The 11th ICFA Seminar on Future Perspectives in High-Energy Physics

Institute of High Energy Physics, CAS, October 27-30, 2014

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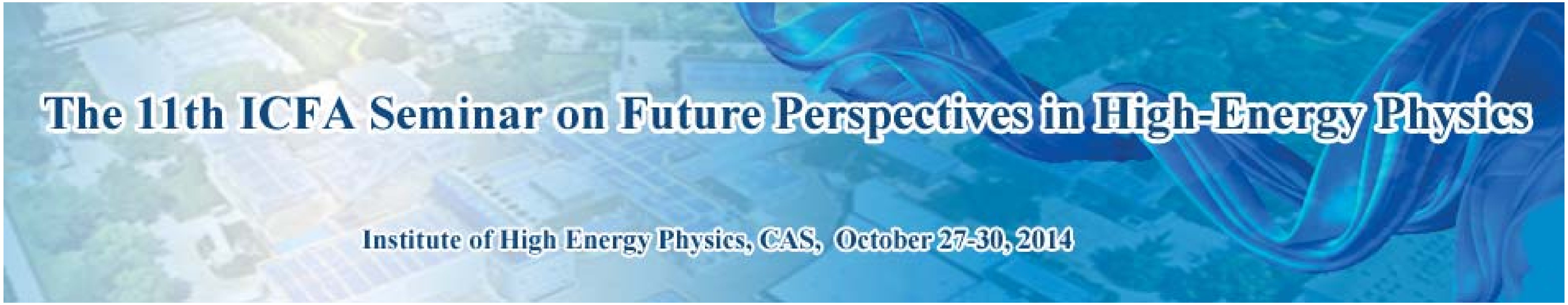
Seminarium Fizyki Wysokich Energii
Warszawa, 5 grudnia 2014



Outline

- Introduction
- Experimental highlights
- Open questions
- Future prospects
- Global strategy
- Conclusions

Introduction

Purpose of ICFA

ICFA was created to facilitate international collaboration in the construction and use of accelerators for high energy physics. It was created in 1976 by the International Union of Pure and Applied Physics. Its purposes, as stated in 1985, are as follows:

- To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators.
- To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses.
- To organize workshops for the study of problems related to super high-energy accelerator complexes and their international exploitation and to foster research and development of necessary technology.

http://www.fnal.gov/directorate/icfa/index.html

ICFA

ICFA membership is (approximately) representative of particle physics activity in the different regions of the world:
CERN member states (3), USA (3), Japan (2), Russia (2), Canada (1), China (1), Other Countries (3).

Members of ICFA are nominated by **designated authorities** in their regions.

The current membership includes the directors of
CERN, Fermilab, IHEP (Beijing) and KEK,
and the DESY and SLAC Particle Physics Directors.

Ex-officio: the Chair of IUPAP Commission 11, chair of ECFA

ICFA Seminar

11th ICFA seminar at IHEP, Beijing, on 27-30 October 2014
http://icfa2014.ihep.ac.cn

The Seminar takes place every three years with the aim of bringing together government officials involved in strategic decisions for High Energy Physics (HEP), representatives of the major funding agencies, the directors of major HEP laboratories, and leading scientists from all of the regions of HEP activity.

ICFA Seminar 2014

159 participants from 24 countries

United States of America 36
Japan 27
China 17
Switzerland 14
Germany 9
France 6
United Kingdom 6
...
Poland 3
...

4 days, 14 sessions, 42 plenary talks

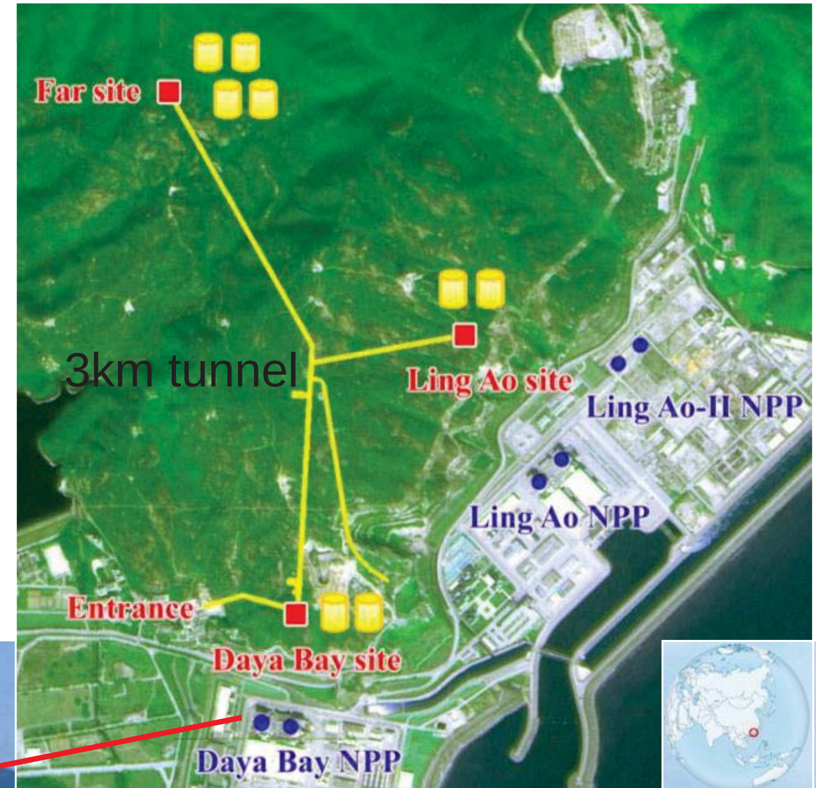
- experimental results (19)
- theory (7)
- future projects and R&D (9)
- regional reports and strategy (5)
- outreach and social impact (2)

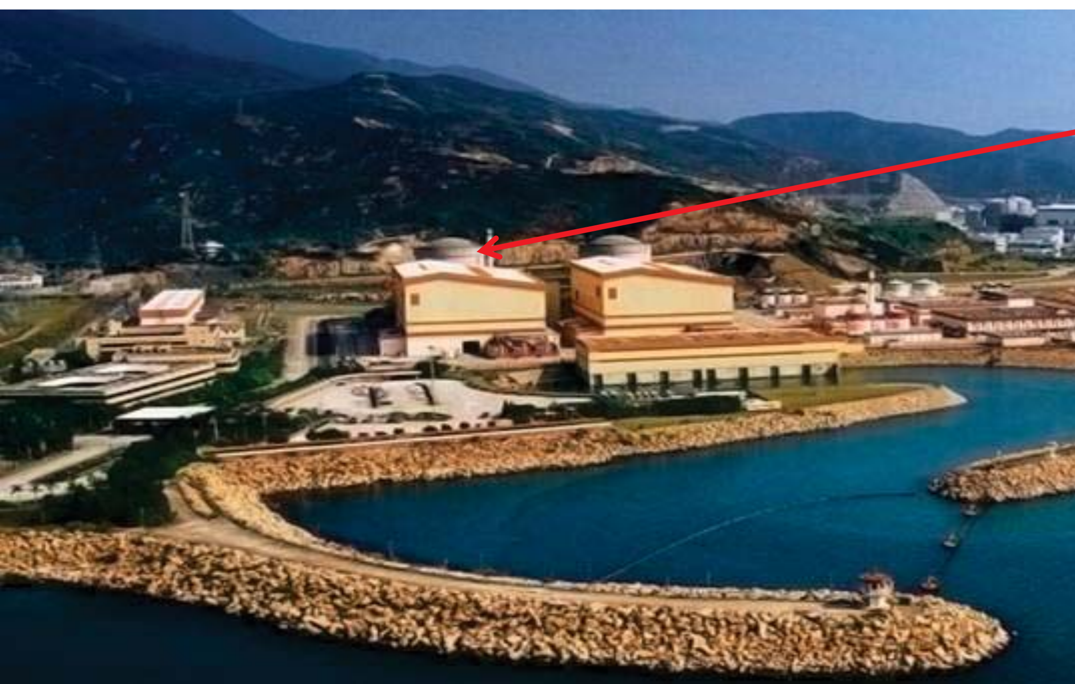

The 11th ICFA Seminar on
Future Perspective in High Energy Physics
October 27-30,2014, Beijing,China

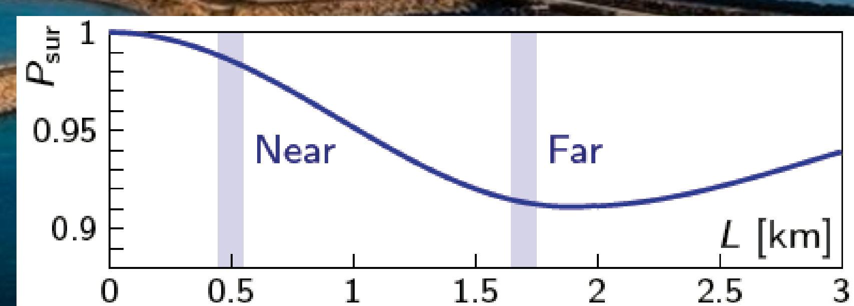
Experimental highlights

The Daya Bay Experiment

- 6 reactor cores, 17.4 GW_{th}
- Relative measurement
  - 2 near sites, 1 far site
- Multiple detector modules
- Good cosmic shielding
  - 250 m.w.e @ near sites
  - 860 m.w.e @ far site
- Redundancy





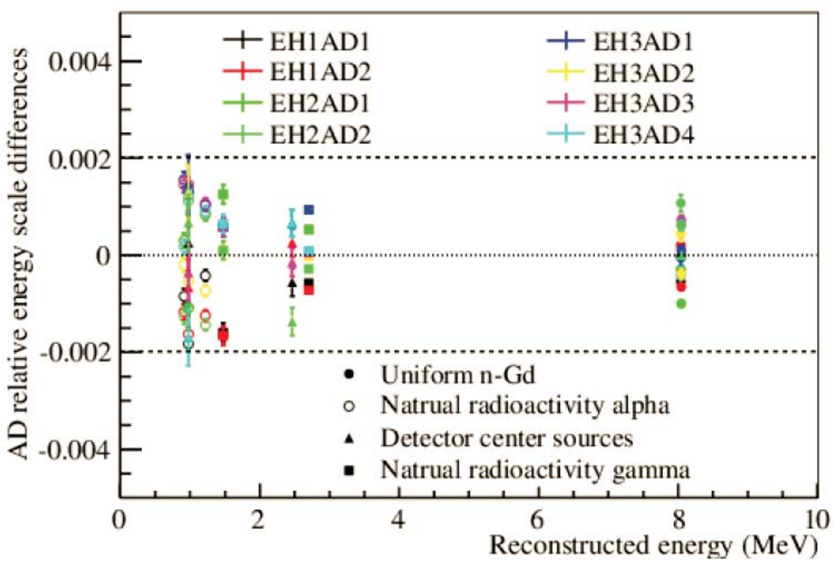


Daya Bay

- **2011.12-2013.11 (621 days)**
- **Detailed and precise corrections for E non-linearity**
- **Continue to improve: reduced backgrounds and systematics**
- **Rate + Shape analysis for nGd events**
- **Rate analysis for nH events**

