

Experiment summary

- *Usual apologies...*
- **Standard Model: W/Z; top; Higgs; Searches**
- **Flavour: K; c; b**
- **Neutrinos: beam; reactor; $\beta\beta$**
- **Hi-E astronomy**
- **Dark Matter searches**
- **Precision measurements**

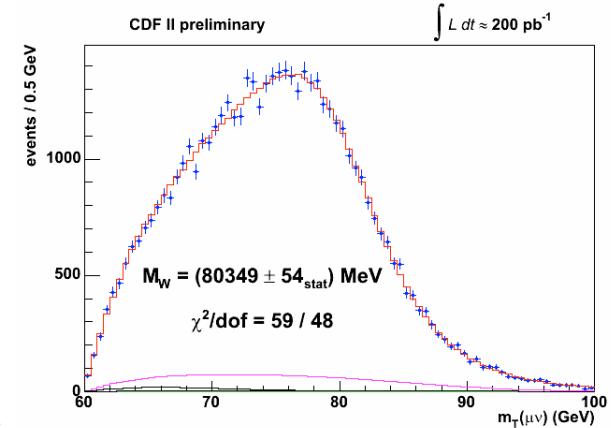


Moriond's new cocktail: the D_{bar} mix

Standard model: W/Z

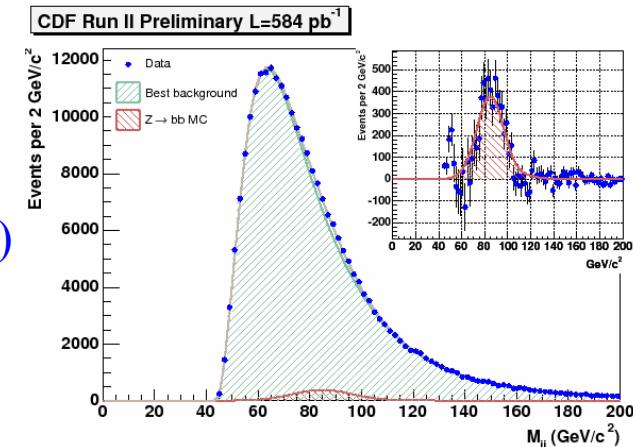
- **W mass in CDF (*O. Stelzer*)**

- Deep knowledge of the detector
- Result (200 pb⁻¹): $m_W = 80413 \pm 48$ MeV
- World av: decreases by 6 MeV; $\delta : 29 \Rightarrow 25$ MeV
- Higgs mass : 83 GeV + 39 – 28 => 80 + 36 – 26 ...



- **W&Z at TeV (*J. Donini*)**

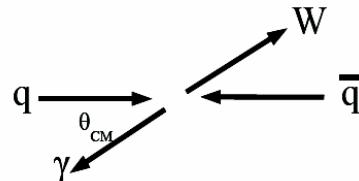
- W&Z as tools:
 - PDF's, QCD... (long. & transv. distributions)
 - Instrument: Z->bb
 - b Jet Energy Scale OK!



Standard Model W/Z

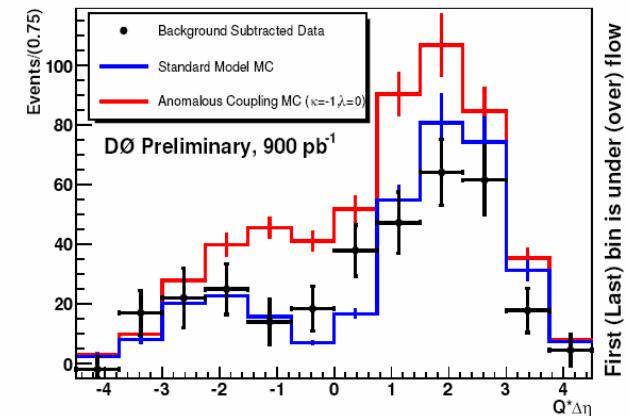
- **Di-boson at TeV (J. Stark)**

- Important 3 Boson couplings...
- WW confirmed, ZZ not seen yet
- First observation of WZ ! (CDF 6 σ ; D0 3.3 σ)
- First observation of W γ amplitude zero (D0)!



$u\bar{d} \rightarrow W^+ \gamma$ has zero at $\cos \theta_{CM} = -\frac{1}{3}$
 $d\bar{u} \rightarrow W^- \gamma$ has zero at $\cos \theta_{CM} = +\frac{1}{3}$

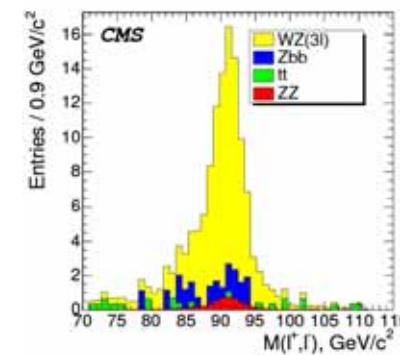
*Excellent performance of the TeVatron:
Analyses with 1 fb⁻¹, 2 fb⁻¹ on tape...*



- **Early E-W measurements at LHC (J. Alcaraz)**

- W, Z, top
 - Understand detector, environment (PDF's), backgrounds
 - Early physics

WZ, 1 fb^{-1}

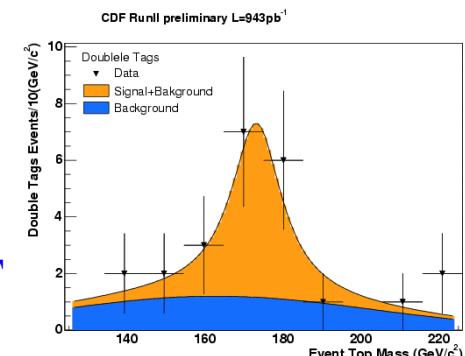


Standard Model: Top

- **Top mass at TeV (*E. Barberis*)**

- Most results now with Matrix Element Method
- 2 new results from D0 (l+jets, ll + jets)
-

All jets from CDF



- Best meas still from l + jets, d: $2.3 (\text{stat} + \text{JES}) \pm 1.3 (\text{syst}) = 2.6 \text{ GeV}$
- **Top mass average (2006) : $171.4 \pm 2.1 \text{ GeV}$**
- “ “ **2007 : $170.9 \pm 1.8 \text{ GeV}$**

NEW!

