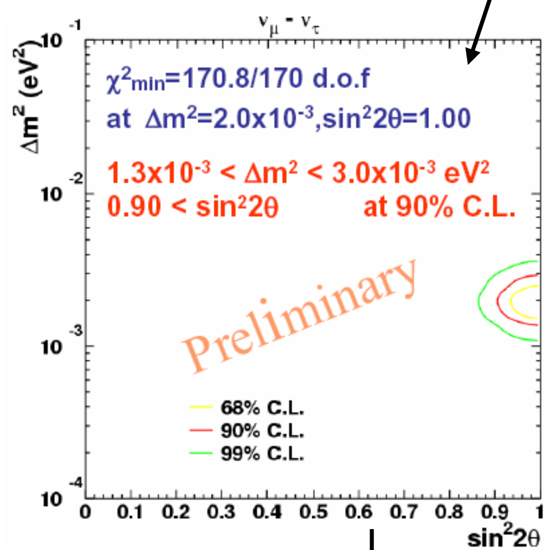
MNS = Maki-Nakagawa-Sakata

Do they really oscillate ??

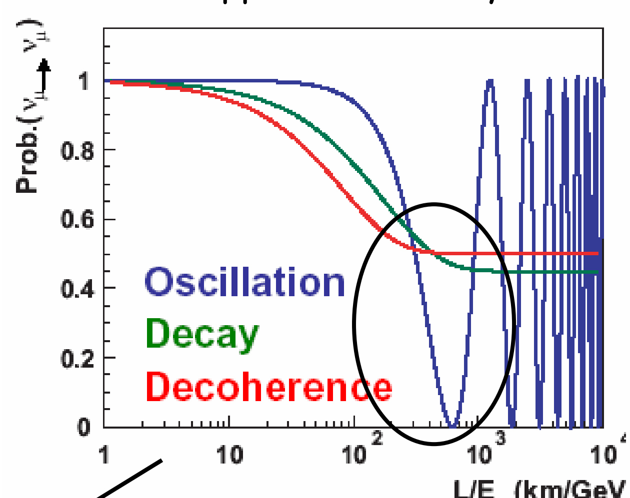
Super Kamiokande

- Atmospheric Neutrinos
  - $\nu_\mu \leftrightarrow \nu_\tau$ 2 flavor oscillations from
    - I. Zenith angle analysis
    - II. L/E analysis

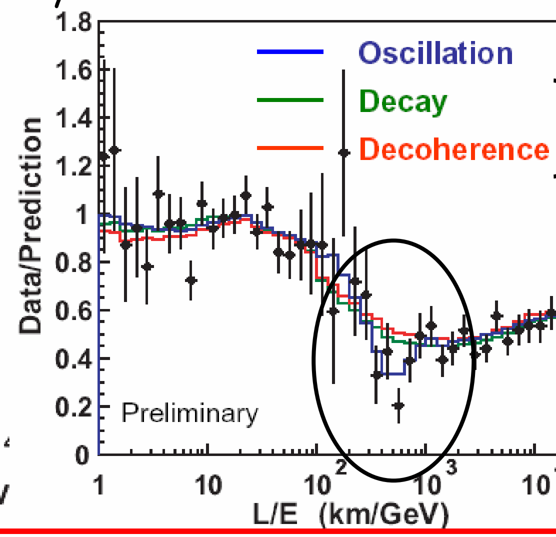




Is disappearance really caused by oscillations ??



3.5sigma disfavored



2 allowed regions are compatible

First evidence that neutrino transition probability obeys sinusoidal function as predicted in neutrino oscillation

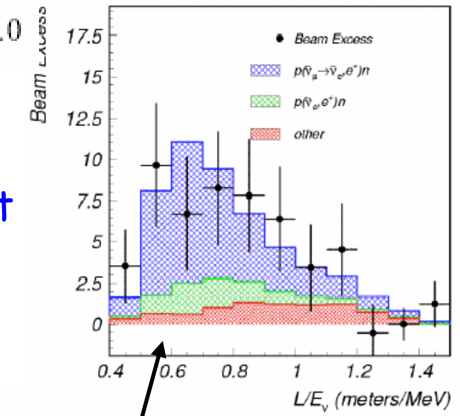
Are there 3 families ??

