All DØ meeting

March 30, 2007

Moriond EW summary

42nd Rencontres de Moriond

Electroweak Interactions and Unified Theories

March 10-17 200, La Thuile, Italy

http://indico.in2p3.fr/conferenceDisplay.py?confId=151

- Goals of the conference
- W, Z, top and H from the Tevatron
- Evidence for D mixing from Belle and Babar
- CKM angles and sides
- Neutrinos: beam, reactor, atmospheric, $0\nu\beta\beta$
- High energy astronomy: photons, CR, neutrinos
- DM searches and precision measurements

UNIVERSITY OF WASHINGTON

Arán García-Bellido

Introduction

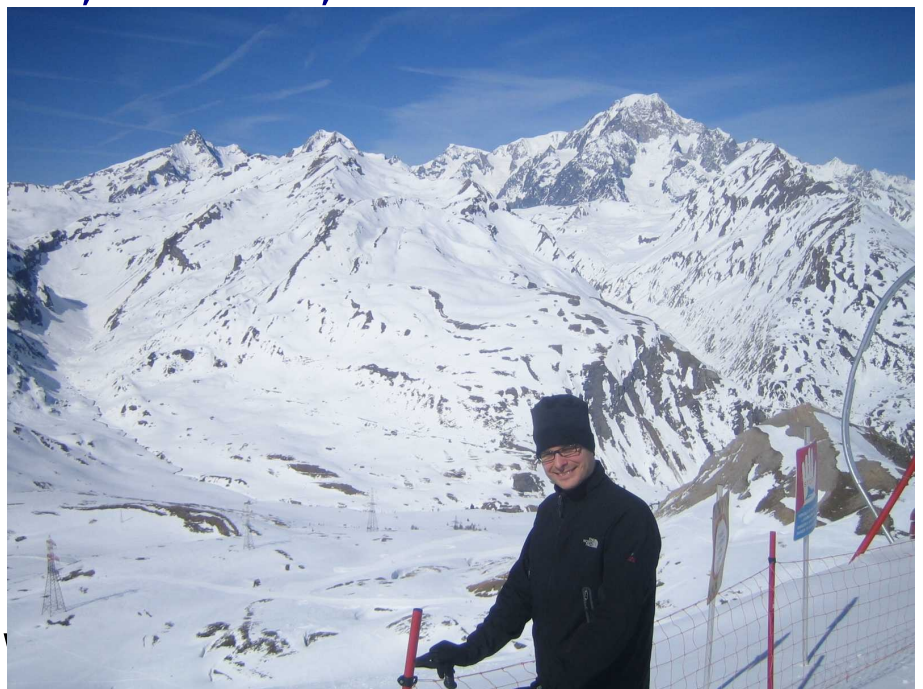
- Purposes of the conference:
  - Bring together theorists and experimentalists in beautiful and inspiring surroundings to discuss recent findings
  - Invite young scientists (~80% below 35 years-old)
- 138 participants, with 94 talks (11 in Young Scientist Forum)
- Excellent talks from the youngest participants!
- Dense program: 3 hours in the morning, 4 hours break, 3 hours in the evening
- Theorists and experimentalists talks mingled
- I will not cover all topics here: I have made a biased selection!
- Largely following the EW summary by B. Mansoulie
- Some updated plots and numbers are from Moriond QCD
  - Big surprise was D-Dbar mixing evidence by Belle & BaBar

Skiing was great!

From glorious “off-piste”

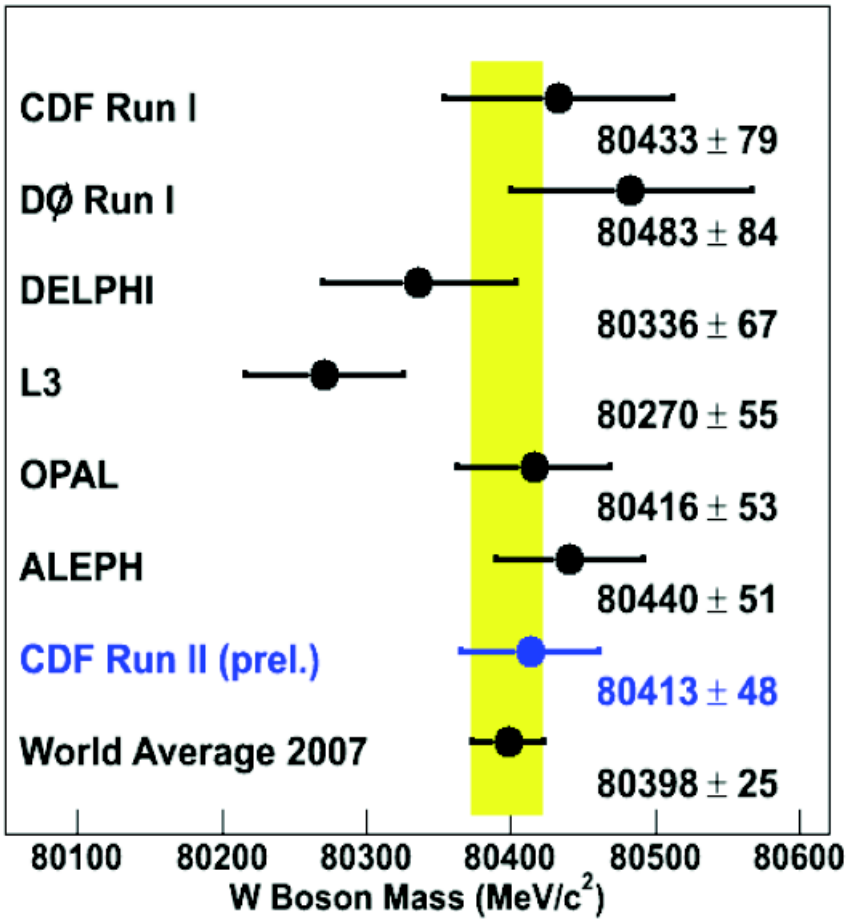
... to embarrassing falls

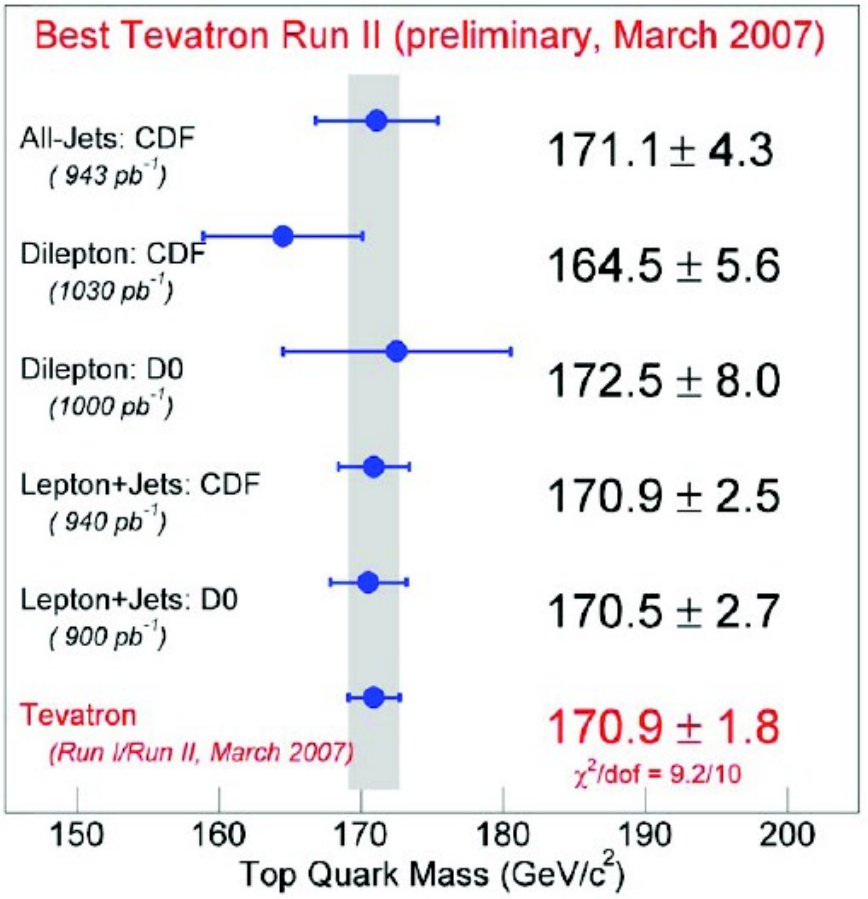
But all with beautiful views of Mont Blanc, Cervino, etc...



A ond E

m_W and m_t





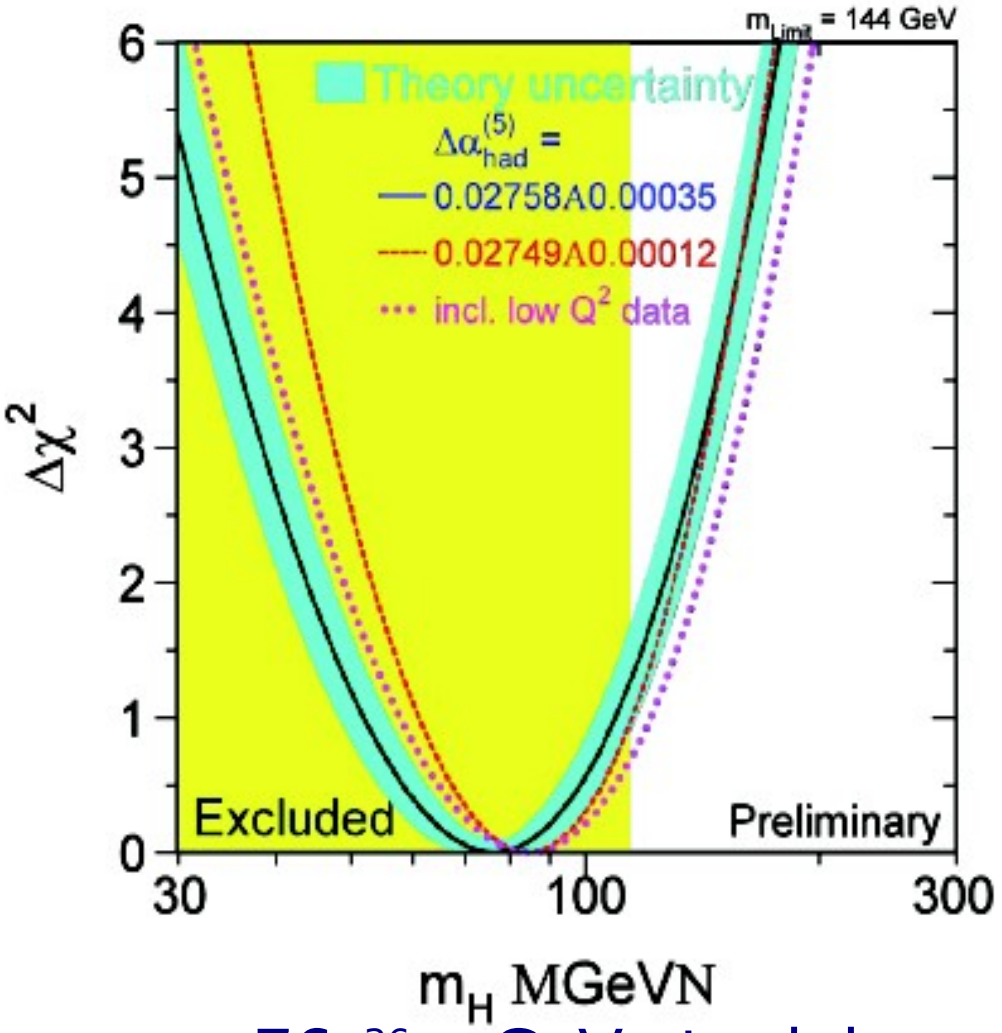
World average decreases by 6 MeV

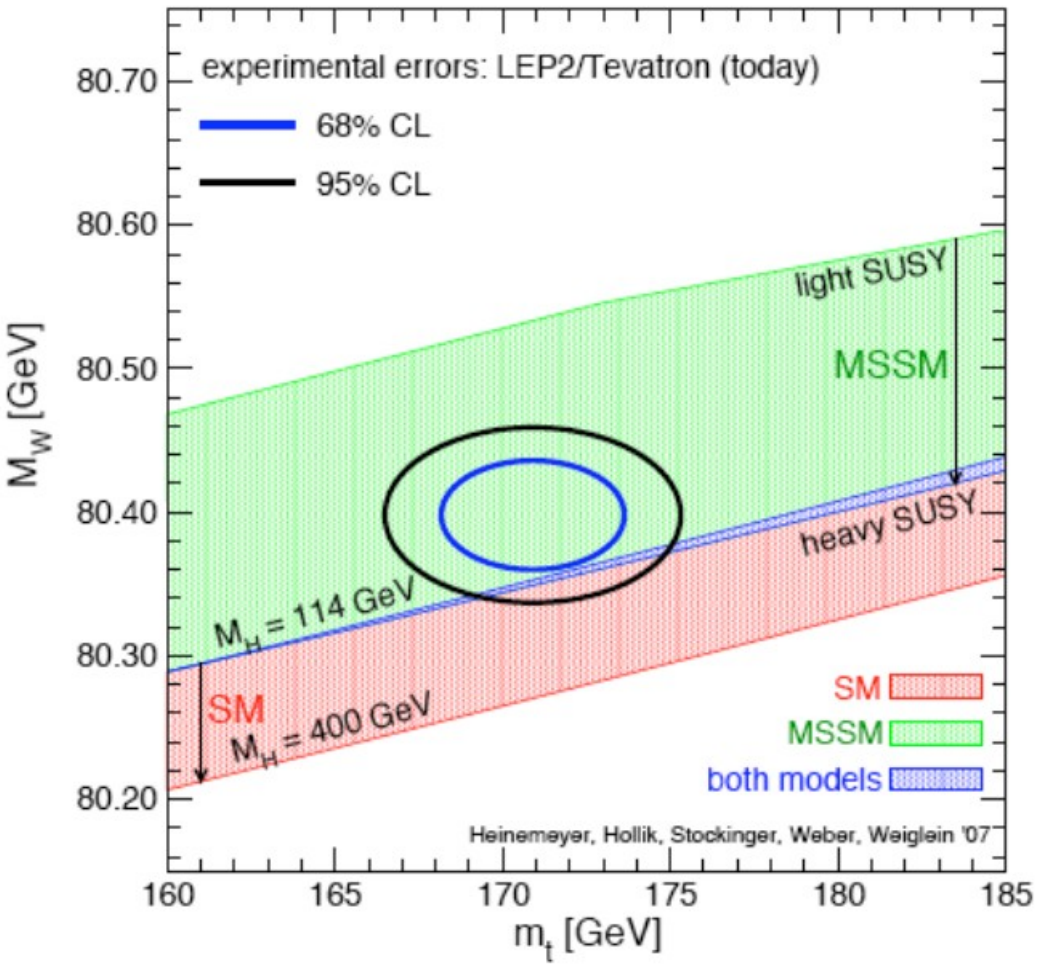
Δm_W decreases from 29 to 25 MeV

World average decreases by 0.5 GeV

Δm_t is now at 1.1%!