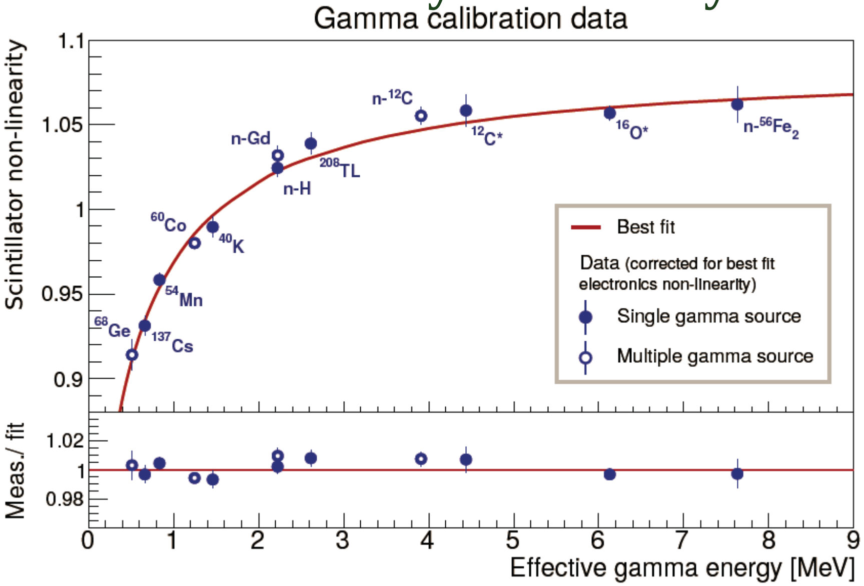
0.5%

Relative energy scale difference: <0.2%



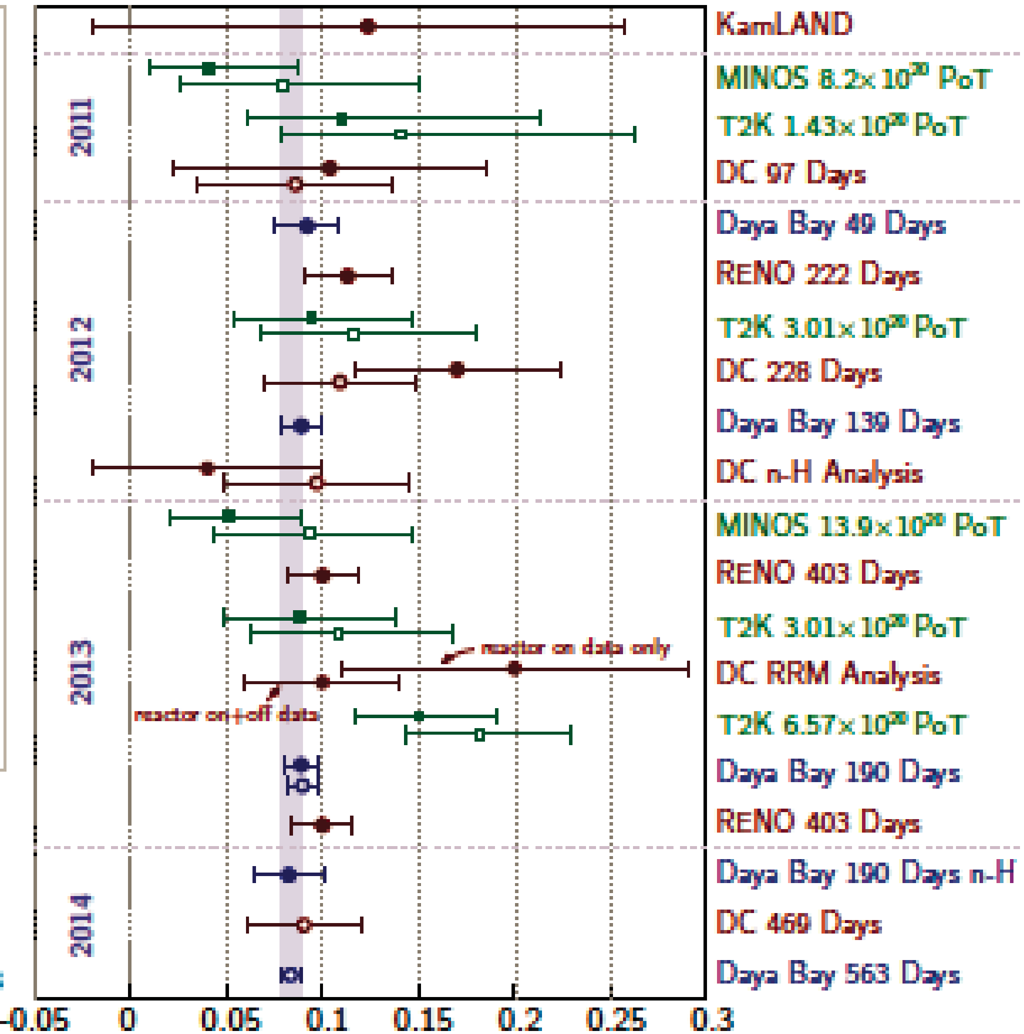
2%

Non-linearity uncertainty < 1%



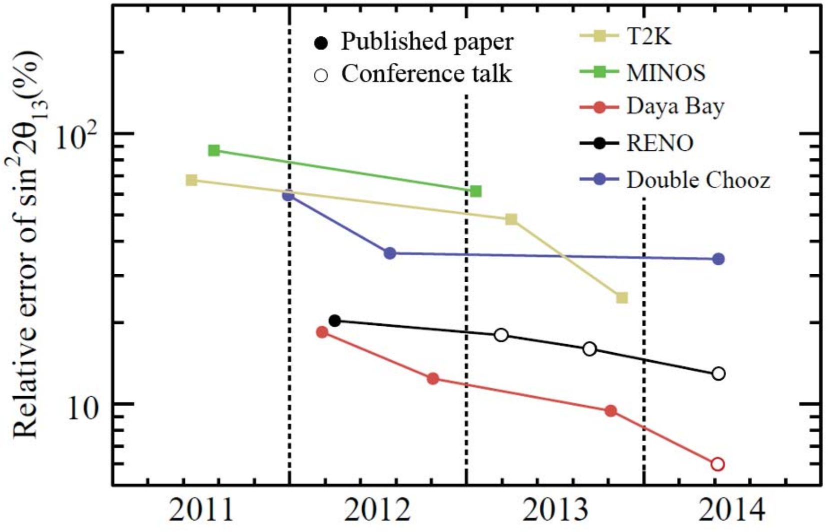
C.Zhang, Neutrino14 & W.Wang, ICHEP14

Remarkable Improvements on θ_{13}



Jetter, Tau2014

Y.F.Wang, Nufact2014



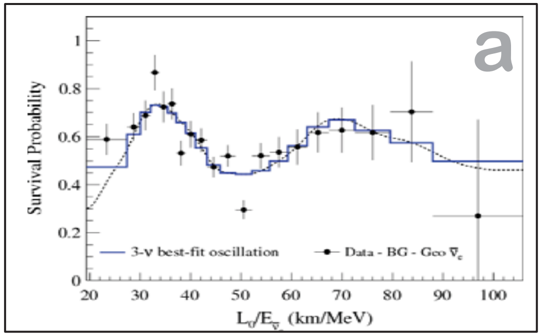
For accelerator experiments assuming $\delta_{CP}=0$, $\theta_{23}=45^o$

Uncertainty reduced significantly → now 6%, will be 3% in 2017.

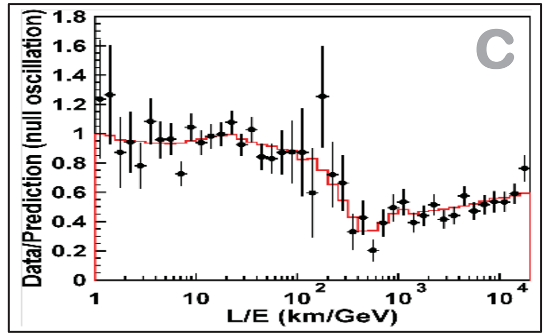
The most precise ν mixing parameter.

Recent discoveries: $\alpha \rightarrow \beta$ oscillations in vacuum and matter

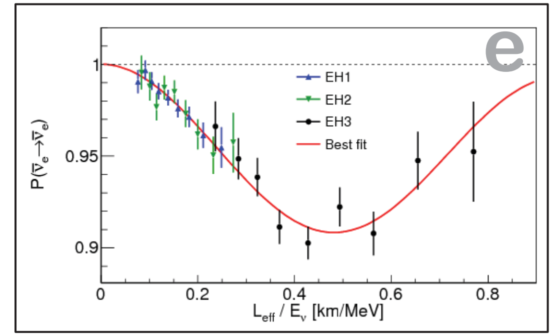
e→e



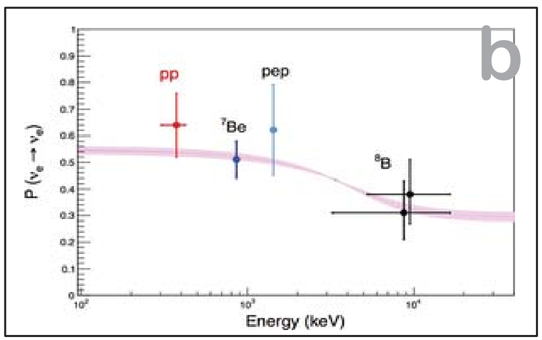
μ→μ



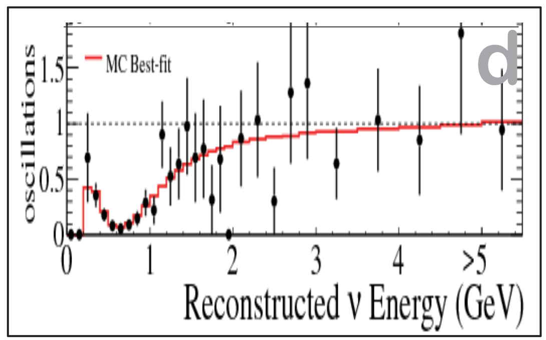
e→e



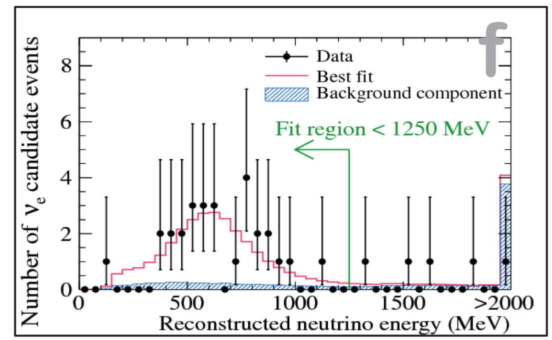
e→e



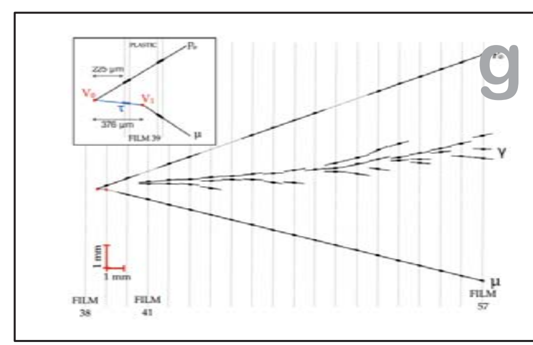
μ→μ



μ→e



μ→τ



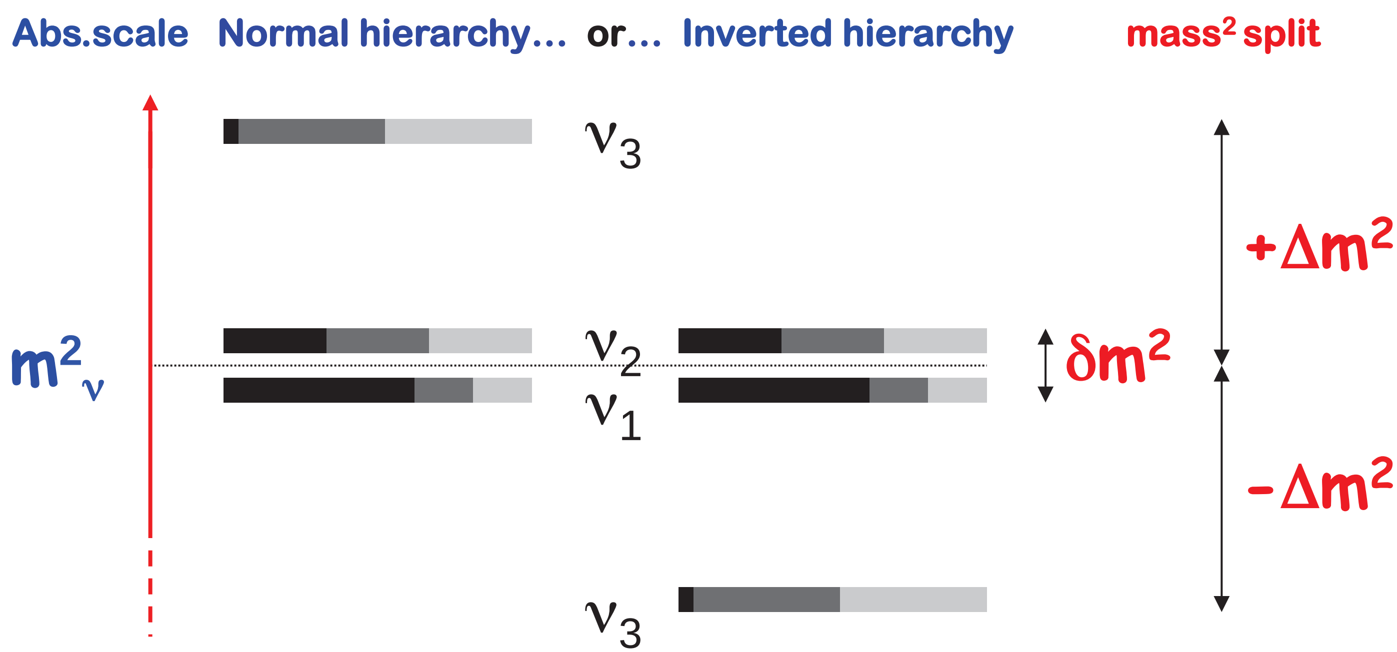
Data from various types of neutrino experiments: (a) solar, (b) long-baseline reactor, (c) atmospheric, (d) long-baseline accelerator, (e) short-baseline reactor, (f,g) long baseline accelerator (and, in part, atmospheric).

(a) KamLAND [plot]; (b) Borexino [plot], Homestake, Super-K, SAGE, GALLEX/GNO, SNO; (c) Super-K atmosph. [plot], MACRO, MINOS etc.; (d) T2K (plot), MINOS, K2K; (e) Daya Bay [plot], RENO, Double Chooz; (f) T2K [plot], MINOS; (g) OPERA [plot], Super-K atmospheric.

See next talks by Jung, Shiozawa, Cao

Current 3ν picture in just one slide (with 1-digit accuracy)

Flavors = e μ τ



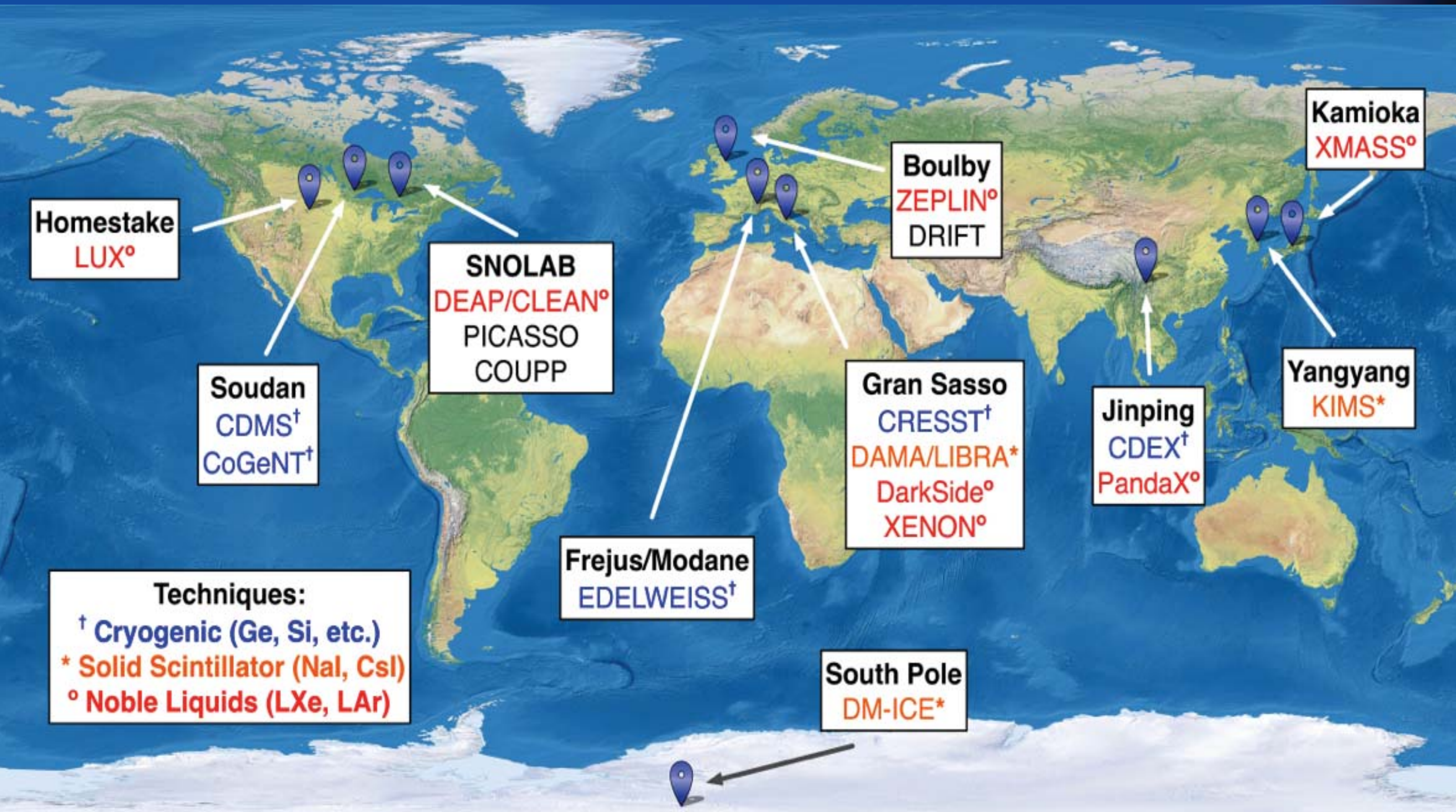
Terra Cognita:

$\delta m^2 \sim 8 \times 10^{-5}$ eV^2
$\Delta m^2 \sim 2 \times 10^{-3}$ eV^2
$\sin^2\theta_{12} \sim 0.3$
$\sin^2\theta_{23} \sim 0.5$
$\sin^2\theta_{13} \sim 0.02$

