Rencontres de Moriond EW 2012

EXPERIMENTAL ~~SUMMARY~~ HIGHLIGHTS
OF AN EXTRAORDINARY
MORIOND EW 2012

1. Pushing the New Physics in the corners

2. The New Physics there is:
   An elementary scalar boson candidate?
   Massive neutrinos properties

3. What do we do next?

Pushing new physics in the corners

Precision measurements

W mass and top mass

Flavor physics

$\mu \rightarrow e \gamma$

B, D decays and asymmetries

Direct searches

Tevatron, LHC

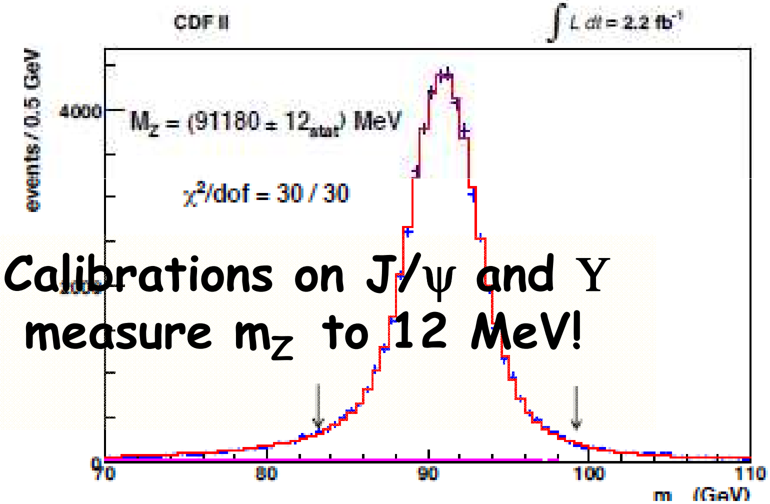
Dark Matter search experiments

Benchmark: Supersymmetry where quantum numbers and thus couplings are ~more or less defined and limits often expressed in particle masses.
Complete fits of pMSSM can be attempted.
(It has become a common currency)

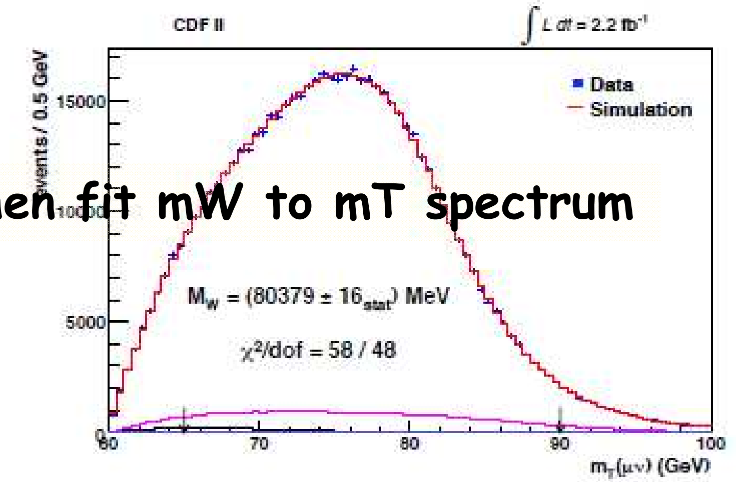
B physics → More generic expressions of new effects for B physics

W mass

New 'best' result from CDF



Calibrations on J/ψ and Υ measure m_Z to 12 MeV!



Then fit mW to mT spectrum

Source	Uncertainty 2.2 fb^{-1} (MeV)
Lepton energy scale	7
Lepton energy resolution	2
Recoil energy scale	4
Recoil energy resolution	4
Lepton removal	2
Backgrounds	3
$p_T(W)$ model	5
PDFs	10
QED radiation	4
Total systematics	*15*
W statistics	12
Total	***19***

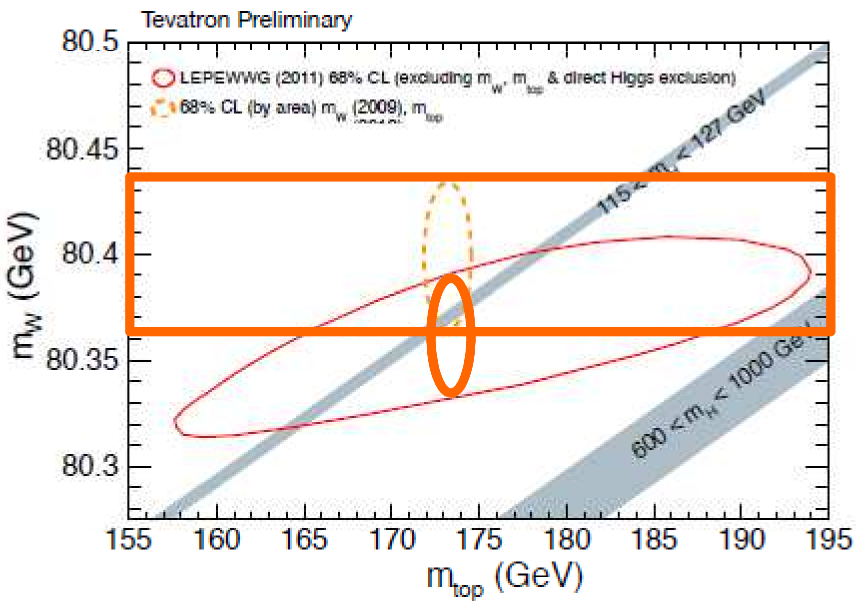
Largest systematics is from QCD initial/final radiation etc... 10 MeV (comp. QED 4 MeV !)

before

With M_W = 80399±23 MeV

$M_H = 92^{+34}_{-26}$ GeV
M_H < 161 GeV @95% CL

LEPEWWG/ZFitter

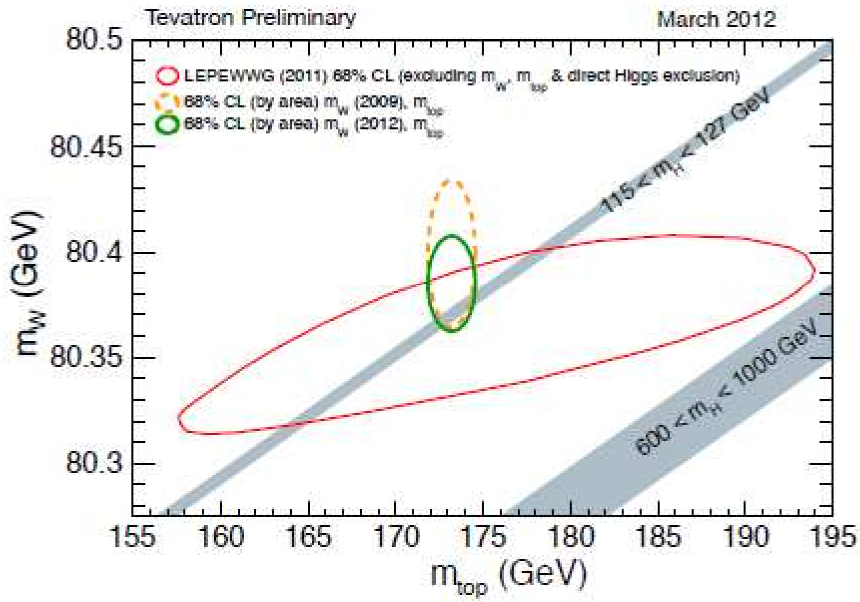


Now m_w is the most contraining variable in the indirect limit to m_H

With $M_W = 80385 \pm 15$ MeV

$M_H = 94^{+29}_{-24}$ GeV
$M_H < 152$ GeV @95% CL

LEPEWWG/ZFitter



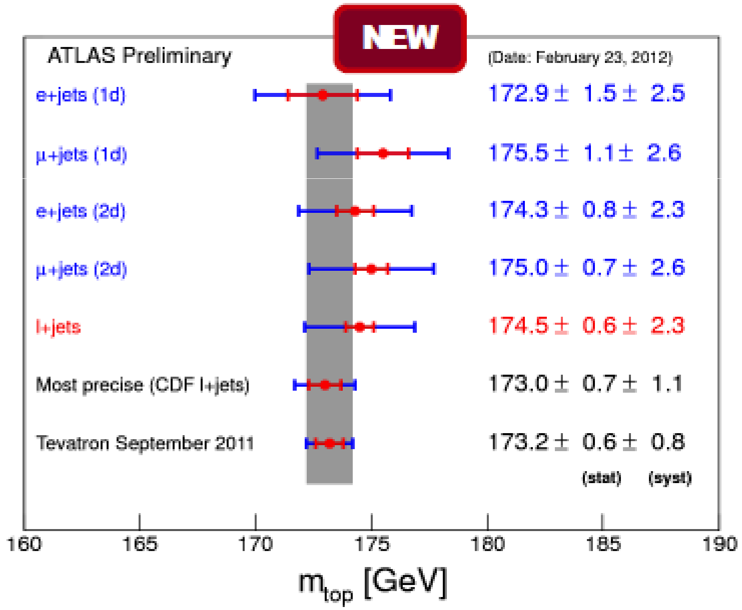
When m_H is known it will be time to review implications of influential BSM physics on all EW precision measurements
-- 4th generation
-- SUSY
-- Higgs triplets
-- etc. etc.

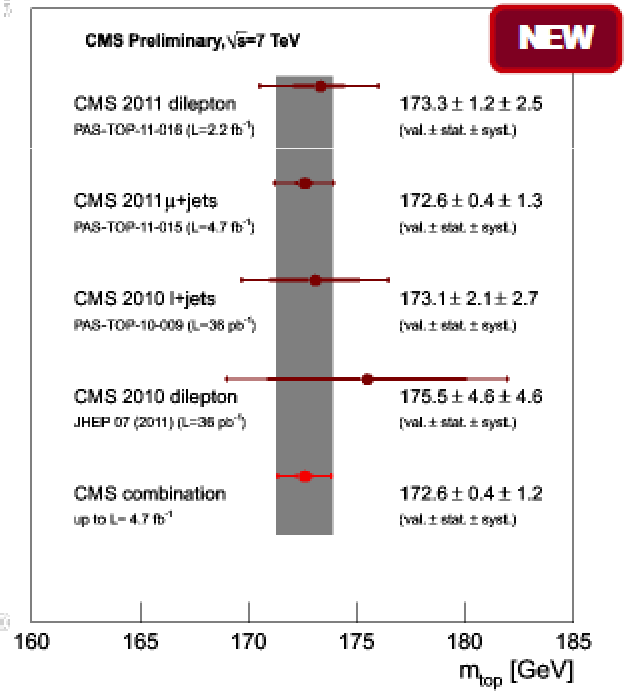
LHC is already in the game for m_{top}!

Top mass combination

CMS-PAS-TOP-11-018

29/32



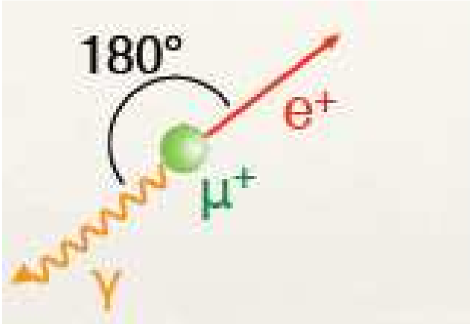


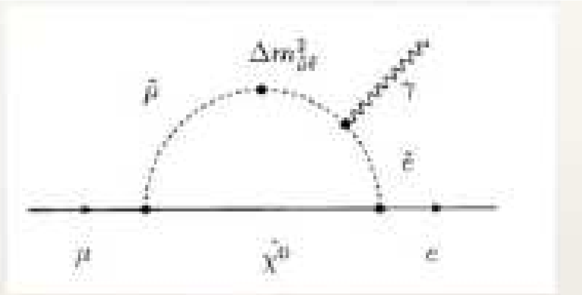
- **… and LHC combination is on the way**
- "Back of the envelope" calculation indicates that result will help decrease the current uncertainty from the Tevatron (partially uncorrelated systematics + higher statistics)

Headache error is color recombination – top quark is not a singlet and has « strings attached » ! (what does 'mass' mean?)
LHC vs tevatron …
Different process → different error? Or even different mass?

MEG expt @ PSI

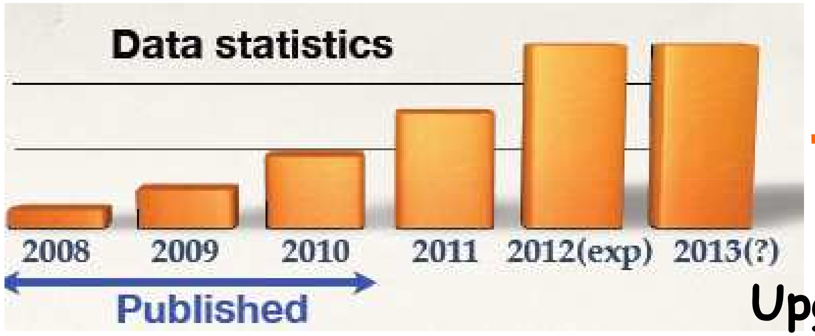
3 10^7 μ/s





Liq Xe calorimeter
DE/E =4% at 50 MeV

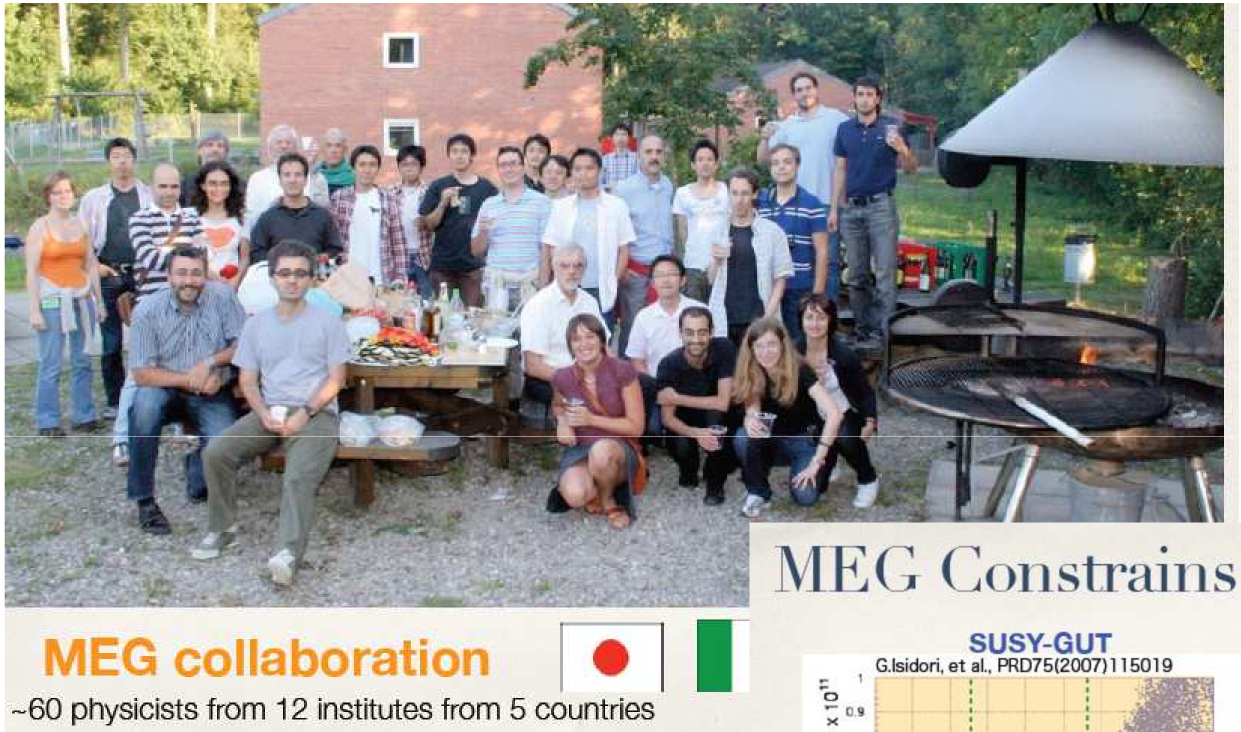
New upper limit: $B\,(\mu\to e\gamma) < 2.4\times10^{-12}$ *(90%C.L.)*

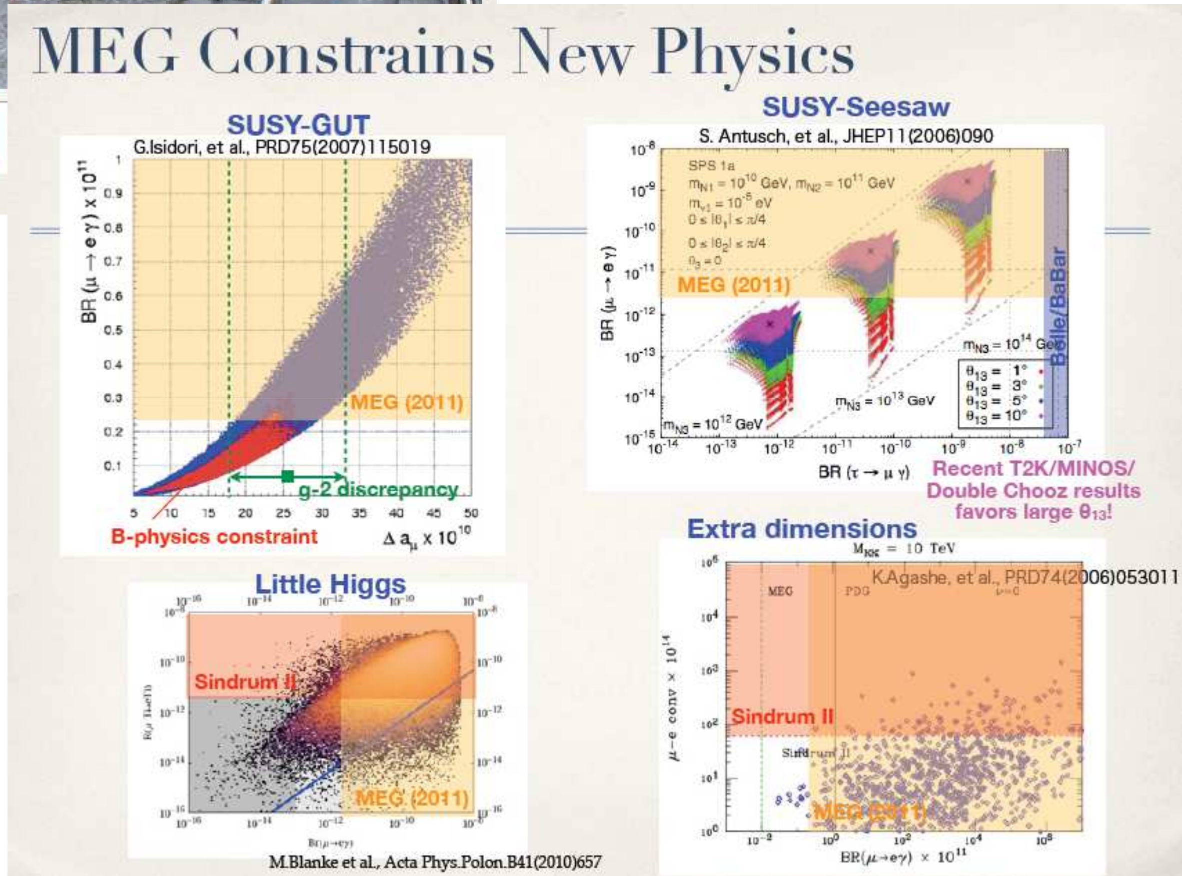


Upgrade?