Electroweak fits



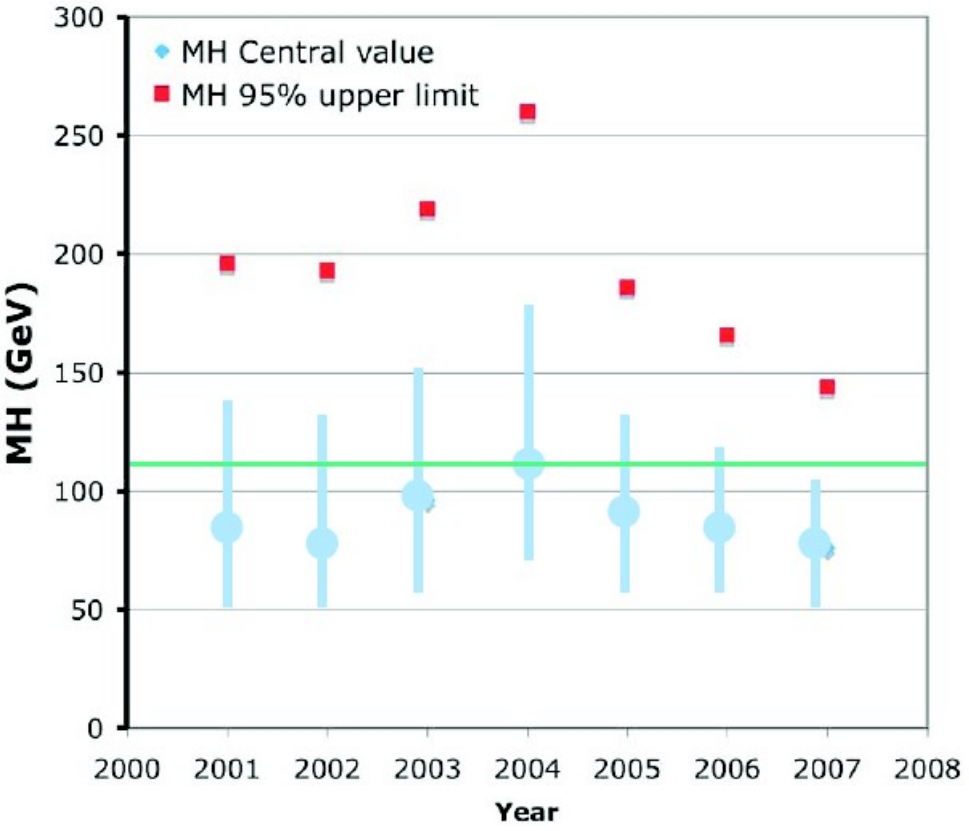


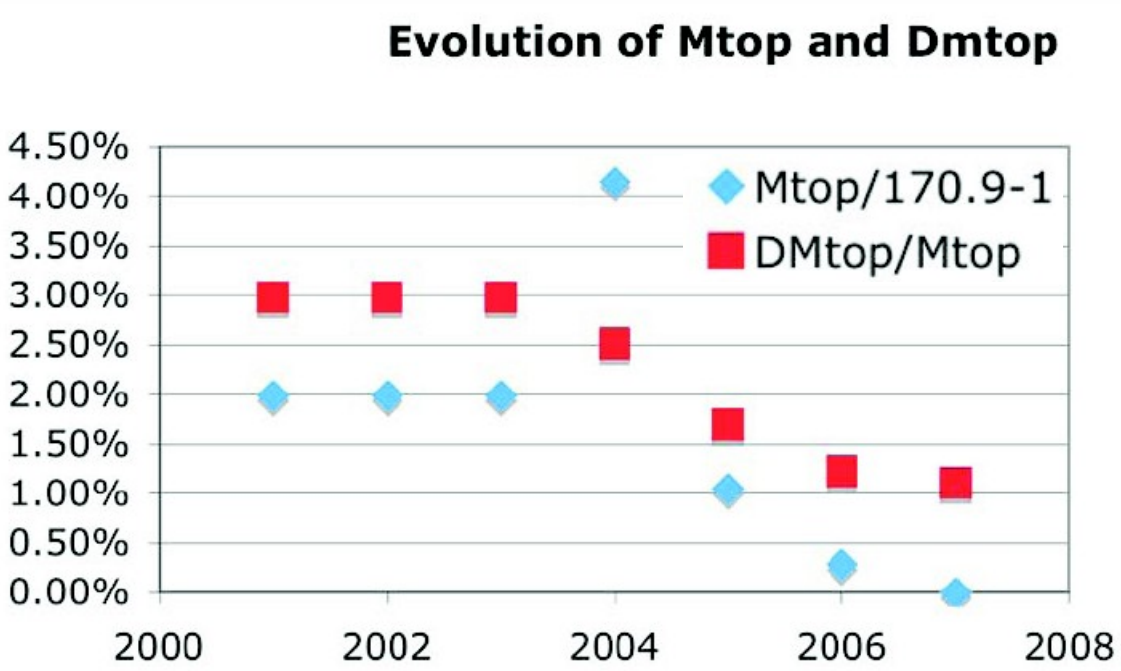
$m_H = 76^{+36}_{-24}$ GeV at minimum

$m_H < 144$ GeV @ 95% CL

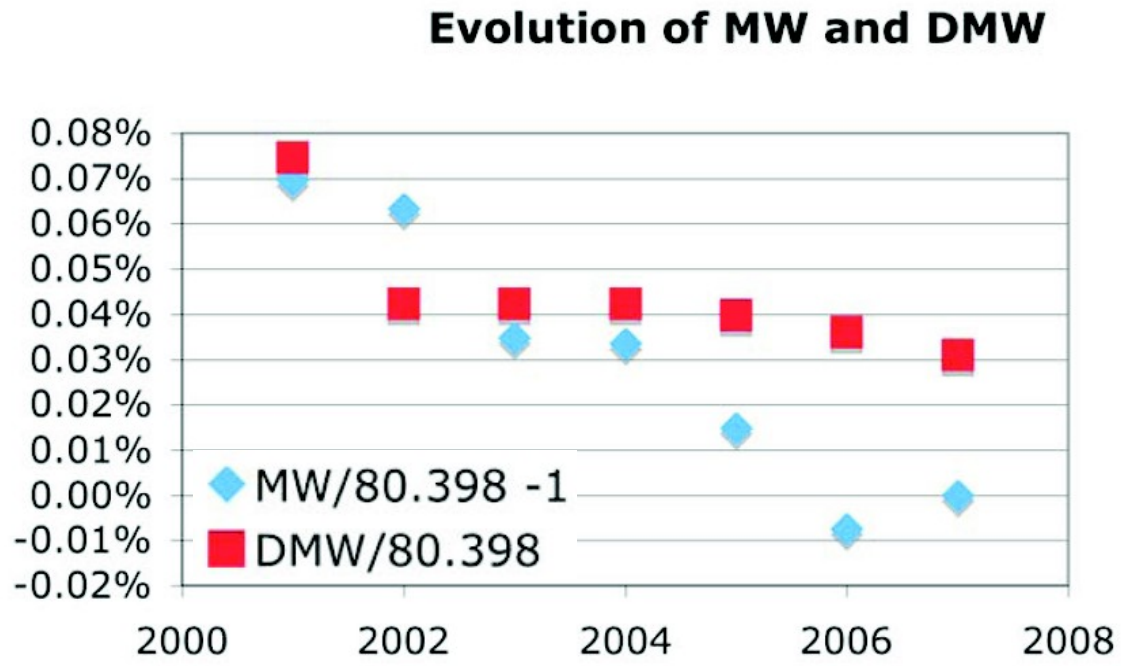
$m_H < 182$ GeV including LEP upper limit

Time evolution

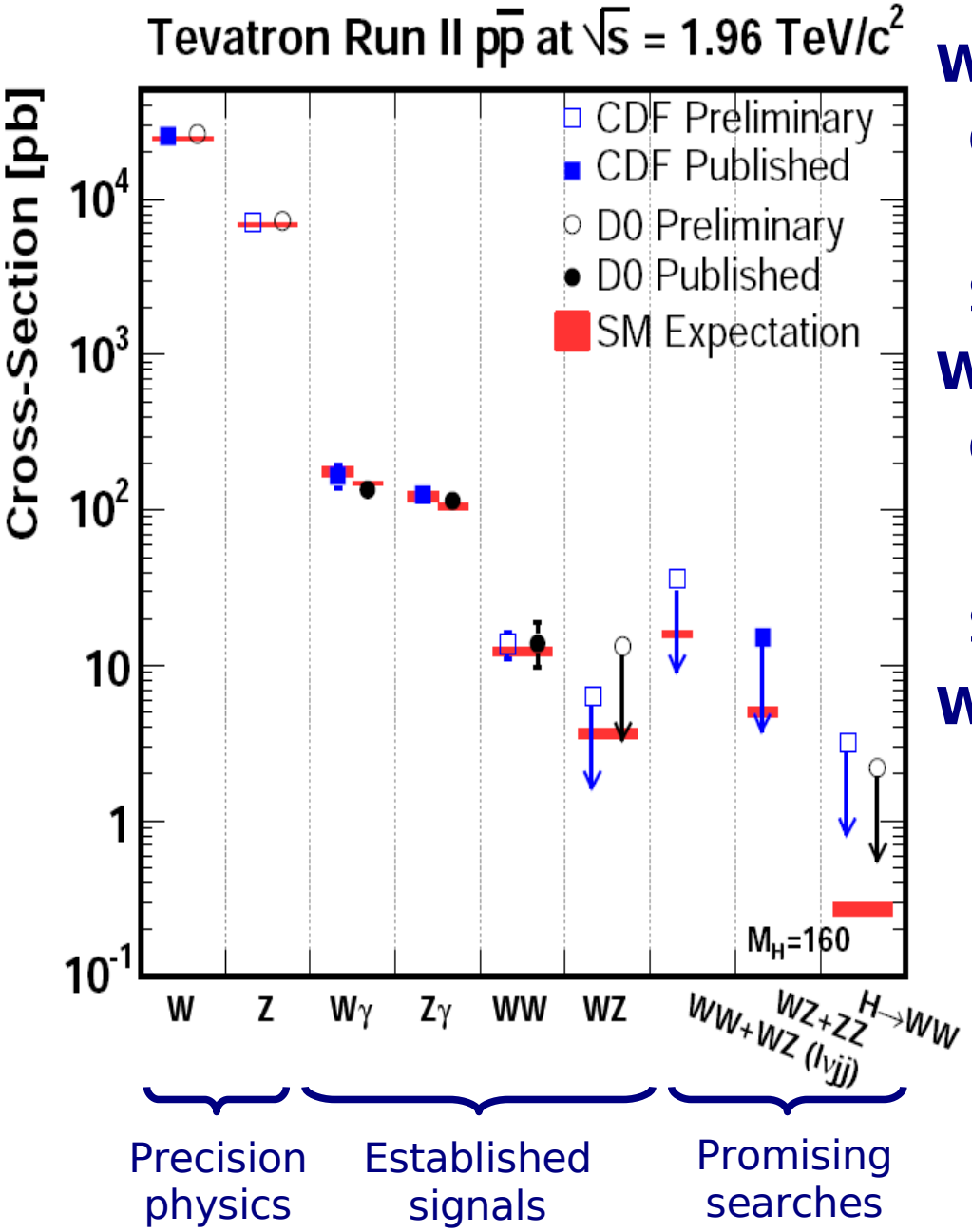




From Gigi Rolandi



W, Z et al.