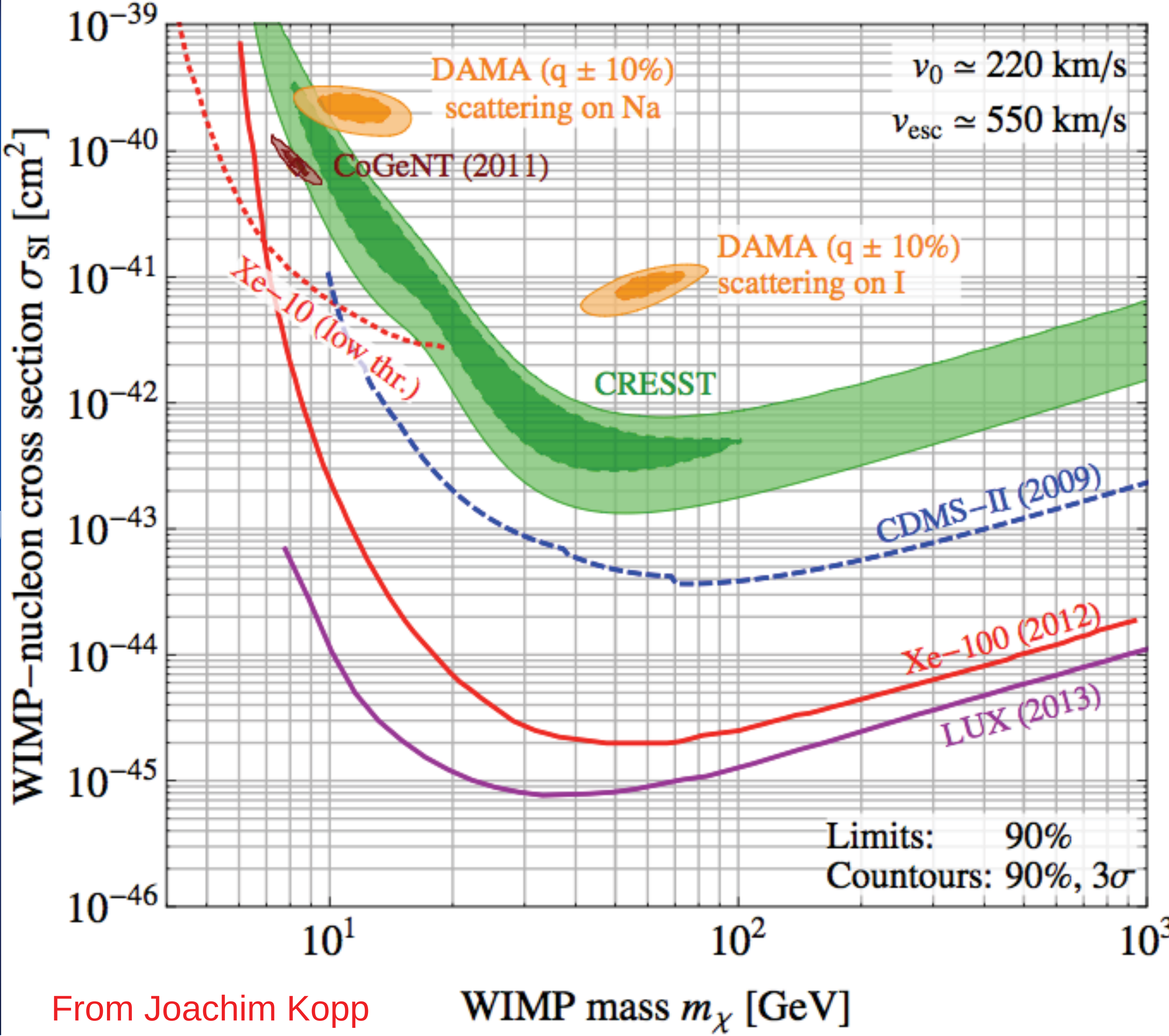
Terra Incognita:

δ (CP)
sign(Δm^2)
octant(θ_{23})
absolute mass scale
Dirac/Majorana nature

UNDERGROUND DARK MATTER LABORATORIES WORLDWIDE



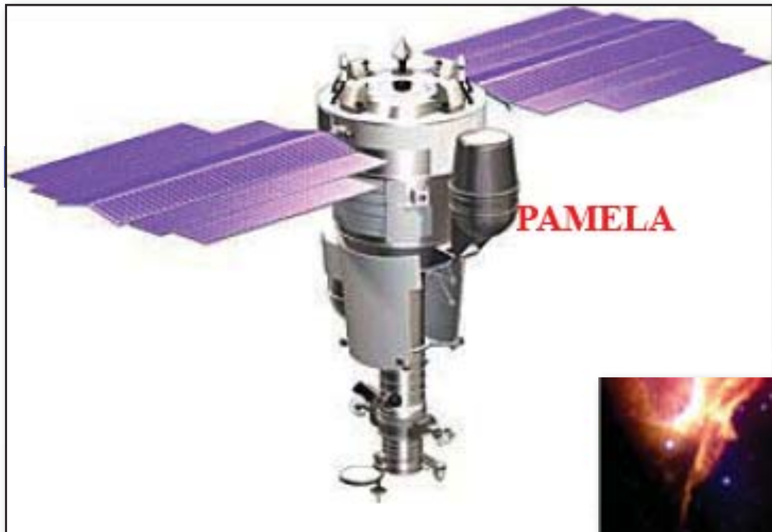
Assumes Spin-Independ. Scattering i.e. scales as A^2



From Joachim Kopp

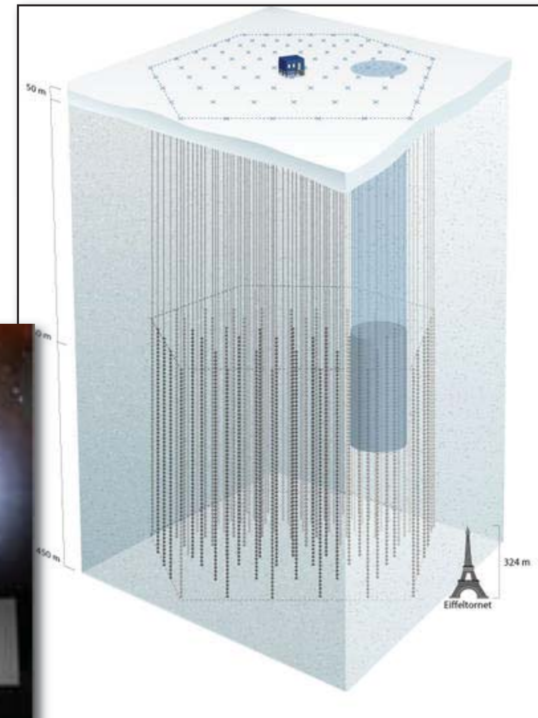
New Indirect Detection Results

Pamela and AMS

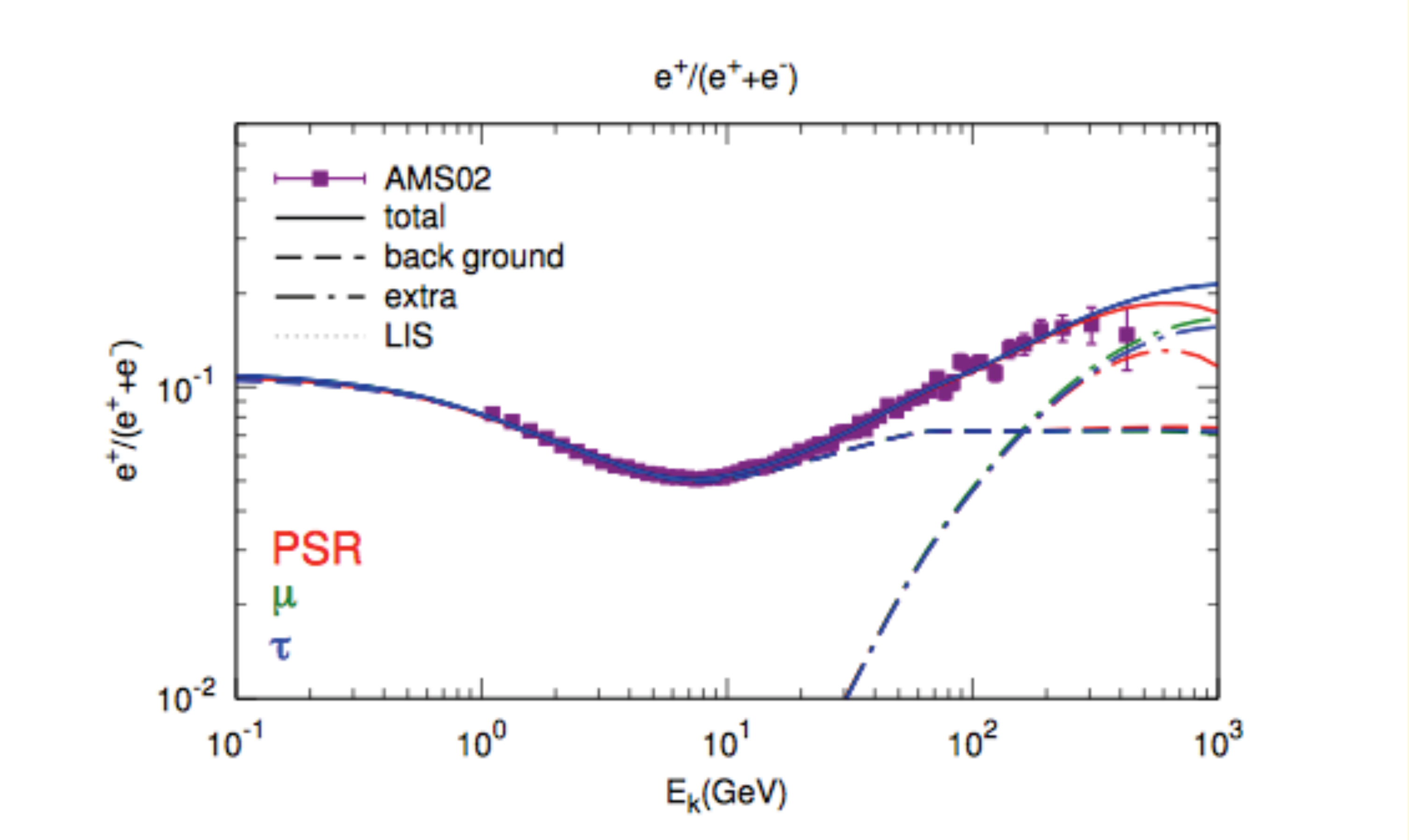


FERMI

IceCube/DeepCore



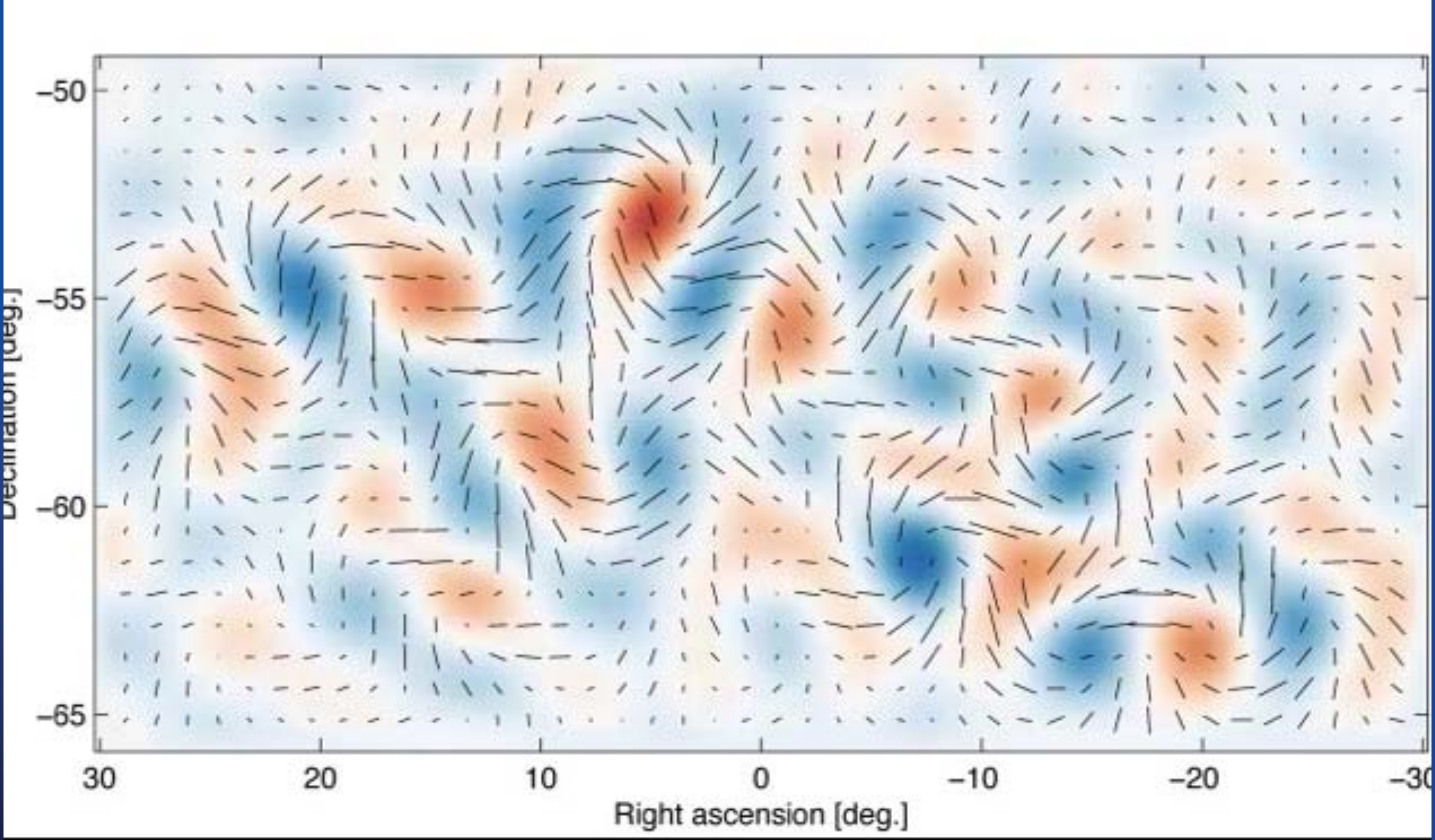
Lin, Yuan, Bi
1409.6248



BICEP2 at the South Pole

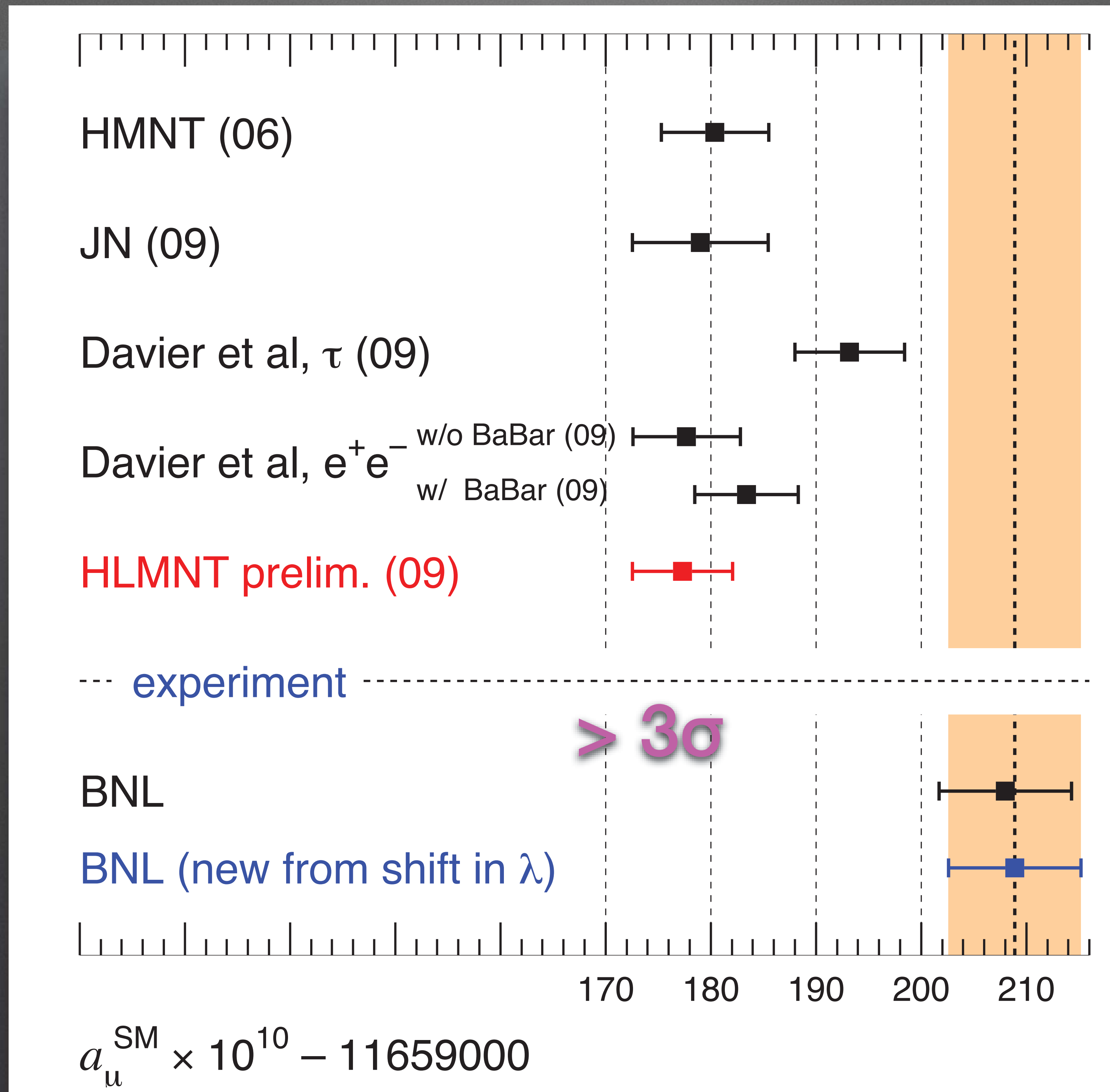
BICEP2 at the South Pole.