Will continue run and upgrade detector towards 10^{-14} sensitivity

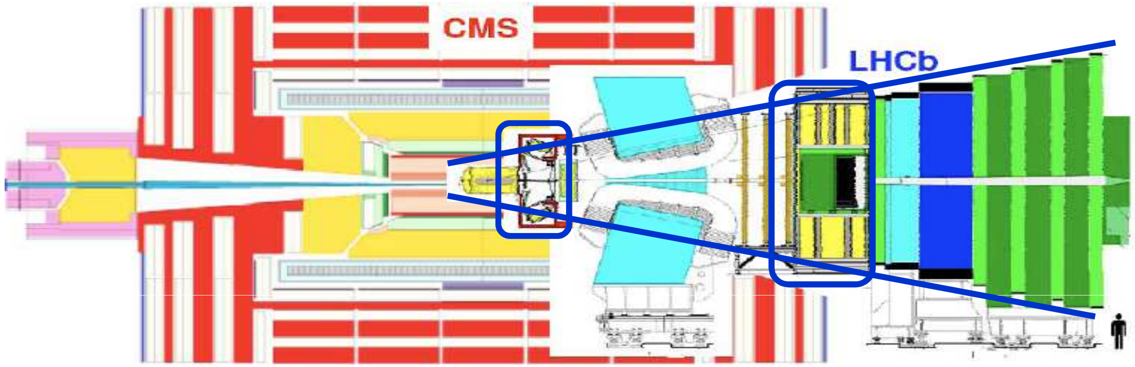
Also: mu2e at FNAL, COMET at KEK, mu3e LOI at PSI…





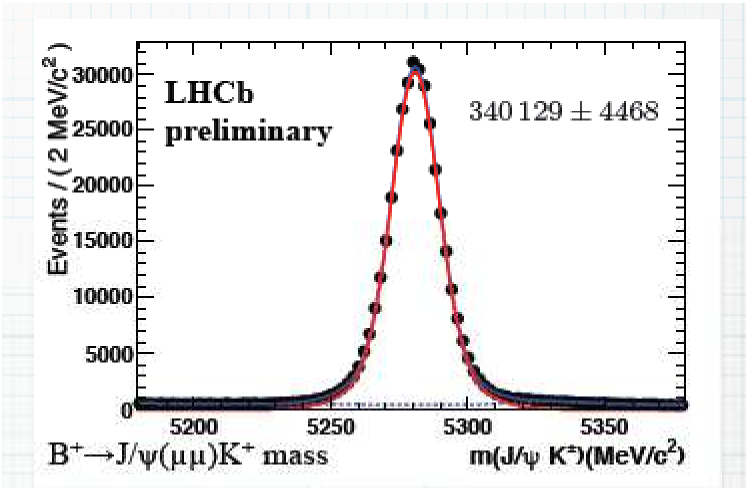
Such a small group of nice people is killing so many theories…

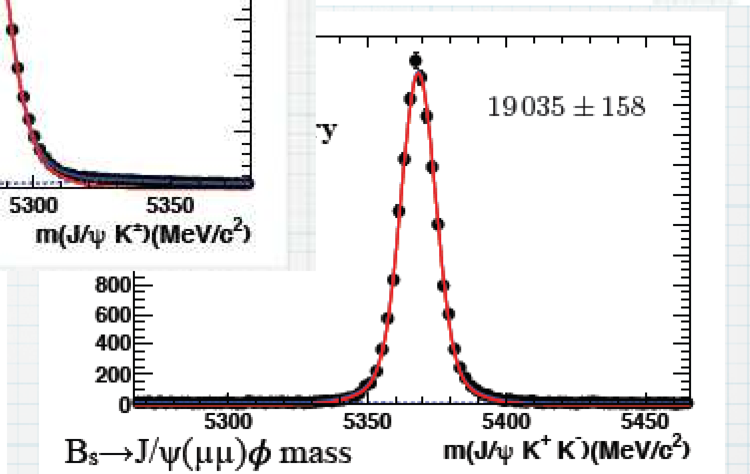
B and D physics : BaBar, Belle, CDF & D0, LHCb, CMS & ATLAS



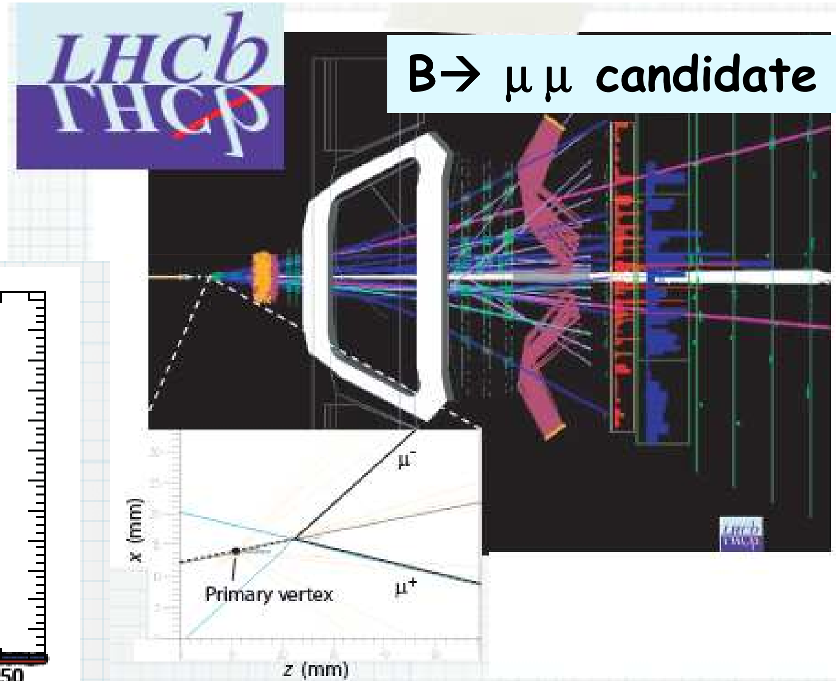
LHCb = a fixed target experiment design
Huge rates 2<η<5, second vtx locator (velo)

The collaboration fits in the hall





B→ μ μ candidate



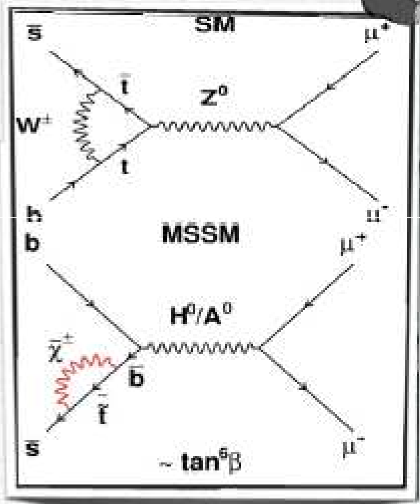
Selected Highlight

BEFORE

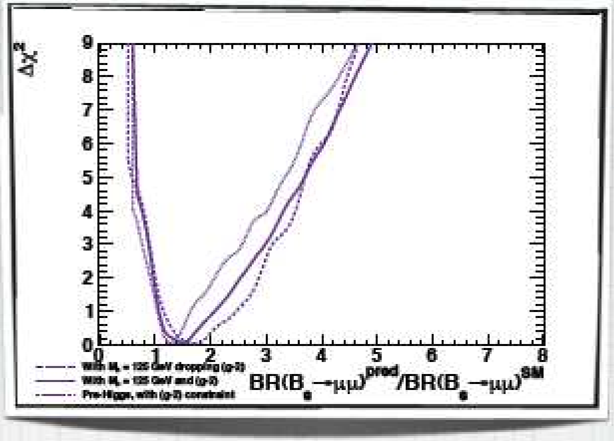
Search for the $B_{(s)} \to \mu\mu$ decay

LHCb-PAPER-2012-007

- SM prediction (FCNC, helicity suppressed)
  - SM $B(B_s \to \mu\mu) = (3.2 \pm 0.2)\ 10^{-9}$ arXiv:1005.5310 arXiv:1012.1447
  - SM $B(B \to \mu\mu) = (0.1 \pm 0.01)\ 10^{-9}$
- Branching ratio very sensitive to NP
- Current Status
  - LHCb limit: [0.37 fb^{-1} arXiv:1112.3515, PLB 707 (2012) 497-505]
    - $B(B_s \to \mu\mu) < 1.4\ 10^{-8}$ 95 % C.L (LHCb)
    - $B(B \to \mu\mu) < 3.2\ 10^{-9}$ 95 % C.L (LHCb)
  - CDF has an excess of events (10 fb^{-1}):
    - $B(B_s \to \mu\mu) = (1.0^{+0.8}_{-0.6})\ 10^{-8}$ (CDF)
  - Best limit 28/02/12 (5 fb^{-1})
    - $B(B_s \to \mu\mu) < 7.7\ 10^{-9}$ 95 % C.L (CMS)



NUHM arXiv:1112.3564



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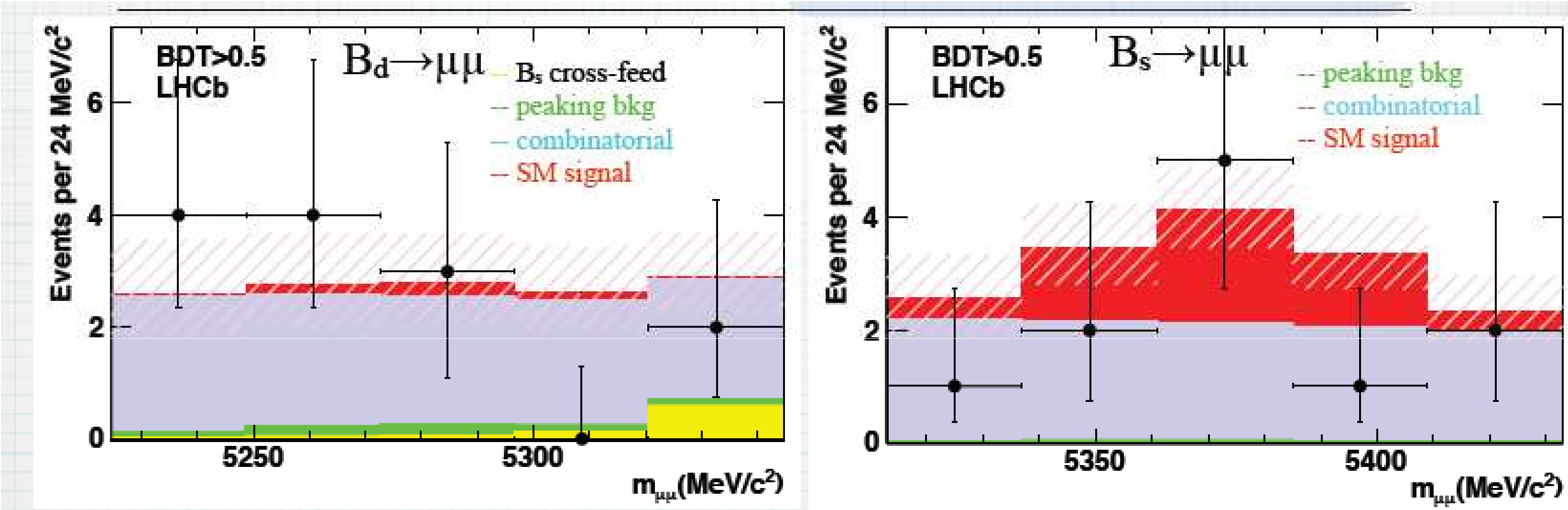
LHCb



$\mathcal{B}(B_s \to \mu\mu) < 4.5\ 10^{-9}$ at 95% CL

$\mathcal{B}(B \to \mu\mu) < 10.3\ 10^{-10}$ at 95% CL

best limit!

- SM prediction (FCNC, helicity suppressed)
  - SM $\mathcal{B}(Bs \to \mu\mu) = (3.2 \pm 0.2)\ 10^{-9}$ arXiv:1005.5310 arXiv:1012.1447
  - SM $\mathcal{B}(B \to \mu\mu) = (0.1 \pm 0.01)\ 10^{-9}$
- Branching ratio very sensitive to NP

SOON these decays will be measured !

This decay being GIM suppressed is very sensitive to (EW coupled) particles contributing to loops …

Direct CPV in $D^0 \to \pi^+\pi^-, K^+K^-$:

CPV in mixing (indirect) can be related to direct CPV via the relation:

$$A_{CP}(h^+h^-) = a_{CP}^{\mathrm{dir}}(h^+h^-) + \frac{\langle t \rangle}{\tau} a_{CP}^{\mathrm{ind}}(h^+h^-)$$

$\langle t \rangle/\tau$ = 1 at B factories, ~2.5 at CDF (displaced trigger)

Independent of the final state

Considering $\pi\pi$ or KK final states we can build the difference:

$$A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = \Delta a_{CP}\,(\text{direct}) + \Delta\langle t \rangle/\tau \; a_{CP}^{\mathrm{ind}}$$

HCP 2011: LHCb, 620 pb^{-1} : first evidence (3.5 σ) of CPV in charm:

$$\boxed{\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = (-0.82 \pm 0.21 \pm 0.11)\%}$$

Moriond 2012: CDF, 9.6 fb^{-1}, confirms this result

$$\boxed{\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = (-0.62 \pm 0.21 \pm 0.10)\,\%}$$

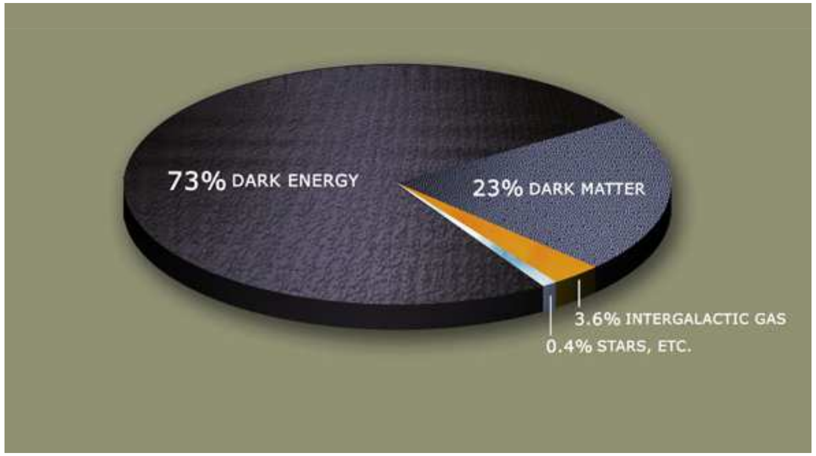
Combination of LHCb and CDF results in a 3.8 σ deviations from zero.

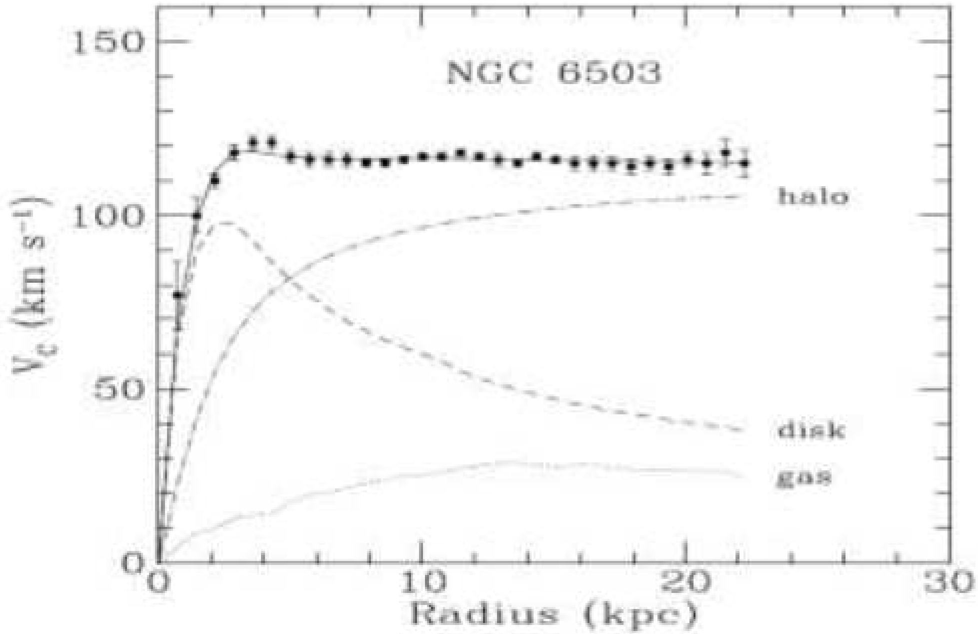
Direct searches

Tevatron, LHC, Dark Matter experiments

Many searches for new particles (SUSY <u>and</u> exotics) leading to the same remarkable result, i.e. the Standard Model always agrees with the data. The models are losing both in energy range and in degrees of freedom (or rather they have to invoke new d.o.f.s to survive the attack of data).