WW cross section:

CDF(0.8fb^{-1}) 13.6±2.3(stat)±1.6(sys)pb

DØ (0.2fb^{-1}): 14.6±5.1(stat)±3.0(sys)pb

SM: 12.4±0.8pb

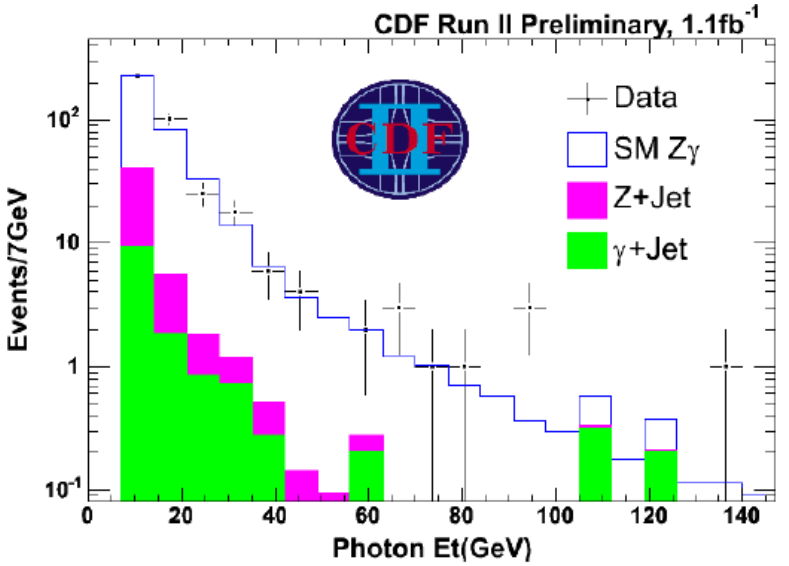
WZ observation:

CDF (1.1fb^{-1}): $5.0^{+1.8}_{-1.4}$(stat)±0.4(sys)pb

DØ (0.8fb^{-1}): $4.0^{+1.9}_{-1.5}$(stat+sys)pb

SM: 3.7±0.3pb → 6σ(CDF) 3.3σ(DØ)

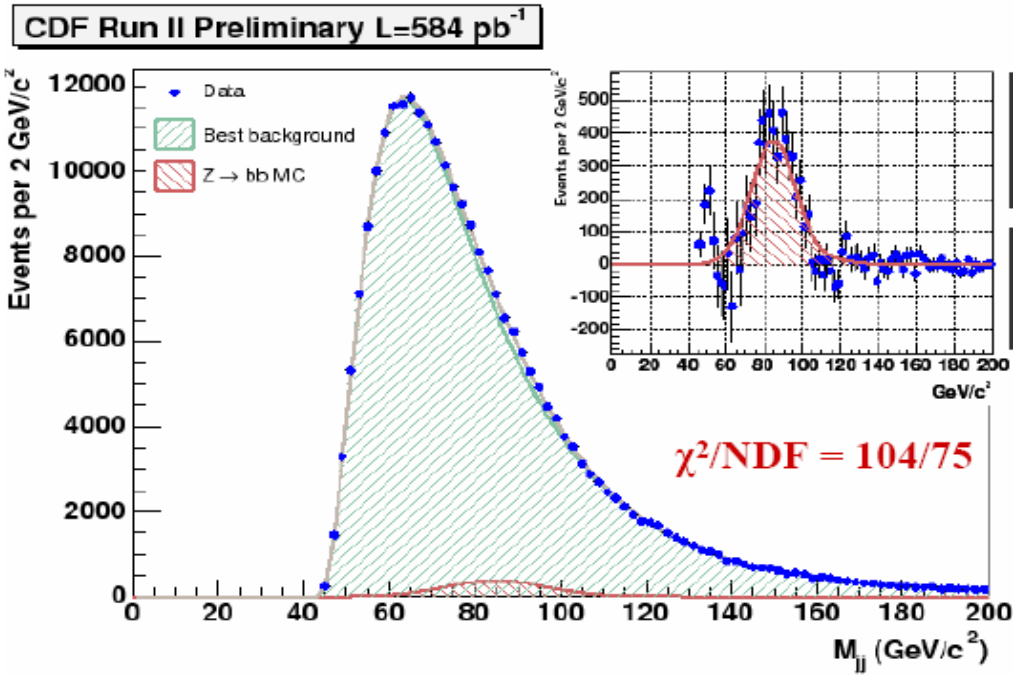
Wγ and Zγ properties in good agreement with SM



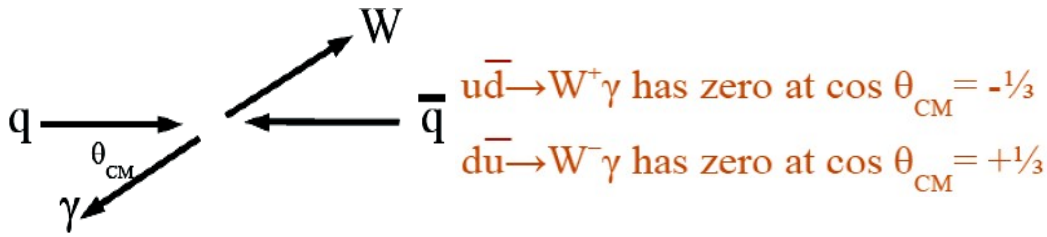
More electroweak

Z→bb sample

- Measure specific b-JES
  - Help top mass measurement
- Improve b-jet energy resolution
  - Help low Higgs mass searches
- Background from data + TRF
- Applicability of b-JES to other analyses under study



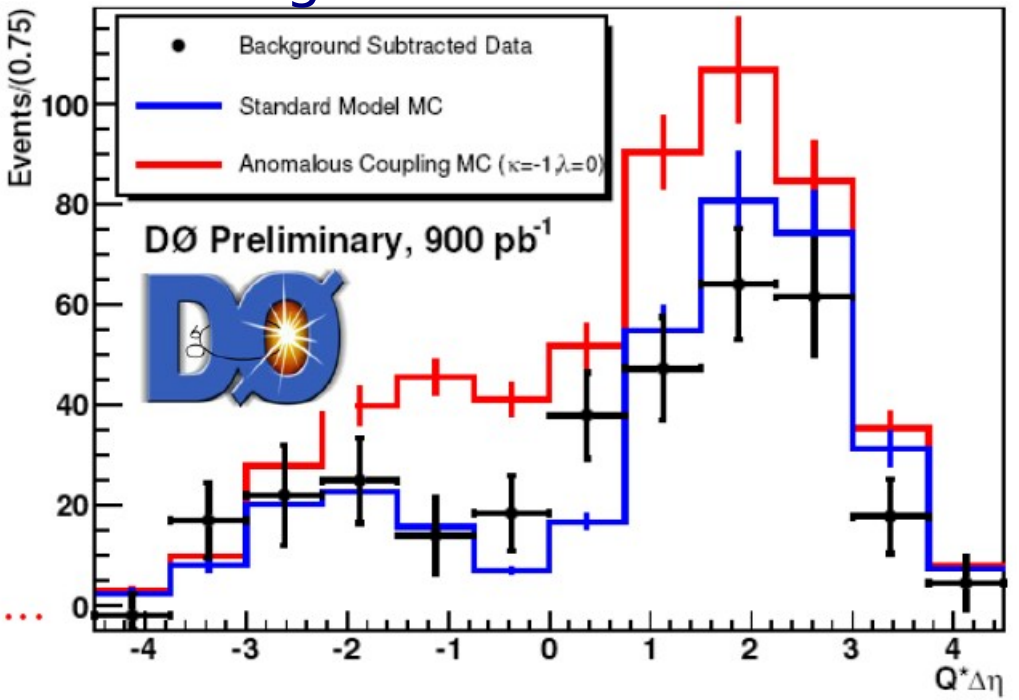
Wγ amplitude zero



Measure $\Delta\eta$ between γ and ℓ

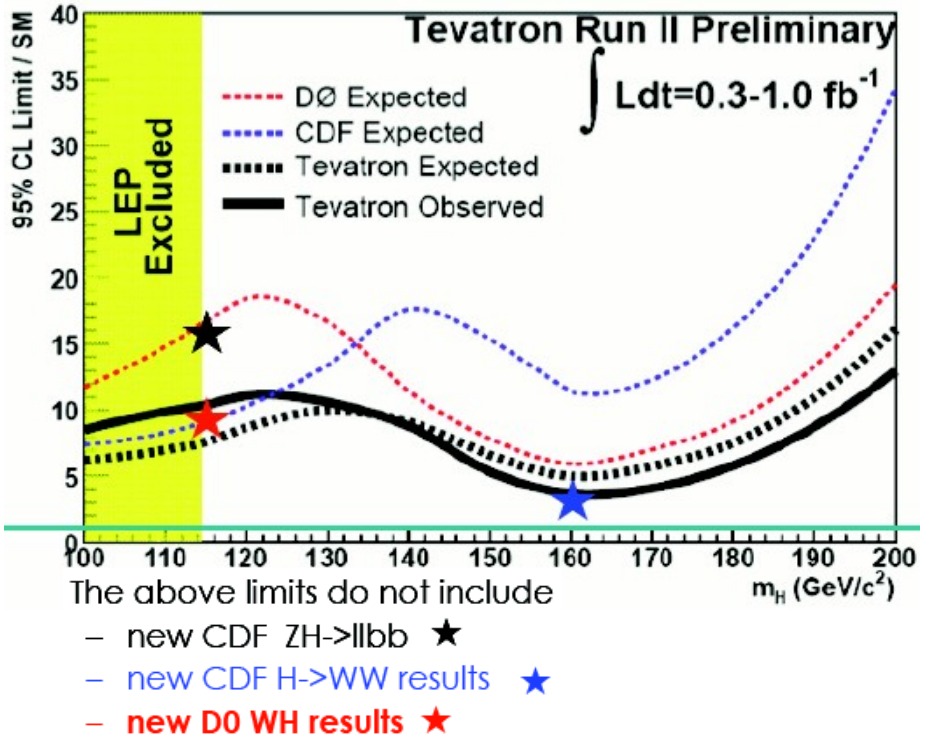
Interferences between leading diagrams induce dip in $Q\Delta\eta$

Good agreement with SM



Higgs

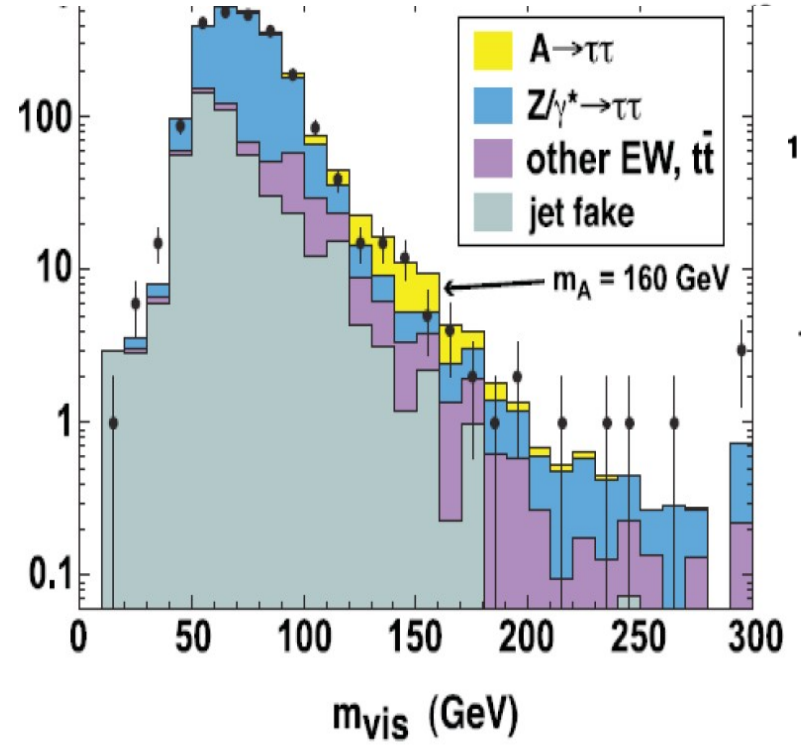
Analysis	CDF limit ($1fb^{-1}$) factor above SM observed (expected)	D0 limit ($1fb^{-1}$) factor above SM observed (expected)
ZH → νν bb @ 115 Technique: M_{jj}	16 (15)	40 (34)*
WH → lν bb @ 115 Technique: M_{jj} Technique: ME	26 (17)	★ 10 (9) ★ 13 (10)
ZH → llbb @ 115 Technique: NN2D	★ 16 (16)	33 (34)
H → WW → lνlν @ 160 Technique: ΔΦ (l,l) Technique: ME	9 (6) ★ 3.5 (5)	4 (5)

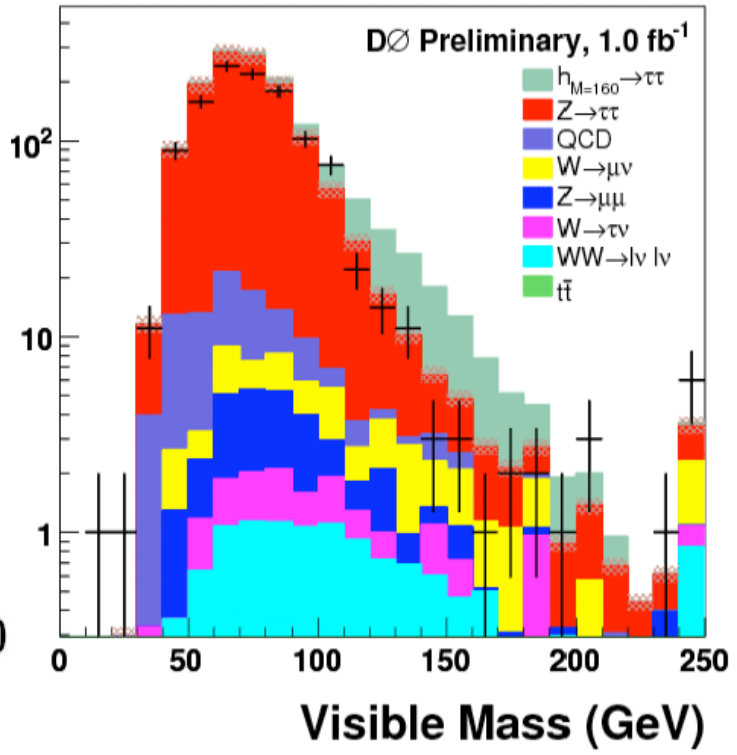


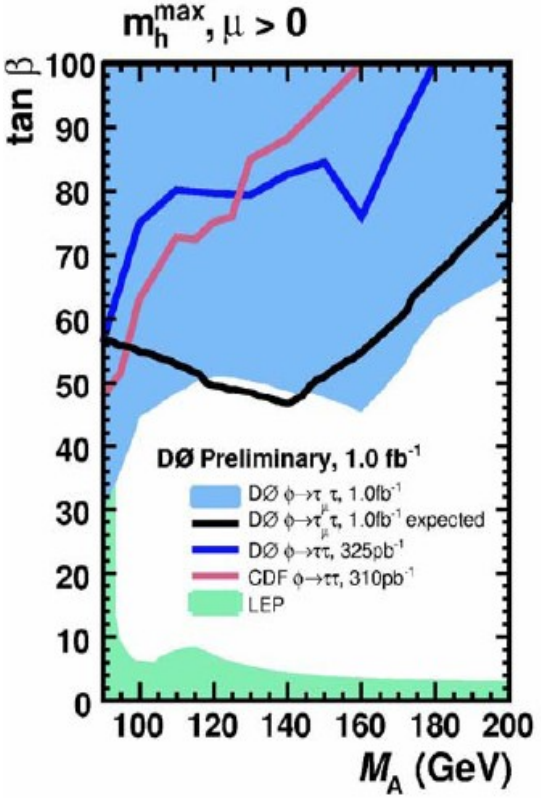
New results scaling much better than 1/sqrt(L)