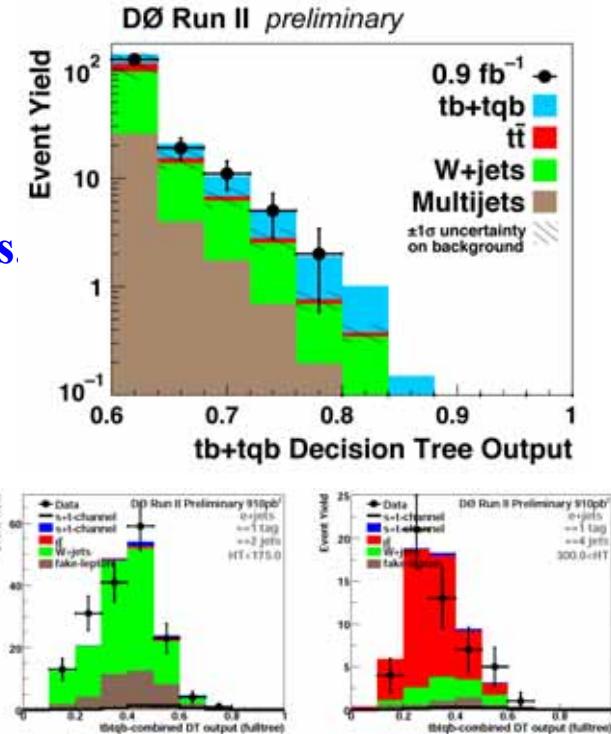
=> new Higgs fit: $m_H < 144$ (153) @95%CL, 182 (189) incl. LEP limit

- **Top production at TeV (*V. Sorin*)**

- Pair cross-section in all modes compatible with SM prediction
 - $\sim 15\%$ level experimental uncertainty
 - theory (NLO) $\sim 12\%$

Standard Model: Top

- Single top (*B Stlezer : CDF; A Garcia-Bellido : D0*)
 - EW production: direct meas of $|V_{tb}|$, source of 100% polarized tops
 - Both experiments use sophisticated analyses techniques (NN, Matrix element, ...)
 - D0: Boosted decision trees
 - Signal seen in D0 in all methods,
 - Allows combination (*new*): 3.5 std observation
 - $\sigma = 4.8 \pm 1.3 \text{ pb}$ for ~ 3 expected
 - $\Rightarrow |V_{tb}| > 0.68$ @ 95%CL
 - CDF less lucky...
 - Positive signal in one method, not in others...
 - But not so unlikely.



Standard Model: Higgs

- **SM Higgs search at TeV (K Peters)**

CDF +D0, 1 fb⁻¹

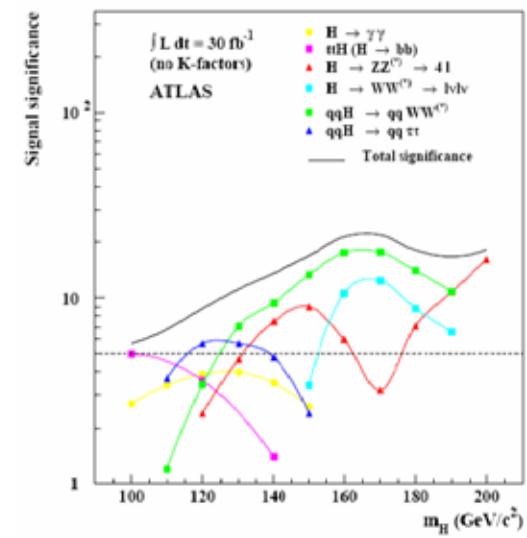
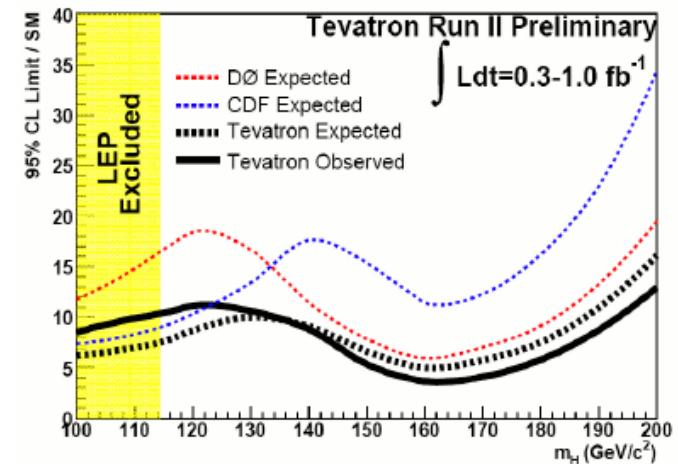
- **mH < 135 (h->bb)** $\sigma_{\text{excl}}/\sigma_{\text{SM}}$
 - WH : 8.5
 - Z(l)lH : 24
 - Z (vv)H, W(lv)H: 15
- **mH > 135 (h-> WW):** => 5 (mH = 160)

**In 2009 with 6-8 fb⁻¹, sensitive to SM Higgs
provided another factor of ~2 gained in analyses**

- **Higgs search at LHC (A Drozdetskiy)**

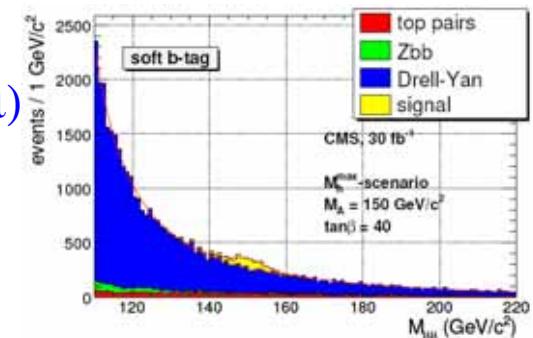
- **Lot of work on classical or new channels (ex : VBF)**
 - Possible discovery with 1 fb⁻¹ for m_H = 170 GeV
 - All mass range with 10 fb⁻¹
- **2008 : 0.1-1 fb⁻¹, 2009 : 5 fb⁻¹ (??)**

But requires a well understood detector...



Searches at high energy accelerators

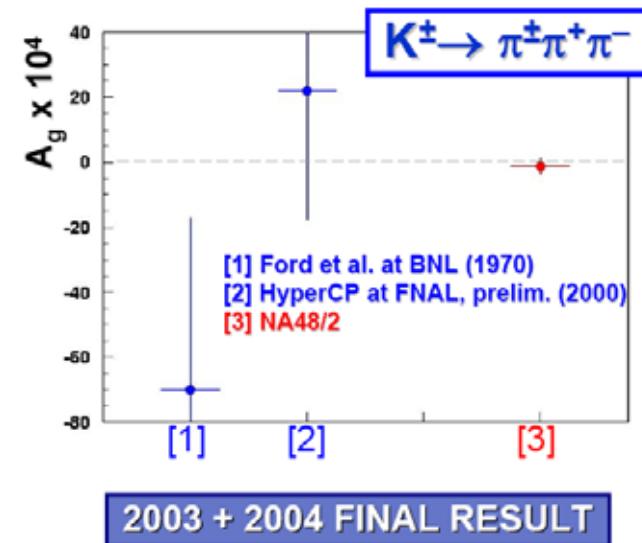
- **Non-SM Higgses**
 - **MSSM neutral Higgs-> $\tau \tau$ at TeVatron:**
 - exclude $\sim (m_A < 200 \text{ GeV}) \& (\tan \beta < 40)$ (*caveats : see Marcela Carena's talk...*)
 - **LHC (T Ekelof)**
 - SUSY: Continuing the saga...new modes; ex $bb\Phi(\mu\mu)$
 - RS radion, Δ^{++} in Little Higgs,...
 - Invisible Higgs (*T. E., J Van der Bij*) , ???
- **Other searches**
 - **TeVatron (T Adams, A Soha)**
 - $W' > 965 \text{ GeV}$ (D0), $Z' > 923 \text{ GeV}$ (CDF), RS gravitons (γ) $> 870 \text{ GeV}$
 - SUSY : squarks, gluinos $> \sim 300 \text{ GeV}$; Chargino/Neutralino in 3-leptons...
 - **Hera (S Schmitt, J Ferrando)**
 - Leptoquark $> 300 \text{ GeV}$ ($\lambda > 0.3$)
 - Excess in high pt leptons in H1 still there...but does not increase in significance