Polarization in BICEP2



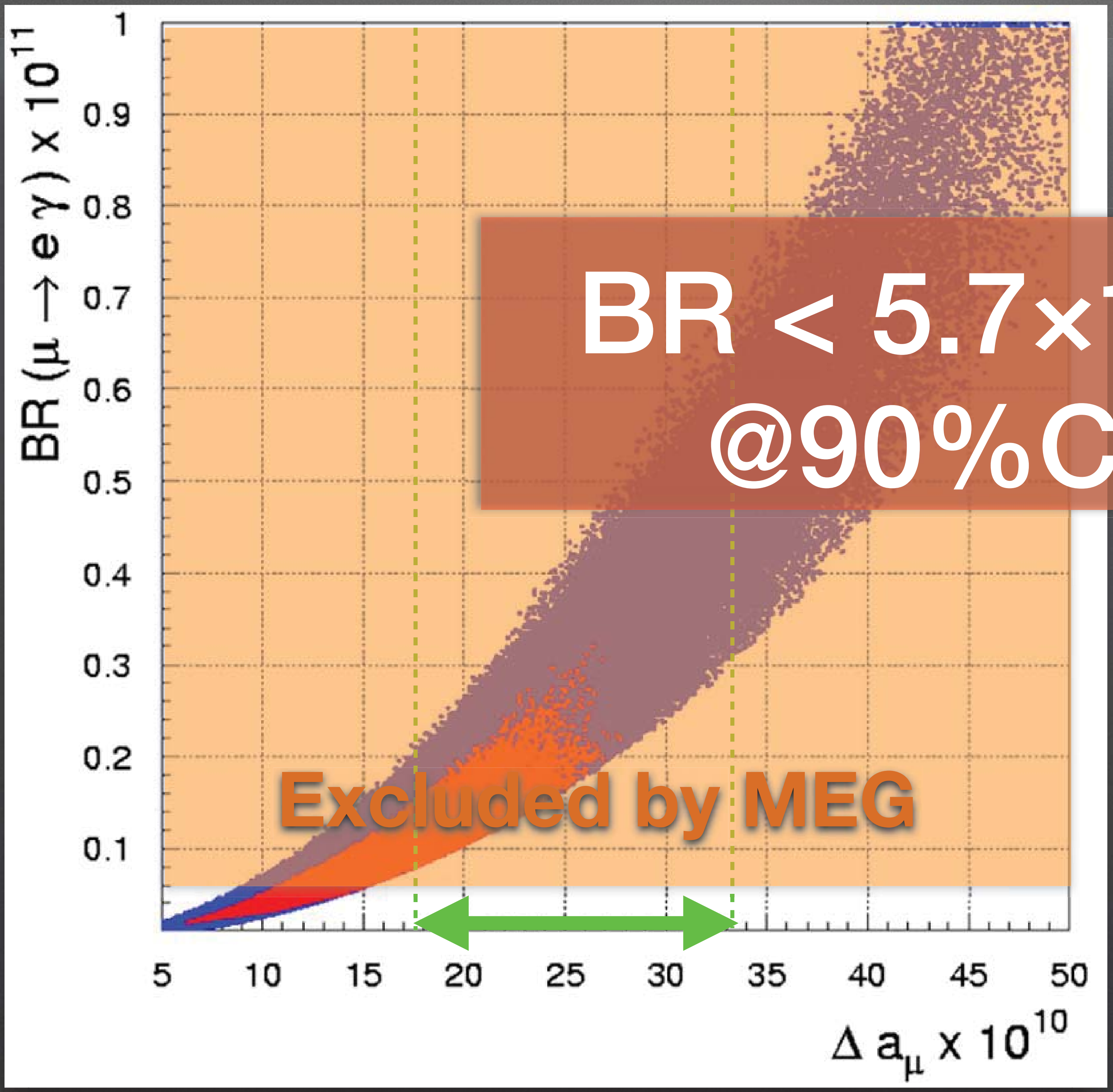
BICEP2 revealed a faint but distinctive twist in the polarization pattern of the CMB. Here the lines represent polarization; the red and blue shading show the degree of the clockwise and counter-clockwise twist.

There is a >3σ evidence!



muon's anomalous magnetic moment g_μ-2

muon (g_μ-2) anomaly



BR < 5.7×10^{-13}
@90%CL

$|\delta_{LL}^{12}| = 10^{-4}$ assumed

G.Isidori et al. PRD75, 115019

muon's anomalous magnetic moment

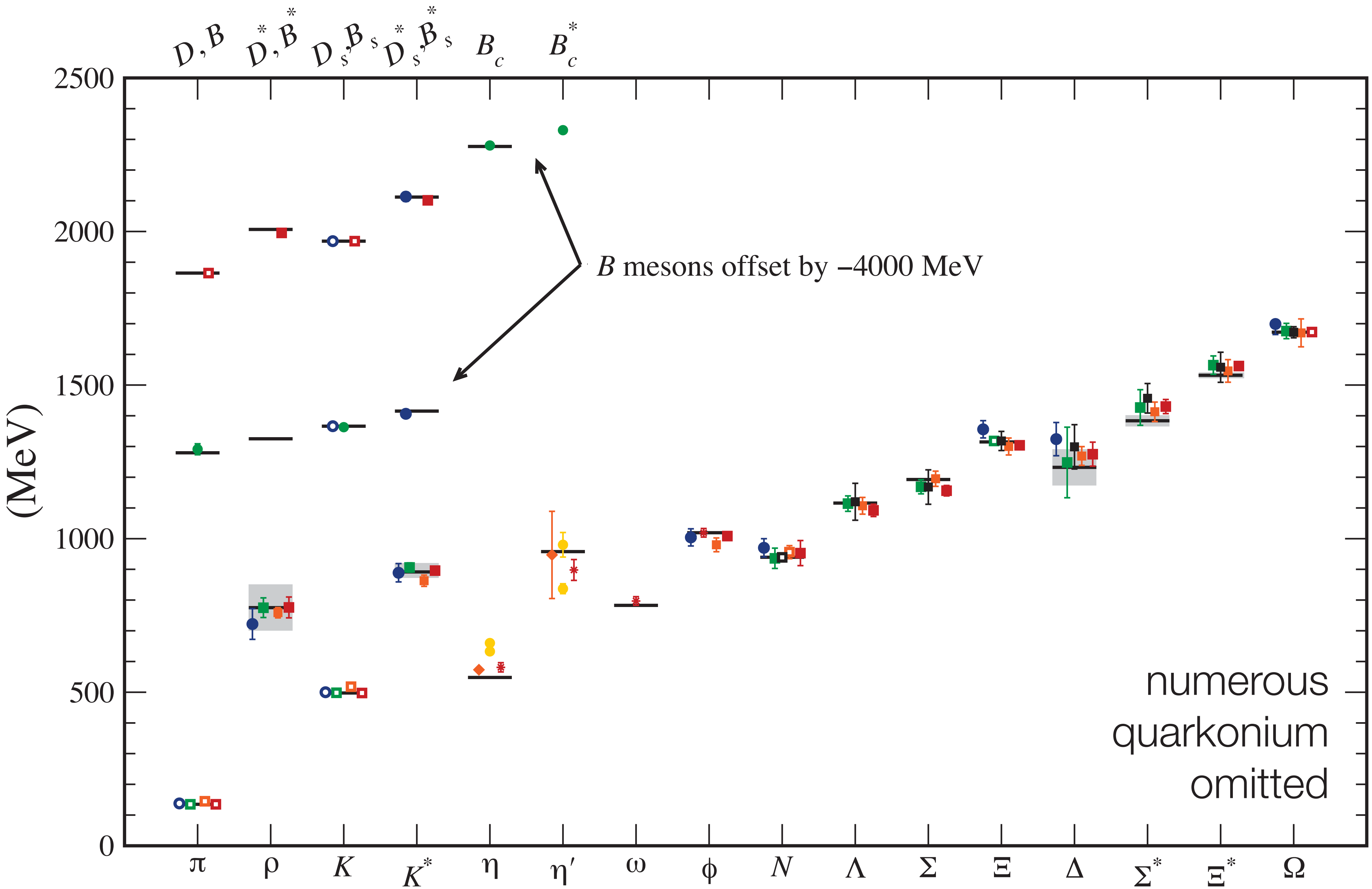
Numerical Lattice QCD

- Nowadays "lattice QCD" usually implies a numerical technique, in which the functional integral is integrated numerically on a computer.
- Big computers:

- Some compromises:
  - finite human lifetime ⇒ Wick rotate to Euclidean time: $x^4 = ix^0$;
  - finite memory ⇒ finite space volume & finite time extent;
  - finite CPU power ⇒ light quarks until recently heavier than up and down.

QCD Hadron Spectrum

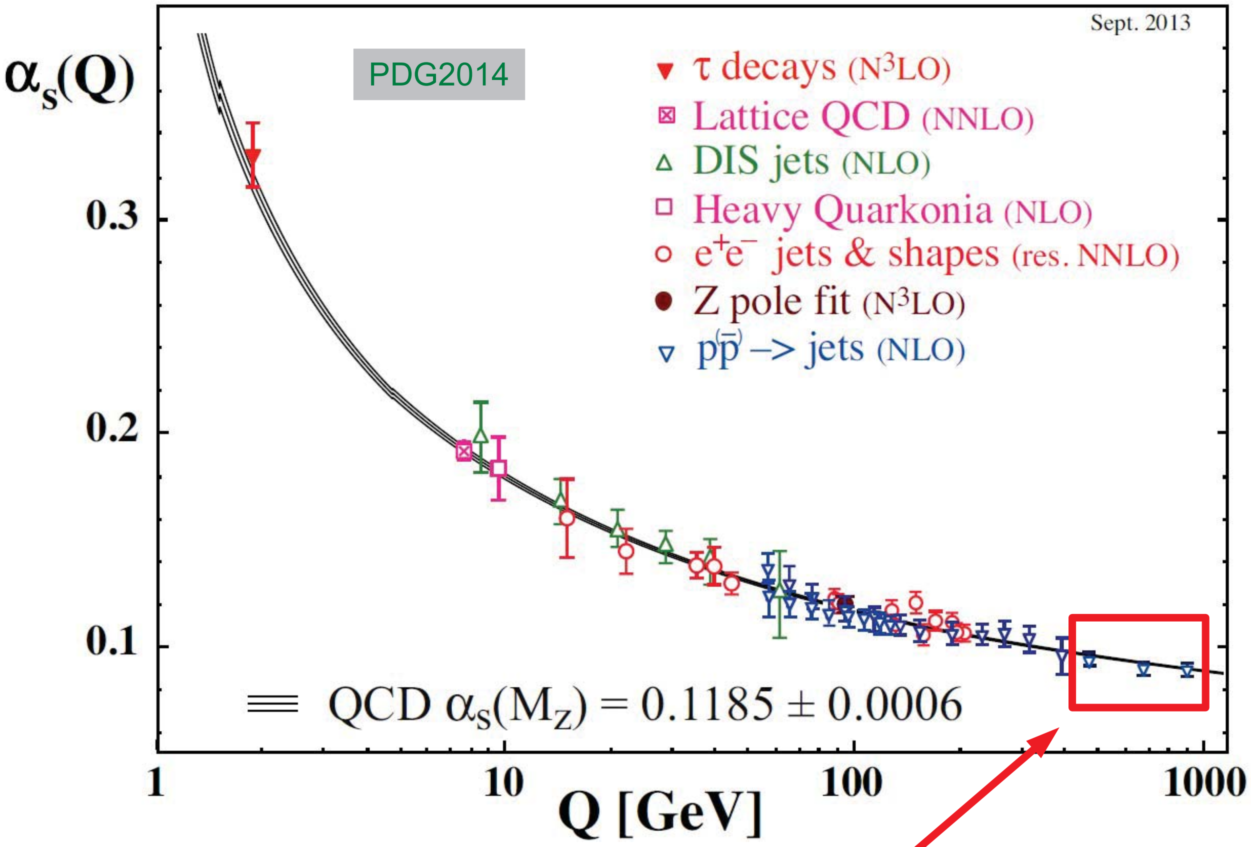
π…Ω: BMW, MILC, PACS-CS, QCDSF; ETM (2+1+1);
η-η′: RBC, UKQCD, Hadron Spectrum (ω);
D, *B*: Fermilab, HPQCD, Mohler&Woloshyn

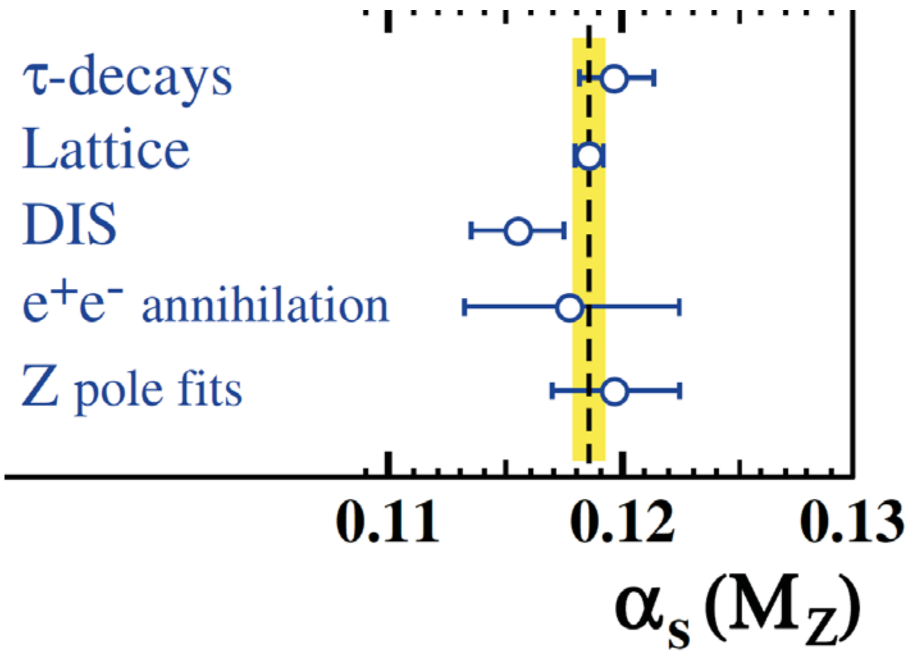


numerous quarkonium omitted

Monday, October 27, 14

PDG α_s Summary





Dominated by Lattice Gauge Theory

CMS data, but not in average since only NLO theory!

$$\alpha_s(M_Z) = 0.1185 \pm 0.0006$$

$$\frac{\Delta\alpha_S(M_Z)}{\alpha_S(M_Z)} = 0.5\%$$

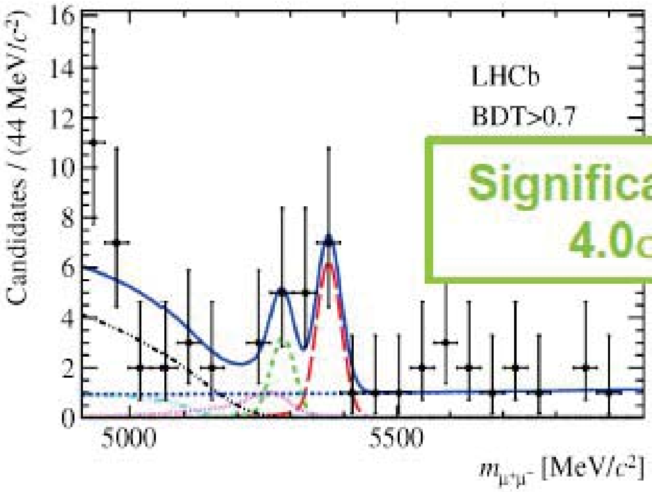
PDG´92: 2.4%

PDG, Chin. Phys. C 38 (2014) 090001.