Sterile neutrinos

Excess ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$, *appearance*): 87.9 ± 22.4 ± 6.0

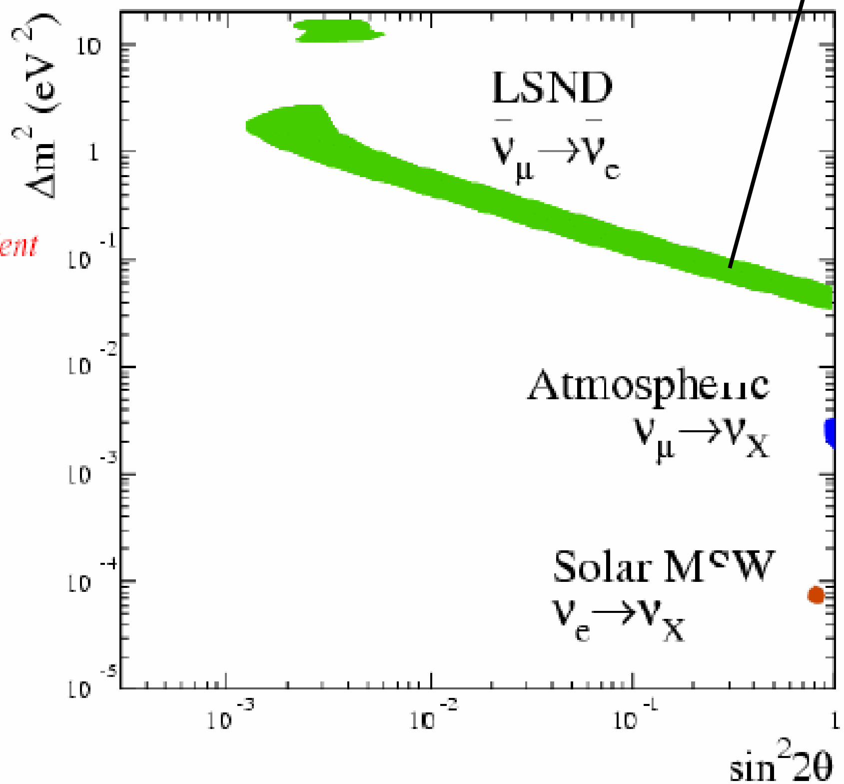
Close to 4 σ

KARMEN excludes part of it



- **ν oscillation signals:**
  - ***Solar***: $\Delta m^2 \sim 10^{-5}\,eV^2$ (SNO, KamLAND, ...)
  - ***Atmospheric***: $\Delta m^2 \sim 10^{-3}\,eV^2$ (Super-K, K, ...)
  - ***Accelerator***: $\Delta m^2 \sim 10^{0}\,eV^2$ (LSND)

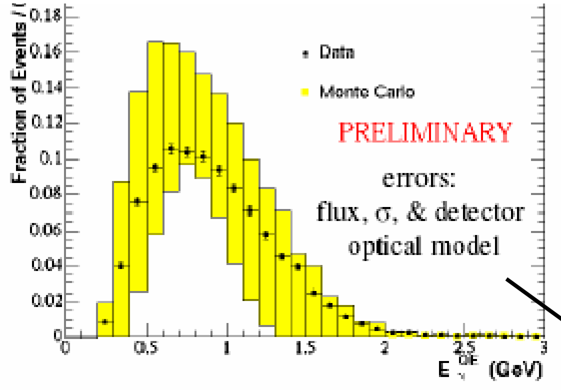
3 vs allow only 2 independent values of Δm^2



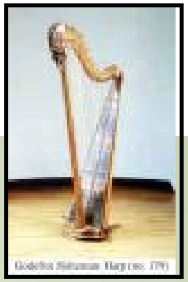
- **What to do?**
  1. An experiment or interpretation is wrong
  2. Add sterile neutrinos: 1, 2, 3 ...
  3. Violate CPT