MSSM Higgs $\phi \to \tau\tau$

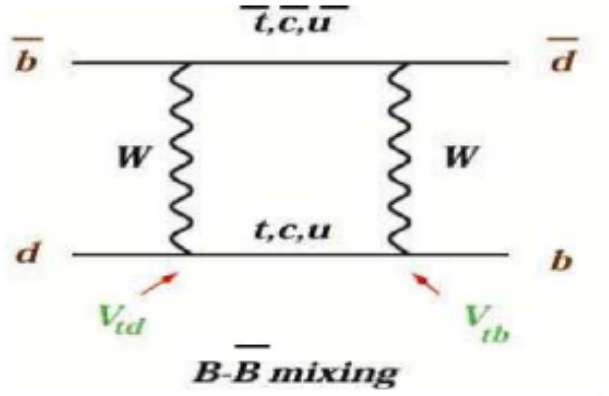
- CDF search in (e,mu)+τ_{had} and e+mu channels
- DØ search in mu+τ_{had} channel
- CDF see <2σ excess in m_{ϕ} ~ 160GeV (σxBR~2pb, tanβ~50)
- DØ has deficit there
- CDF search in dilepton channel is not conclusive

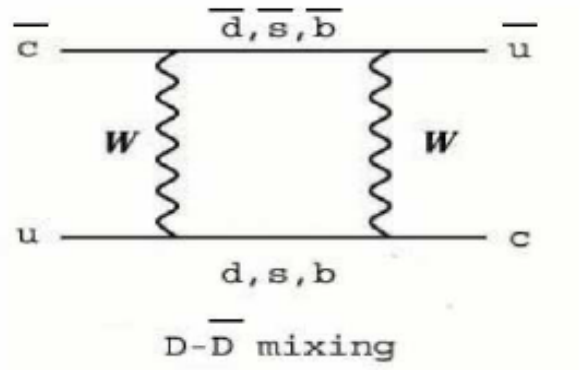






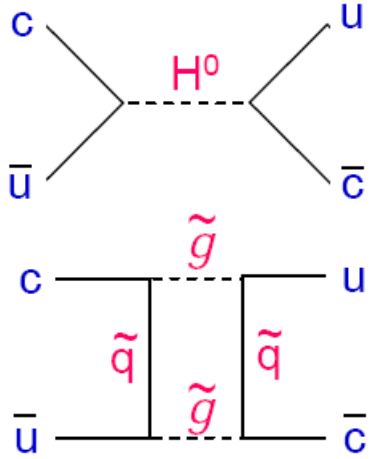
Evidence for D-D mixing: Intro





D mixing	B mixing
intermediate down-type quarks	intermediate up-type quarks
SM: b quark contribution is negligible due to V_{ub}	SM: t quark contribution is dominant
$\Delta M \sim$ [SU(3) breaking]^2 ΔM dominated by light q loops	$\Delta M \propto m_t^2$ and sizeable
sensitive to long distance QCD	described by local Lagrangian
small in SM: NP	large in SM

New physics:



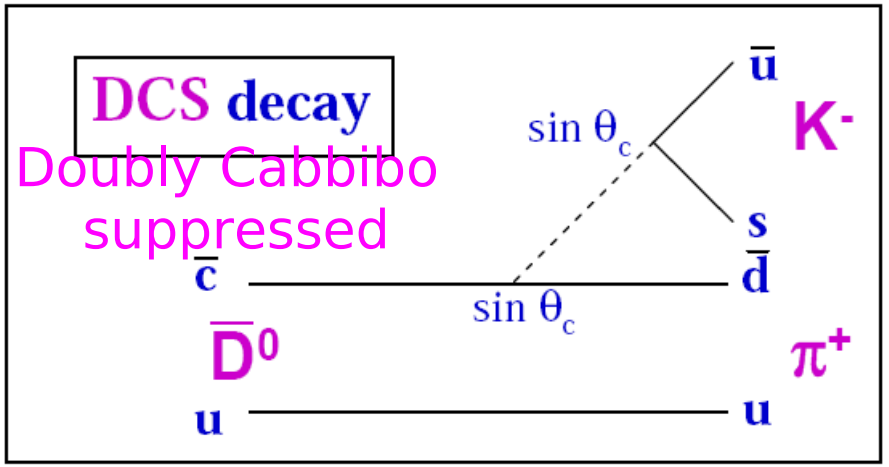
$$\frac{\partial}{\partial t}\begin{pmatrix} D^0 \\ \bar{D}^0 \end{pmatrix} = -i\left(M - i\frac{\Gamma}{2}\right)\begin{pmatrix} D^0 \\ \bar{D}^0 \end{pmatrix}$$

$$x \equiv \frac{\Delta M}{\Gamma} = \frac{M_2 - M_1}{\Gamma}, \quad y \equiv \frac{\Delta\Gamma}{2\Gamma} = \frac{\Gamma_2 - \Gamma_1}{\Gamma}.$$

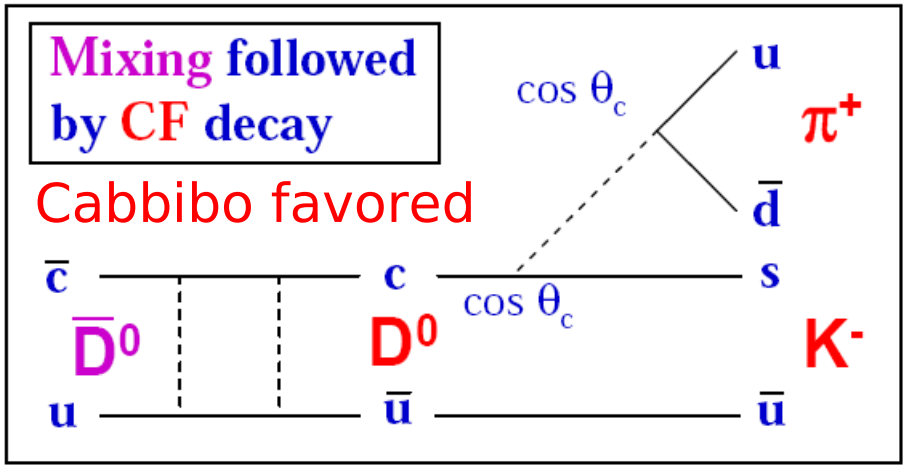
x and y are similar and small o(10^{-3}) in the SM

Experimentally

- Select sample of $D^{*\pm} \to \pi^{\pm}_s D^0$. Use $\pi^{\pm}_s$ to tag the event
- Right sign sample: $D^0 \to K^- \pi^+$ (+cc)
- Wrong sign sample: $D^0 \to K^+ \pi^-$ (+cc) has DCS and mixing+CF



$\bar{D}$



- Right sign sample gives D^0 lifetime and resolution model
- Mixing is any deviation from this in the wrong sign sample

$$\Gamma(D^0(t) \to K^+\pi^-) \propto e^{-\Gamma t}\left[R_D + \sqrt{R_D}\, y'\,(\Gamma t) + \frac{x'^2 + y'^2}{4}(\Gamma t)^2\right]$$

$R_D \sim \tan^4\theta_C \sim 0.3\%$ (DCS/CF rate)

$$x' = x\cos\delta + y\sin\delta, \quad y' = -x\sin\delta + y\cos\delta$$

δ strong phase between DCS and CF amplitudes

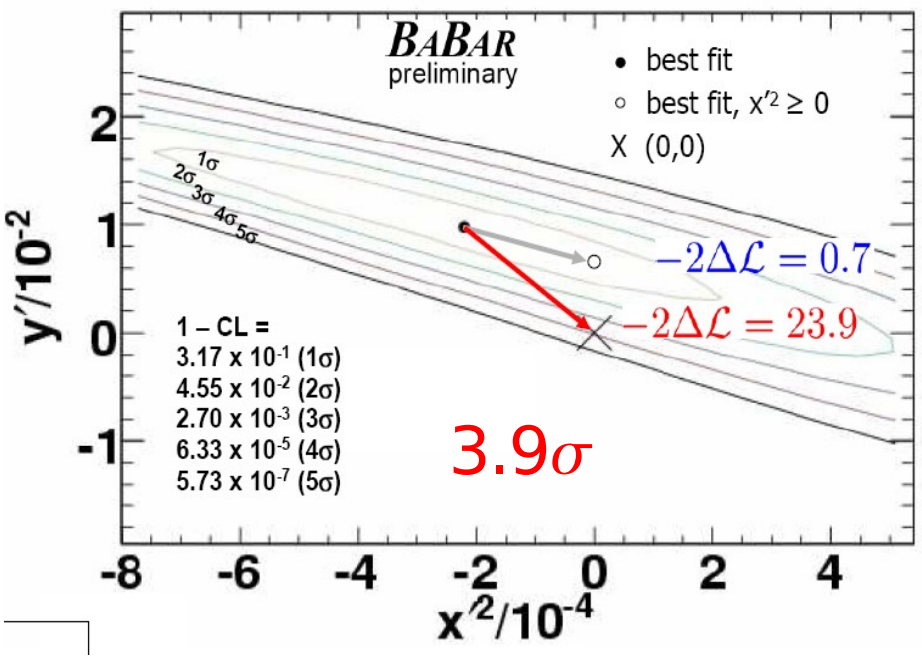
➔ Measure x'^2 and y'

Results: evidence for mixing

R_D: $(3.03 \pm 0.16 \pm 0.06) \times 10^{-3}$

x'^2: $(-0.22 \pm 0.30 \pm 0.20) \times 10^{-3}$

y': $(9.7 \pm 4.4 \pm 2.9) \times 10^{-3}$



1. $D^0 \to K^+\pi^-$ unbinned fit to time distrib.

$$R_D = (0.364 \pm 0.017)\%$$

$$x'^2 = (0.18^{+0.21}_{-0.23}) \times 10^{-3}$$

$$y' = (0.6^{+4.0}_{-3.9}) \times 10^{-3}$$

2. Dalitz analysis of $D^0 \to K^0\pi^+\pi^-$

$$x = 0.80 \pm 0.29 \pm 0.17\ \%$$

$$y = 0.33 \pm 0.24 \pm 0.15\ \%$$

excludes no mixing @ 95% CL

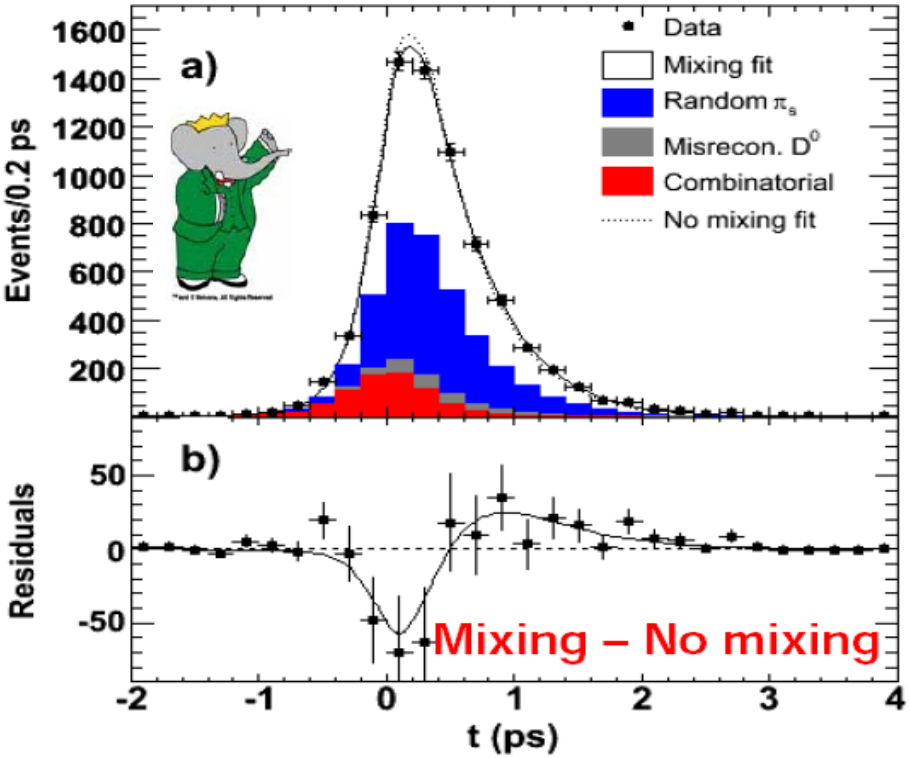
3. Lifetime diff. $D^0 \to K^-\pi^+$ and $D^0 \to K^+K^-$

$$y_{CP} = 1.31 \pm 0.32 \pm 0.25\ \%$$ 3.2σ

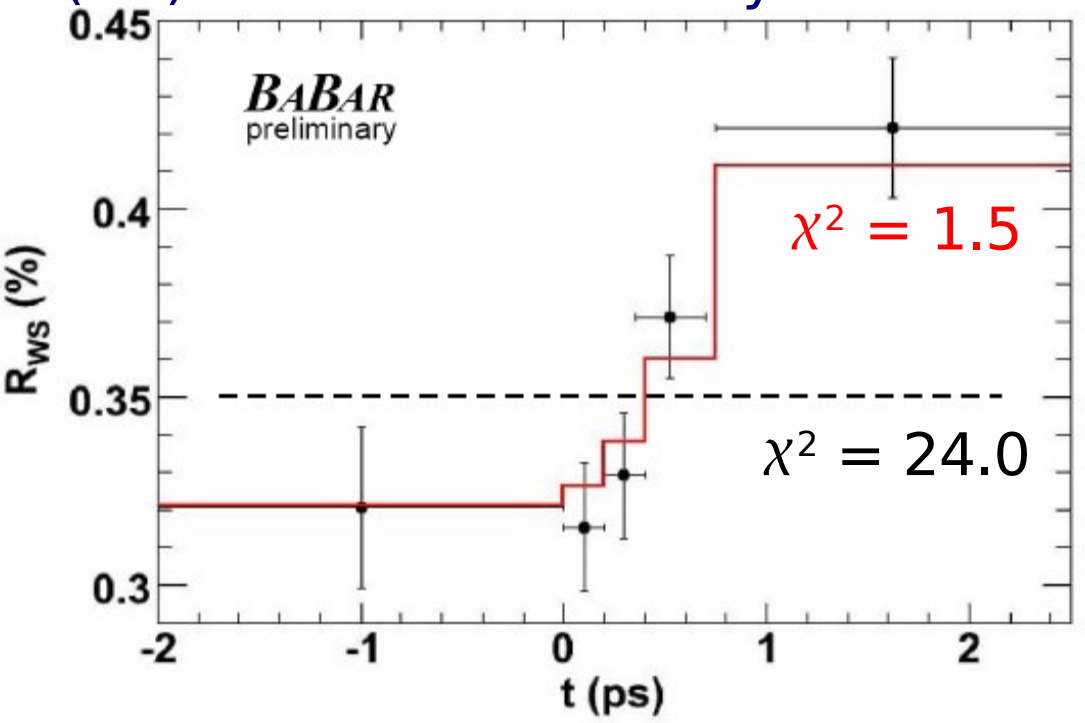
y_{CP} = y in CP conservation limit

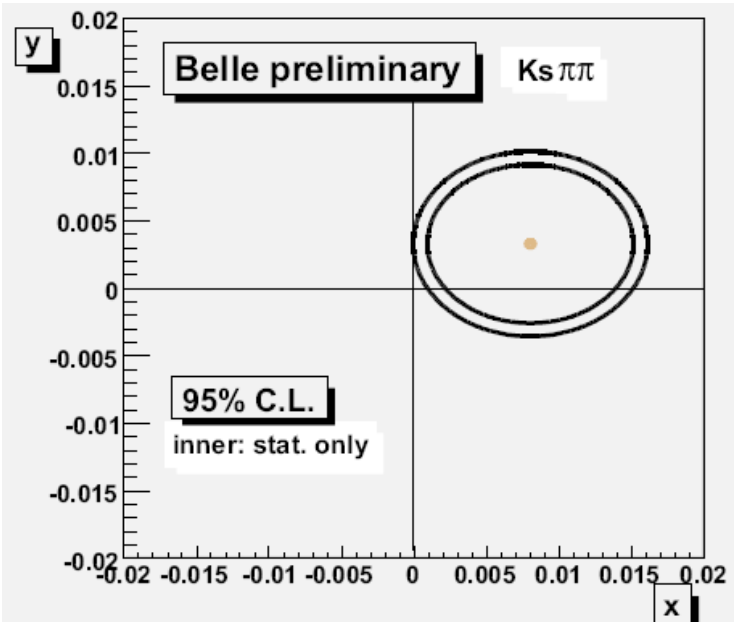
- No hint of new physics in D mixing: x ~ y
- No indication of CP violation yet
- D is too light to be treated as heavy and too heavy to be treated as light: so new theory predictions are not expected soon
- Test of non-perturbative QCD