- **Nov 2012: LHCb found the first evidence for $B_s \to \mu^+\mu^-$ using 2.1fb^{-1}**

- Update: full dataset: 3fb^{-1}
  - Improved BDT
  - Expected sensitivity: **5.0σ**

PRL 111 (2013) 101805



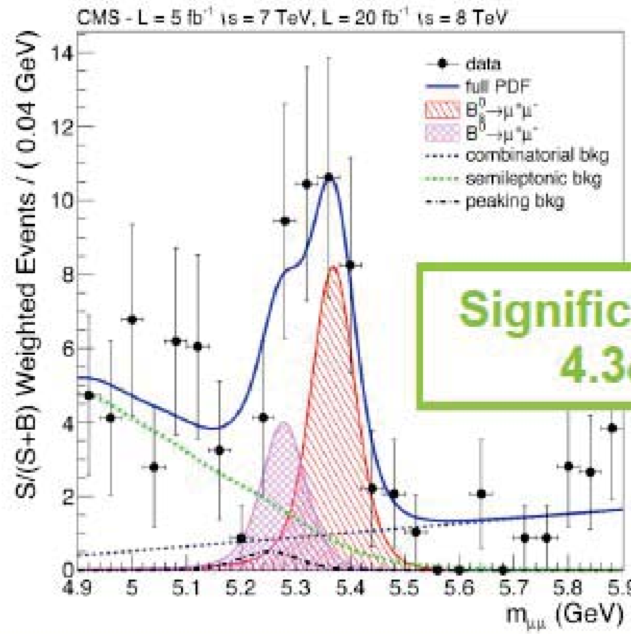
Significance: 4.0σ

$$BR(B_s \to \mu^+\mu^-) = (2.9^{+1.1}_{-1.0}) \times 10^{-9}$$

$$BR(B^0 \to \mu^+\mu^-) = (3.7^{+2.4}_{-2.1}) \times 10^{-10}$$

$$BR(B^0 \to \mu^+\mu^-) < 7 \times 10^{-10} \ @95\%CL$$

- Update to 25fb^{-1}
  - Cut based → BDT based
  - Improved variables
  - Expected sensitivity: **4.8σ**



Significance: 4.3σ

PRL 111 (2013) 101804

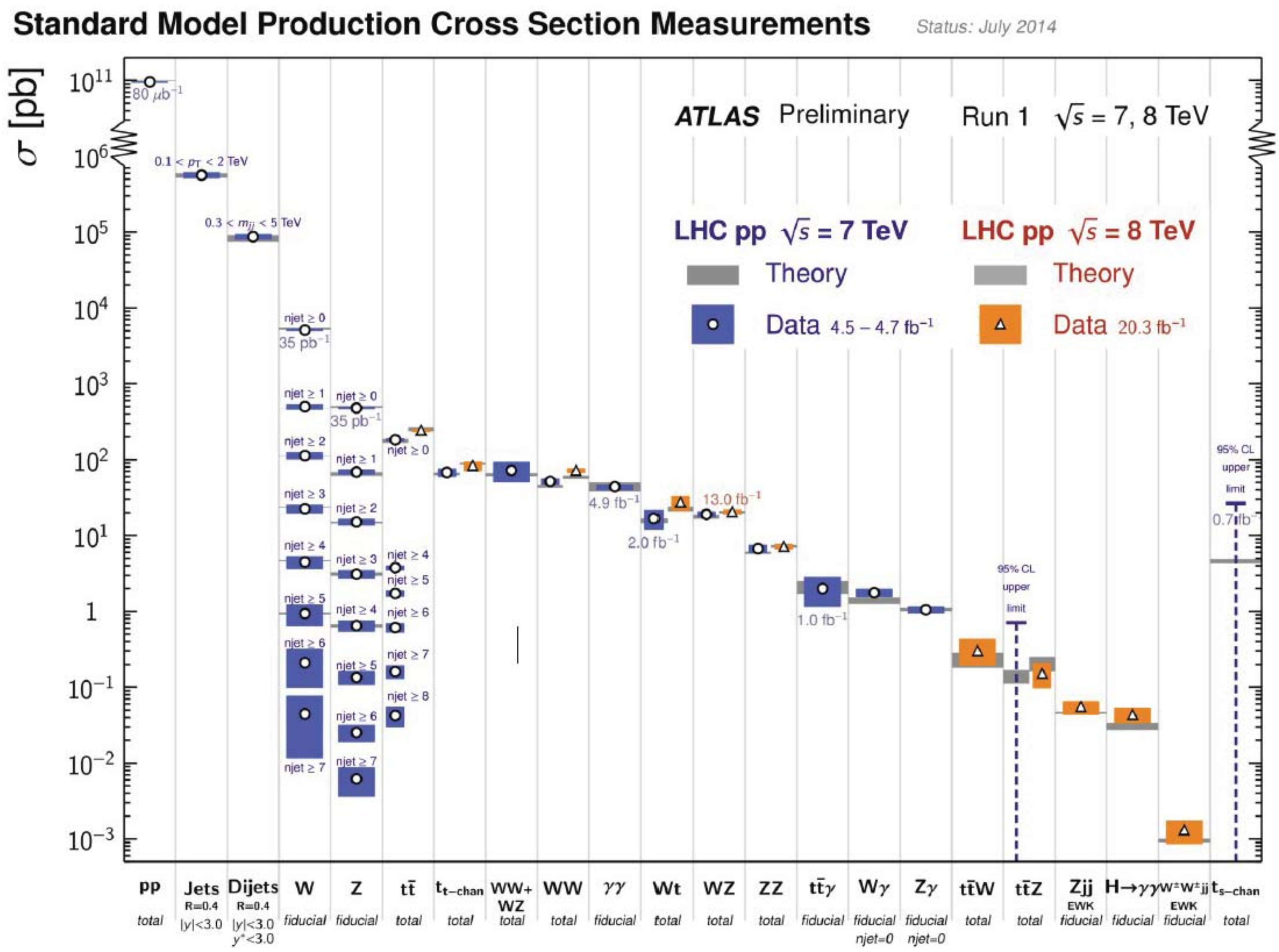
$$BR(B_s \to \mu^+\mu^-) = (3.0^{+1.0}_{-0.9}) \times 10^{-9}$$

$$BR(B^0 \to \mu^+\mu^-) = (3.5^{+2.1}_{-1.8}) \times 10^{-10}$$

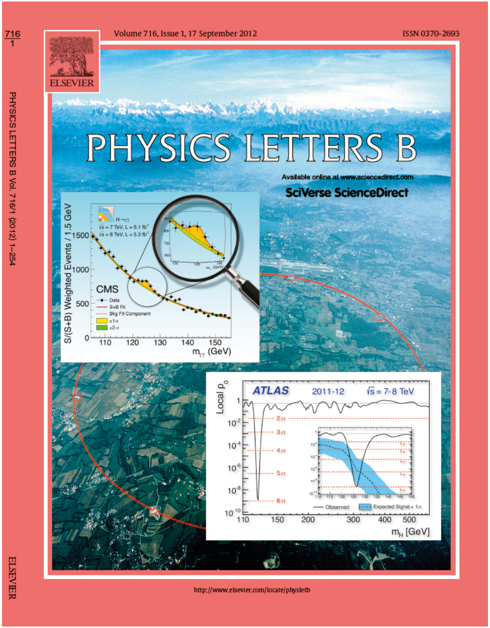
$$BR(B^0 \to \mu^+\mu^-) < 11 \times 10^{-10} \ @95\%CL$$

B_s combined: 6.2 σ significance

LHC – Standard Model Deepest Tests



July 2012: discovery of a new particle.



With the data taken 2011, and $\sim$ 5 fb^{-1} of data taken during 2012, the CMS and ATLAS experiments clearly discover the new particle with $\geq 5\,\sigma$ sigificance

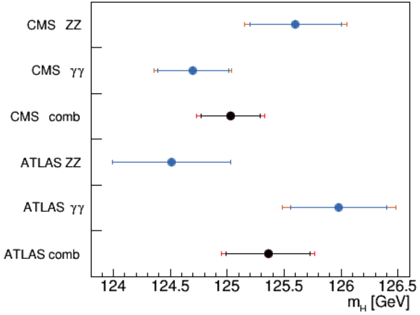
- Driven by decays to boson pairs: $\gamma\gamma$, $\boldsymbol{ZZ}$, $\boldsymbol{WW}$

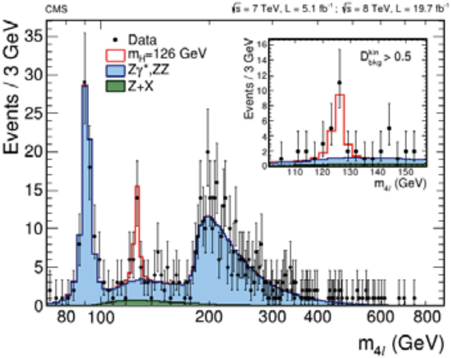
Focus since summer 2012:

- Study of the properties of the new particle
- Search for decays into fermion pairs
  - ⋆ First evidence from Tevatron in 2012

Mass measurement.

- Measured in high resolution channels $H \to \gamma\gamma$ and $H \to 4\ell$
- Careful calibration of electromagnetic calorimeters and muon momentum scale



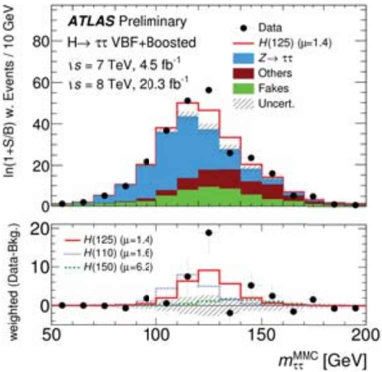


- Precise mass measurement is an important input to couplings measurements
  - ⋆ E.g. $\Delta m_H = 0.2$ GeV shifts prediction for BR($H \to ZZ$) by 2.5%

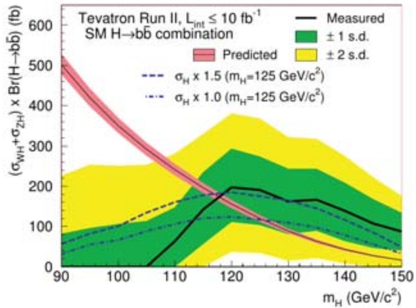
Decays to fermions.

- More challenging to observe than decays to bosons, but important to understand coupling of Higgs to SM particles

$H \to \tau\tau$



$H \to b\bar{b}$



Important channel to constrain total width due to large BR

CMS

$\mu_{\tau\tau} = 0.8 \pm 0.3$ 3.2 σ (3.7 σ exp)

$\mu_{bb} = 1.0 \pm 0.5$ 2.1 σ (2.3 σ exp)

ATLAS

$\mu_{\tau\tau} = 1.4 \pm 0.4$ 4.5 σ (3.5 σ exp)

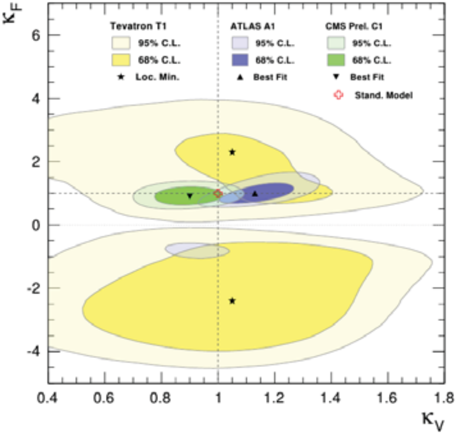
$\mu_{bb} = 0.5 \pm 0.4$ 1.4 σ (2.6 σ exp)

$\mu = \frac{\sigma_{meas}}{\sigma_{SM}}$

Tevatron

$\mu_{bb} = 1.6 \pm 0.7$

Coupling measurements from LHC and Tevatron.



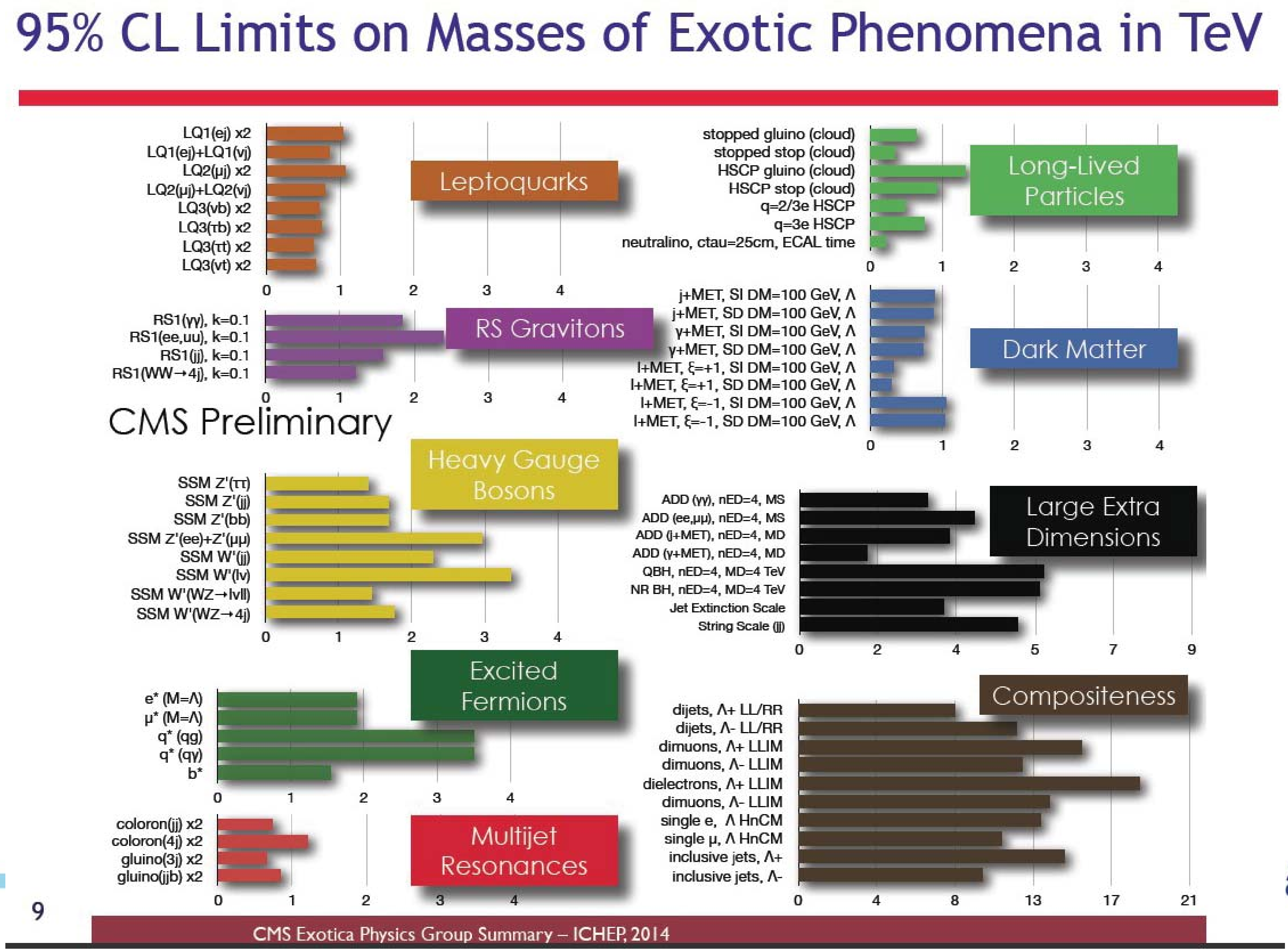
Common couplings scaling factor for all vector bosons (κ_V) and all fermions (κ_f)