Flavour Physics : K

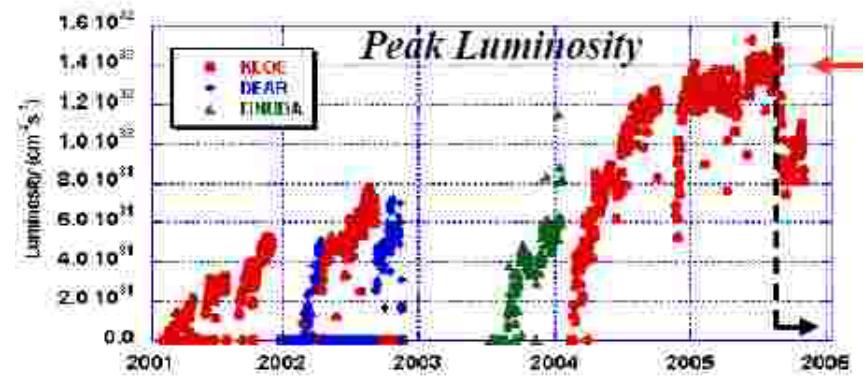
- **NA48 (M Raggi)**
 - **Results from charged K runs 2003-2004**
 - Main goal: CP violation in K^\pm decays ;
 - $A_g(3\pi c) = -1.5 \pm 2.1 \cdot 10^{-4}$ [8/20]
 - $A_g(3\pi n) = -1.8 \pm 1.8 \cdot 10^{-4}$ [8/10]
 - Large K sample: other measurements
 - $K^\pm \rightarrow \pi^\pm \pi^0 \gamma$
 - **First observation of $K^\pm \rightarrow \pi^\pm e^+ e^- \gamma$**
 - $Ke3, K\mu3$ decay rates $\Rightarrow V_{us}$
 - **Result Ks runs 2002: $\Xi^0 \rightarrow \Lambda^0 e^+ e^-$**

- **KTeV (H Nguyen)**
 - **Rare decays**
 - New $K_L \rightarrow \pi^0 \gamma \gamma$: agrees with NA48 (correct cluster shape)
 - **Dalitz (1/2 PDG error)**
 - $K_L \rightarrow \pi^0 \pi^0 \mu e < 1.6 \cdot 10^{-10}$; $\pi^0 \rightarrow \mu e < 3.6 \cdot 10^{-10}$



Flavour Physics : K

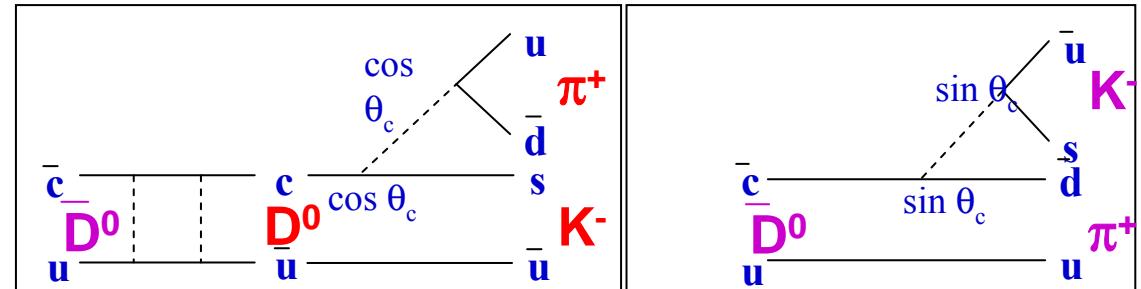
- **KLOE (A di Domenico)**
 - Many results : excellent operation of DaΦne ($L > 10^{32}$), $>> 10^9 K^\pm$ and K^0
 - K Branching ratios
 - $K_S \rightarrow e+e-(\gamma) < 2.1 \times 10^{-8}$
 - $K_S \rightarrow \gamma\gamma = (2.35 \pm 0.14) \times 10^{-6}$
 - $K_L \rightarrow e\pi\nu\gamma 0.92 \pm 0.03 \%$
 - All compatible with SM...*
 - Tests of CPT, quantum coherence
 - $V_{us} \times f+(0) = 0.2158 \pm 0.0006$ from Kl3 decays
- **V_{us} (M Jamin)**
 - Review 3 determinations of $|V_{us}|$ (2006) :
 - Kl3 decays , F_K/F_π , τ decays
 - $\Rightarrow |V_{us}| = 0.2240(11)$
 - Point at problem with unitarity in u column? $\delta = 1.58 \pm 0.72 \cdot 10^{-3}$: 2.2σ effect
Tension : continuously at 2 σ level...



Flavour Physics : c; D^0 mixing

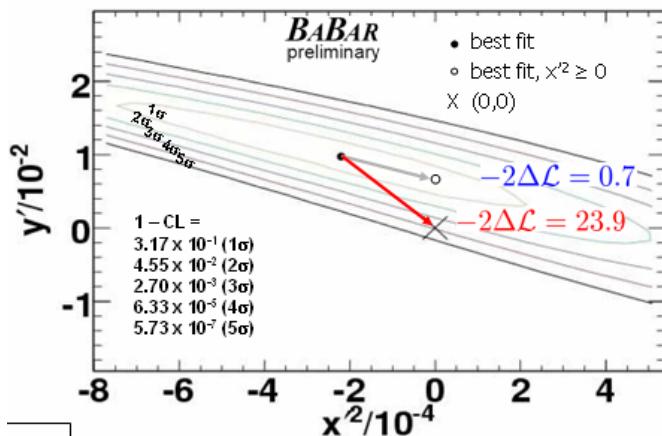
- **$D^0 \bar{D}^0$ mixing (*M Staric, K Flood*) Babar and Belle**