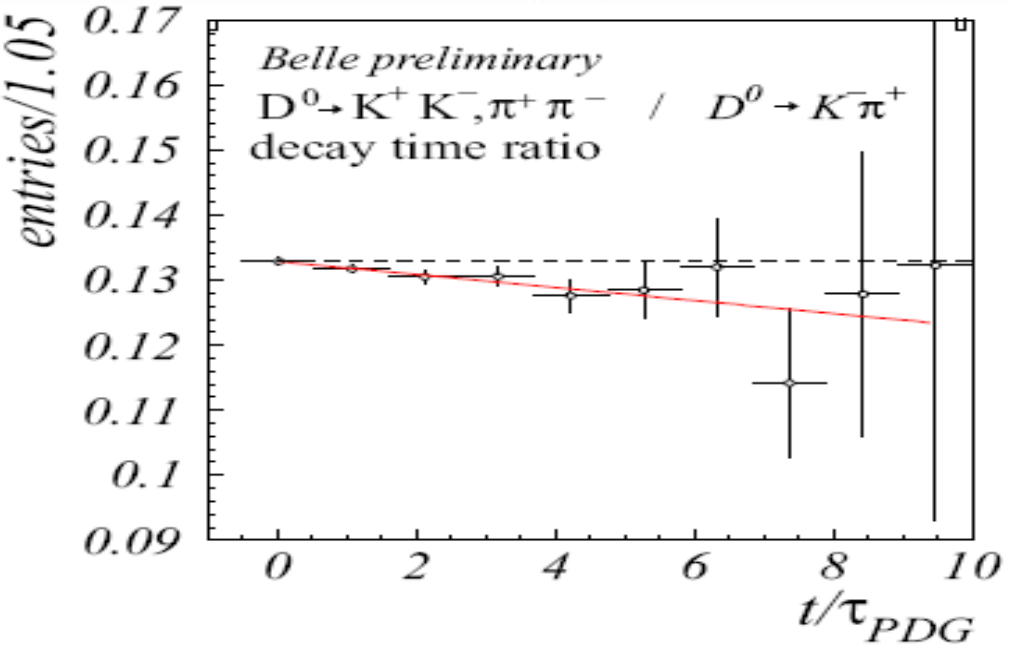
Consistency



M(Kπ) vs ΔM fit in 5 decay time bins:



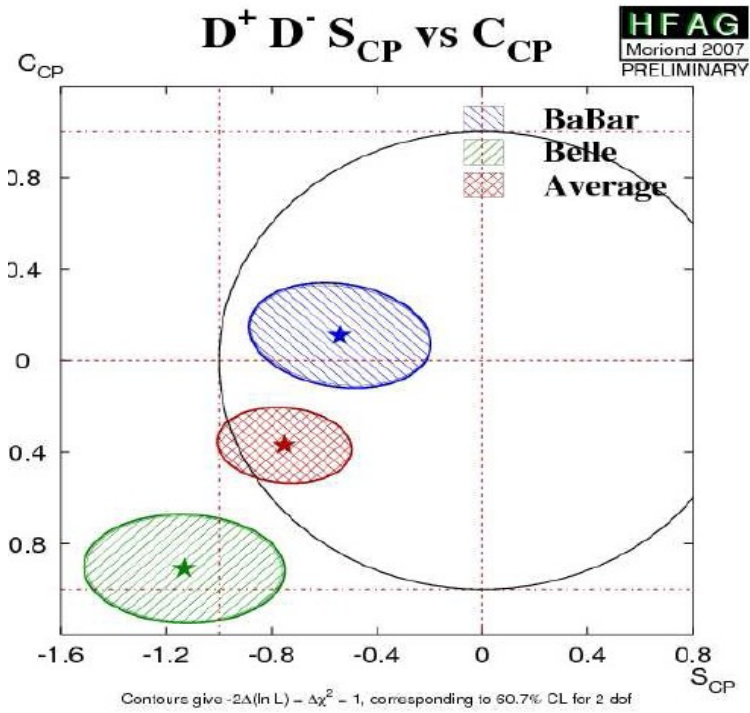




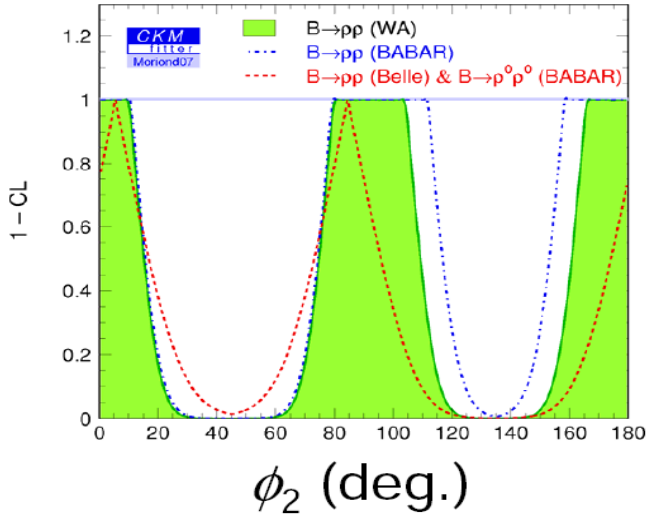
Arán García-Bellido Morio

CKM angles of CP violation

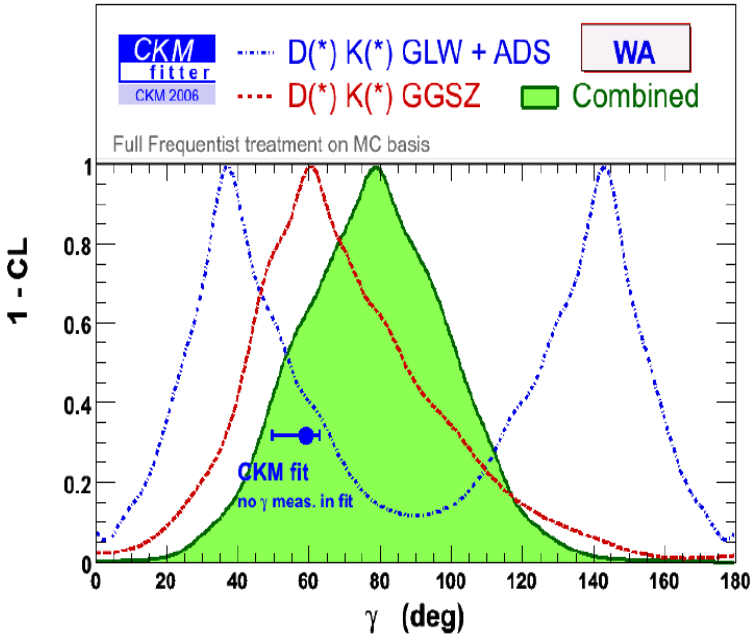
- β (ϕ_1) BaBar + Belle
  - $\sin 2\beta = 0.678 \pm 0.026$ from $J/\psi K_s$
  - Belle CPV in $B \to D^+D^-$ at 4σ (not confirmed by BaBar)
  - $\cos 2\beta > 0$ from different approaches
    First measurement! Standard solution favored $\beta=(21.3\pm1.0)°$
  - Hints of difference between penguin modes and charmless (cc)K decays persist



- α (ϕ_2) BaBar + Belle
  - $B \to \pi\pi$, $\rho\rho$, $\rho^+\pi^-$, $a_1^+\pi^-$
  - $B^0 \to \rho^0\pi^0$ Dalitz
  - $\alpha = (93.5^{+10.8}_{-9.6})°$



- γ (ϕ_3) BaBar + Belle
  - $B^\pm \to DK^\pm$, $D^*K^\pm$, $DK^{*\pm}$: $\gamma=53\pm18(\text{stat})\pm3(\text{sys})\pm9(\text{model})$
  - $B^\pm \to DK^\pm$, $D^*K^\pm$: $\gamma=92\pm41(\text{stat})\pm11(\text{sys})\pm12(\text{model})$
  - $\gamma = (77 \pm 31)°$



CKM sides

- V_{ub} from BF($B \to X_u \ell \nu$) in excl. decays (8%expt,15%theory) and incl. decays (15%, 5%)
- V_{cb} measured with 2% accuracy from fit of ℓ moments in $B \to X_c \ell \nu$

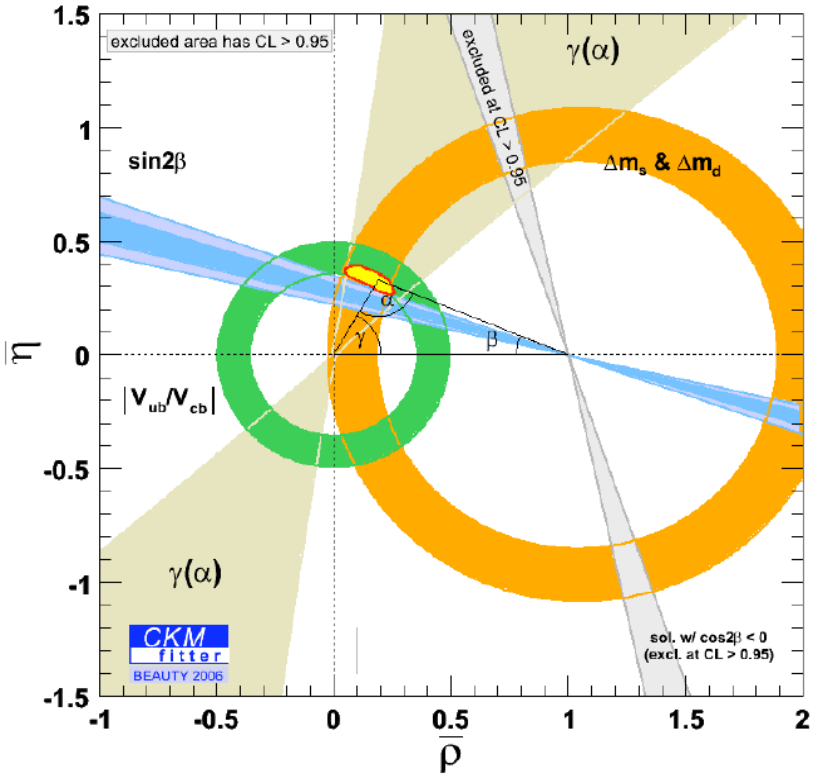
$V_{ub} = (4.1 \pm 0.5) 10^{-3}$ $V_{cb} = (41.5 \pm 0.5) 10^{-3}$ $V_{tb} > 0.68$ @ 95%CL

- Belle&Babar V_{td}/V_{ts} in BF($B \to \rho/\omega\gamma$)/BF($B \to K^*\gamma$) agrees with CDF value from B_s mixing

$$\left|\frac{V_{td}}{V_{ts}}\right|_{\rho/\omega\gamma} = 0.202 \underbrace{{}^{+0.017}_{-0.016}}_{8.2\,\%} \pm \underbrace{0.015}_{7.4\,\%}$$

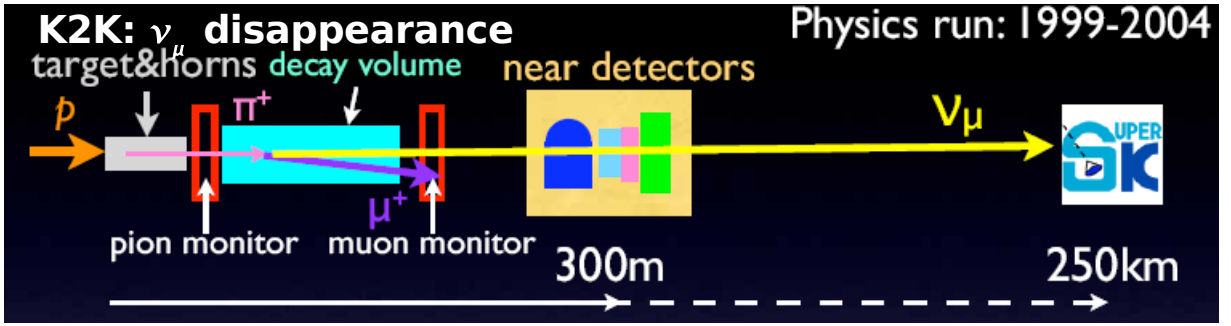
$$\left|\frac{V_{td}}{V_{ts}}\right|_{\Delta m_d/\Delta m_s} = 0.2060 \pm 0.0007 {}^{+0.0081}_{-0.0060}$$