Fair agreement with SM predictions

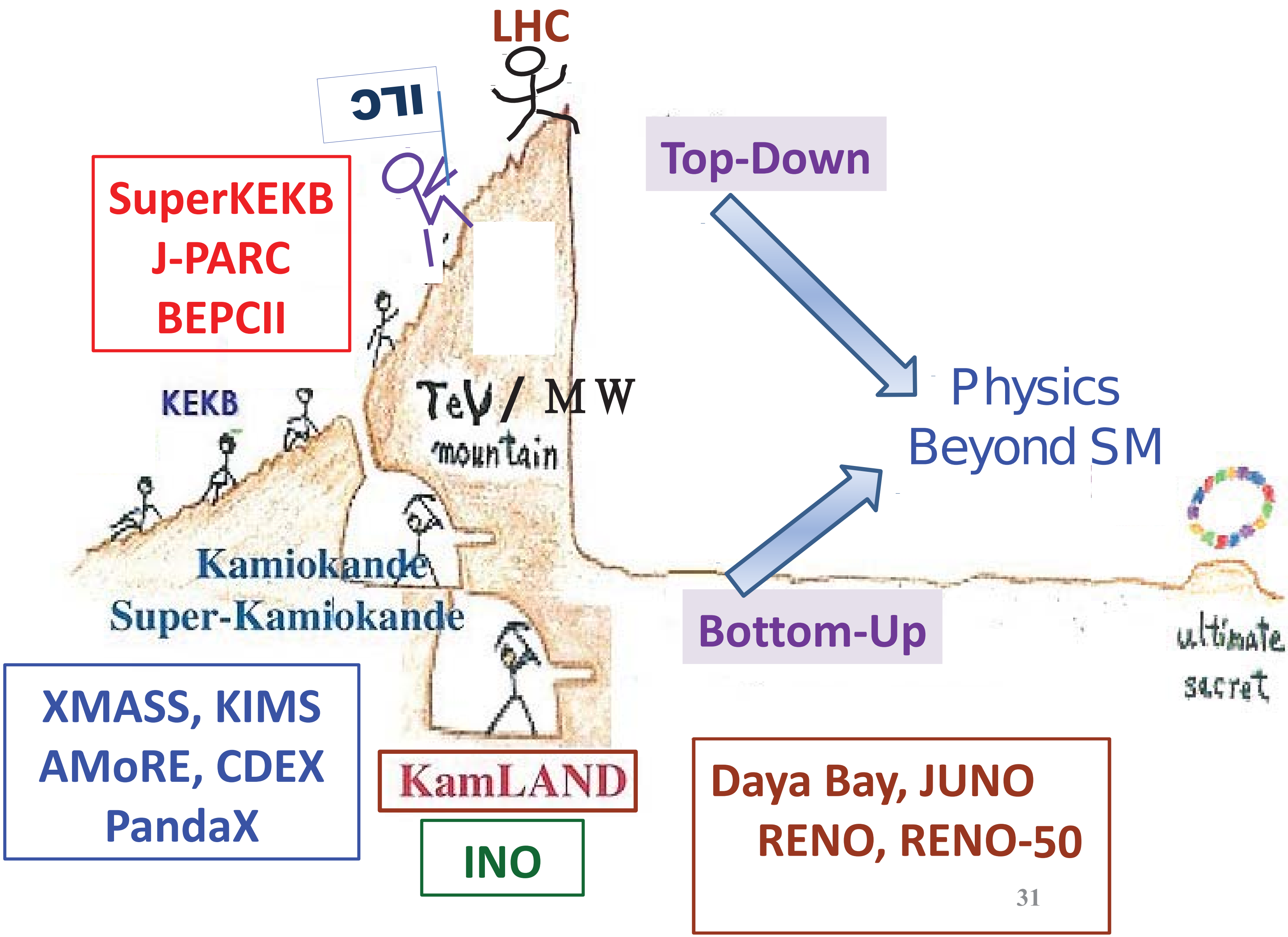
$H \to \gamma\gamma$ has sensitivity to relative sign of κ_V and κ_f through interference of W and t in the loop

Measurements from ATLAS and CMS have been superseeded by updated measurements

No Hints of New Physics in Run 1

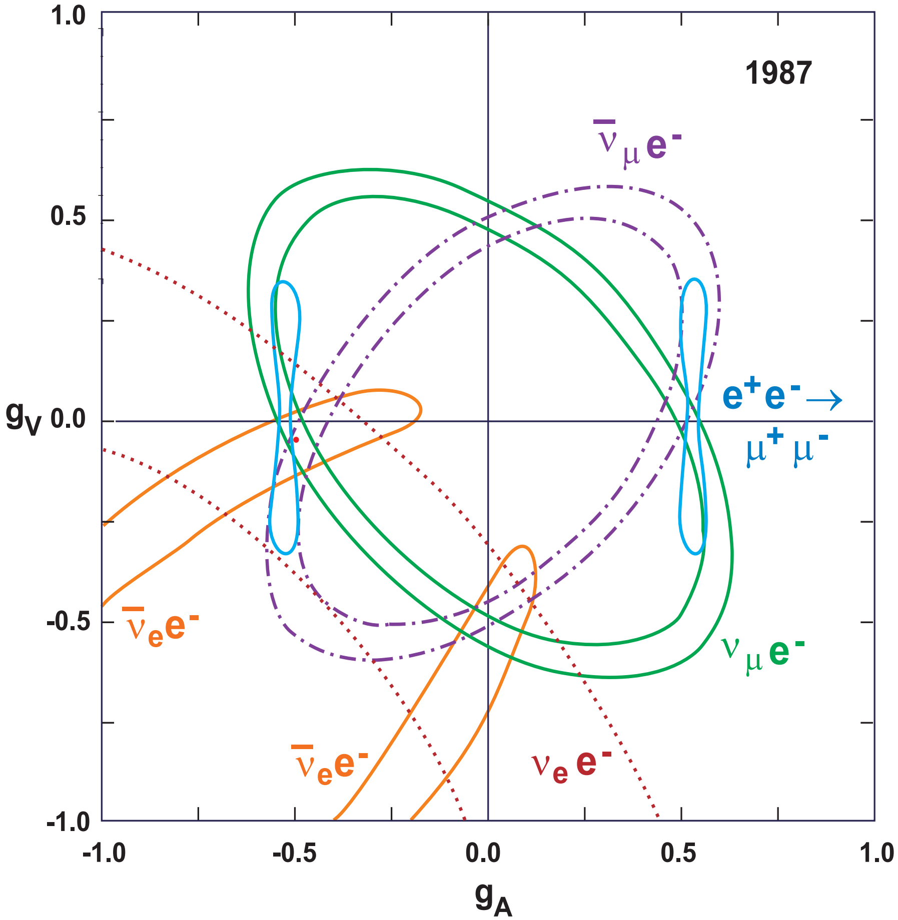


8. Summary Particle Physics Activity in Asia

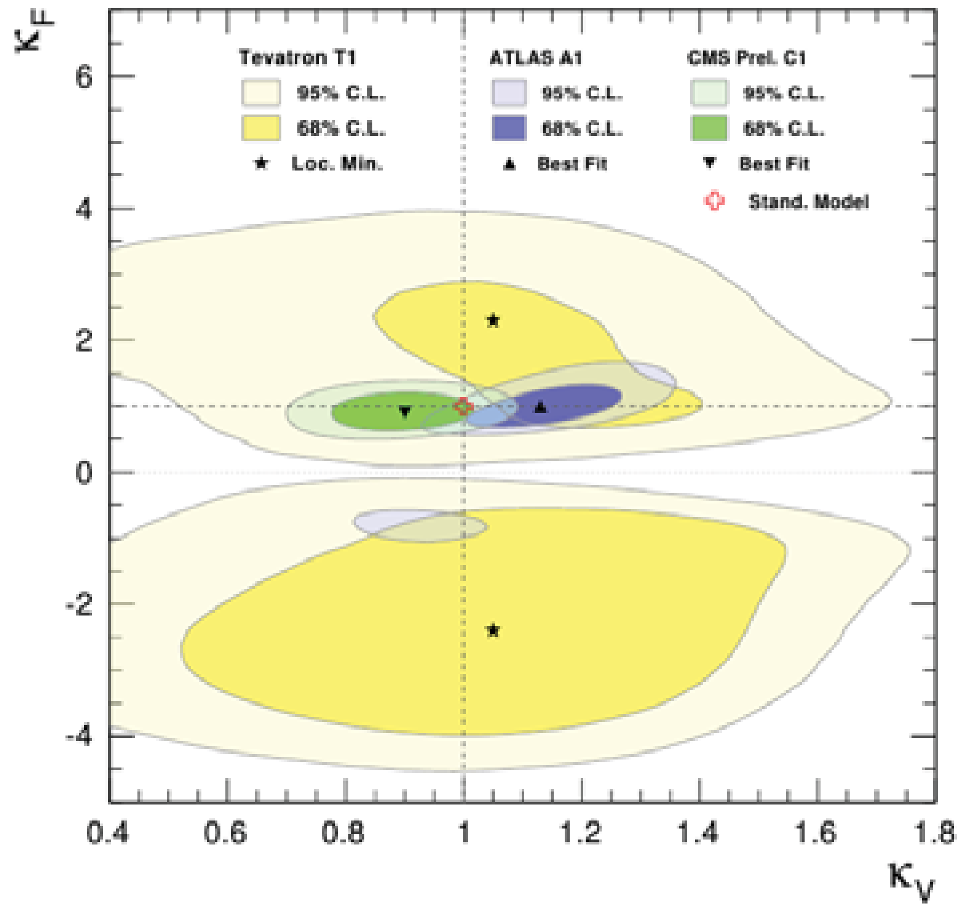


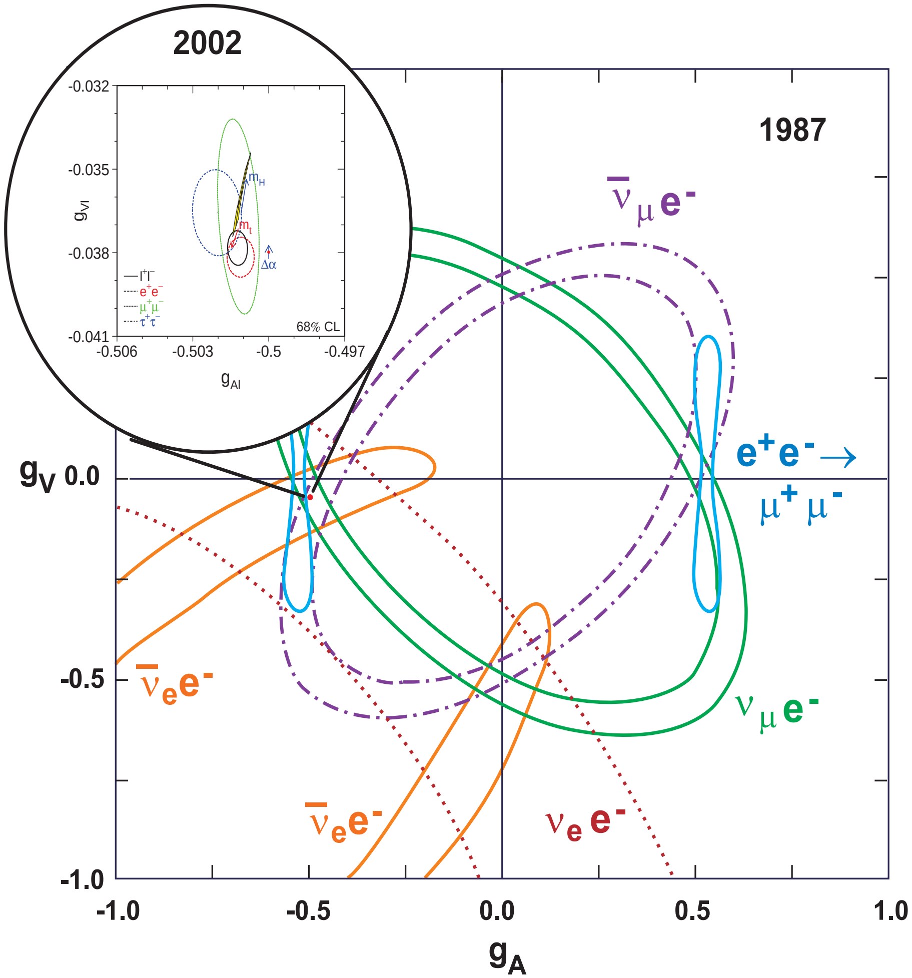
Open questions

Z couplings in 1987:



Higgs couplings in 2014:

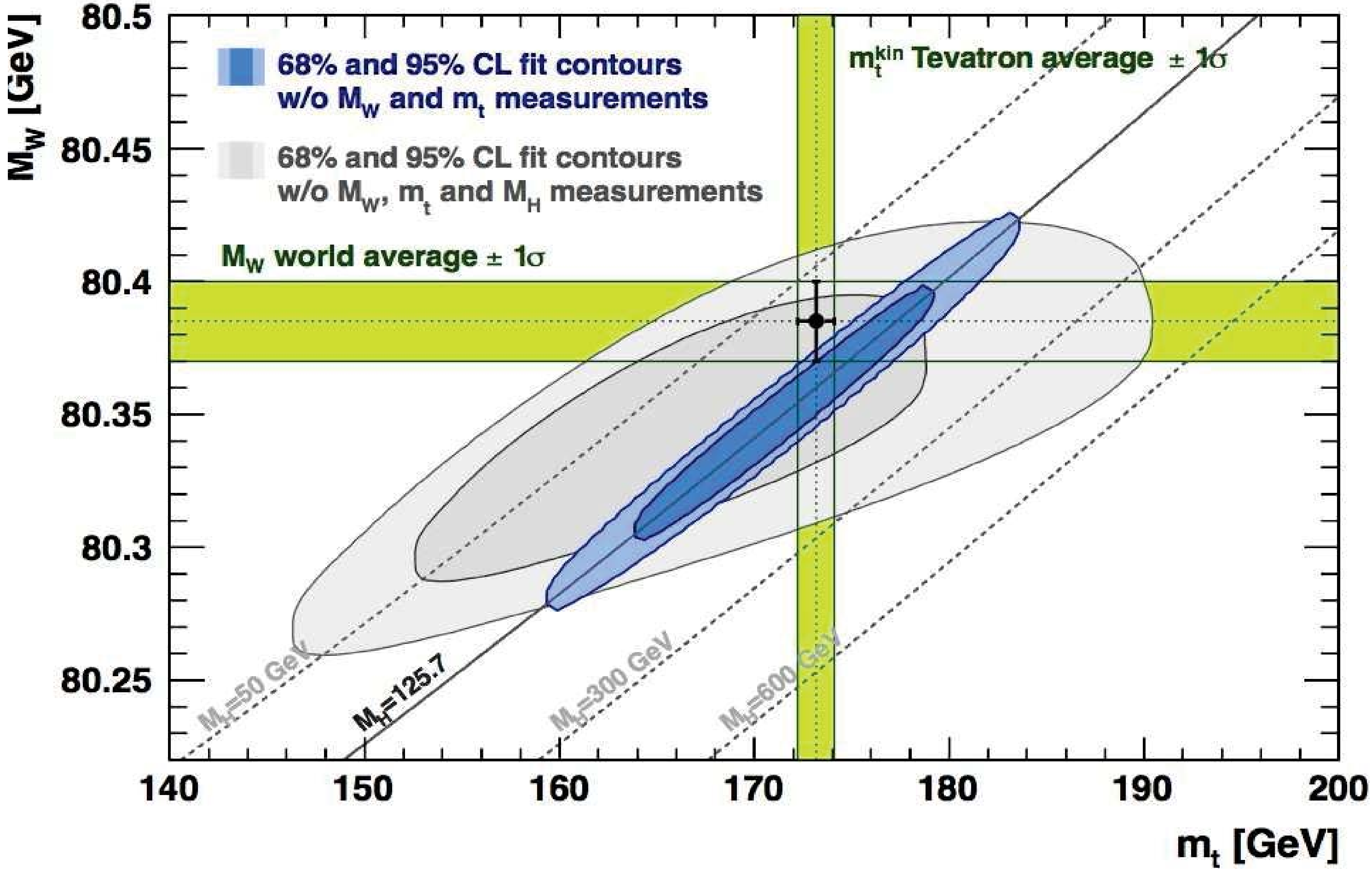




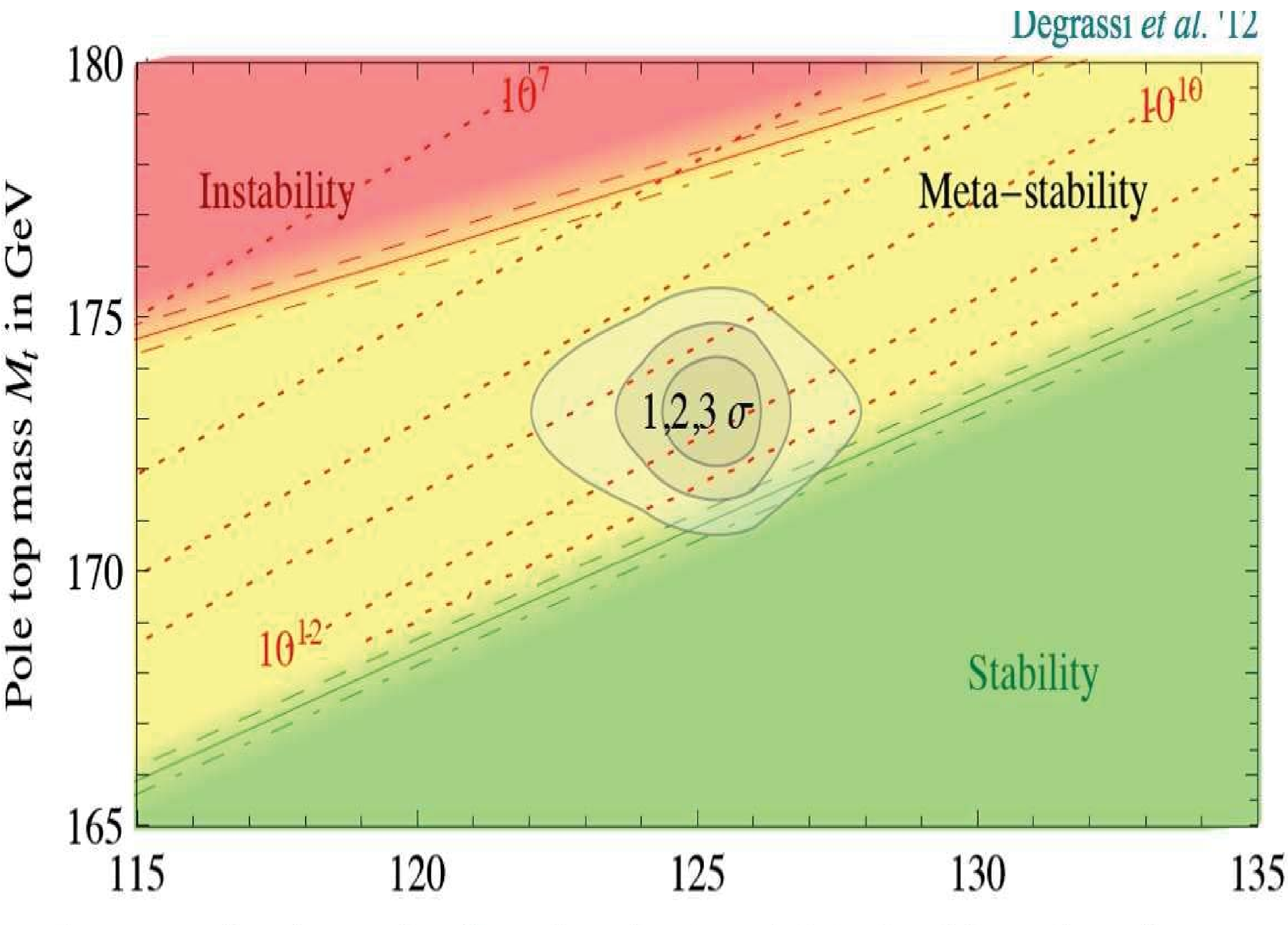
Without inclusion of loop effects now the SM would have been ruled out!

$M_W = 80.404 \pm 0.030$ GeV (measured), $80.376 GeV (theory)$

$m_t = 172.5 \pm 2.3$ GeV (measured) 172.9 GeV (theory)



SM rocks! **LOOP Level**!


Degrassi et al. '12
Pole top mass M_t in GeV
180
175
170
165
115
120
125
130
135
10^7
10^{10}
10^{12}
Instability
Meta−stability
Stability
1,2,3 σ

Statement number 1:

"In the present state of physical science, therefore, a question of extreme interest arises: Is there any principle on which **an absolute thermometric scale** can be founded?"

Statement number 2:

" There is nothing new to be discovered in physics now, All that remains is **more and more precise measurement**."

2014: of the Higgs and top properties!

The Particle Physics Primary Challenge

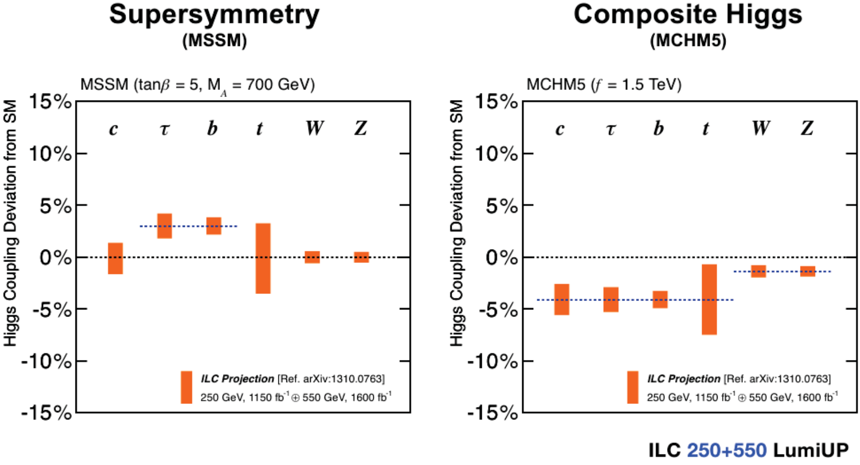
- Where are the particles beyond the standard model?
- What is dark matter?
- Neutrinos…..more to learn and more surprises?
- What is the cosmos telling us?

- What do we do next to prepare for the future?

Peeping through the Higgs window!

How well do we need to measure the couplings?

- Want to disentangle various possible extensions (SUSY, composite Higgs, ...) of the SM, and their parameters
- Requires %-level accuracy in measurements of couplings of SM-like Higgs



Future prospects

Goal of High Luminosity LHC (HL-LHC):

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

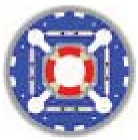
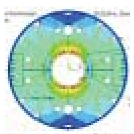
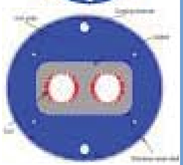
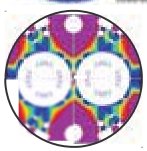
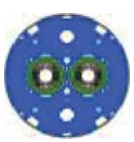
Prepare machine for operation **beyond 2025 and up to 2035**

Devise beam parameters and operation scenarios for:

- # enabling a total integrated luminosity of **3000 fb^{-1}**
- # implying an integrated luminosity of **250-300 fb^{-1} per year**,
- # design for $\mu \sim$ **140 ($\sim$ 200)** (➔ peak luminosity of **5 (7) 10^{34} cm^{-2} s^{-1}**)
- # design equipment for 'ultimate' performance of **7.5 10^{34} cm^{-2} s^{-1}** and **4000 fb^{-1}**

➔ Ten times the luminosity reach of first 10 years of LHC operation

HL-LHC magnet specs

		Type	Material	Field/Gradient (T)/(T/m)	Aperture (mm)	Length (m)	Units (-)
	Q1,Q3 Q2	Single aperture	Nb_3Sn	(12.1) 140	150	8 6.7	40
	D1	Single aperture	Nb-Ti	5.2	150	6.7	6
	D2	Twin aperture	Nb-Ti	3.5…5.0	95…105	7…10	6
	Q4	Twin aperture	Nb-Ti	(5.9) 120	90	4.2	6
	DS 11T	Twin aperture	Nb_3Sn	10.8	60	11	40

200 magnets

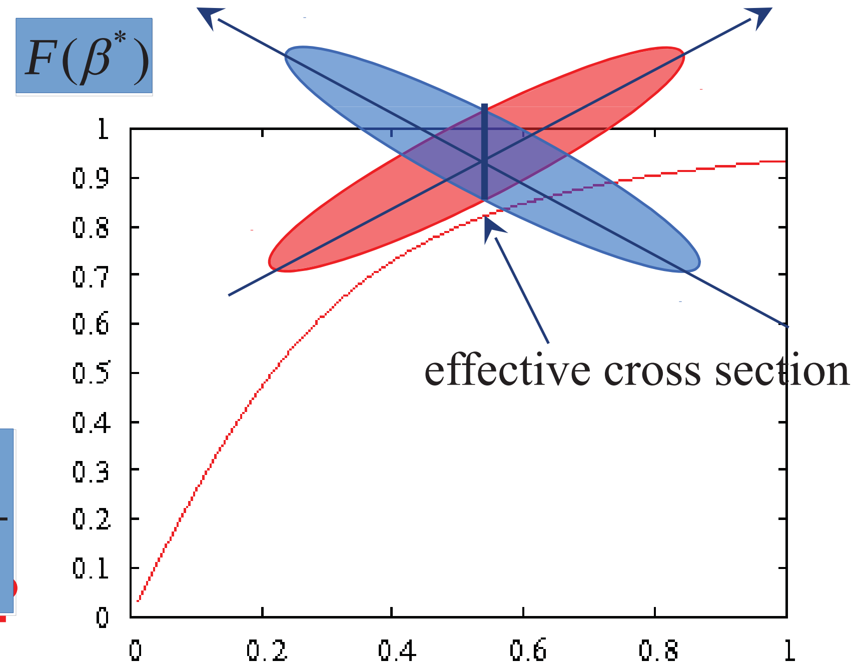
HL-LHC Upgrade Ingredients: Crab Cavities

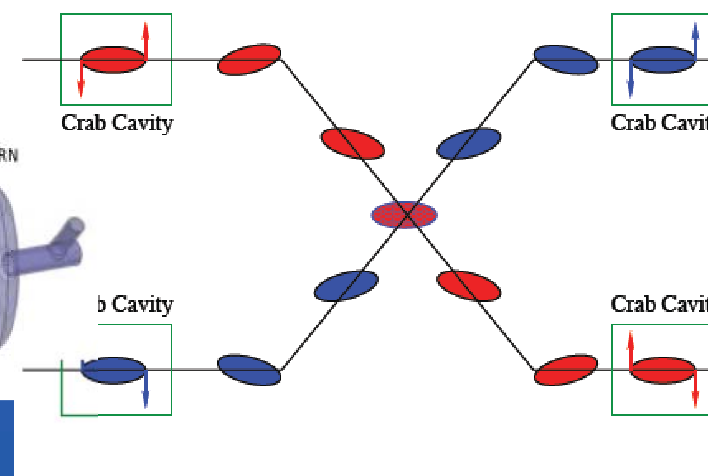
Crab cavities:

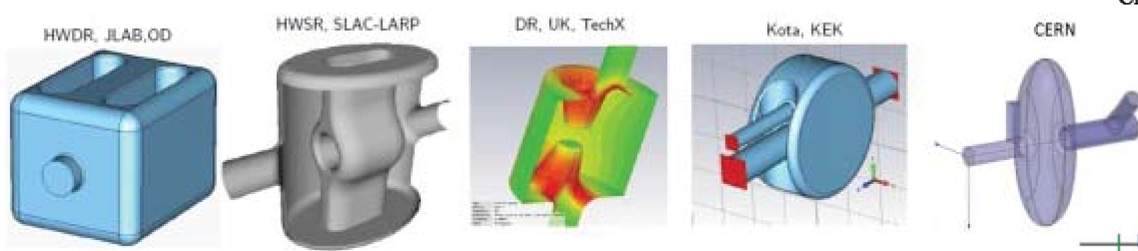
- Reduces the effect of geometrical reduction factor
- Independent for each IP

$$F = \frac{1}{\sqrt{1+\Theta^2}}; \quad \Theta \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$