- D^0 tagged by $D^* \rightarrow D \pi$
- Measurement in $K\pi$

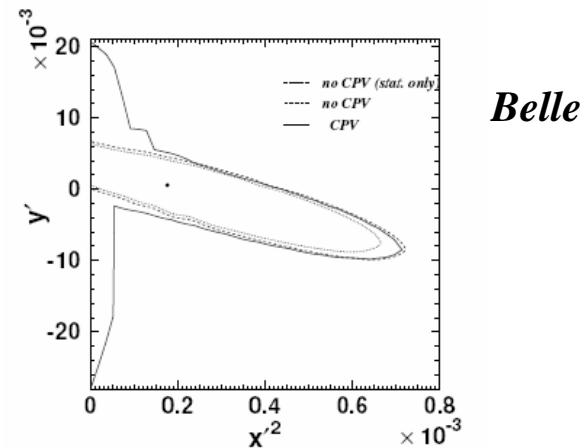


- Fit decay time of RS and WS events with mixing parameters x' and y'

4σ signal



$R_D: (3.03 \pm 0.16 \pm 0.06) \times 10^{-3}$
 $x'^2: (-0.22 \pm 0.30 \pm 0.20) \times 10^{-3}$
 $y': (9.7 \pm 4.4 \pm 2.9) \times 10^{-3}$



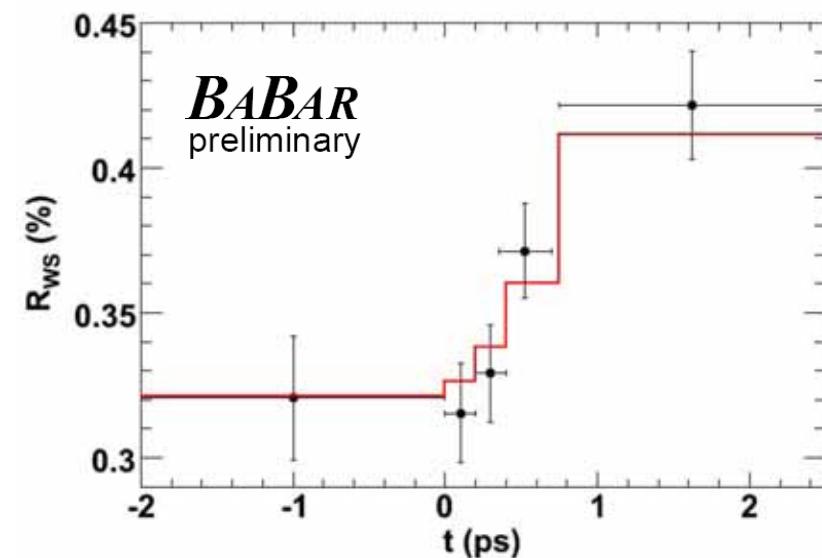
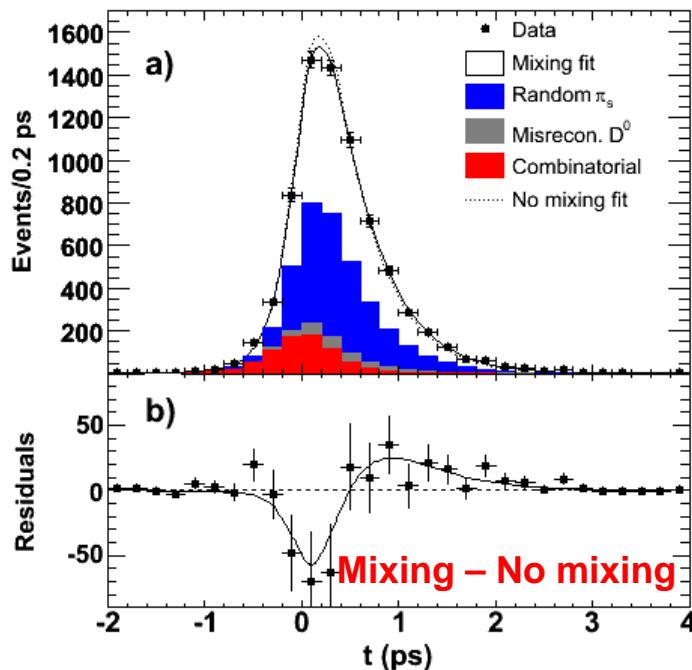
$$R_D = (0.364 \pm 0.017)\%$$

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

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

D⁰ mixing

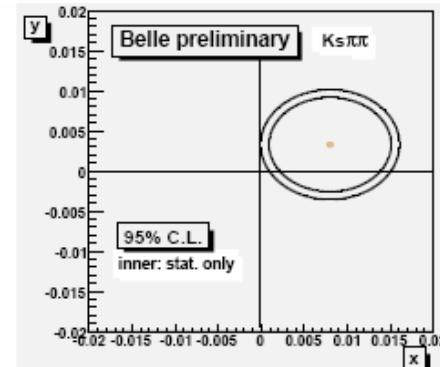
- Babar D⁰ mixing analysis: tests of consistency



- Compare D⁰ and \bar{D}^0 : no sign of CP violation

D⁰ mixing

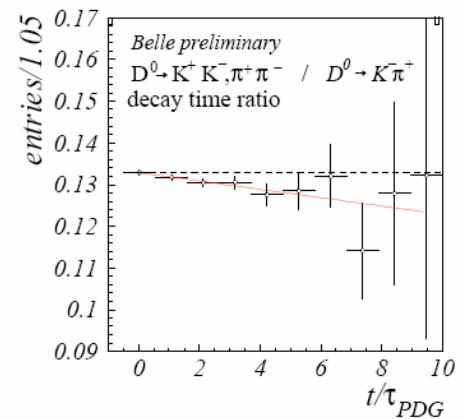
- D⁰ → K⁰π⁺π⁻ Dalitz analysis (Belle)
 - Just excludes no-mixing at 95% CL



- Lifetime difference D⁰ → Kπ and D⁰ → KK, ππ (Belle)

$y_{CP} = 1.31 \pm 0.32 \pm 0.25 \%$
(3σ signal)

$$y_{CP} = \frac{\tau(K^-\pi^+)}{\tau(K^+\pi^-)} - 1$$



- D⁰ mixing reasonably established
(see also P Ball's talk)

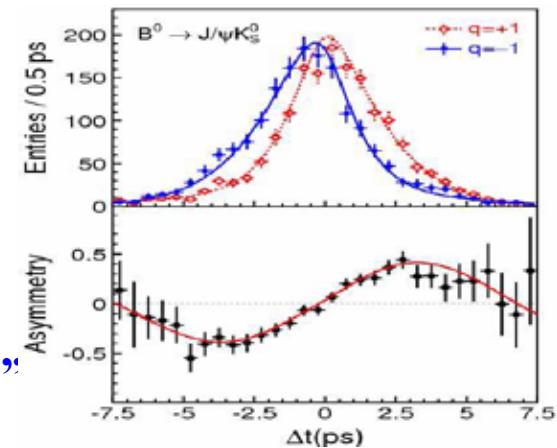
- **CLEO-c results (*B Athar*)**
 - **Many precision results**
 - Limit on $D \rightarrow \tau \nu$
 - $D_s \rightarrow \mu \nu, D_s \rightarrow \tau \nu$ BR's
 - D semi-lept decays $\Rightarrow |V_{cs}|$ and $|V_{cd}|$, agree w previous measurements
- **BES results (*X Shen*)**
 - **BES II results with 58 M J/ψ , 14 M $\psi(2S)$**
 - Peak in $J/\psi \rightarrow \gamma(\omega\phi)$
 - $\psi(3770) \rightarrow DD$ and non DD modes
 - $\eta \rightarrow$ invisible $< 6.4 \times 10^{-4}$; $\eta' \rightarrow$ invisible $< 1.4 \times 10^{-3}$