- Overall consistency (M. Neubert)
  - sin2β from $B \to J/\psi K_s$ ~ 0.68±0.03
  - sin2β from penguins $B \to \Phi K_s$ ~ 0.50±0.06
  - 2.6σ deviation
  - sin2β from V_{ub} and V_{td} discrepancy at 2.9σ
  - Need for low energy experiments (B, K, g-2, ν, EDM) to complement the high energy frontier



Neutrinos

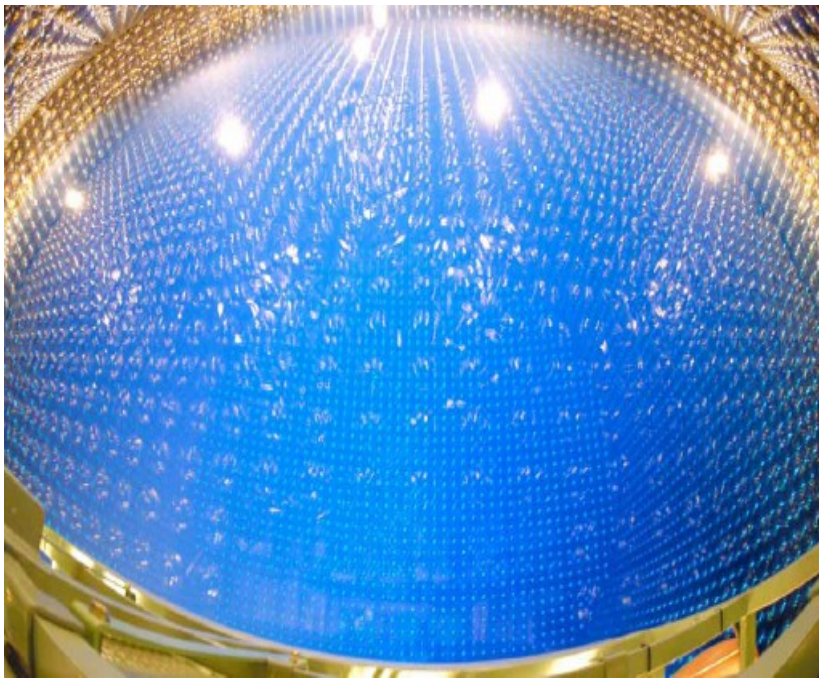
- HARP (p_{beam}~1.5-15 GeV) and MIPP (p_{beam}~120 GeV, $p_{sec.\ beam}$~ 5-85 GeV)
  - Neutrino fluxes for K2K, MiniBooNE, hadron production for NuMI-Minos
  - π/K yields for targets in ν factories and Super-beams
  - HARP results in use (K2K, MiniBooNe), MIPP results will appear in the summer
- K2K: 4.3σ evidence
  - Final results: 112 obs. events
  - 158±9 exp. w/o oscillations



- T2K: first beam in Apr'09
  - Off axis scheme 295km: search for $\nu_\mu \rightarrow \nu_e$
- SuperK: running since last summer
- SuperK → Gadzooks!
  - Proposal to add 100 tons of gadolinium ($GdCl_3$)

$$\bar{\nu}_e + p \longrightarrow e^+ + n$$

  - 5k evt/y from reactors → x10 better Δm_{12}^2
  - Discover diffuse SN ν background ~5 evt/y

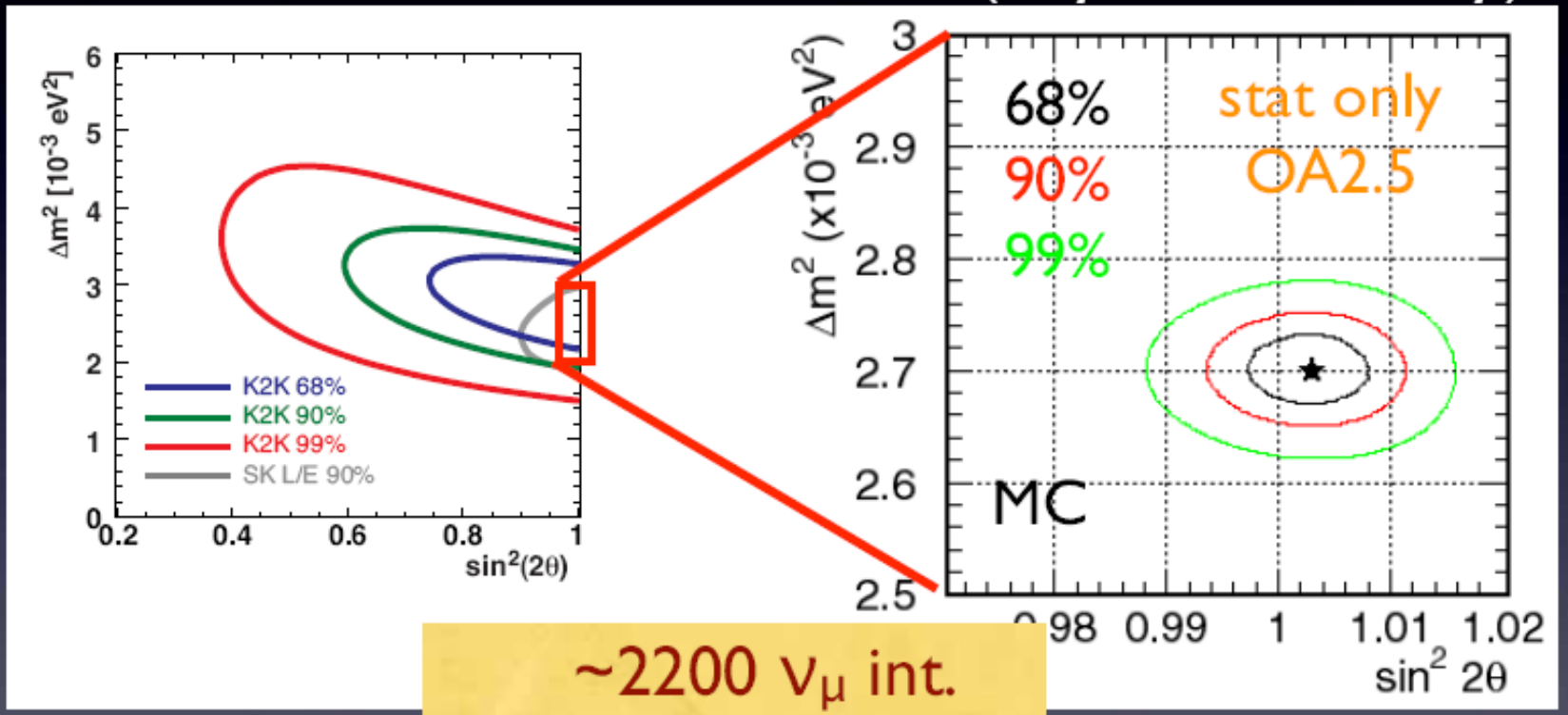


K2K → T2K

Precise measurement of $\Delta m^2_{23}/\theta_{23}$

K2K/Super-K

T2K 5×10^{21} POT
(~5yr full intensity)



~2200 ν_μ int.
~1600 ν_μ CC
per year,
~0.4% ν_e @ peak

$\delta(\sin^2 2\theta_{13})\sim0.01$

$\delta(\Delta m^2_{23})<10^{-4}\text{eV}^2$

Latest results from K2K and S

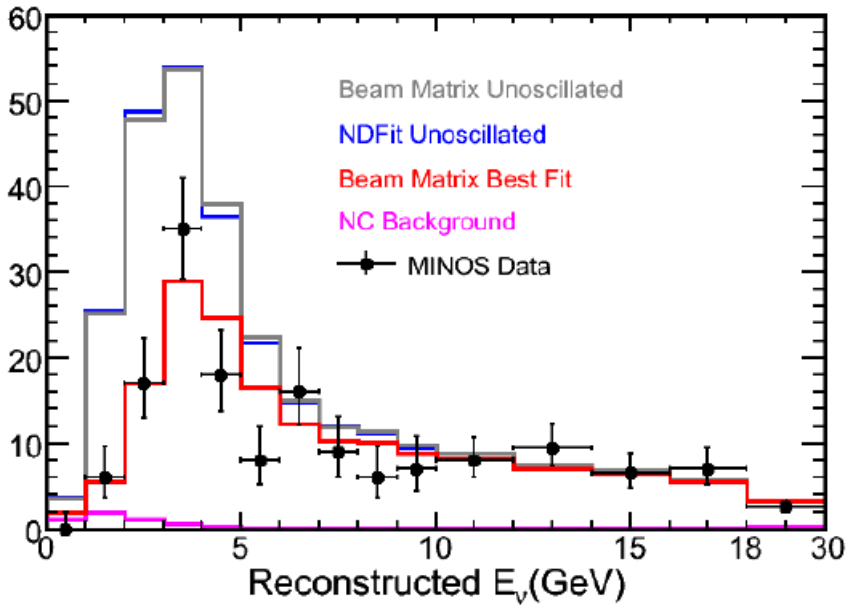
22/24

More accelerator neutrinos

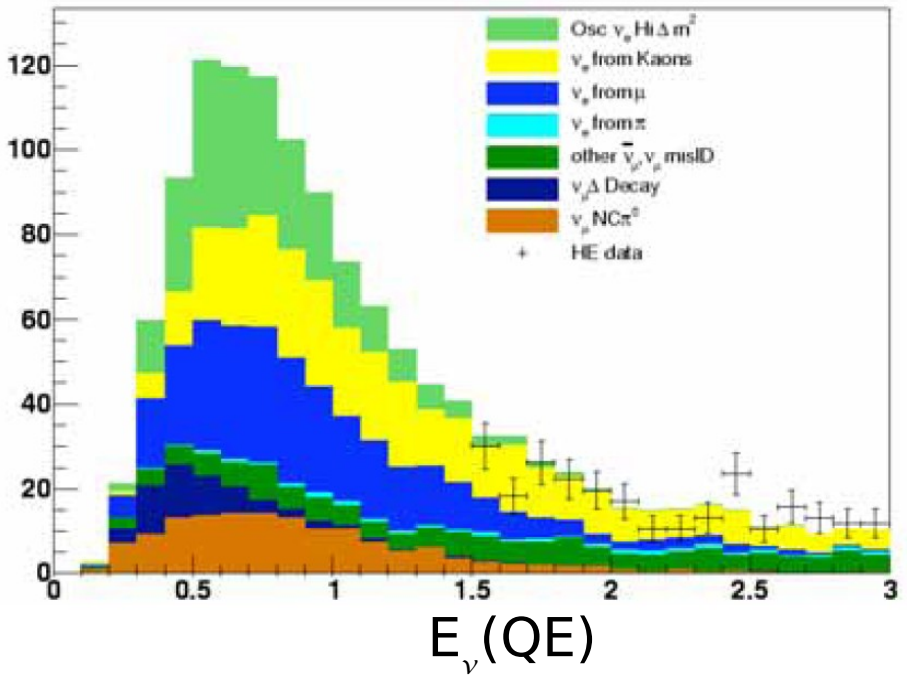
- NUMI-MINOS: test $\nu_\mu \rightarrow \nu_\tau$ osc. in 735km flight from near/far detectors
  - Results from 1st year: 1.27 10^{20} pot
  - Exclude no-disappearance at 6.2σ (rate only)
  - Consistent with other experiments

$$|\Delta m^2_{32}| = 2.74\ ^{+0.44}_{-0.26}\ \text{(stat.+syst.)} \times 10^{-3}\ \text{eV}^2$$

$$\sin^2 2\theta_{23} = 1.00\ _{-0.13}\ \text{(stat.+syst.)}$$



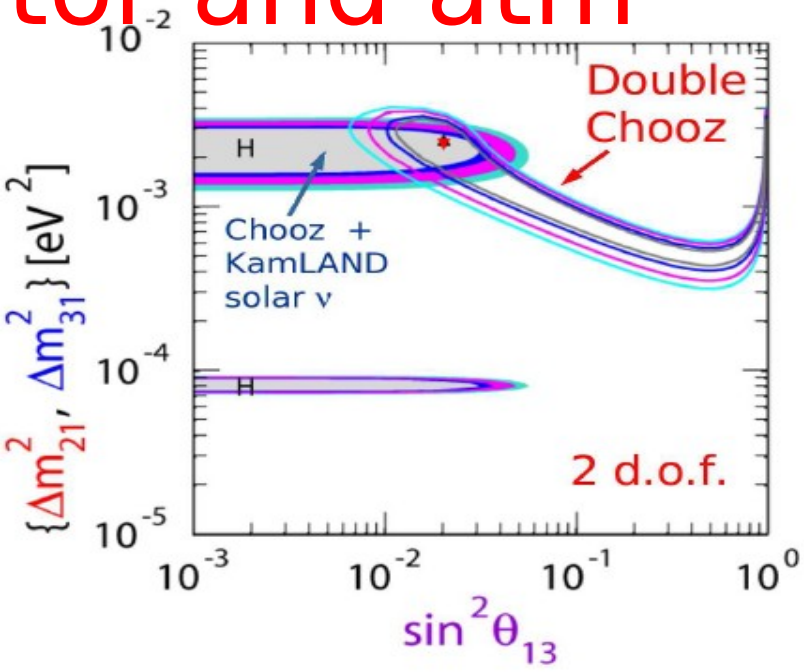
- CNGS-Opera
  - Beam commissioned to nominal p/spill in 2006 → 10^{19} pot by end of 2007?
  - First beam-ν events recorded in Opera!
  - 1k emulsion bricks installed → 100k fall '07
- MiniBooNE: confirm/refute LSND
  - $\nu_\mu \rightarrow \nu_e$ osc. with similar L/E to LSND
  - Timing and ℓ ID are crucial in evt. reco.
  - Blind analysis of ν_e appearance
  - Several difficult backgrounds
  - No results yet! Stay tuned