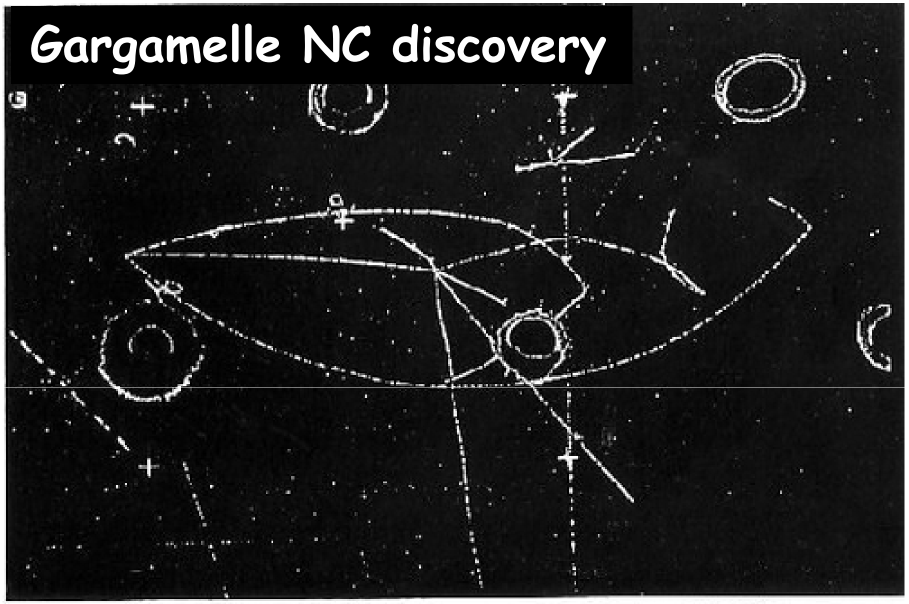
I concentrate on the Dark Matter search because we know that there is Dark Matter – we just dont know what it is.

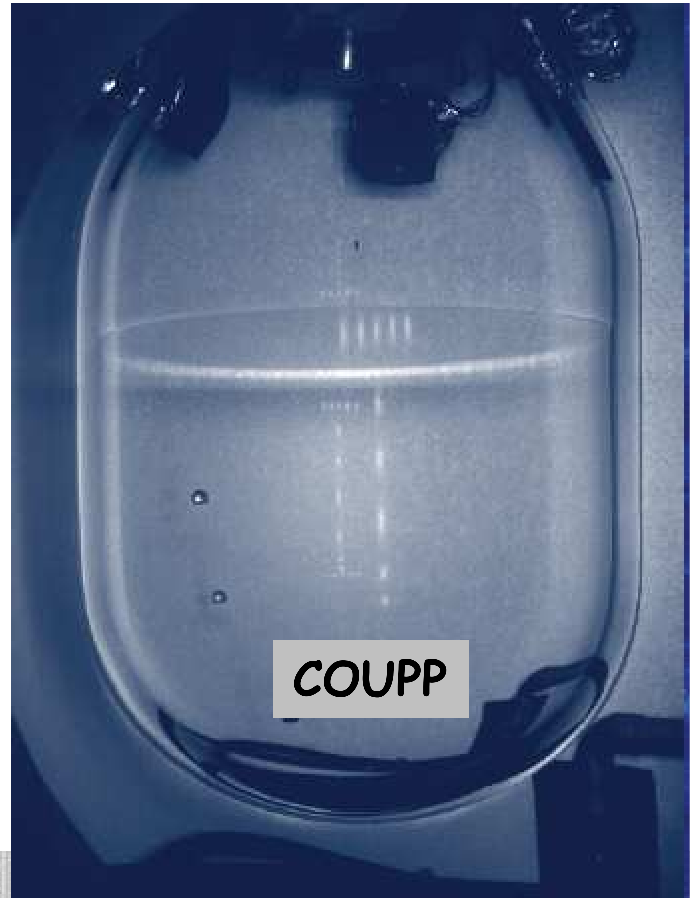




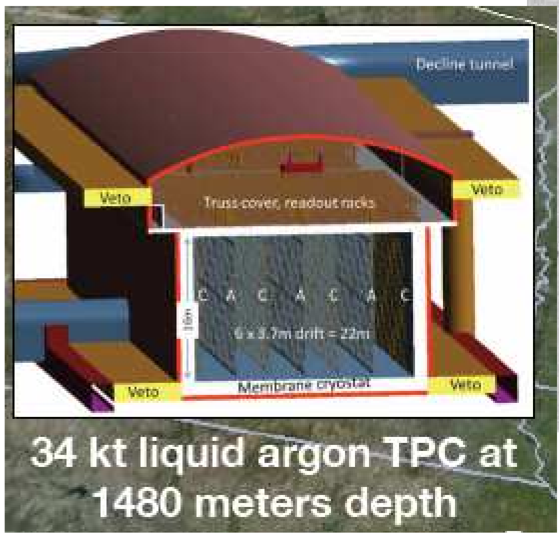
Rotation curve for Galaxy

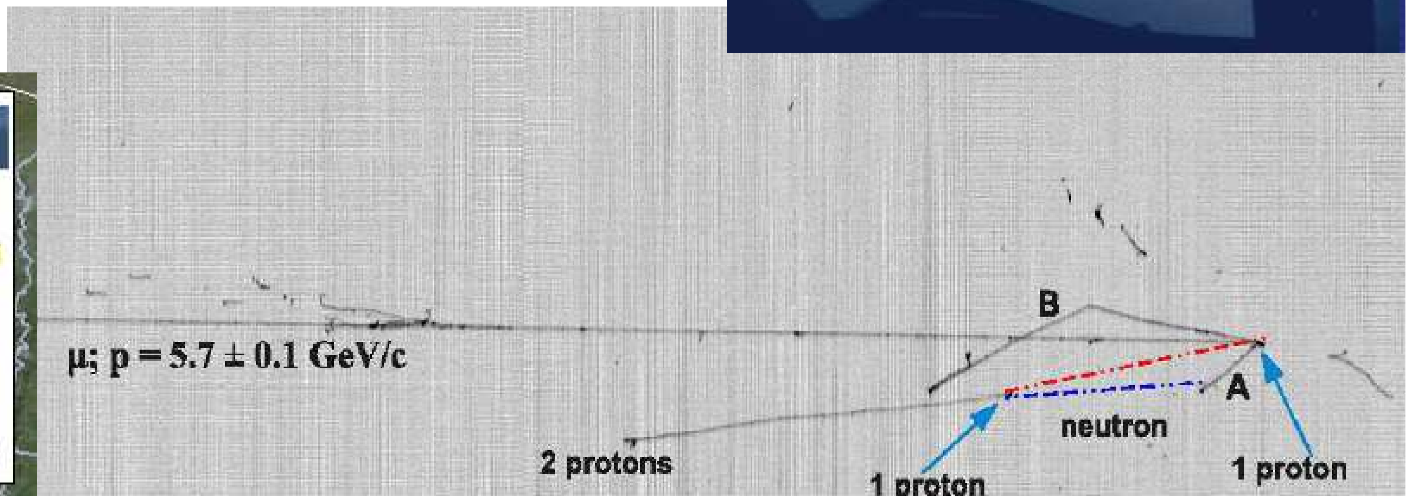
Heavy Liquid Bubble Chamber – Le retour



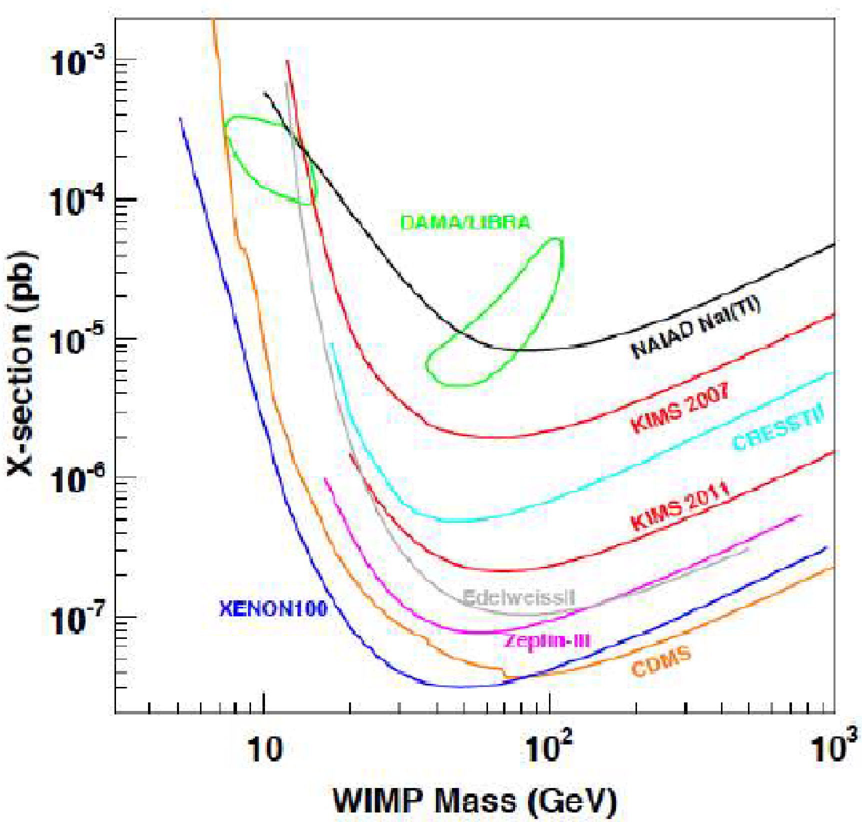


ICARUS

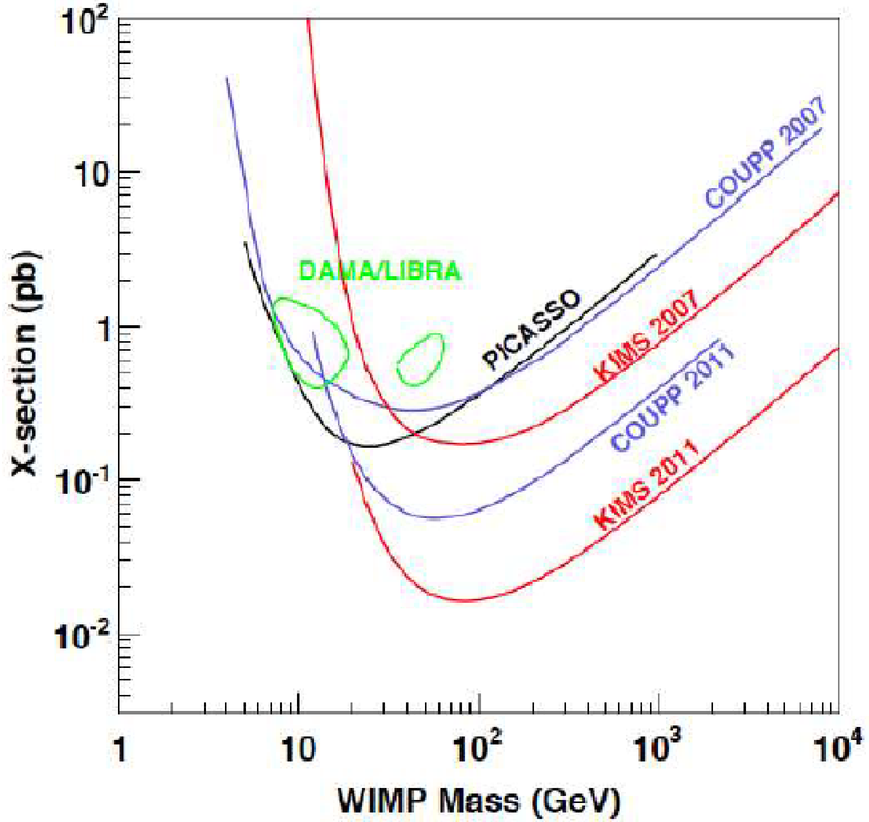




The new exclusion limits from KIMS



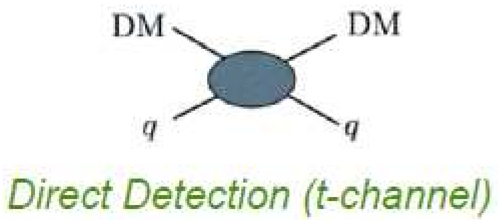
Spin-Independent interaction

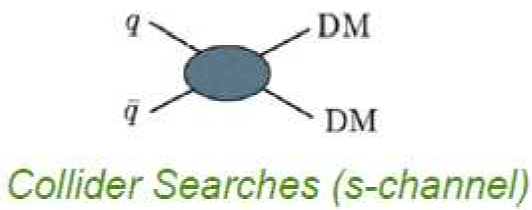


Spin-dependent
proton interaction

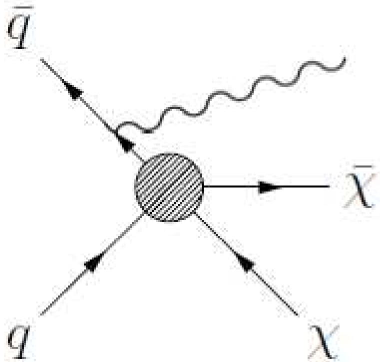
Kim, KIMS DM

Direct Dark Matter search **Collider Dark Matter search**

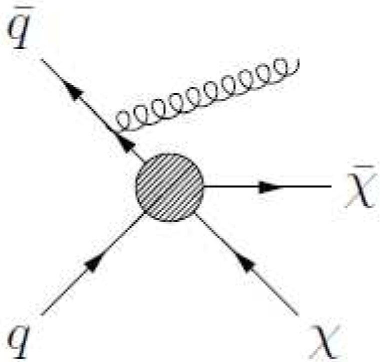




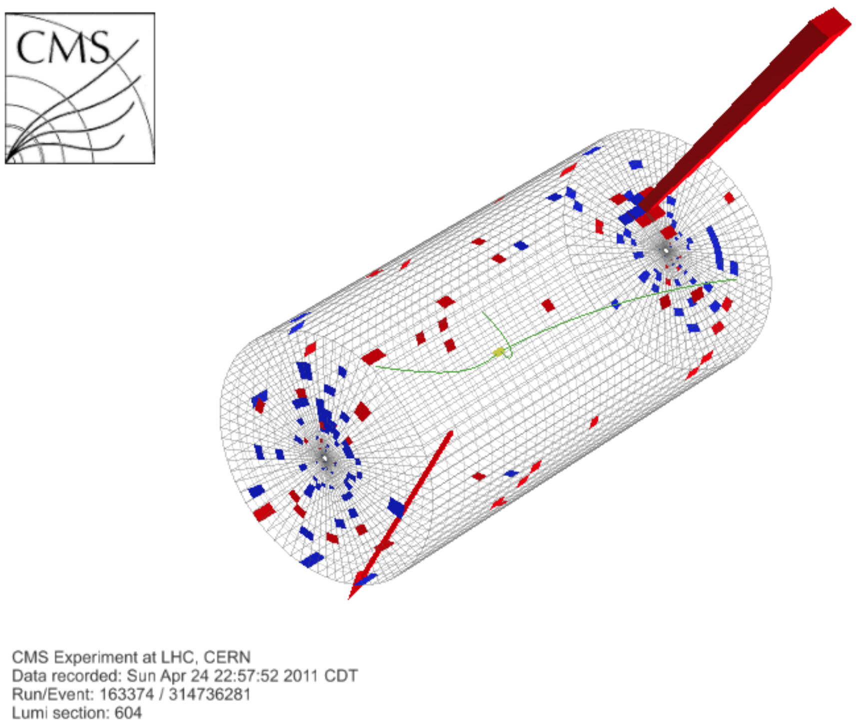
Isolated high Pt photon or jet + missing Transverse Energy (MET)