(confirmation needed): --> miniBOONE

miniBOONE energy spectrum requires more precise cross section data



Physics goals

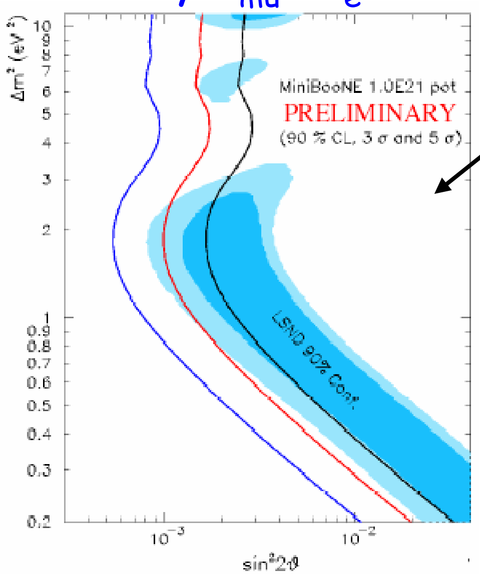


- ***Systematic study of HAdRon Production:***
  - Beam energy: *2-15 GeV*
  - Target: *from hydrogen to lead*
- ***Motivation:***
  - Pion/kaon yield for the design of the proton driver of *neutrino factories* and SPL-based *super-beams*
  - Input for precise calculation of *atmospheric neutrino flux*
  - Input for prediction of neutrino fluxes for the *MiniBooNE* and *K2K* experiments
  - Input for *Monte Carlo* generators (GEANT4, e.g. for LHC, space applications)

Use identical targets at HARP

4

Sensitivity n_{mu}->n_e

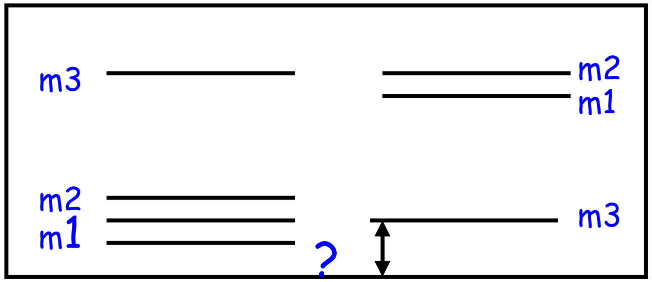


miniBOONE will cross-check LSND result

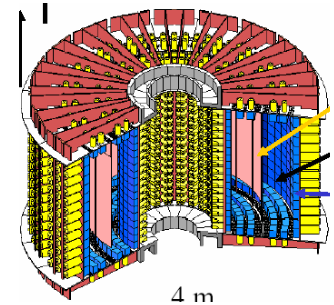
Depends on Tevatron programme

What about the absolute mass scale and hierarchy ??

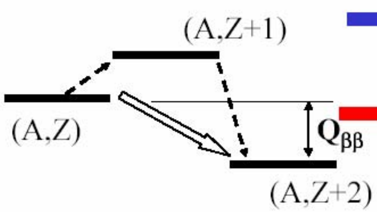
We only know mass differences squared $\Delta(m^2)$



NEMO:



Neutrinoless double beta decay



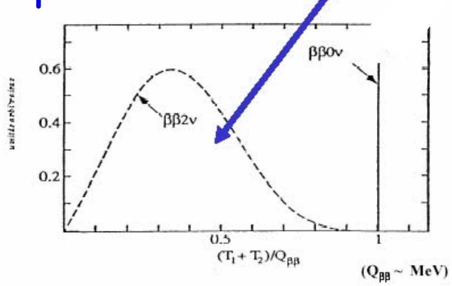
$\beta\beta 2\nu$: allowed SM process $T_{1/2} \sim 10^{20}$y

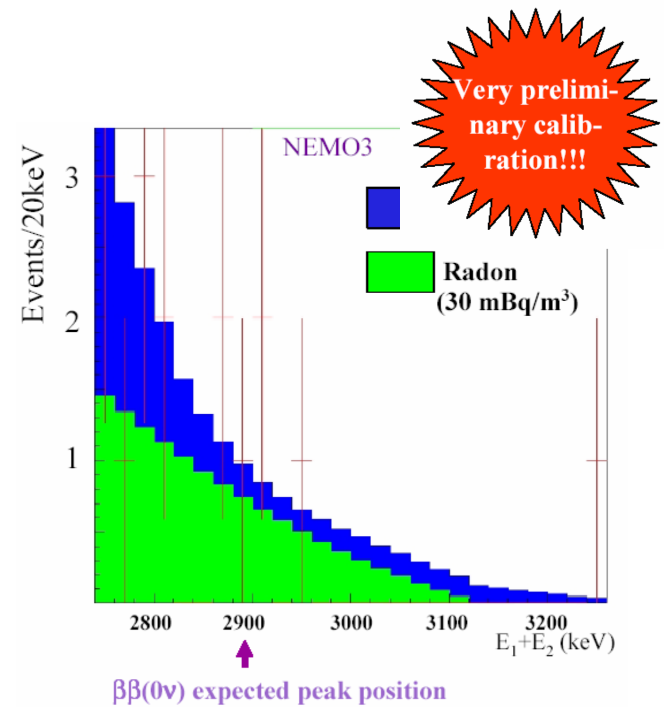
$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\nu$ $(2n \rightarrow 2p + 2e^- + 2\nu)$