Neutrinos from reactor and atm

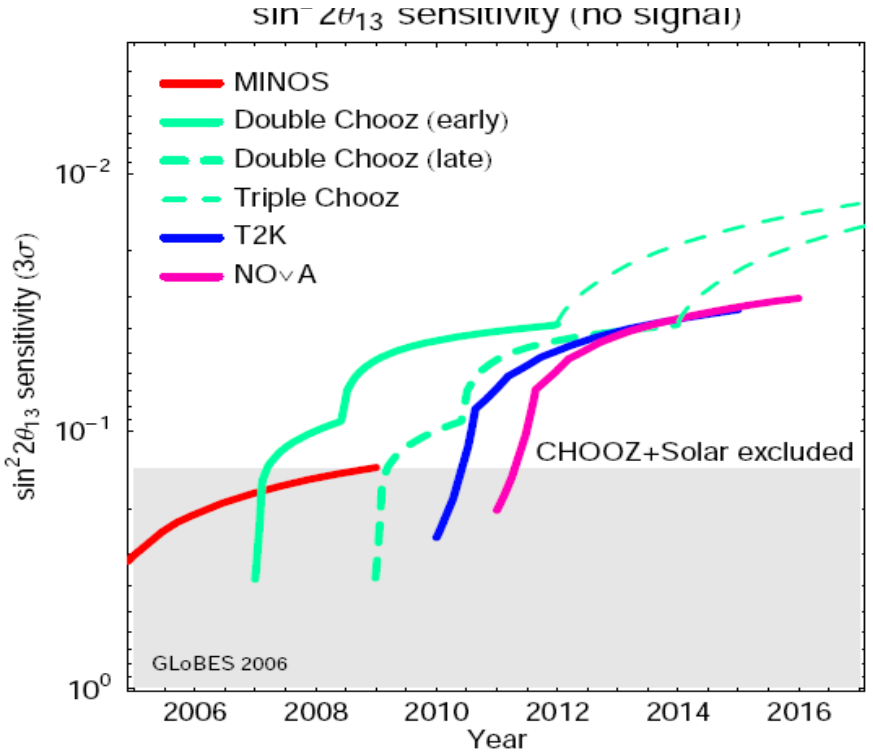
Reactor neutrinos

- Sensitive to θ_{13} and complementary to beams: no CP or matter effects
- Inverse β reaction: ν+p→ n[delay]+e$^+$[prompt]
- Double CHOOZ (end 2007): near and far (1km) detectors to cancel flux systematics
  - Gd detectors (n-Gd capture ~ 30μs)
  - Reach of $\sin^2\theta_{13}$ to 0.02 in 3y



Atmospheric

- Reactor and beam data gives no info on:
  - Mass hierarchy (sign of Δm_{31}^2)
  - "Octant" from 2 sols. of θ_{23} (sign of θ_{23}-π/4)
  - CP phase
- Future exps. on atm. ν will provide complementary information to man-made ν

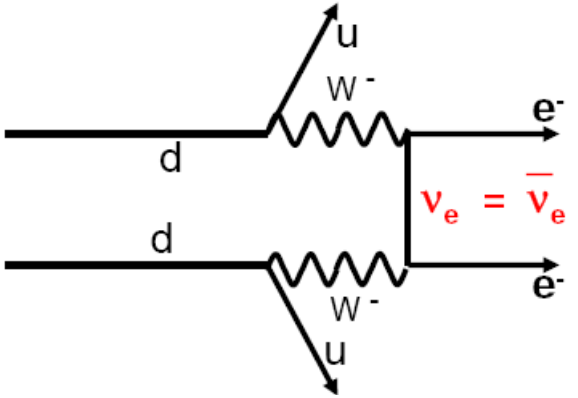


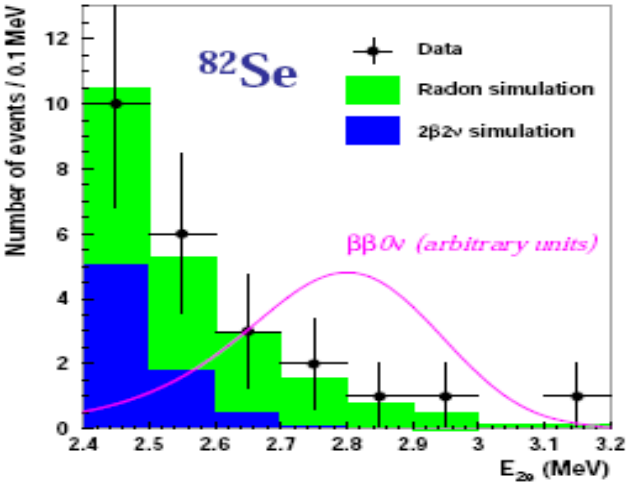
Neutrinoless Double β decay

- Determine Majorana nature of ν
  - Nuclear matrix elements calculations disagree
  - Shell model vs QRPA now closer (x2 difference)
  - More theoretical efforts needed
- Experimental results
  - Need different isotopes (experiments)
  - Heidelberg-Moscow (^{76}Ge, 10kg, 71.7 kg year): debated evidence at 4σ
  - Nemo3 (10kg + tracking):

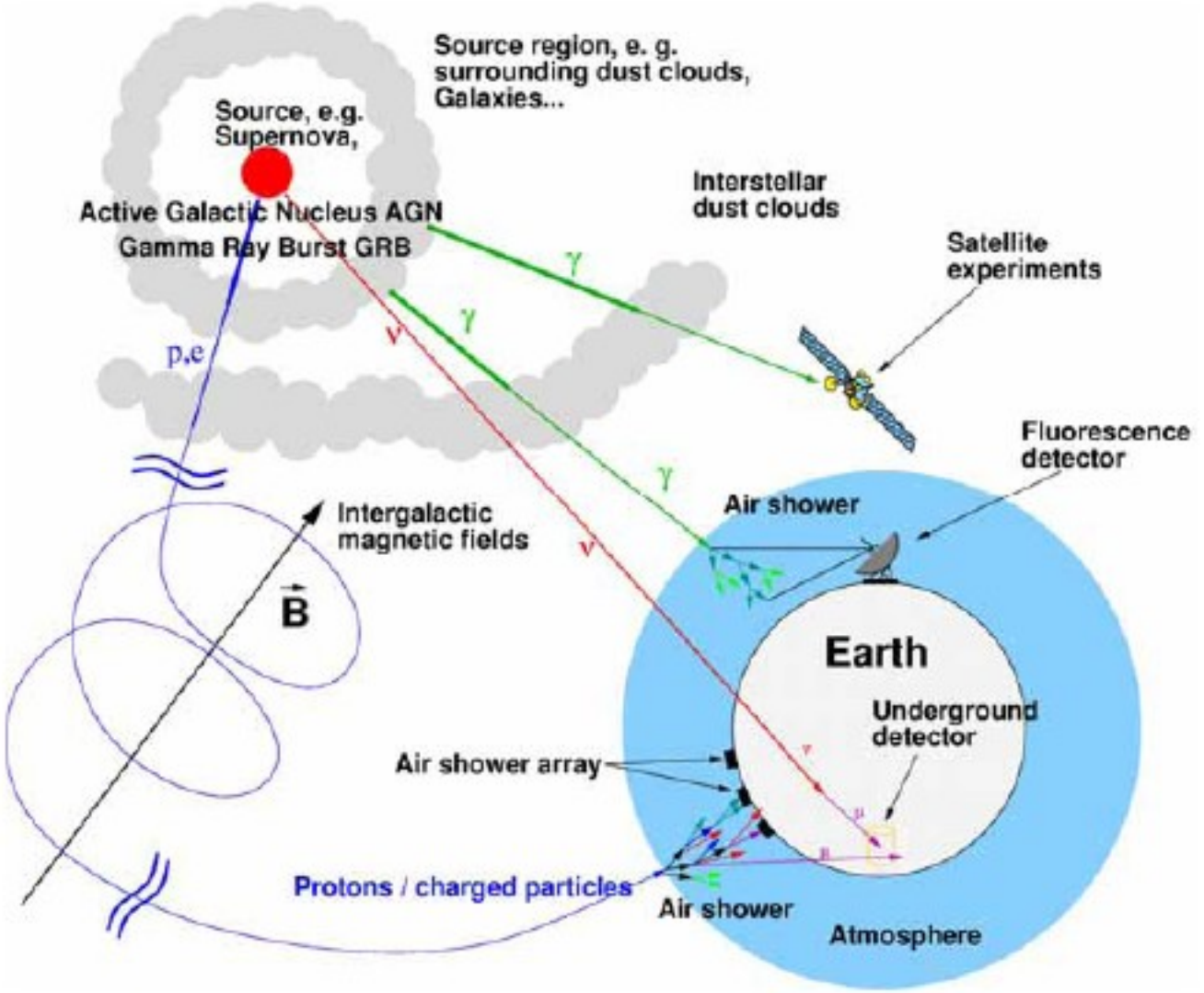
    $T_{1/2}(^{100}Mo) > 4.6\ 10^{23}$ y $\Rightarrow m_\nu < 0.66\text{-}2.81$eV
  - Cuoricino (TeO_2 bolometers, 10kg)

    $T_{1/2}(^{130}Te) > 2.4\ 10^{24}$ y $\Rightarrow m_\nu < 0.18\text{-}0.94$eV
- Future experiments
  - Gerda (^{76}Ge) end of 2008, Cuore (TeO_2) aim for 1 ton year
  - Reach inverted hierarchy mass 0.01-0.1eV





Particles from outer space



- photons

  + points to source
  + detect over large E range
  - universe sort'a opaque

- protons (nuclei)

  + detect over large E range
  ~ can id at low E, not so easily at high E (AUGER)
  - does not point to source

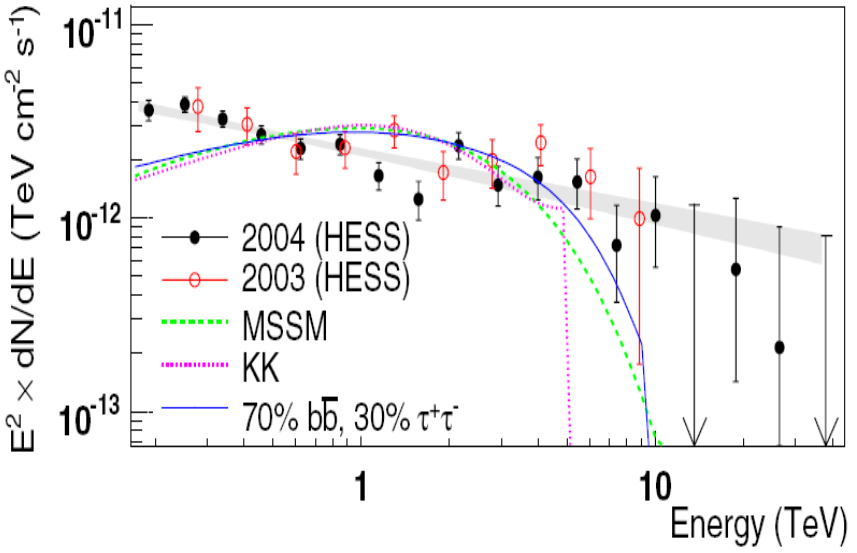
- neutrinos

  + points to source
  - hard to detect

High Energy astronomy

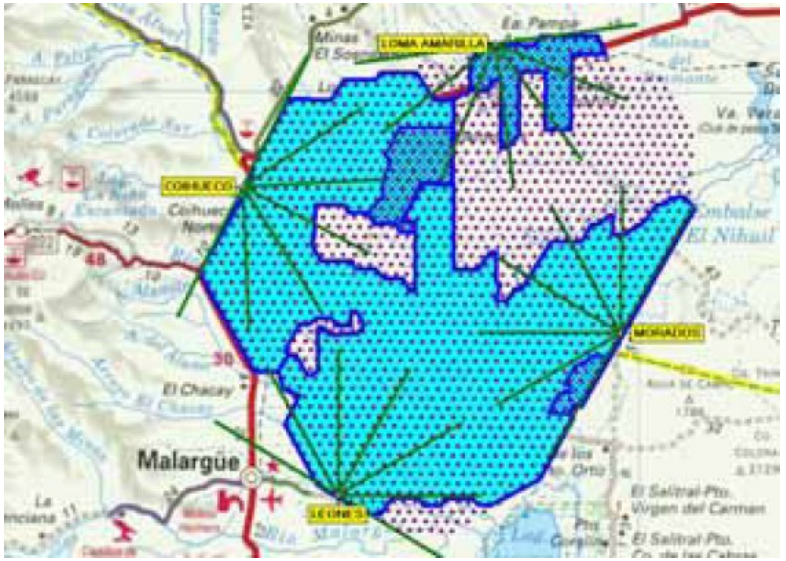
Photons: γ ray Cherenkov telescopes

- Magic: One 17m mirror telescope
  - ~15 extragalactic VHE γ sources (4 new) from blazars and 1 radio galaxy
  - 13 GRB discovered (GRB alert: 40s positioning)
  - 2nd telescope first light this year
- HESS: Four 13m-telescopes (107m²)
  - ~30 new VHE sources
  - PhaseII: 30m telescope (2008+)
- Future: CTA
  - x10 sensitivity of MagicII/HESSII



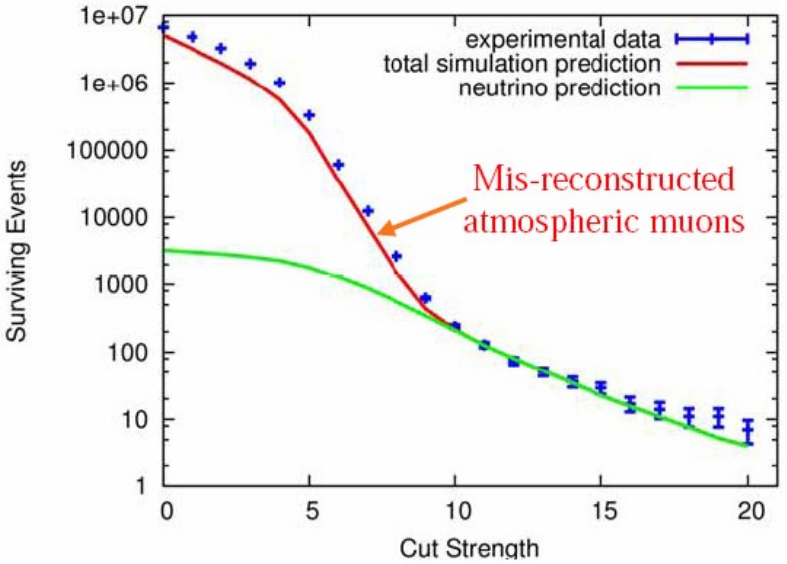
Auger: Ultra High Energy cosmic rays

- 1600 tanks (1000 active) cover 3000km²
- 4 Fluorescent detectors
- Cosmic ray spectrum at GZK cutoff: not yet!
- New limits on anisotropy (no confirmation of galactic center signals in AGASA/SUGAR)
- Sensitive to grazing ν_τ showers!