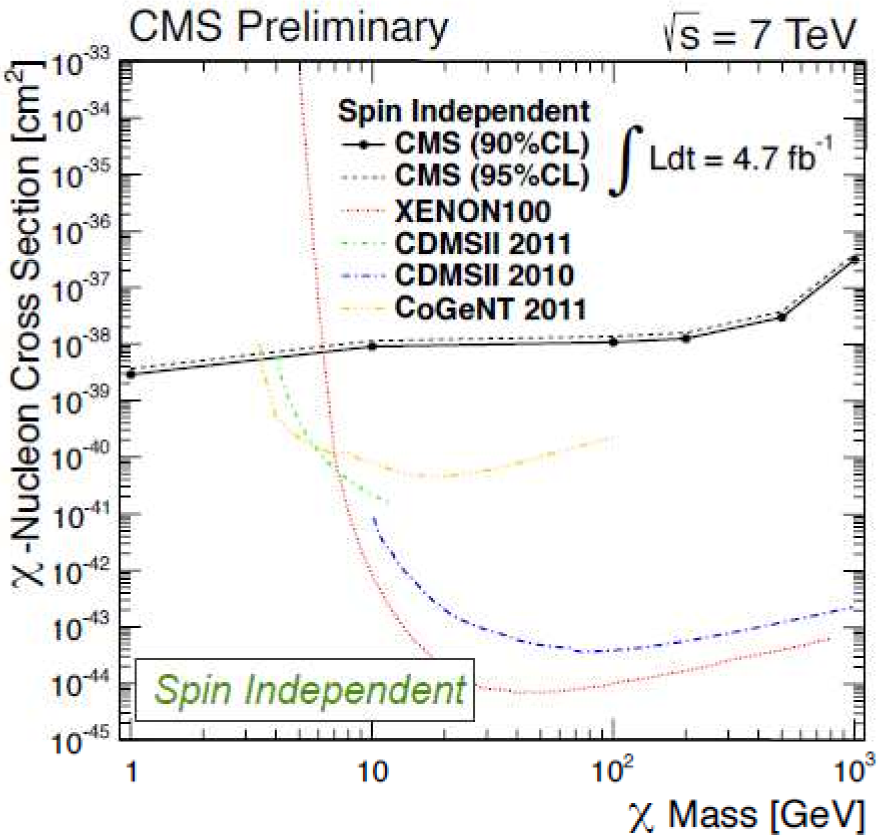


Monophoton + MET

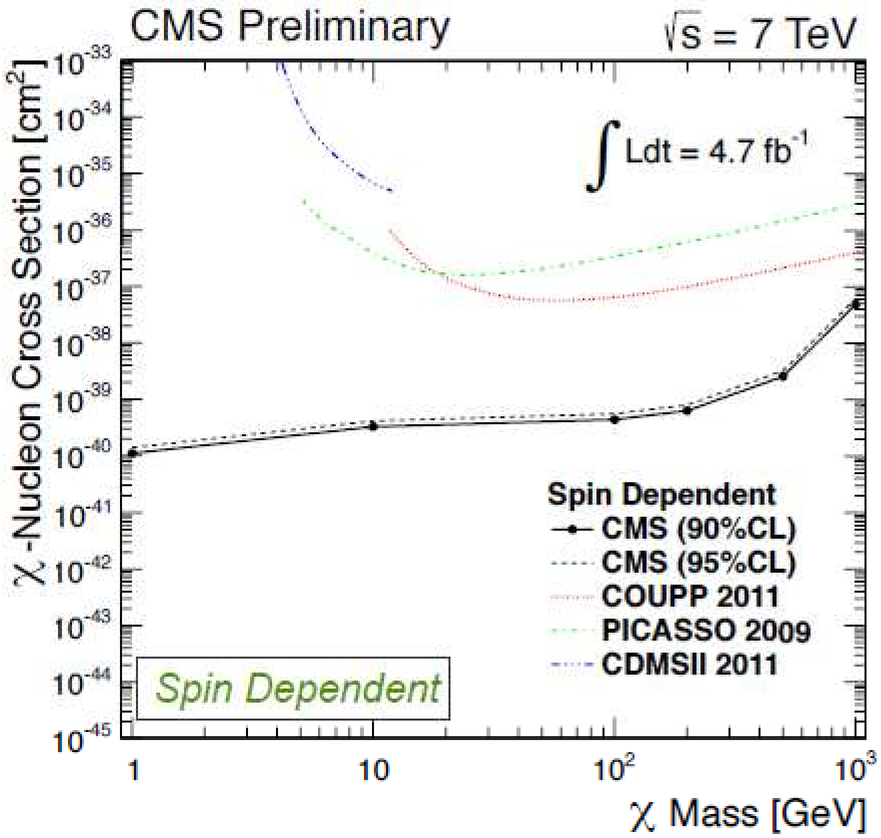


Monojet + MET





CMS Preliminary
$\sqrt{s}$ = 7 TeV
$\int$ Ldt = 4.7 fb^{-1}
Spin Independent
CMS (90%CL)
CMS (95%CL)
XENON100
CDMSII 2011
CDMSII 2010
CoGeNT 2011
Spin Independent
χ-Nucleon Cross Section [cm^2]
χ Mass [GeV]



CMS Preliminary
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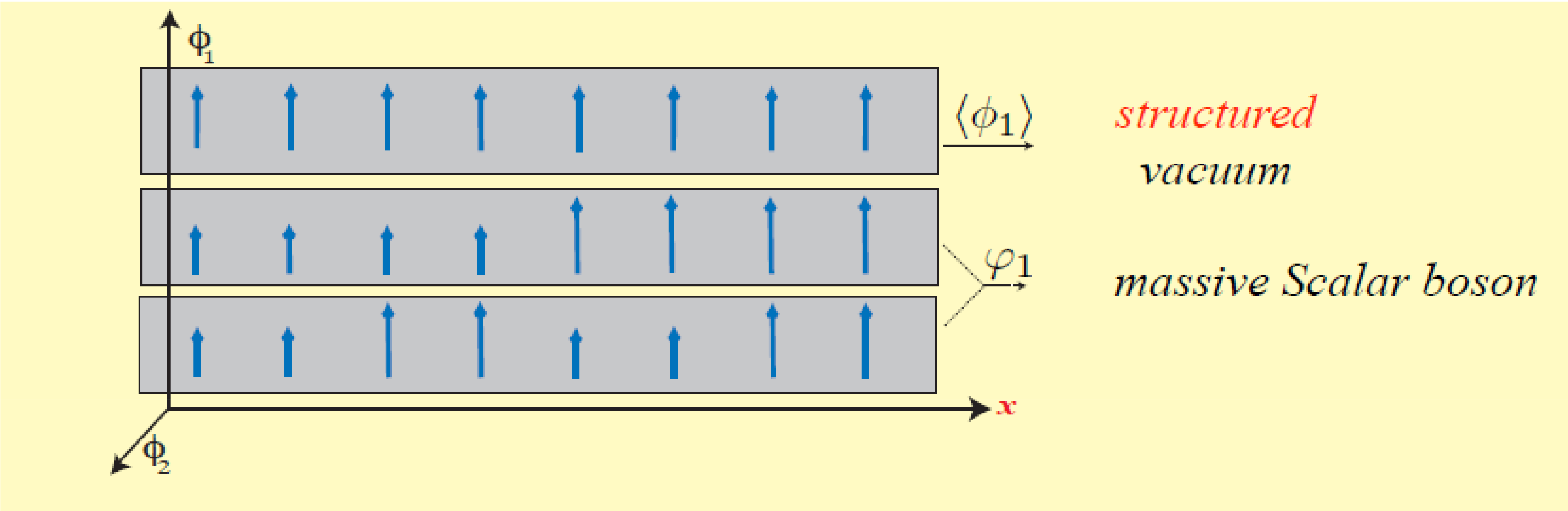
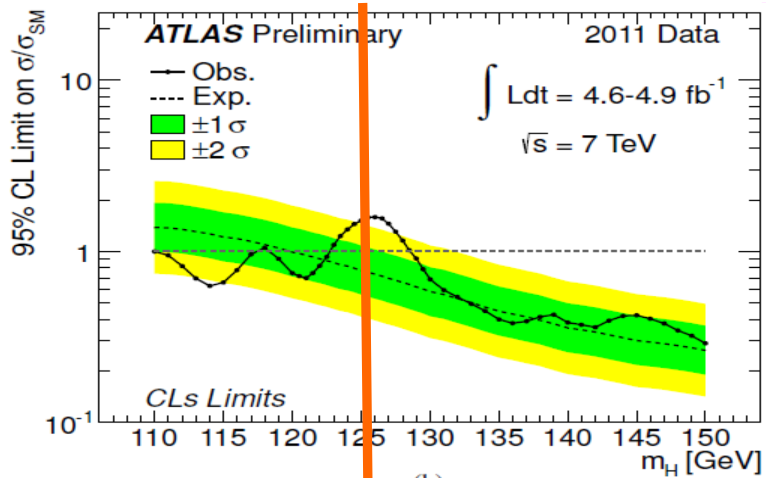
Spin Dependent
CMS (90%CL)
CMS (95%CL)
COUPP 2011
PICASSO 2009
CDMSII 2011
Spin Dependent
χ-Nucleon Cross Section [cm^2]
χ Mass [GeV]

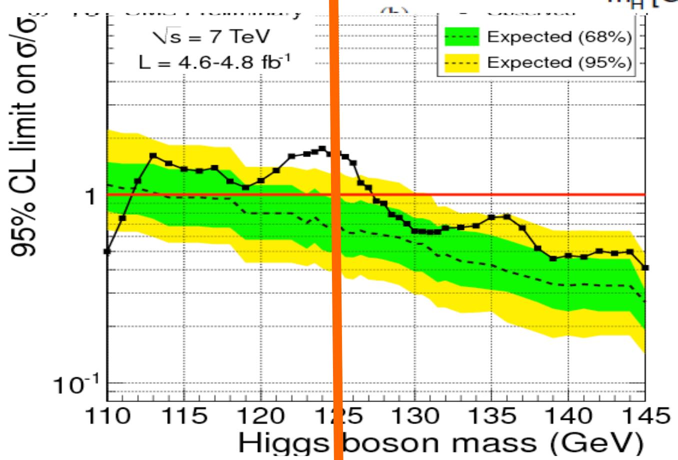
Steven Worm

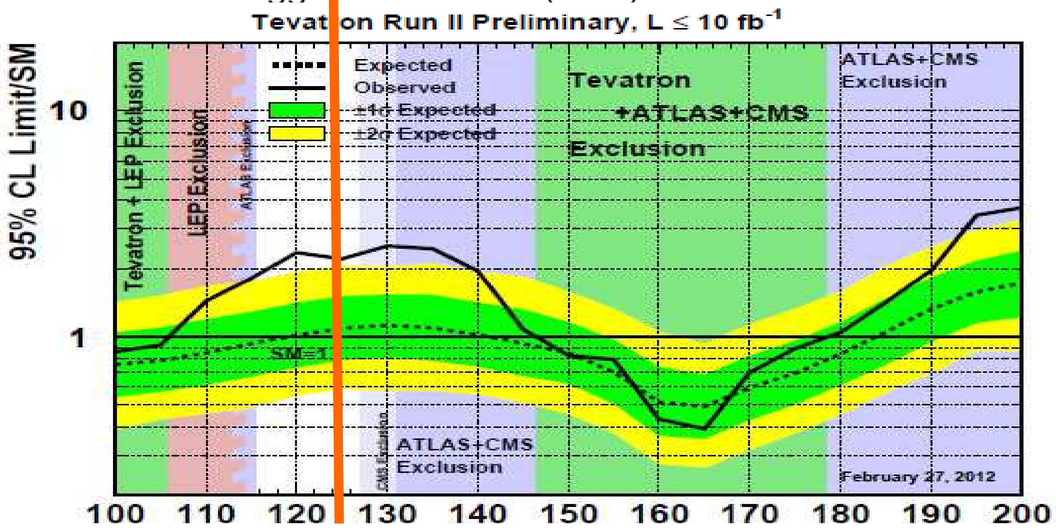
THE BOSON



François Englert







Both ATLAS and CMS exclude a SM scalar boson up to ~550 GeV except in range (117-128 GeV): excess 2.5-2.9 σ at 125-126 GeV/c² (consistent)

ATLAS : γγ and ZZ
CMS : γγ
CDF+ D0 mostly $b\bar{b}$&WW

Too soon to claim even evidence, but…
'Who would bet against Higgs boson @125 GeV?'

My guess: Look Elsewhere + Look There
→ CL probably >~ local significance of 2d experiment

More data in 2012→ 5σ and more channels!

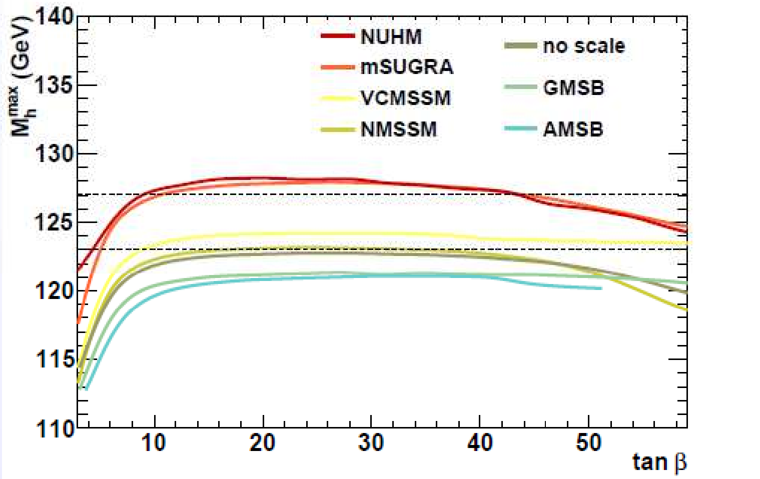
We should wait until the « 125 GeV effect » is either killed or established.
A particle decaying in two photons is not spin 1 and more probably spin 0

Is it elementary? Does it have all properties of the SM scalar of EBH et al?
It will be exciting to investigate this NEW object!

Just as for EWRCs, its discovery would eliminate a great number of hypotheses.

Consequences of a 125 GeV Higgs on constrained MSSM scenarios

Maximal Higgs masses



A. Arbey, M. Battaglia, A. Djouadi, F.M., J. Quevillon, Phys.Lett. B708 (2012) 162

model	AMSB	GMSB	mSUGRA	no-scale	cNMSSM	VCMSSM	NUHM
$M_h^{\max}$	121.0	121.5	128.0	123.0	123.5	124.5	128.5

End of AMSB and GMSB in their minimal versions!

How shall we study X(125)?

At LHC

It is there, and will do it.
The question: with which precision? O(10%) or worse (assume 600fb^{-1})
Effect of pile-up?. Etc. etc.
do we need another machine to study more properties or more precisely?
Performance on couplings self couplings and invisible width?

At a linear collider ?

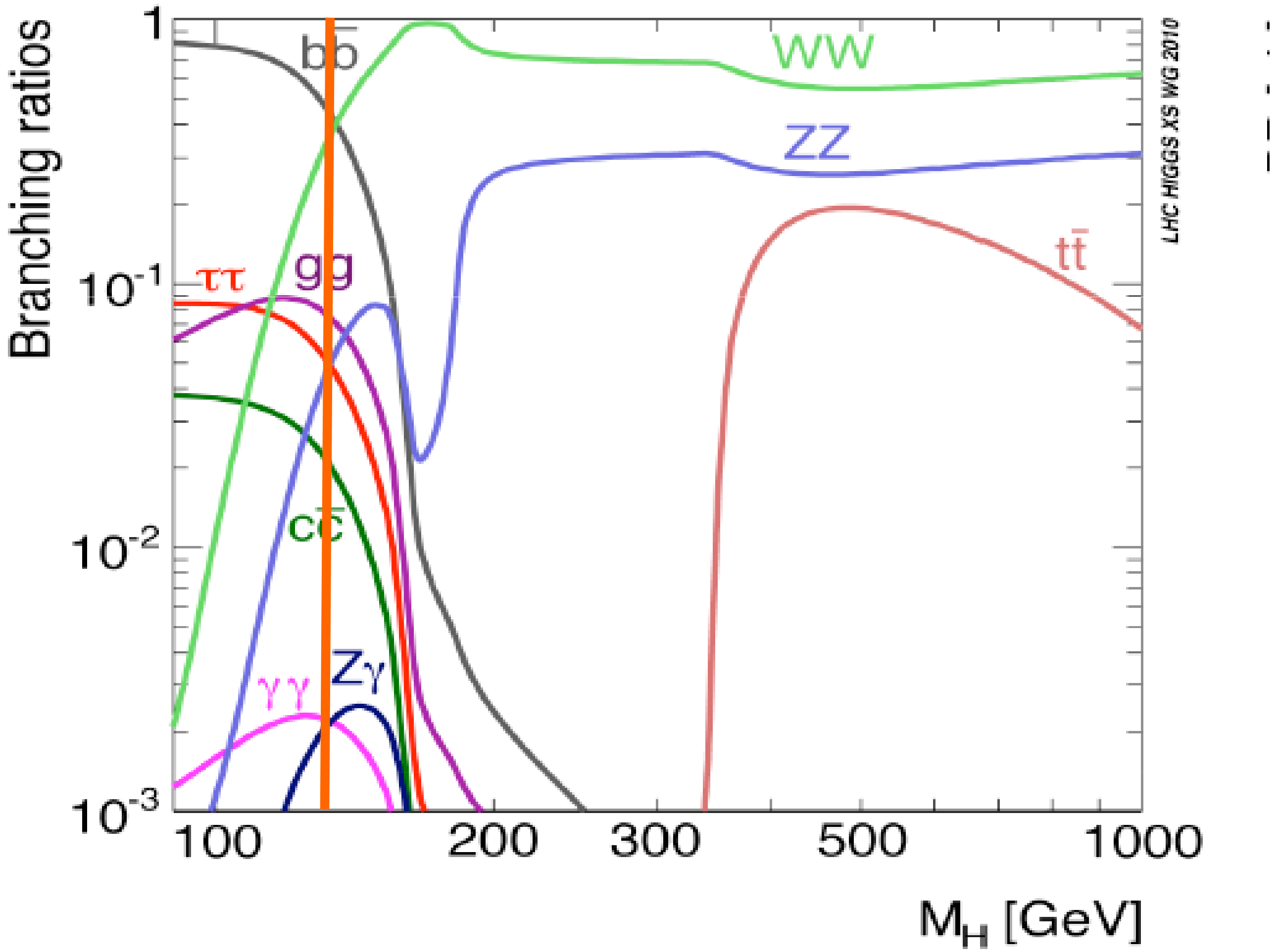
For 125 GeV Higgs, peak cross-section at ~250 GeV = m_H+m_Z+30 GeV
But.. 250 GV of acceleration and luminosity at that energy still requires a large amount of power and superb alignment. *Cost?*

At a small e+ e- machine?