b Physics : CP violation angles

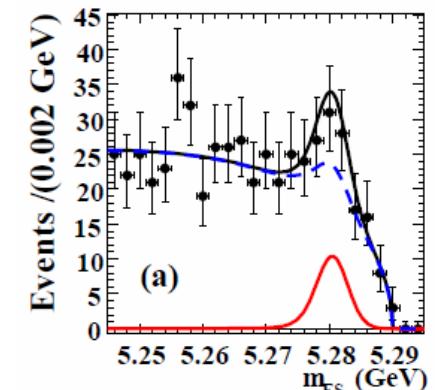
- **β (*D Lange*) Babar + Belle**
 - $J/\psi K_S \sin(2\beta) = 0.678 \pm 0.026$
 - Other charm decays...
 - DD (Belle), D 0 (Babar)... ~consistent w $J/\psi K_S$
 - First measurement of sign($\cos 2\beta$) : favors “standard”
 - Charmless (penguin) decays : $0.50 \pm 0.06 \Rightarrow ??$

- **α (*A Kusaka*) Babar + Belle**
 - $B \rightarrow \pi\pi, \rho\rho, \rho^+\pi^-, a_1^+\pi^-$
 - $B^0 \rightarrow \rho^0\pi^0$ Dalitz analysis
 - $\alpha = 93.5^\circ + 10.8 - 9.6$

- **γ (“”)**
 - $D(*) K \Rightarrow \gamma = 77^\circ \pm 31$

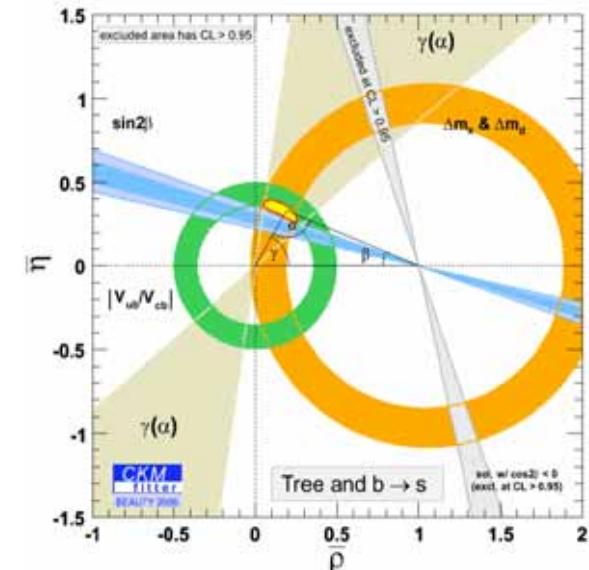


*First $\rho^0 \rho^0$
Babar*



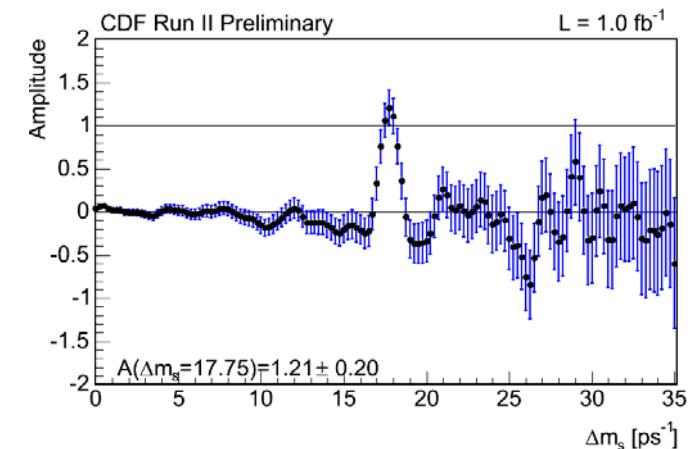
b Physics : CKM elements moduli

- **V_{ub}, V_{cb} (*R Sacco*) Babar + Belle**
 - **V_{cb} from fit of $B \rightarrow X_c l \nu$ (moments) to 2% level**
 - **V_{ub}**
 - exclusive decays: 8% expt + 15 % model dependence
 - inclusive : 15% expt + 5% theory ... => encouraging..
- **V_{td}/V_{ts} (*P Bechtle*) Babar**
 - $B \rightarrow \rho/\omega \gamma \Rightarrow |V_{td}/V_{ts}| \rho \gamma = 0.202 \pm 0.23$, agrees with $\Delta m_d/\Delta m_s$ and SM
 - first observation of $B^+ \rightarrow \rho^+ \gamma$ (Babar)
- ***Overall consistency of CKM matrix (M Neubert)***
- “Tension” between 3 ingredients ($\sim 2 \sigma$)?
 - β from $J/\psi K_S$
 - β from penguins
 - V_{ub}
- ***Well... 2 of the determinations agree so well?***



- **B_s lifetime and mixing (*A Heijboer, A Sanchez*) TeVatron**

- Lifetime : world's best measurement (D0, semi-lept)
- Δm_s : oscillation confirmed
 - *D0* : now ~ 1.6 s effect at 18 ps^{-1}
 - **CDF: 5.4σ effect: $17.77 \pm 0.1 \pm 0.07 \text{ ps}^{-1}$**
- $\Delta \Gamma_s$: angular analysis on $B_s \rightarrow J/\psi \phi$ [D0]
 $\Delta \Gamma_s = 0.13 \pm 0.09 \text{ ps}^{-1}$, ϕ compatible w 0 => agrees with SM