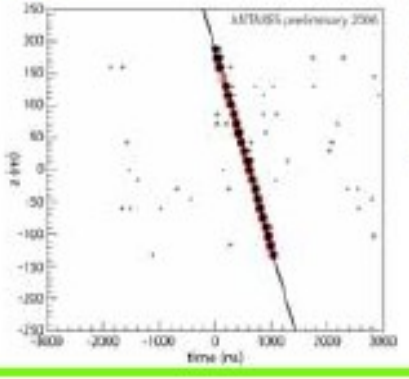


High energy astronomy: neutrinos

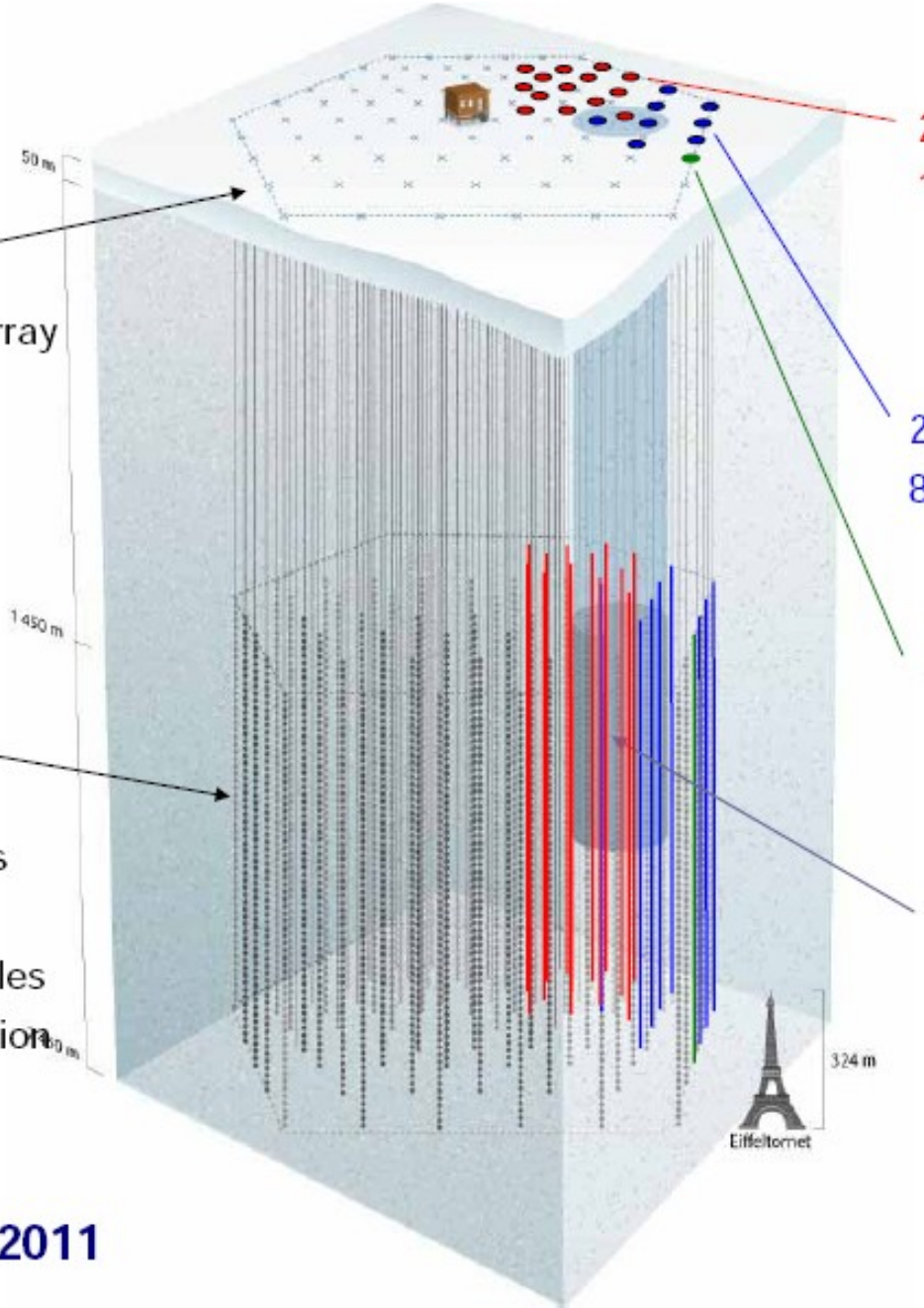
- **Amanda/Icecube *(B Fox)* [Ice, South pole]**
  - **Amanda operational since 2000 (19 lines)**
    - no point source found
    - limit on diffuse flux
  - **Ice Cube progress**
    - 22 strings deployed (complete 70 in 2011)
    - upward-going neutrinos clearly seen



- **Antares *(J Brunner)* [Mediterranean sea]**
  - **5 lines deployed (complete 12 in 2008)**
  - **Downgoing tracks=> resolution**
  - **A few up-going neutrinos seen**



Amanda/IceCube



IceTop

Surface air shower array

IceCube

70-80 strings, each
w/60 optical modules

17 m between modules
125 m string separation

Completion by 2011

2006-2007:
13 strings - all good

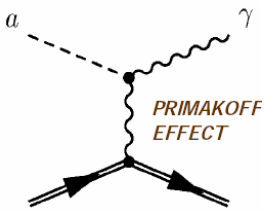
2005-2006:
8 strings - all good

2004-2005 : 1 string
First data in 2005

AMANDA

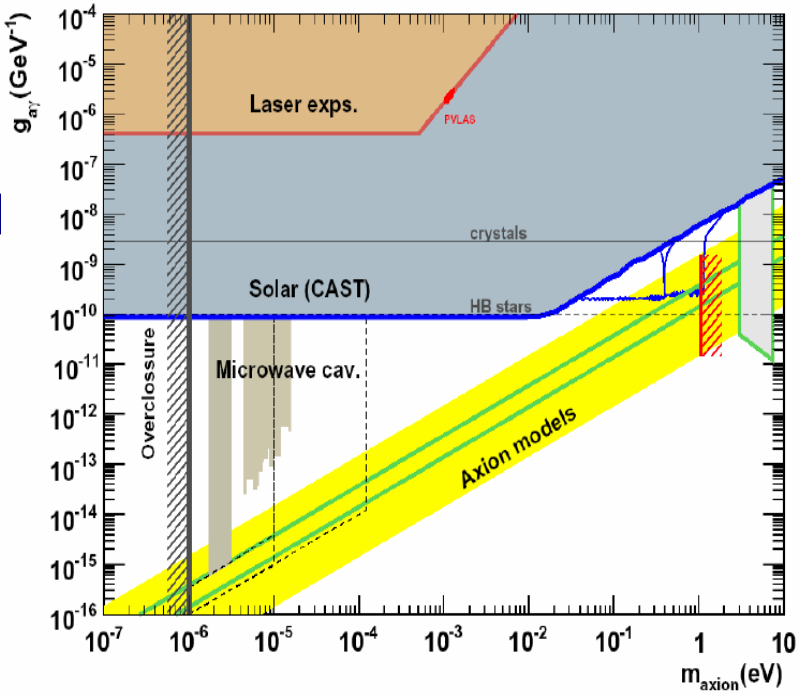
19 strings
677 modules

Dark Matter searches



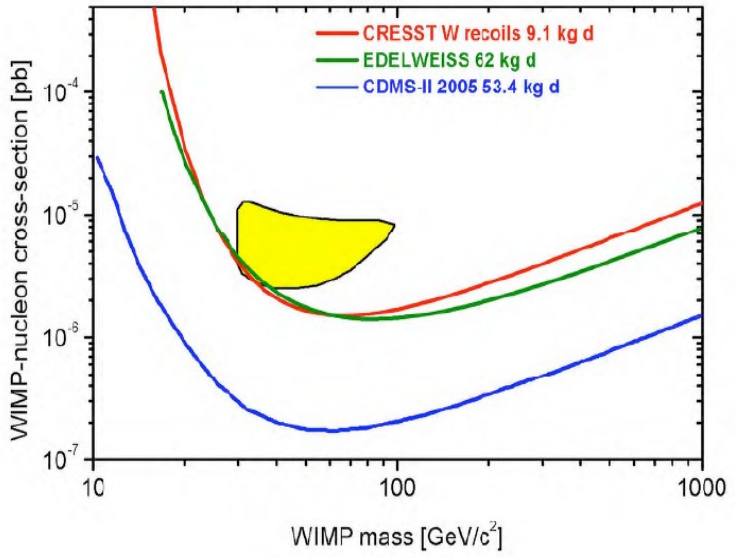
Axions (very light neutral pseudoscalar)

- CAST axion-helioscope (LHC test magnet)
  - 200h in Phase I improves x7 previous limits
- PVLAS: rotation of light polarization in B-field
  - Observed signal not compatible with SM
  - Confirmation by “light thru wall” experiment?
- ADMX: tunable resonant cavity
  - Search very low mass axions



WIMPs: elastic NC scattering by nuclei

- New liquid noble gas detectors: revolution!
- Field will soon be dominated by liquid exps!
- WARP: Liquid Ar ionization+scintillation
- CDMS limits are still the best, though



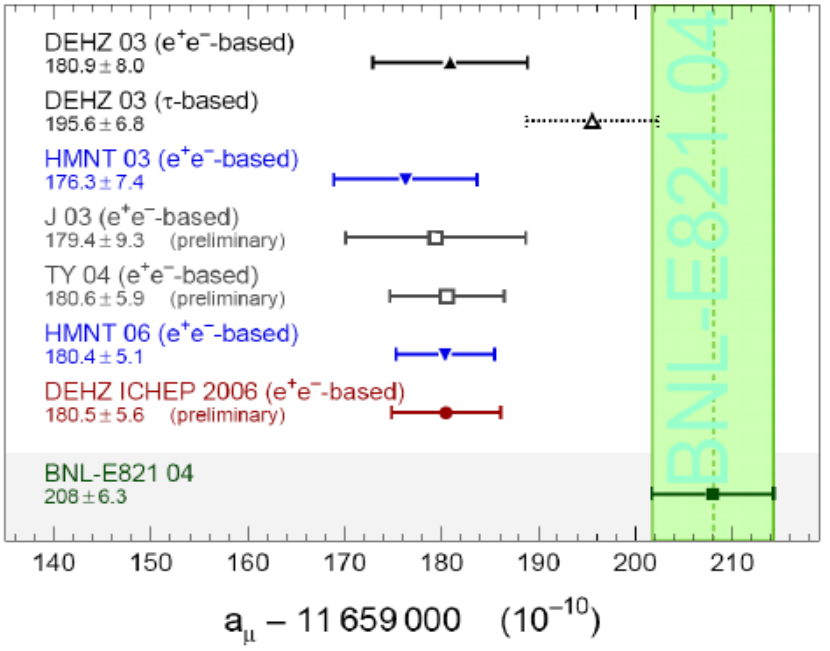
Precision measurements

Muon lifetime and g-2

- MuLan new result:

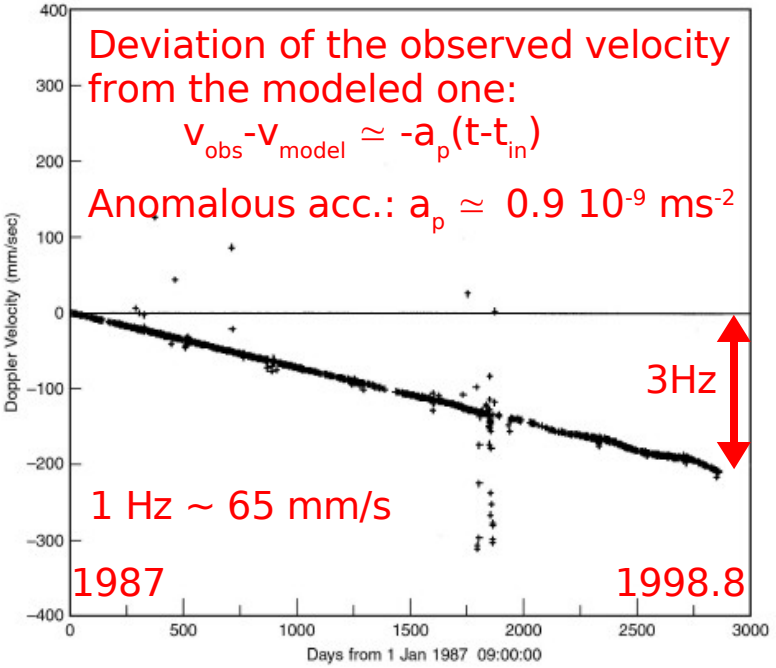
  τ_μ=2.197013(24) μs 11ppm → G_F to 5ppm

- BNL g-2: $a_\mu(\text{Expt.}) = 11659208.0(6.3)\times10^{-10}$
  - Need to measure cyclotron and spin precessions and the magnetic field $\omega_a = \frac{q}{m} a_\mu B$
  - Achieves 0.54ppm (theory 0.48ppm)
  - Strongest experimental evidence of BSM: 3.4σ
  - Although a τ based prediction agrees at 1σ



Gravity from 50μ to 50 AU

- Short distance (Eöt-Wash): Yukawa interaction with gravitational strength has range λ<56μm
- Mid distance (Doppler velocimetry on Cassini, from Jupiter to Saturn): GR accurate to 10^{-5}
- Very long distance: Pioneer anomaly unexplained
  - Constant small anomalous acceleration towards the Sun (blue-shift) in two probes: P10 and P11
  - On-board hardware systematics, external effects, all ruled out as possible explanations



Conclusions

- Excellent atmosphere for discussions and interactions
- Some very good talks (from young people, and from nuclear physicists!)
- Still some difficulty for theorists to understand experimental talks and viceversa
- Tevatron made a very strong showing
- Celebrated announcement of the evidence for D mixing
- SM in good shape, a few (small) deviations persist
- Big emphasis in coming years will be searches for BSM
  - Lots of places to look at: flavor physics, g-2, LHC, etc...
- High energy astronomy is booming ... very exciting
- GR in good shape, except the curious Pioneer anomaly