LEP3 in LHC tunnel (see next slides)
Much easier and cheaper than LC but not expandable.

At a muon collider ?

Feasibility study ongoing. Not an easy machine!
Ionization cooling (MICE experiment)
Virtue: s-channel production $\mu^+ \mu^- \rightarrow H$, exquisite energy calibration and very small energy spread if needed.



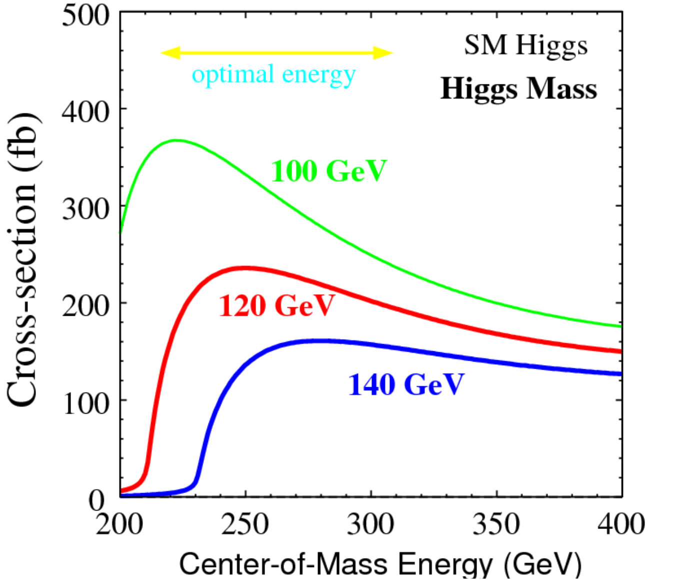
125 GeV is really a good place to be:
$\bar{b}b$, WW, gg, $\tau\tau$, ZZ, $\bar{c}c$ are all above a few % and $\gamma\gamma$ is ~maximal

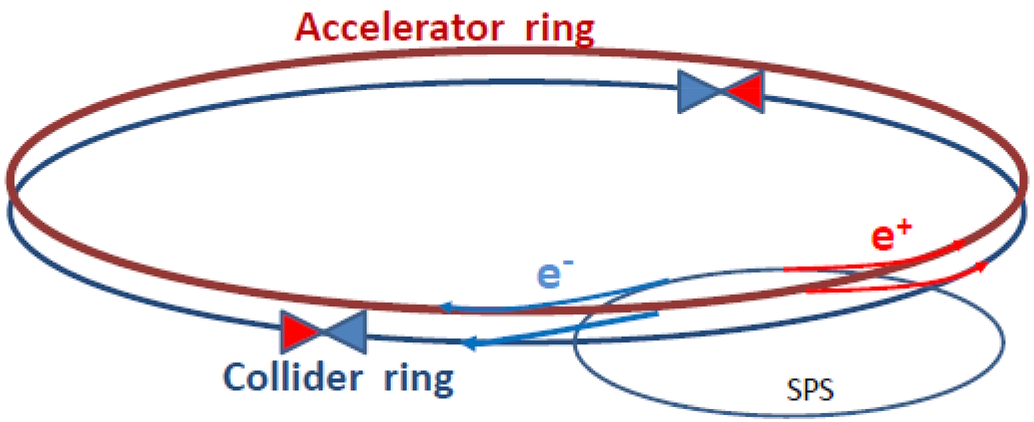
LEP3 Scheme arXiv:1112.2518

LEP operated at 104.5 GeV/beam with
$\mathcal{L} = 10^{32}$ /cm²/s, (peak luminosity)
τ_b = 6h beam life-time
P_{SR}= 20 MW Synchrotron Radiation power

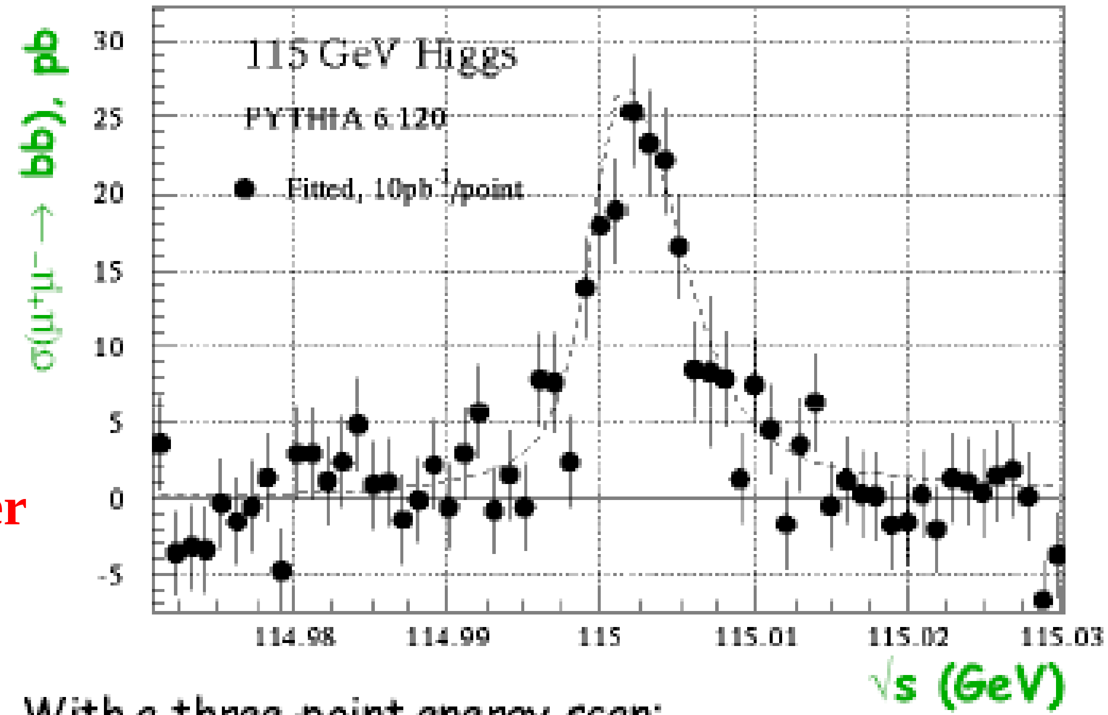
Modify parameters (reduce beam sizes by more focusing)
to increase instantaneous luminosity without increasing intensity too much
$\mathcal{L} = 1.5\ 10^{34}$ /cm2/s, (peak luminosity)
τ_b = 12 min beam life-time
P_{SR}= 50 MW Synchrotron Radiation power
Inject continuously using ancellary accelerator.
➔ $\mathcal{L} = 1.5\ 10^{34}$ /cm2/s

2 10^4 ZH events per year





Muon collider



Murray

With a three-point energy scan:

Observable	With 100 pb^{-1}	With 2.5 fb^{-1}
Mass	$\pm$ 0.1 MeV/c^2	$\pm$ 0.05 MeV/c^2
Width	$\pm$ 0.5 MeV	$\pm$ 0.1 MeV
σ_{peak}	$\pm$ 1 pb	$\pm$ 0.2 pb

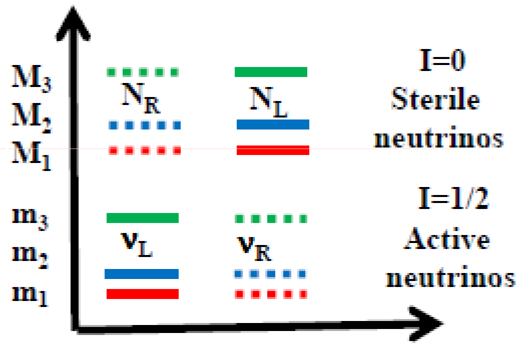
Statistics limited !

Janot

Still to be tried:

A scan in $\delta E/E$

Neutrinos : the New Physics there is… and a lot of it!

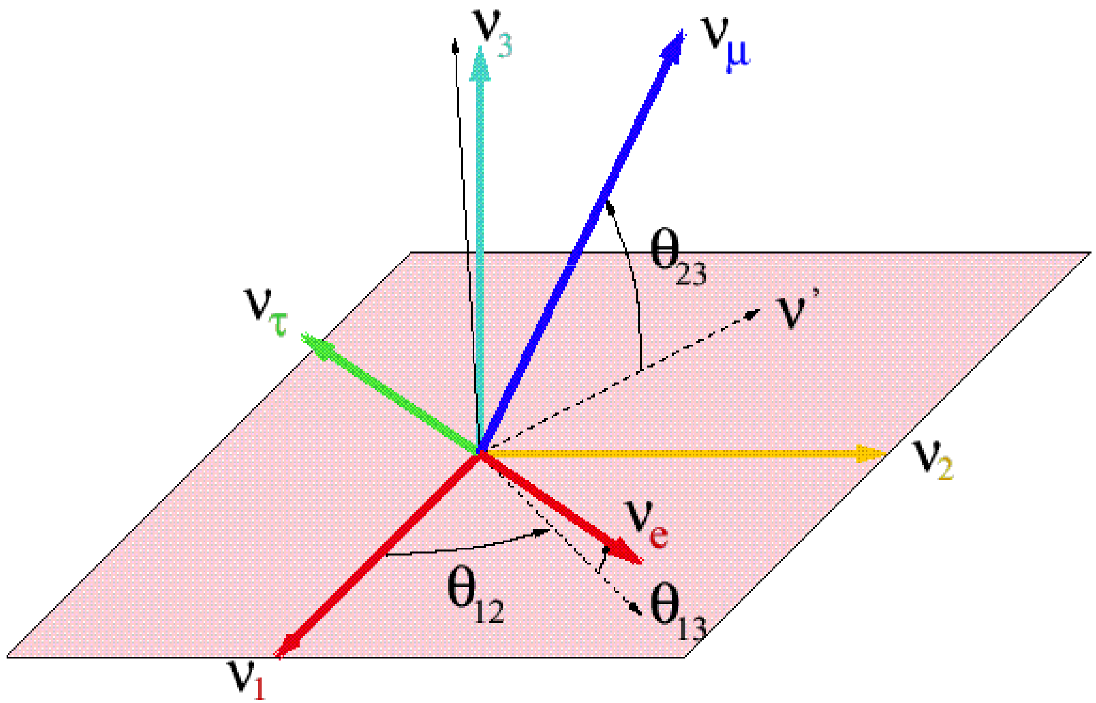
SM	Dirac mass term only	Majorana mass term only	Dirac AND Majorana Mass terms
ν_L $\bar{\nu}_R$ I= $\frac{1}{2}$ $\frac{1}{2}$	ν_L ν_R $\bar{\nu}_R$ $\bar{\nu}_L$ $\frac{1}{2}$ 0 $\frac{1}{2}$ 0	ν_L ν_R $\frac{1}{2}$ $\frac{1}{2}$	
X 3 Families	X 3 Families	X 3 Families	
6 massless states	3 masses 12 states 3 active neutrinos 3 active antinu's 6 sterile neutrinos… 3 mixing angles 1 CP violating phase	3 masses 6 active states No steriles 3 mixing angles 3 CP violating phases $0\nu\beta\beta$	6 masses 12 states 6 active states 6 sterile neutrinos… More mixing angles and CPV phases $0\nu\beta\beta$ ➔ Leptogenesis and Dark matter

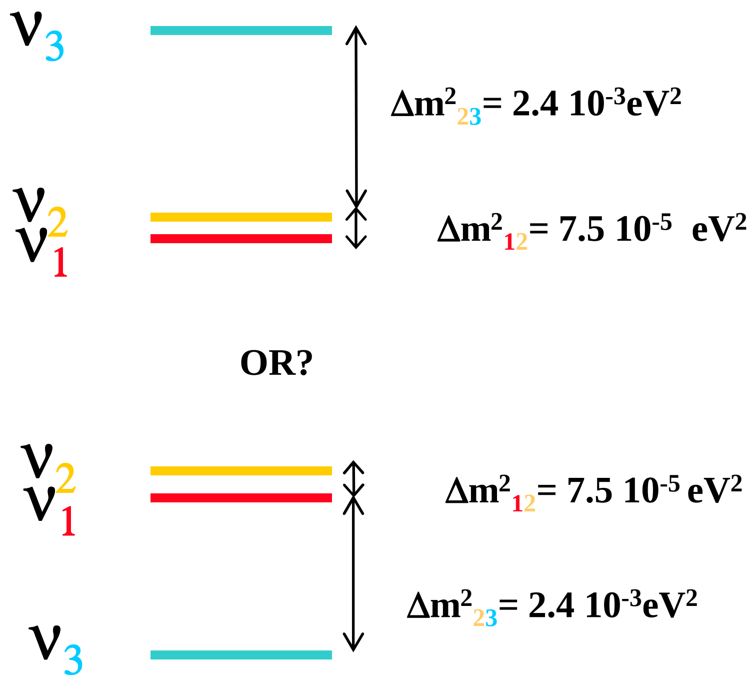
Mass hierarchies are all unknown except $m_1 < m_2$

Preferred scenario has both Dirac and Majorana terms …

… a bonanza of extreme experimental challenges

The neutrino mixing matrix: 3 angles and a phase δ





One year ago:

θ_{23} (atmospheric) ~ 45^0, θ_{12} (solar) ~ 32^0, θ_{13} (Chooz) < 13

$$U_{MNS}: \begin{pmatrix} \sim \frac{\sqrt{2}}{2} & \sim -\frac{\sqrt{2}}{2} & \sin\theta_{13}\, e^{i\delta} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim -\frac{\sqrt{2}}{2} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim \frac{\sqrt{2}}{2} \end{pmatrix}$$

Unknown or poorly known
θ_{13}, phase δ, sign of Δm_{13}

Oscillation maximum $1.27\ \Delta m^2\ L / E = \pi/2$

Atmospheric $\Delta m^2 = 2.4\ 10^{-3}\ eV^2$ $L = 500$ **km @ 1 GeV**
Solar $\Delta m^2 = 7.6\ 10^{-5}\ eV^2$ $L = 16000$**km @ 1 GeV**

Consequences of 3-family oscillations:

I There will be $\nu_\mu \leftrightarrow \nu_e$ and $\nu_\tau \leftrightarrow \nu_e$ oscillation at L_{atm}

(acc) $P(\nu_\mu \leftrightarrow \nu_e)_{max} =\sim \frac{1}{2} \sin^2 2\theta_{13}$ +... (small)
(reactor) $P(\nu_e \leftrightarrow \nu_e)_{max} =\sim 1 - \sin^2 2\theta_{13}$ +...(small)

II There will be CP or T violation

CP: $P(\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e) \neq P(\nu_\mu \leftrightarrow \nu_e)$

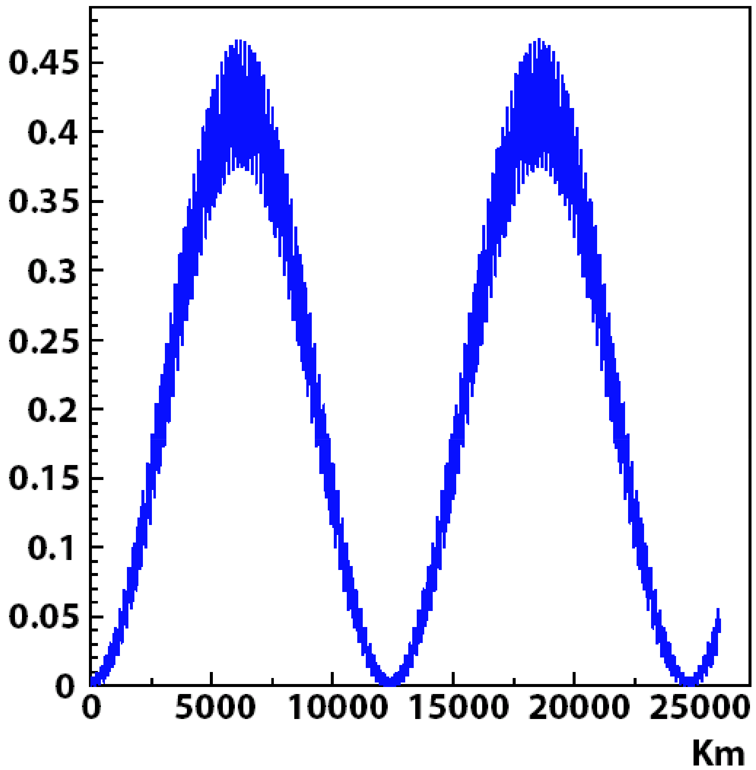
T : $P(\nu_\mu \leftrightarrow \nu_e) \neq P(\nu_e \leftrightarrow \nu_\mu)$

1^{st} maximum $\neq$ second maximum

III. we do not know if the neutrino ν_1
(which contains more ν_e)
is the lightest one (natural?) or not.

Oscillations of 250 MeV neutrinos;

$P(\nu_\mu \leftrightarrow \nu_e)$



$$P(\nu_e \to \nu_\mu) = |A|^2 + |S|^2 + 2\,A\,S\ \sin\delta$$

$$P(\nu_e \to \nu_\mu) = |A|^2 + |\overline{S}|^2 - 2\,\overline{A}\,S\ \sin\delta$$

$$\frac{P(\nu_e \to \nu_\mu) - P(\bar{\nu}_e \to \bar{\nu}_\mu)}{P(\nu_e \to \nu_\mu) + P(\bar{\nu}_e \to \bar{\nu}_\mu)} = A_{CP}\ \alpha\ \frac{\sin\delta\ \ \sin(\Delta m^2_{12}\, L/4E)\ \ \sin\theta_{12}\, \sin\theta_{13}}{\sin^2 2\theta_{13} + \text{solar term}\ldots}$$

… need large values of $\sin\theta_{12}$, Δm^2_{12} (LMA-- we have it!) but *not* large $\sin^2\theta_{13}$

… need APPEARANCE … $P(\nu_e \to \nu_e)$ is time reversal symmetric (reactors or sun are out)

… can be large (100%) for suppressed channel (one small angle vs two large)

at wavelength at which ‘solar’ = ‘atmospheric’ and for $\nu_e \to \nu_\mu$, ν_τ

… asymmetry is opposite for $\nu_e \to \nu_\mu$ and $\nu_e \to \nu_\tau$

NOTES:

Asymmetry can be very large.