$\beta\beta 0\nu$: beyond the SM $T_{1/2} \geq 10^{25}$y

$n \rightarrow p + e^- + \nu$

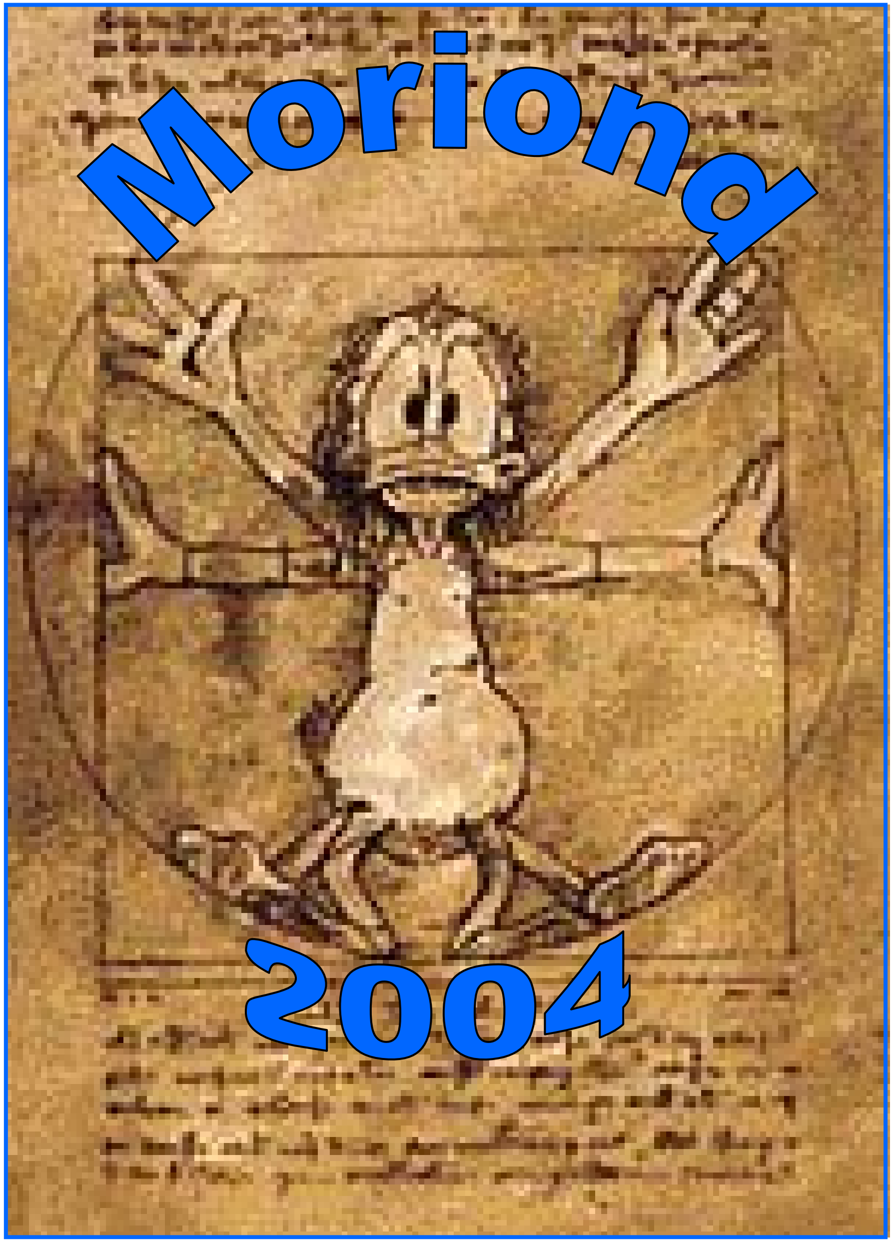
Lepton number violation





Radon down factor 10


I will leave CERN on the 1st of June
ciao
NL


Moriond
2004