- **Heavy states, rare decays**

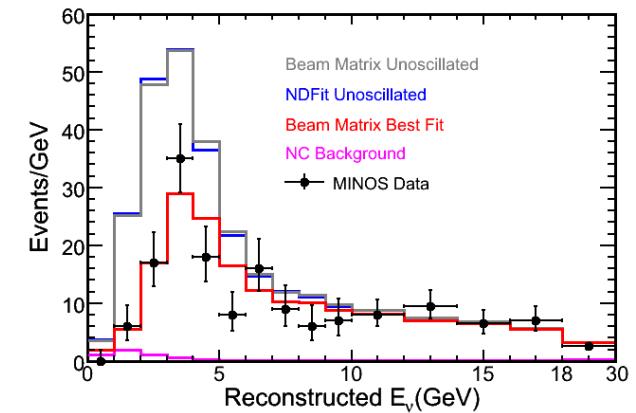
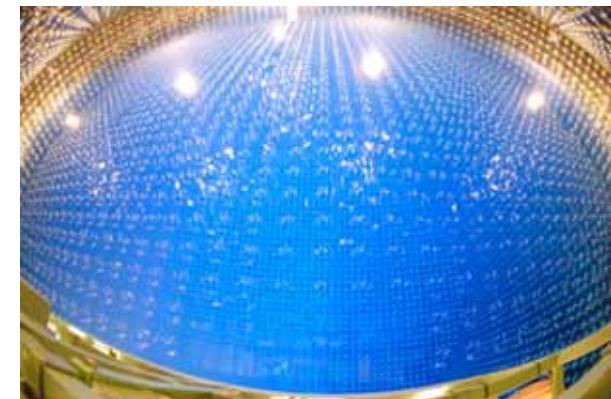
- Σ_b discovery by CDF (*J Pursley*)
- Λ_b lifetime (CDF + D0)
- $B \rightarrow \mu\mu$ by D0 => $< \mathcal{O}(10^{-7}) \sim 20 \times \text{SM}$ (search for FCNC, remember $\tan^6\beta$ MSSM!)
- **Lepton flavour violation limits (*Mike Roney*) [Babar + Belle]** $\tau \rightarrow e\gamma, \tau \rightarrow \mu\gamma$ 10^{-7} - 10^{-8}

Neutrinos : beam experiments

- **HARP (*B Popov*) at Cern**
 - Large set of hadron production measurements to be used in neutrino experiments
 - (MIPP (*A Lebedev*) at FNAL ...in progress)

- **K2K/T2K (*M Yokoyama*)**
 - Final K2K result with 112 evts
 - Use Harp data $\Delta m^2_{32} / \sin^2(2\theta_{23})$
 - Exclude no-oscillation at $4.3 \sigma \Rightarrow (2.8 \times 10^{-3}, 1.0)$
 - Super-K detector PM's all replaced!
 - Tokai J-Parc progresses towards first beam in Apr 2009

- **MINOS (*T Raufer*)**
 - 735 km beam from FNAL/ near detector/ to Soudan
 - Result for first year : 1.27×10^{20} p o t
 - Exclude no-disappearance at 6.2σ
 - Compatible with previous expts

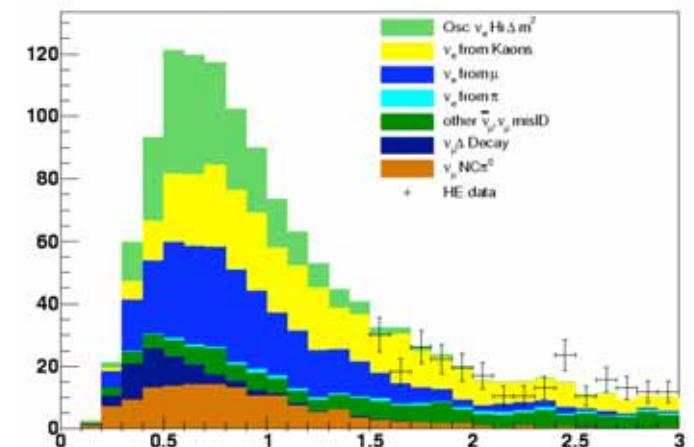
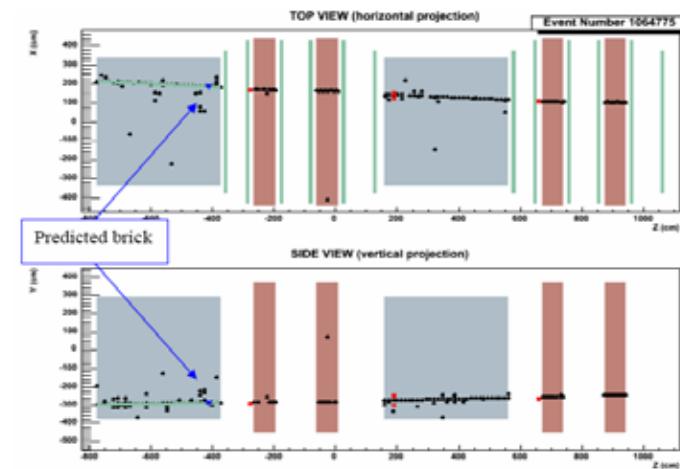


Neutrinos : beam experiments

- **CNGS/Opera (E Gschwendtner, J Marteau)**
 - Cern ν beam commissioned to nominal p/spill in 2006
 - Opera
 - ~ all electronic detectors commissioned: recorded first beam- ν events !
 - Emulsion “bricks” prod. and install. ~ 1000 in Oct '06 > 100 000 in fall '07

- **MiniBoone (K Mahn)**
Much expected measurement: LSND result?!
=> not yet...
 - Number of pot = expected
 - Fighting several backgrounds...careful
 - Blind analysis

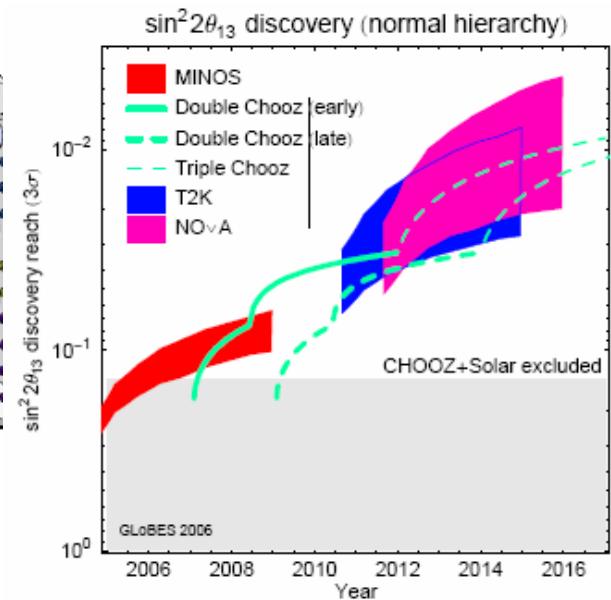
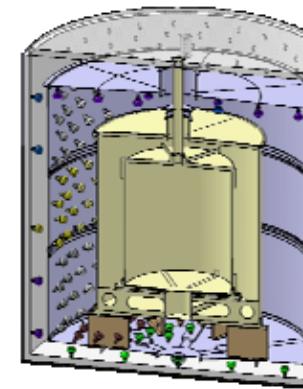
Stay tuned...