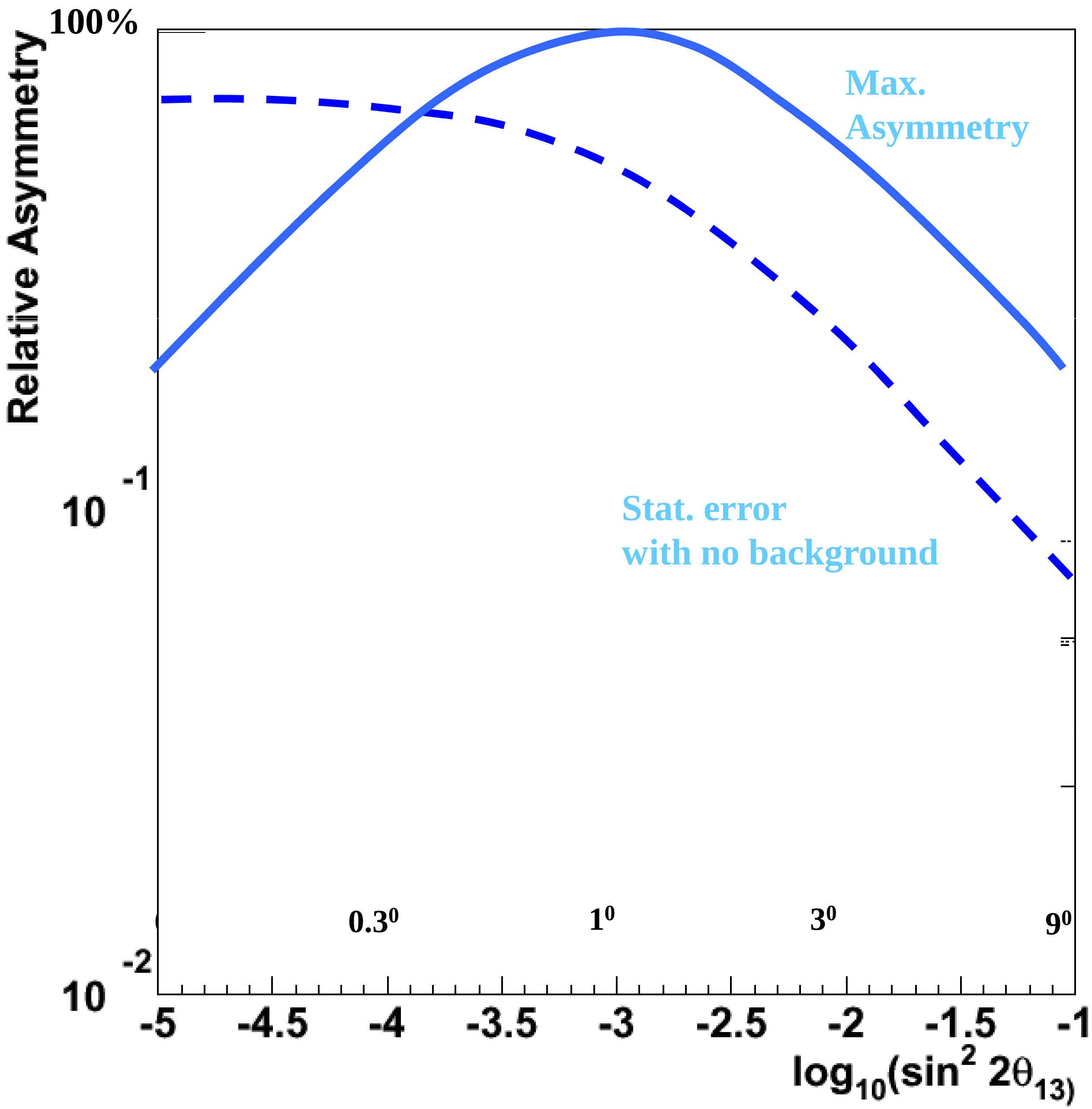
Stat. sensitivity in absence of bkg is ~independent of θ_{13} down to max. asym. point

Asymmetry changes sign from one max. to the next.

Sensitivity at low values of θ_{13} is better for short baselines, sensitivity at large values of θ_{13} is better for longer baselines (2d max or 3d max.)

sign of asymmetry changes with max. number.

T asymmetry for sin δ = 1

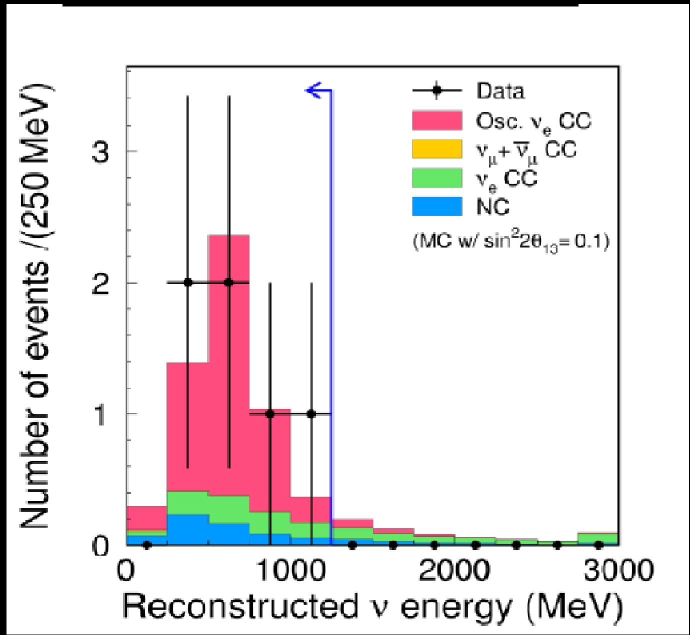


Otani, Results from T2K

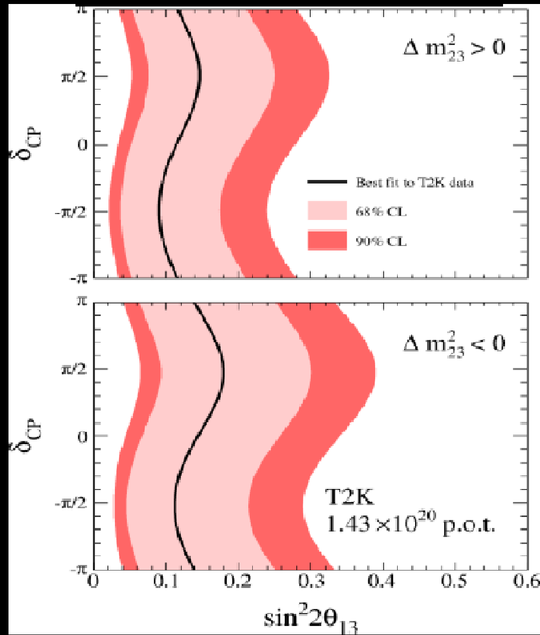
$\nu_\mu \rightarrow \nu_e$ Result

Phys. Rev. Lett. 107:041801, (2011)

Reconstructed ν_e energy



68%/90% CL region



Expected 1.5 ±0.3 BG and observed 6 event. $\theta_{13} = 0$ probability is only 0.7%.

$0.03 < \sin^2 2\theta_{13} < 0.28$(normal)
$0.04 < \sin^2 2\theta_{13} < 0.34$(inverted)

We observed the indication of $\theta_{13} \neq 0$

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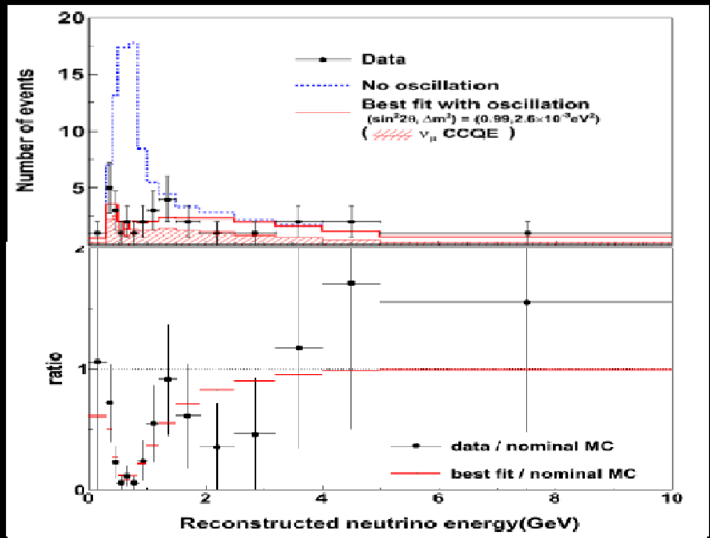
- selection cuts fixed already in early 2010
- Far detector prediction (295 km) determined from flux (+ NA61 prod data)
+ normalisation using Near Detector (280m)
-- earthquake on 11 March 2011 « forced » publication!

$\nu_\mu \rightarrow \nu_x$ Result

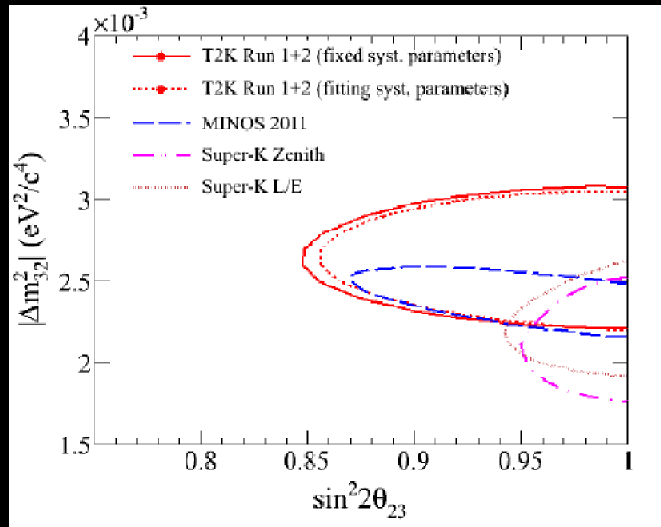
Phys. Rev. D 85, 031103(R)

Reconstructed ν_μ energy



Clear oscillation pattern is observed with off-axis beam

90% CL region



90% CL boundary includes $(1.0, 3.1\times10^{-3}eV^2)$, $(0.84, 2.65\times10^{-3}eV^2)$ and $(1.0, 2.2\times10^{-3}eV^2)$

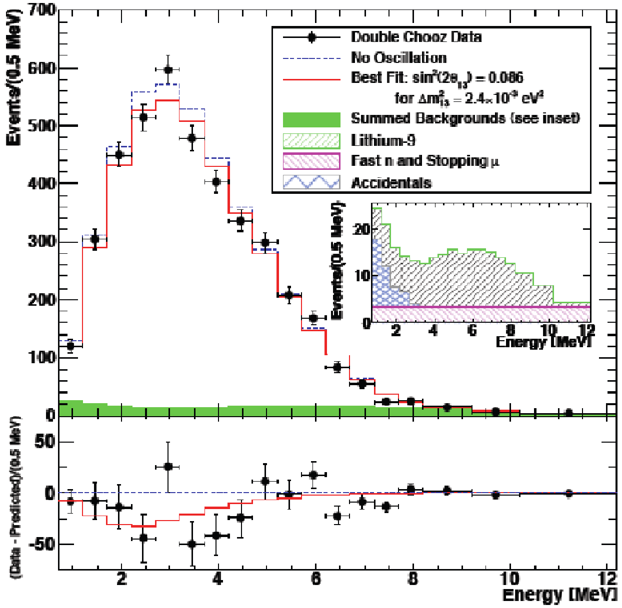
First observation of ν_μ disappearance using off-axis beam.

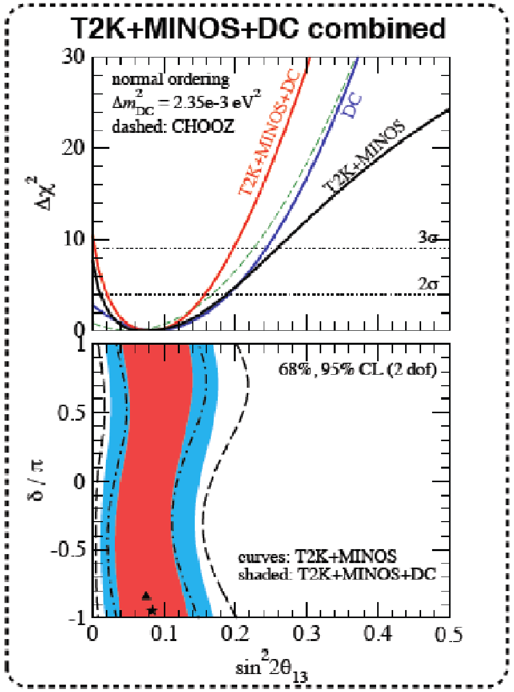
Otani, Results from T2K
T2K has restarted , one year after dramatic stop on 11 March 2011

Also results from MINOS and Dchooz:

Fit results

(hep-ex) arXiv:1112.6353 / Submitted to PRL





DChooz

Rate-only fit : $\sin^2 2\theta_{13}$ = 0.104 ± 0.030(stat.) ± 0.076(syst.)

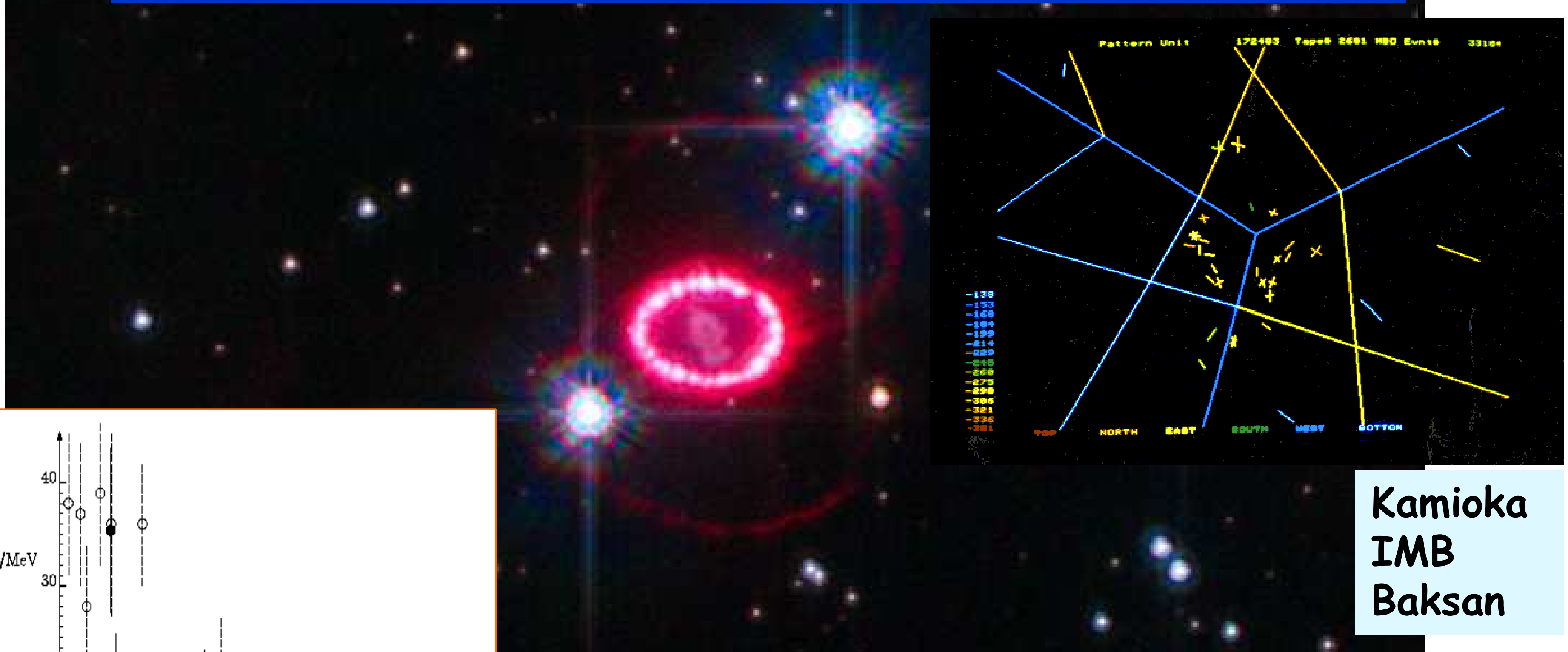
Rate+shape fit : $\sin^2 2\theta_{13}$ = 0.086 ± 0.041(stat.) ± 0.030(syst.)

→ No oscillation excluded by 94.6% C.L.

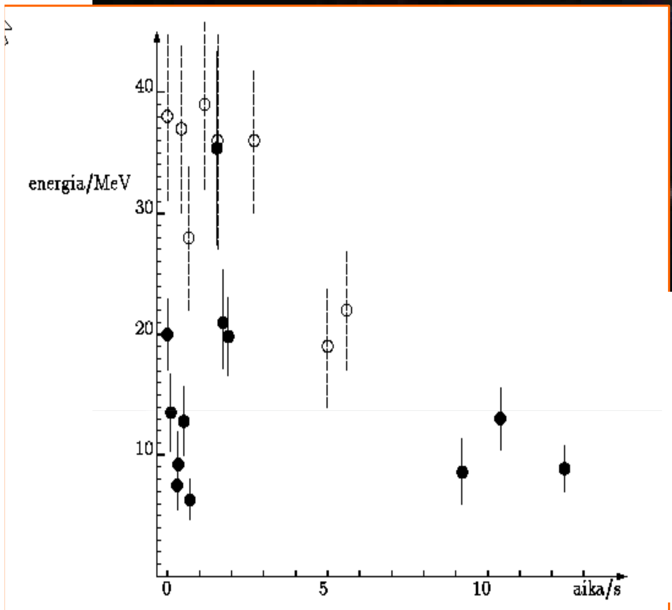
Tsunayuki, Double Chooz

It is a tradition of Moriond that experiments around the planet work very hard to produce results for the meeting….

SN1987A 23 Feb 1987 — 23 February 7:35 UT



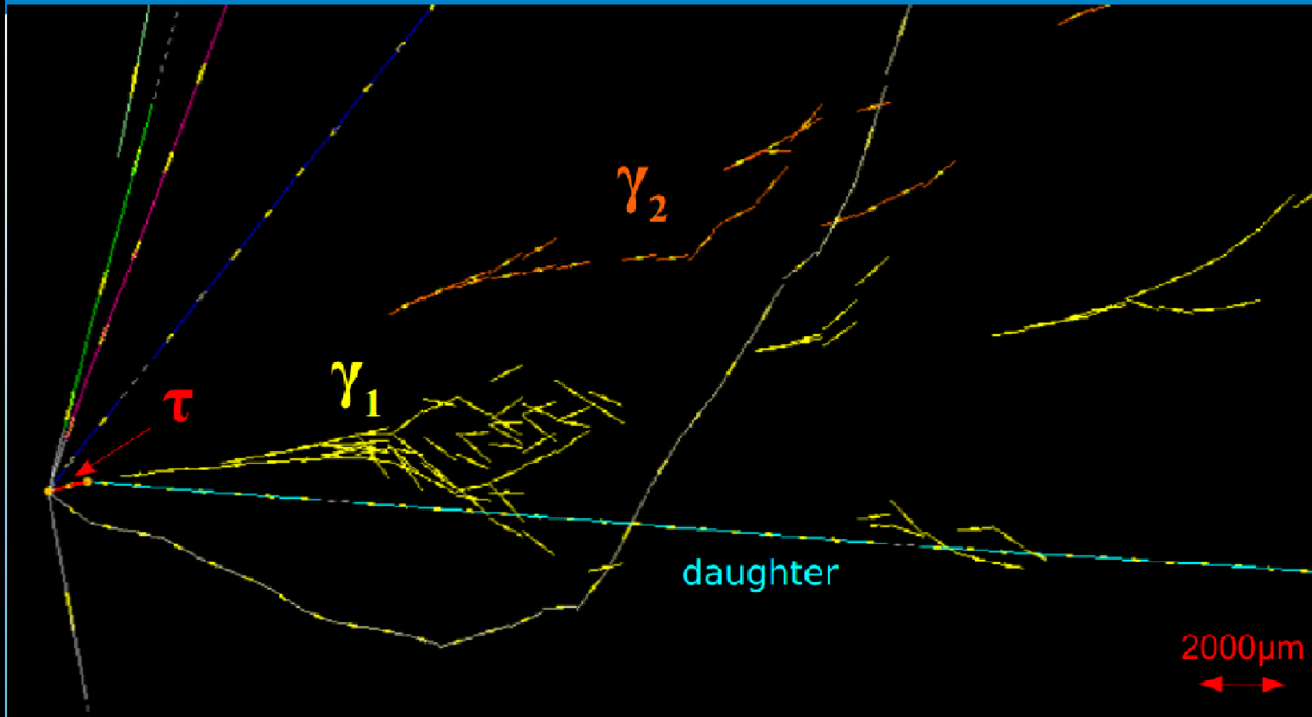
Kamioka
IMB
Baksan



24 neutrino interactions observed at 7:35 within 13s!
Between 9:20(not seen) and 10:48 (seen) the light from the Super Nova reached earth.
168 000 light years away ➔

$(v-c)/c < 2\ 10^{-9}$

OPERA claim: $2.5\ 10^{-5}$



$\tau^- \rightarrow \rho^- + \nu_\tau$ (B.R. ~25%)

$\rho^- \rightarrow \pi^0 + \pi^-$ 640^{+125}_{-80} (stat.)$^{+100}_{-90}$ (sys.) MeV/c^2

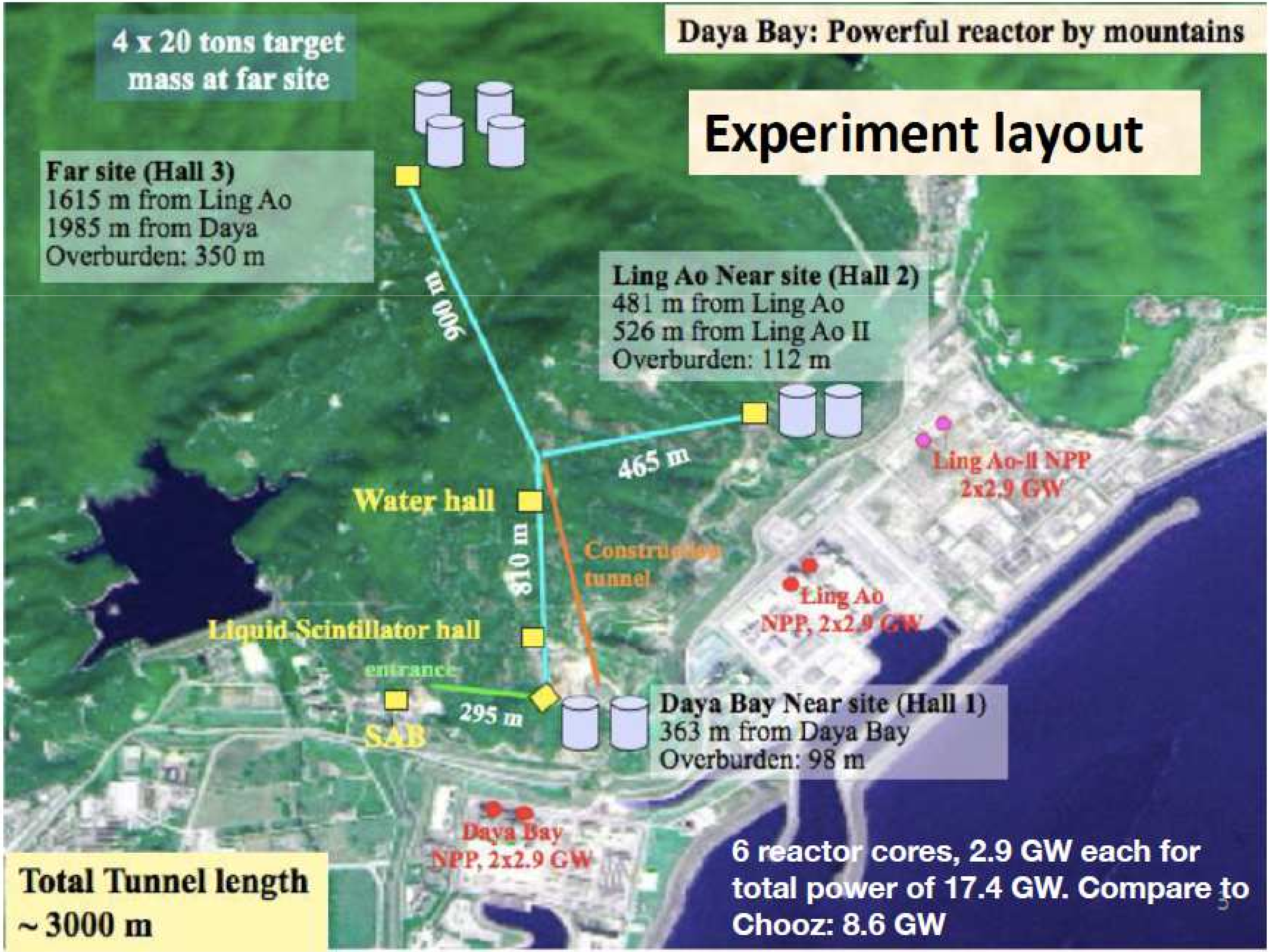
$\pi^0 \rightarrow \gamma\gamma$ 120 ± 20(stat.) ± 35(sys.) MeV/c^2

τ candidate

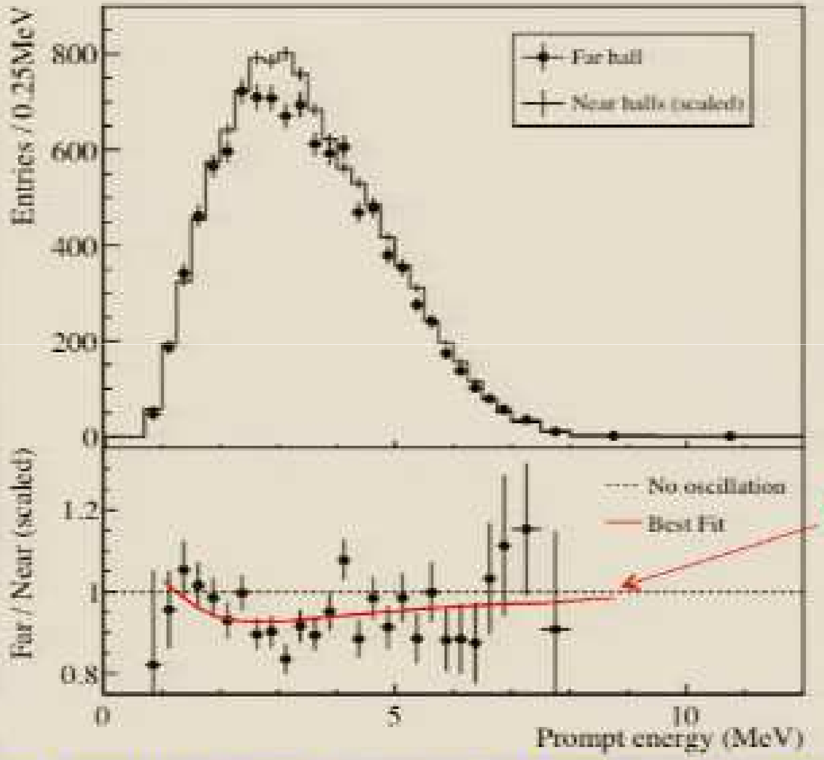
Variable	Cut-off	Value
Missing P_T at primary vertex (GeV/c)	<1.0	$0.57^{+0.32}_{-0.17}$
Angle between parent track and primary hadronic shower in the transverse plane (rad)	$>\pi/2$	3.01 ± 0.03
Kink angle (mrad)	>20	41 ± 2
Daughter momentum (GeV/c)	>2	12^{+6}_{-3}
Daughter P_T when γ-ray at the decay vertex (GeV/c)	>0.3	$0.47^{+0.24}_{-0.12}$
Decay length (μm)	<2 lead plates	1335 ± 35

Longhin, Opera results

Seen 1 event, expect 1.65 bkg 0.16
On full exposure (end 2012) expect 7.5


Daya Bay: Powerful reactor by mountains
Experiment layout
4 x 20 tons target mass at far site
Far site (Hall 3)
1615 m from Ling Ao
1985 m from Daya
Overburden: 350 m
900 m
Ling Ao Near site (Hall 2)
481 m from Ling Ao
526 m from Ling Ao II
Overburden: 112 m
465 m
Ling Ao-II NPP
2x2.9 GW
Water hall
810 m
Construction tunnel
Ling Ao
NPP, 2x2.9 GW
Liquid Scintillator hall
entrance
295 m
SAB
Daya Bay Near site (Hall 1)
363 m from Daya Bay
Overburden: 98 m
Daya Bay
NPP, 2x2.9 GW
Total Tunnel length
~ 3000 m
6 reactor cores, 2.9 GW each for total power of 17.4 GW. Compare to Chooz: 8.6 GW
5

Far vs. Near Comparison : Spectrum



$\sin^2 2\theta_{13} = 0.092$

Spectral distortion consistent with oscillation.

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$\sin^2 2\theta_{13} = 0.092 \pm 0.016\ (\text{stat}) \pm 0.005\ (\text{syst})$

$\sin^2 2\theta_{13} = 0$ excluded at 5.2σ

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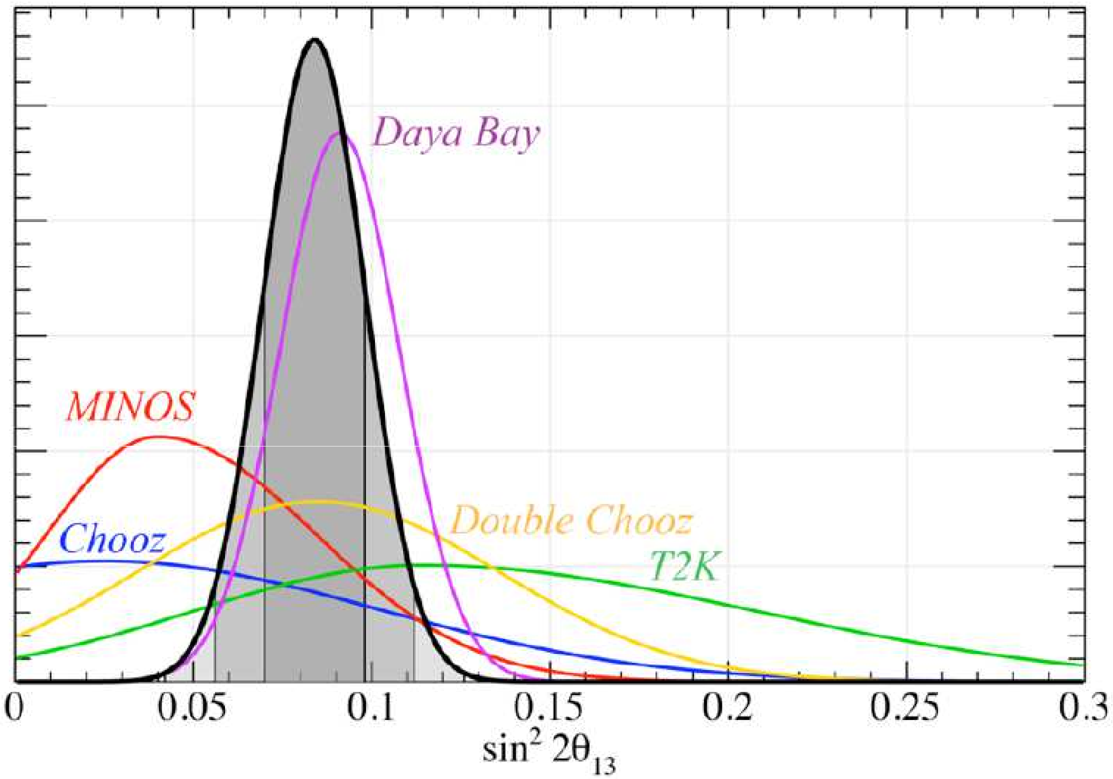
NB I doubt that the release date was decided because of Moriond…
If it was triggered by the 5σ effect, I would predict that value will go down somewhat…



Ideogram of recent θ_{13} results for normal hierarchy, δ_{CP}=0, and maximal θ_{23}

$\sin^2 2\theta_{13} \sim 0.084 \pm 0.014$

Consequences :
Mass hierarchy becomes easier
CP violation: more events, less asymmetry →
no gain statistically , more sensitive to systematics.

Reactor have no δ_{CP} or mass hierarchy dependence:

$$P(\bar{\nu}_e \to \bar{\nu}_e) = \sin^2(2\theta_{13})\sin^2\left(1.27\Delta m^2_{32}[\text{eV}^2]\frac{L\ [\text{m}]}{E\ [\text{MeV}]}\right) + \sin^2(2\theta_{23})\cos^4(\theta_{13})\sin^2\left(1.27\Delta m^2_{21}\ [\text{eV}^2]\frac{L\ [\text{m}]}{E\ [\text{MeV}]}\right)$$

Long baseline appearance experiments depend on both.