Neutrinos: reactor, atmospheric

- **Reactor neutrinos (*A Cabrera*) [Double-Chooz]**

- “Fast” way to improve θ_{13} knowledge
- Near + Far (~1 km) detectors (10 m³ targets)
 - Cancel flux systematics
- Complementary to beams
 - No CP effect
 - No Matter effect

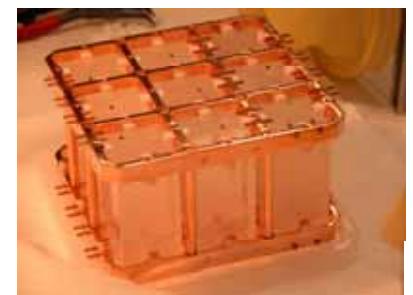
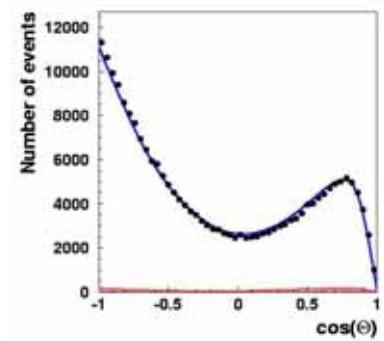
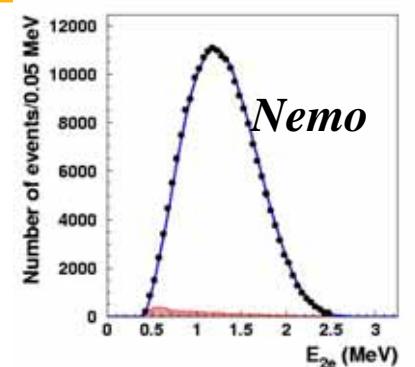


- **Atmospheric (*M Maltoni*)**

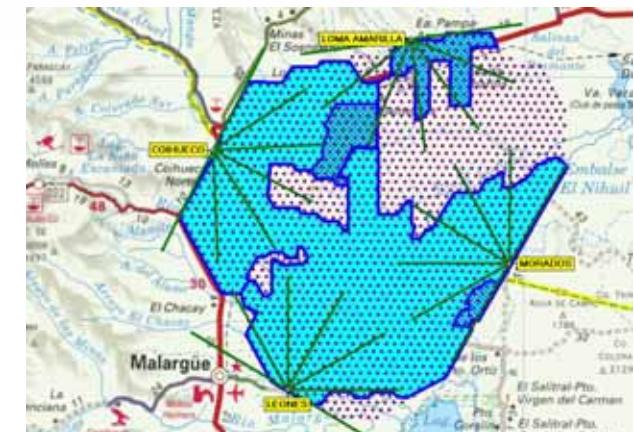
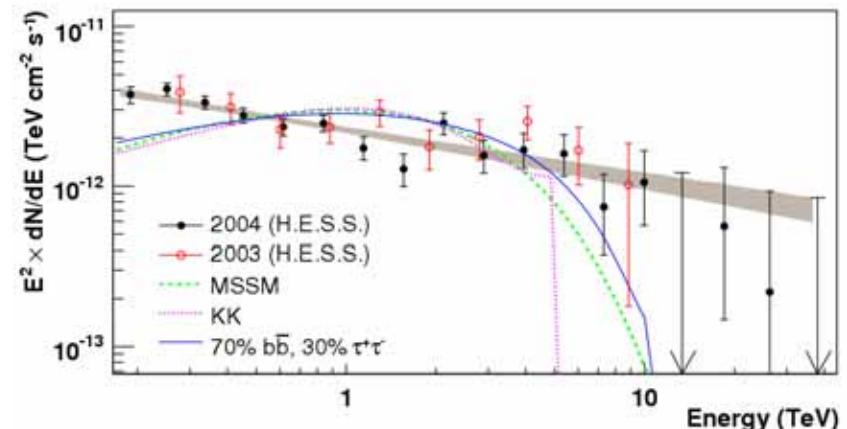
- Accelerator and reactor experiments leave ambiguities
 - Mass hierarchy
 - “Octant” (2 solutions for θ_{23})
 - CP phase
- Atmospheric ν measurements can help...

Neutrinos: $\beta\beta$ decay

- (*S Schoenert, S Cappelli*)
 - Recent progress in nuclear matrix elements calculations
 - Uncertainty ~factor 2 to 4
 - All $\beta\beta$ -sensitive nuclei have ~the same theoretical sensitivity
 - Experimental results
 - Heidelberg Moscow (^{76}Ge , 10 kg, Gran Sasso)
 - Positive signal... debated...
 - NEMO-3 (“tracko-calorimeter”, 10 kg, Modane)
 - Limits on Mo : $>4.6 \cdot 10^{23}$ years $\Rightarrow \langle m_\nu \rangle < 0.66 - 2.8$ eV
 - Cuoricino (TeO_2 bolometers, 10 kg, Gran Sasso)
 - $> 2.4 \cdot 10^{24}$ years $\langle m_\nu \rangle < 0.18 - 0.94$ eV
 - Planned experiments
 - GERDA (^{76}Ge), CUORE (TeO_2) : aim for 1 ton.year
 \Rightarrow Reach “inverted hierarchy” mass range: 0.01-0.1 eV

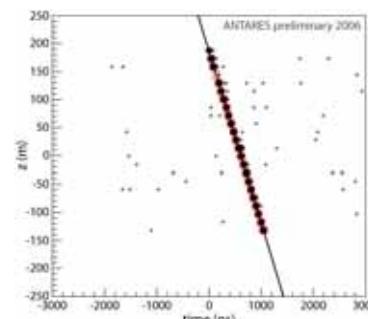
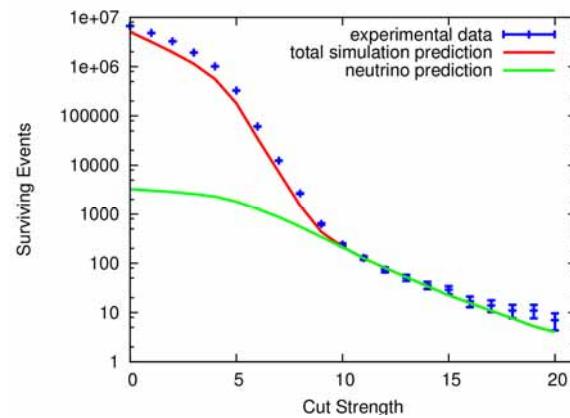


- **Photons (review by M Martinez)**
 - Large harvest of new astrophysical results, sources, etc (HESS...)
 - Particle physics :
 - search for Dark Matter annihilation at the galactic center: unlikely but not yet sensitive to Susy models
 - **Auger (V Van Elewyck)**
 - 1000 tanks active (/1600 total)
 - Cosmic ray spectrum at GZK cut-off: **not yet!**
 - New limits on anisotropy (...galactic center)
 - Prelim ν_τ search with grazing showers



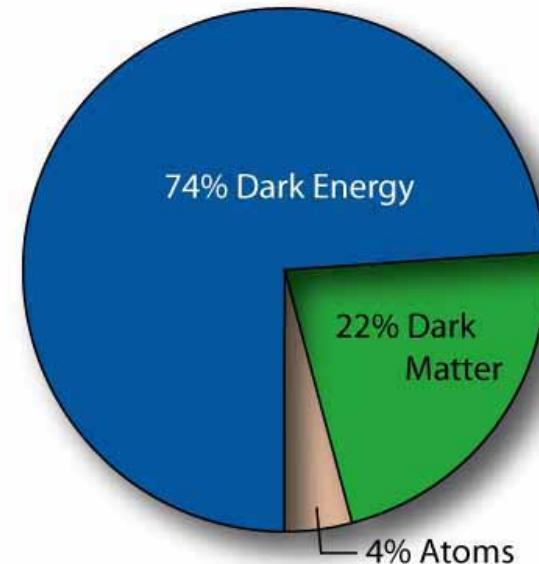
High Energy astronomy: neutrinos

- **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**



Dark Matter searches

- **Explaining the nature of Dark Matter with the right abundance is a powerful unifying viewpoint and an incentive to inventiveness!**



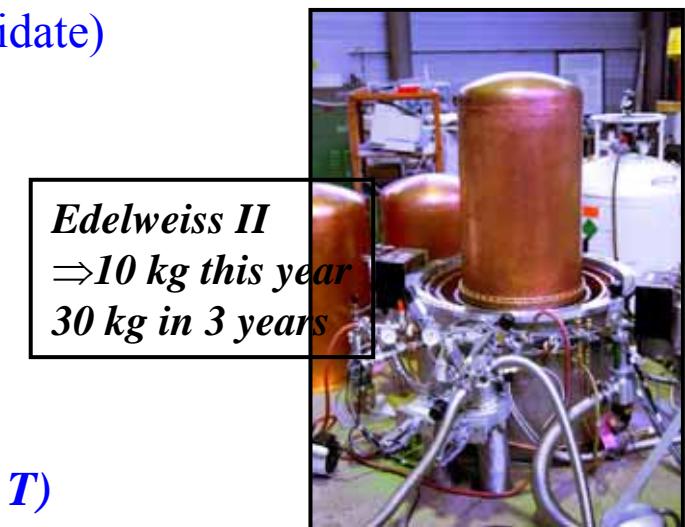
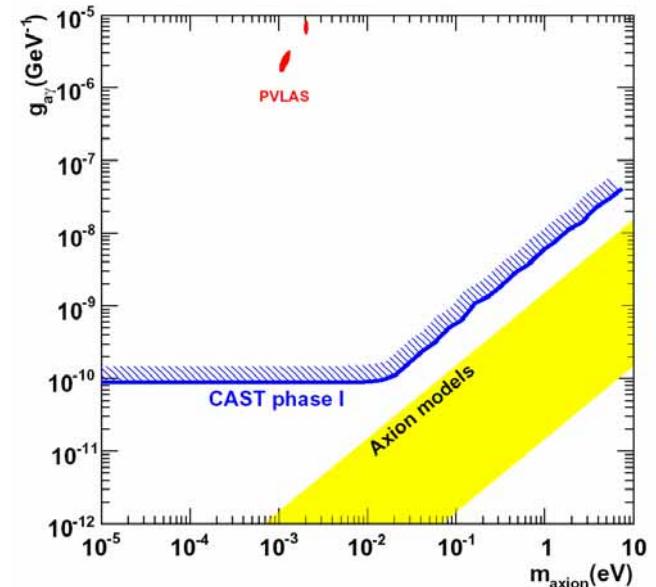
Ex:

- **SuSy DM: direct search /collider searches / hi-E photon astronomy/ ($g-2$) μ**
- **Light DM**
 - 511 keV photons from galactic center (*J Orloff*) [Integral satellite data]
 - $Y(1s)$ invisible decays (*T Higuchi*) [Belle] > limit

Dark Matter searches

- **Axions (*I Irastorza*)**
 - Cast (solar axions converted in B-field) => limit
 - Not yet at QCD axion models...but soon
 - PVLAS (rotation of light polarization in B-field)
 - Positive result...to be confirmed
 - by “light thru wall” experiment ?
 - ADMX (de-tuning of cavity)
 - Search very low mass axions (dark matter candidate)

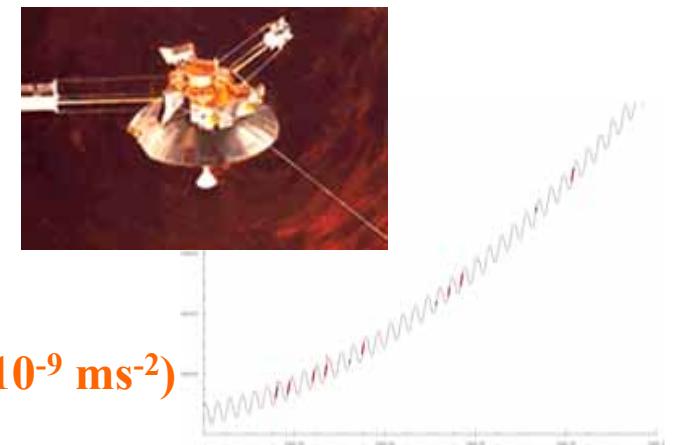
- **Wimps (*C Galbatti*)**
 - Warp: Liquid argon ionization + scintillation
 - Predict liquids will quickly dominate the field...
 - *But the devil in the details...*
 - *And up to now best limit is CDMS (Ge at ultra low T)*



Precision measurements

- **Quantum mechanics at 5 GeV: B^0 - \bar{B}^0 system (*A Bay*) [Belle]**

- Rule out decoherence at $\sim 5\%$ level
- (KLOE result with $K: 10^{-6}$!)



- **Gravity from 50 μ to 50 A. U. (*review: S Reynaud*)**

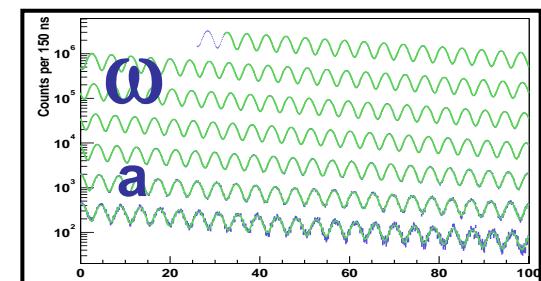
- Short distance: Newton's law \sim **OK to 0.1 mm**
- Mid distance (planets) accurate to **$2 \cdot 10^{-5}$**
- Very long distance: Pioneer anomaly unexplained...(10^{-9} ms^{-2})

- **Standard model tests at low energy**

- Neutron decay (*M Schumann*) at PSI : limits on anomalous couplings
- Muon lifetime (*D Hertzog*) at PSI: $\tau(\mu)$ to 11 ppm \Rightarrow **G_F to 5 ppm**

- **Muon g-2 (*D H.*)**

- BNL experiment: final result a_μ to .54 ppm
- “Mainstream” theoretical calculation : **off by 3.4σ !**
- But alternate way (using τ decays) only by 1σ (*Z Zhang*)...



Conclusion

- I had not been to Moriond since ~20 years...
 - ⇒ The spirit is well kept!
 - ⇒ Although individuals may be specialized, the field is uniting through large common concepts:
 - dark matter, hierarchy problem, CP...
 - united searches for signs of physics beyond the Standard Model
 - ⇒ Allows for wide (wild) and stimulating discussions
 - ⇒ Many thanks to the organizers
 - ⇒ ... and participants.