Neutrinos the next steps

In fact there are several directions to study the neutrino paradigm

1. Neutrino oscillations: determine mass hirarchy and search CP violation. Measure precisely the mixing parameters

2. Search for neutrino less double beta decay
Present level 0.5 eV. Next level 200 meV. Need more than one isotope!

3. Search for sterile neutrinos (a..k.a. right handed neutrinos)
– if there is a Dirac mass term they should exist!

4. Determine the mass of neutrinos by direct measurement.

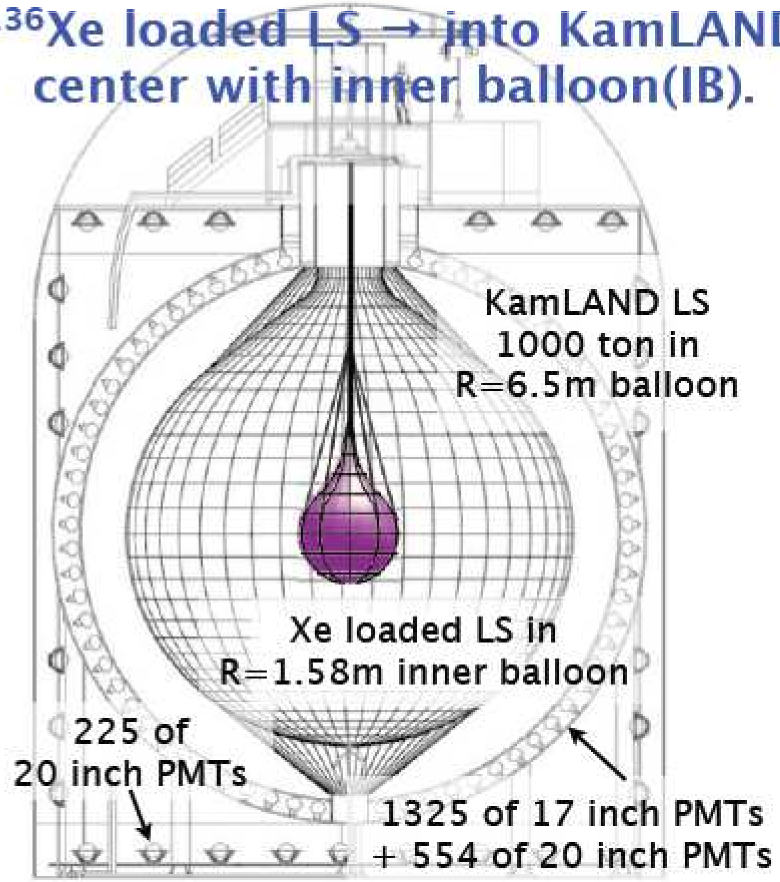
KamLAND-Zen(Zero neutrino double beta decay)

KamLAND-Zen :

Modification of KamLAND.
1,000 tons of highly purified liquid scintillator.

BIG & Low BG

^{136}Xe loaded LS → into KamLAND center with inner balloon(IB).



Double beta decay isotope

~300 kg of ^{136}Xe (91% enriched)
Largest amount for DBD experiment.
Already have another 200kg for next phase.
Q-value : 2.476MeV

Target for 1st phase

Search for KKDC claim and Degenerated hierarchy.

Why Xe?

- Soluble to LS ~3% by weight.
- easily extracted.
- Isotopic enrichment, purification established.

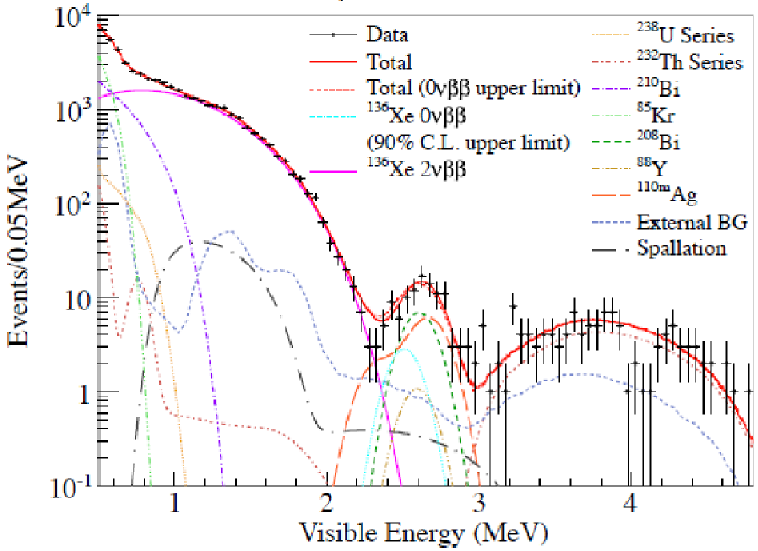
Schedule

2011 Aug. Modification
Sep. 24th, 2011 data taking start
Oct. 12th, 2011 -Jan 2nd, 2012.
77.6 days data for 1st result.

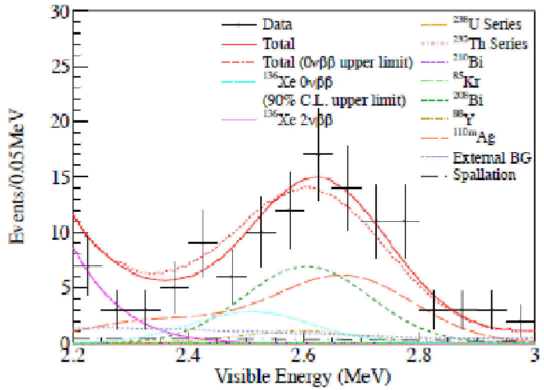
Search for neutrinoless double beta decay

^{136}Xe $2\nu\beta\beta$ & $0\nu\beta\beta$ Half life

arXiv:1201.4664v1 [hep-ex]



- livetime 77.6 days.
- 129 kg of ^{136}Xe



$T^{2\nu}_{1/2}$=2.38±0.02(stat)±0.14(syst) ×10^{21} years

- high precision measurement.
- consistent with EXO result. $T^{2\nu}_{1/2}$=2.11±0.04(stat)±0.21(syst) ×10^{21} yr
- verification of discrepancy of $T^{2\nu}_{1/2}$. (DAMA result $T^{2\nu}_{1/2}>1.0\times10^{22}$ yr)

$T^{0\nu}_{1/2}$ > 5.7×10^{24} years at 90% C.L.

$\langle m_{\beta\beta}\rangle$ <0.3~0.6 eV QRPA, shell model - Top class measurement.

Azusa Gando, KamLAND Zen 2 beta decay

Searching for sterile neutrinos

-- approach 1: LSND result taken as possible sign of sterile neutrino.
Design experiment that rules out (or sees) a $\bar{\nu}_\mu \to \bar{\nu}_e$ or $\nu_e \to \nu_\mu$ transition in a compatible place in the (Δm^2 , θ) plane.

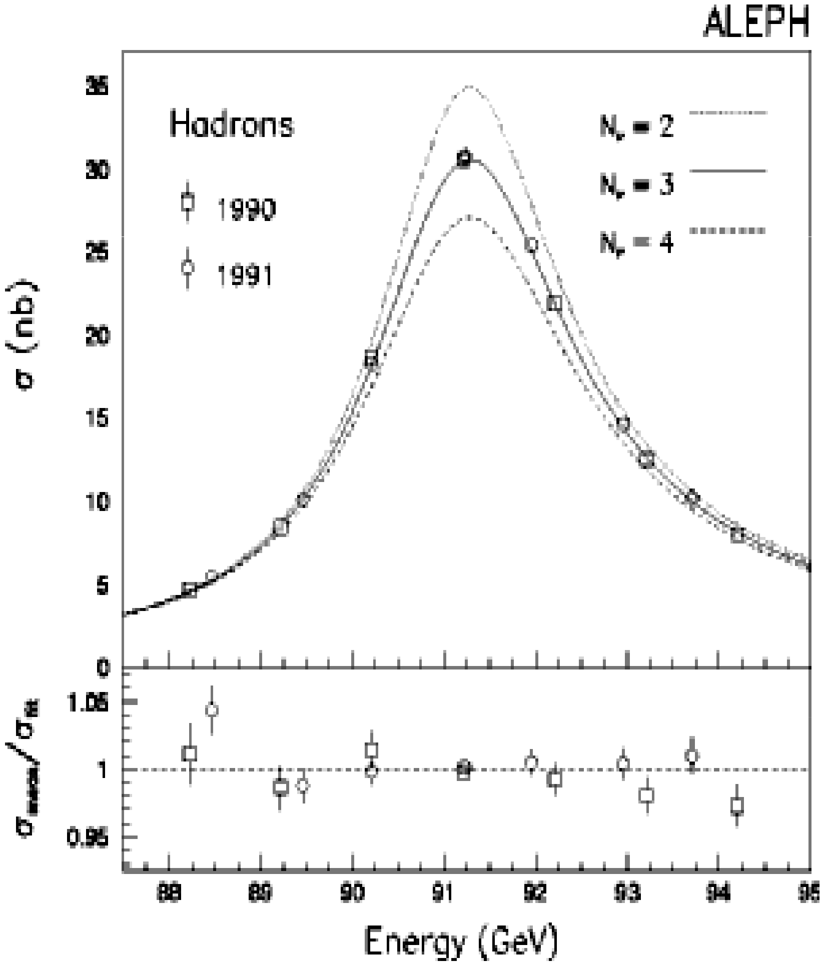
LSND and MiniBooNE had no near detector. This is

-- approach 2: search for mixing of active neutrinos with massive steriles

This can manifest itself by apparent (and energy dependent) violations of unitarity
Ex: at the Z pole

1989 The Number of light neutrinos

$$e^+e^- \to Z \to q\bar{q}\ ,\ vs \quad e^+e^- \to Z \to \nu\bar{\nu}$$



ALEPH+DELPHI+L3+OPAL in 2001 N_ν = 2.984 ±0.008

Error dominated by systematics on luminosity.

Getting our feet on (under) the ground:

A. Rubbia

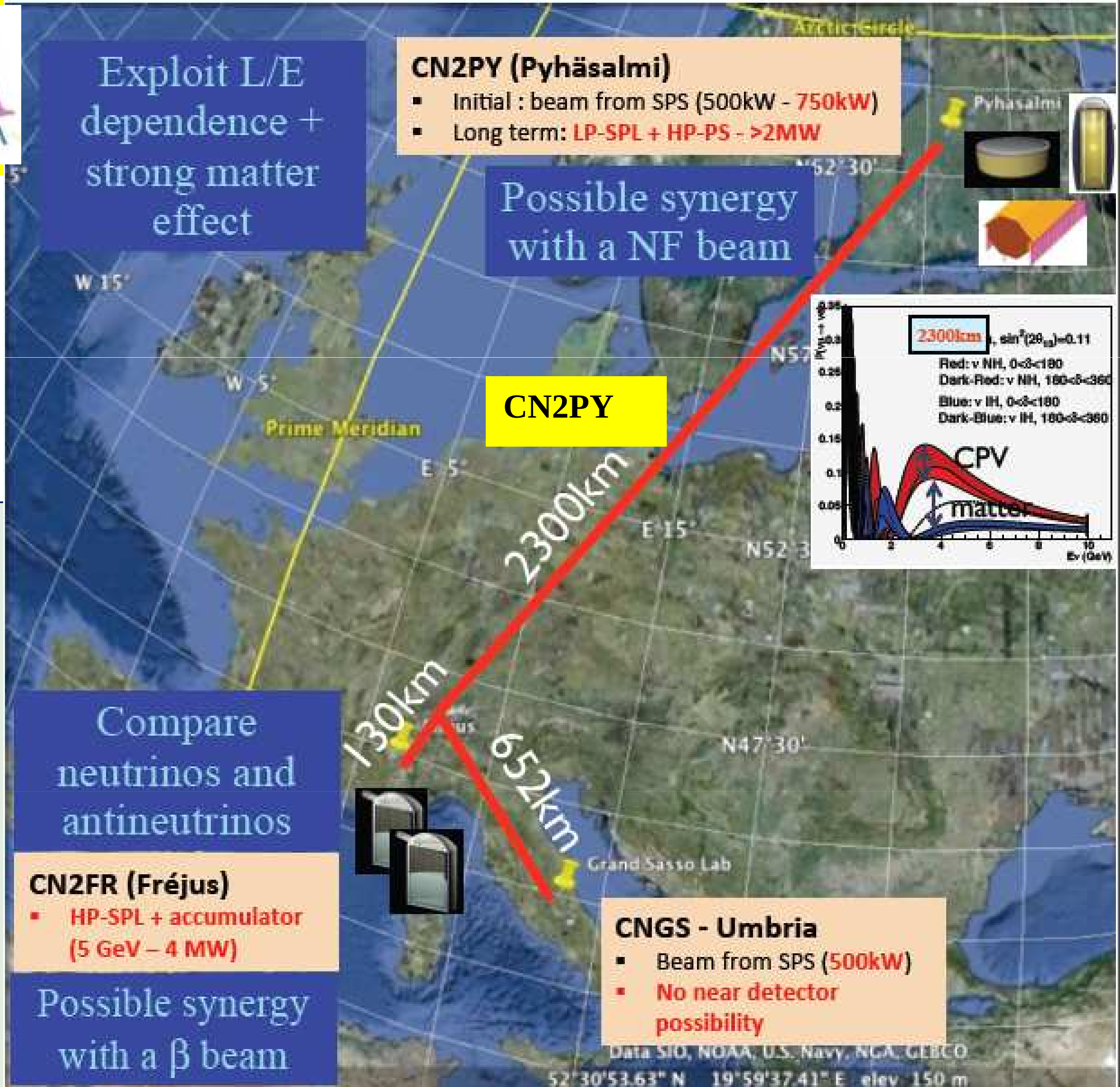
LAGUNA –LBNO
new FP7 design study
2011-2014

2 main options

Short distance: 130km
Memphys at Frejus
SPL+beta beam
CP and T violation

Long distance: 2300km
Pyhasalmi
Fine grain detector
e.g. 20kton fid. Larg
 + Magnetized detector
Long distance allows
rapid sensitivity to
sign(Δm^2_{13})

1st step easier: SPS C2PY
➔ consortium 1st priority
Nextsteps HP 50 GeV PS …
…or neutrino factory



Medium term plans include long term plans

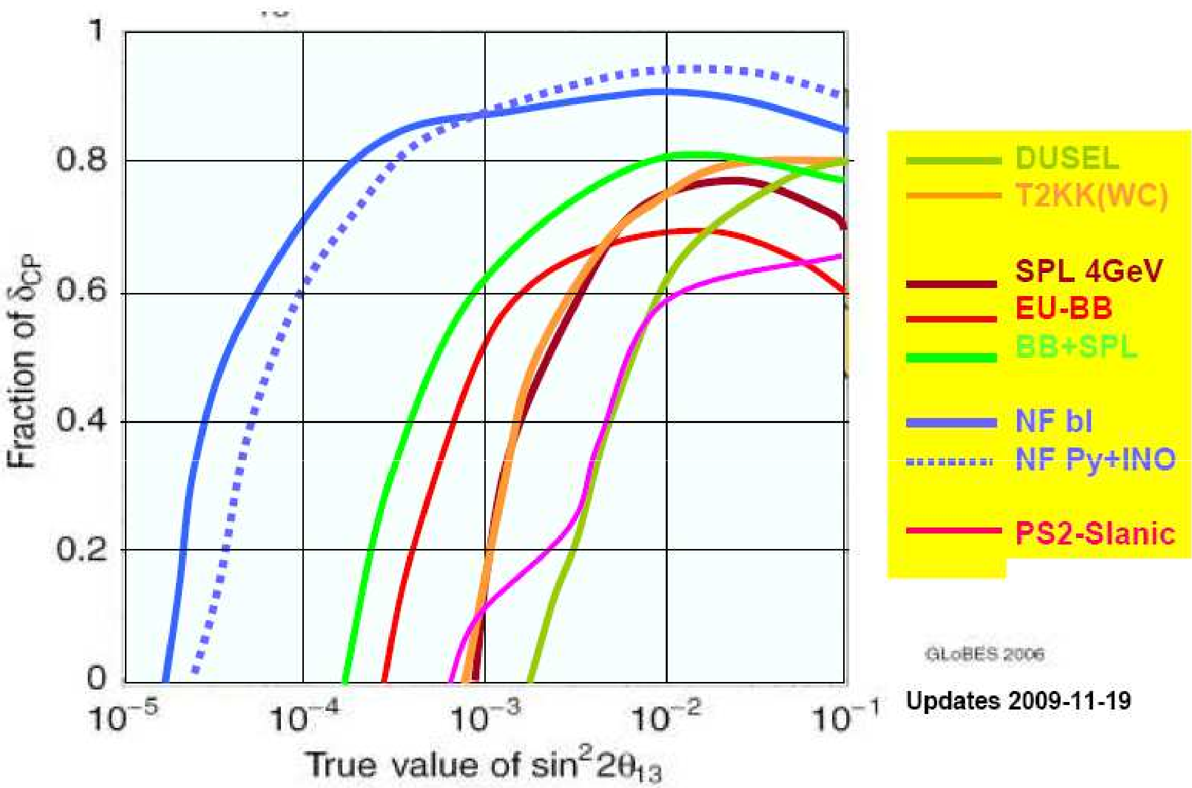


Figure 2 A representative compilation of sensitivities of some future long baseline projects. Here the fraction of d_{CP} where CP violation can be observed at 3 standard deviations is plotted as a function of q_{13}.

T2KK: *T2K 1.66 MW beam to 270 kton fid volume Water Cherenkov detectors in Japan (295km) and in Korea (1050 km);*
DUSEL*: a WBB from Fermilab to a 300 kton WC in Dusel (1300km);*
SPL 4 GeV, EU-BB and BB+SPL: *CERN to Fréjus (130km) project;*
NF bl *is the Neutrino Factory baseline (4000km and 7000km baselines) and*
NF Py+INO *represents the concrete baseline from CERN to Pyhasalmi mine in Finland (2285 km) and to INO in India (7152 km);*
PS2-Slanic *is a preliminary superbeam study at 1500km based on an upgrade of PS2 to 1.66MW and a 100kton Liquid Argon TPC*

Conclusions and outlook

This has been an extraordinary Moriond EW session!

Results results results! And many shown first at Moriond…

The near future is exciting!

-- confirm existence of 125 GeV effect
-- study its properties
-- study/understand what should be the next step
  LHC only? Linear collider? Ring collider (e+e- or mu+ mu-?)
  (much too soon to make decision)

Continue looking for effect of new particles in rare phenomena and precise measurements (dont forget sterile neutrinos!)
including $0\nu\beta\beta$ which would put neutrinos definitely beyond the SM.

Make decision on next neutrino facilities now that θ_{13} is known to $\pm$20%.
Incremental path … but not dead end!

Moriond is good because the physics is good

Looking forward to MORIOND EW 2013!