- Noise from cavities to beam??
- Challenging space constraints

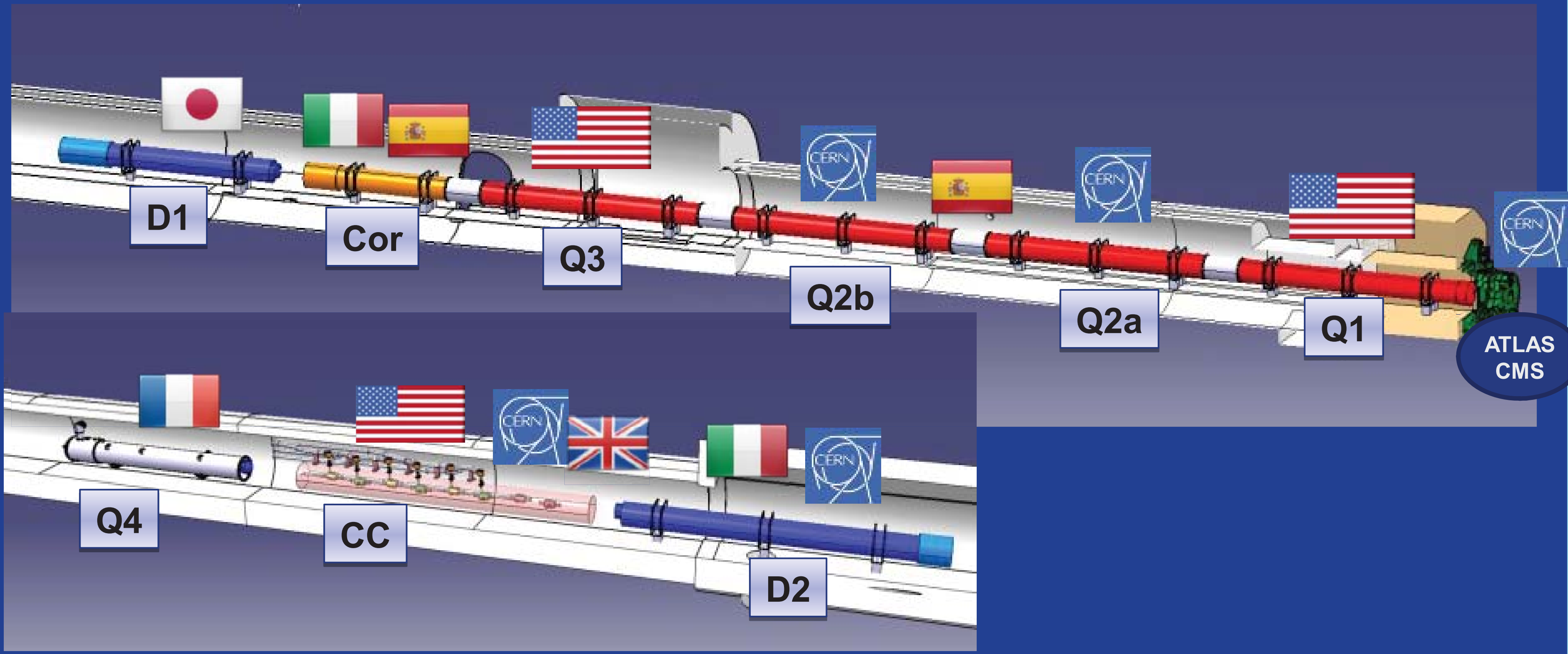






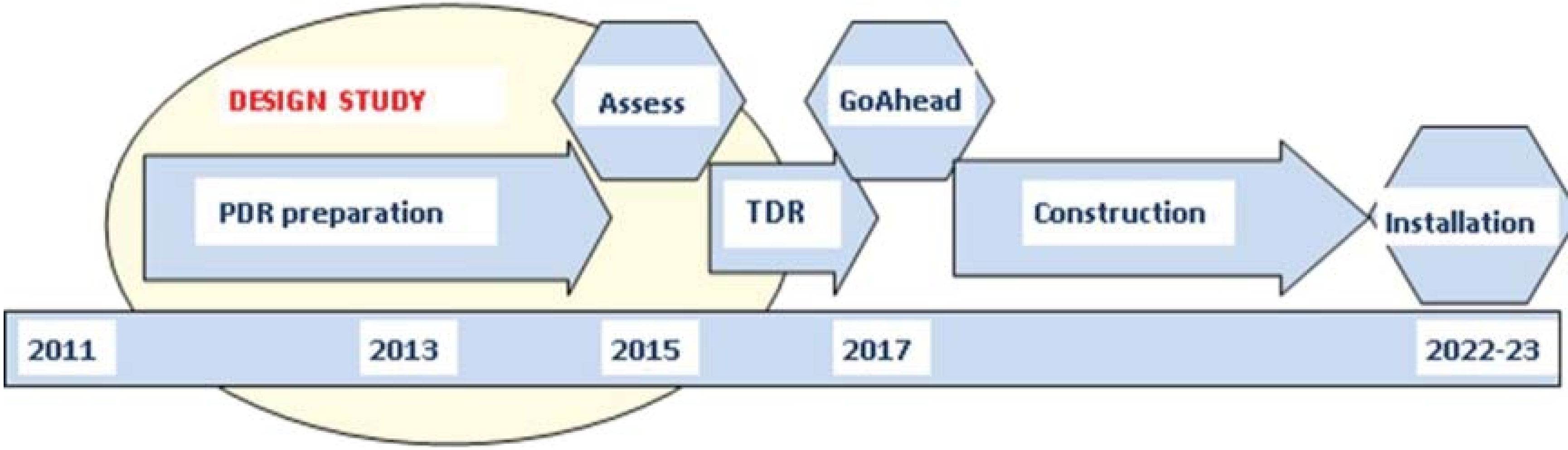
Compact cavities aiming at small footprint & 400 MHz, ~5 MV/cavity

Good Example of International Collaboration



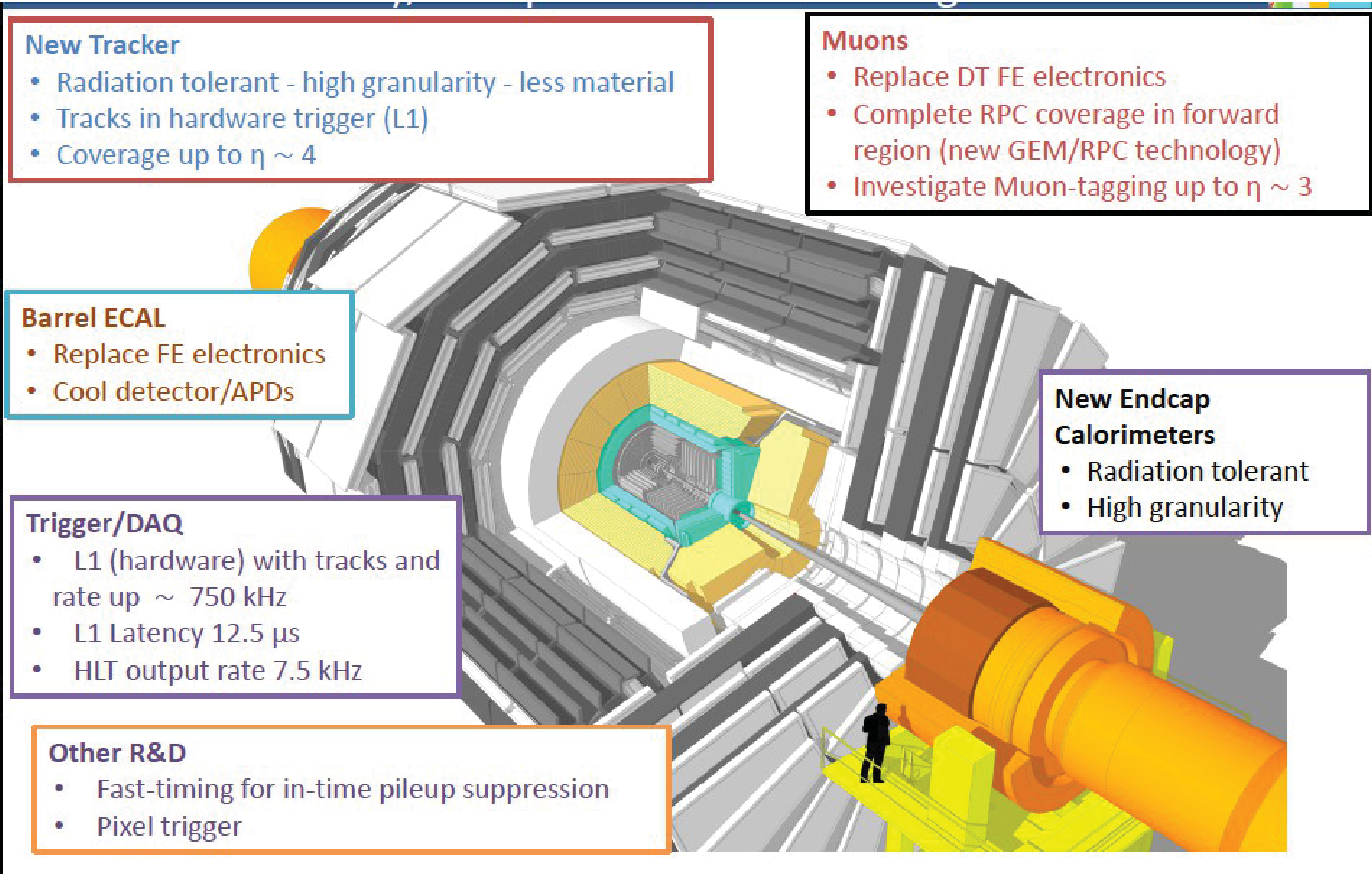
Baseline design of HL-LHC Interaction Region (Bordry)

Implementation plan

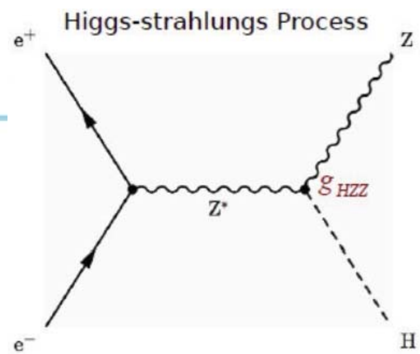


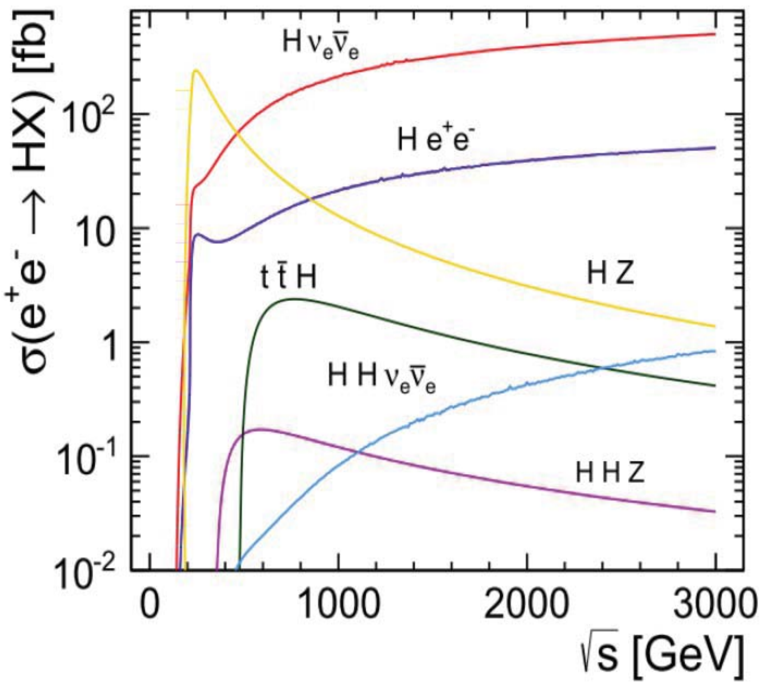
- PDR: Oct 2014 ; Ext. Cost & Schedule Review in March 2015;
- TDR: OCT 2015; TDR-v2 : 2017
- Cryo, SC links, Collimators, Diagnostics, etc. starts in LS2 (2018-2019)
- Proof of main hardware by 2016; Prototypes by 2017 (IT, CC)
- Start construction 2018 from: IT, CC, other main hardware
- IT String test (integration) in 2019-20; Main Installation 2023-24
- Tough but – based on LHC experience – feasible

CMS Phase II Upgrade



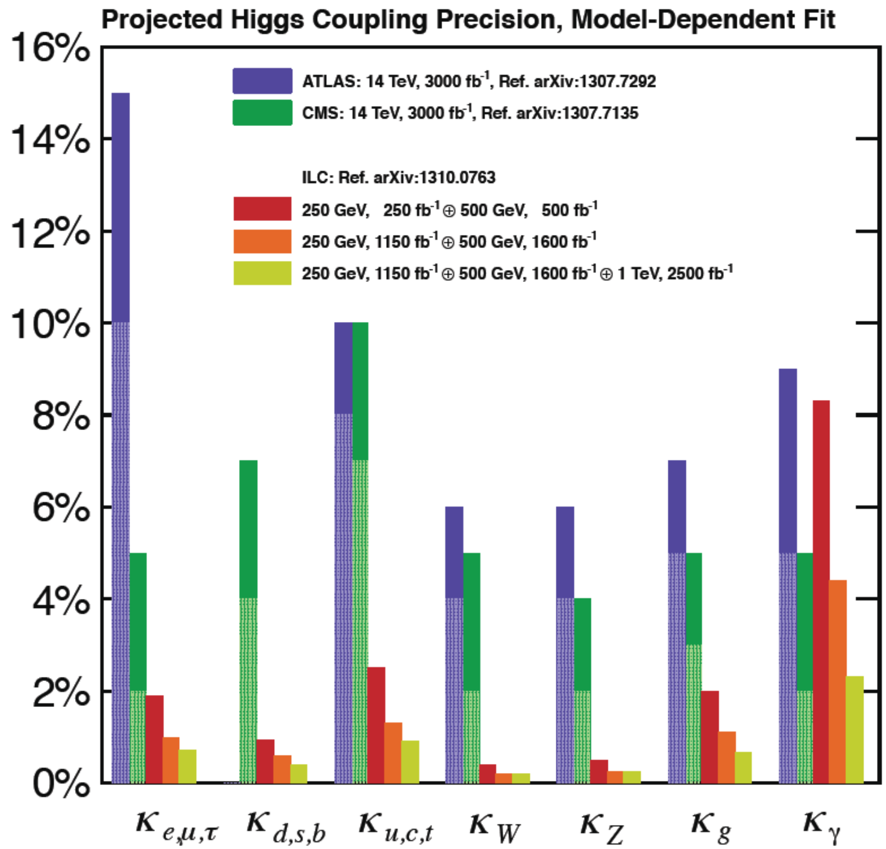
Higgs Studies at the (I)LC





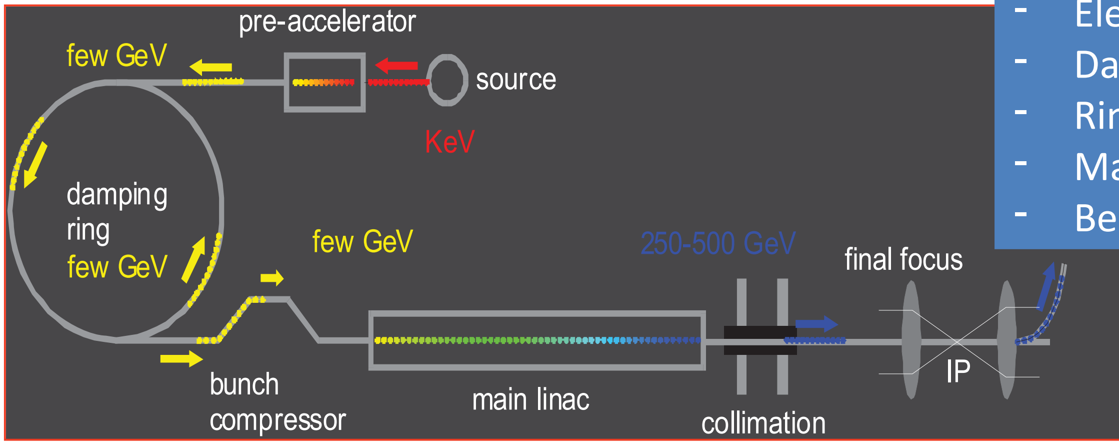
Higgs Couplings (1/2)

[With assumptions; not model-independent.]



The precision couplings measurements at HL-LHC in the 2—10% range can be reduced at the ILC by an order of magnitude, while providing a model independent determination of Higgs partial widths

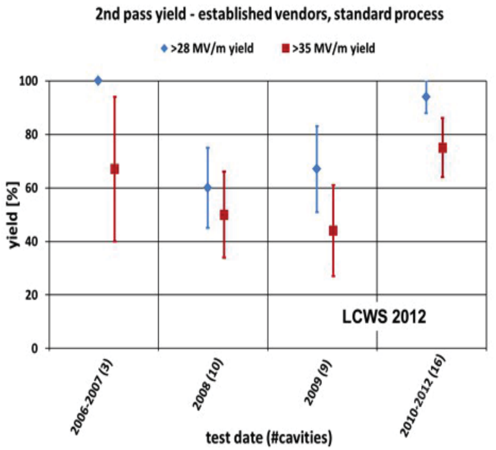
The ILC Accelerator Concept



- Electron and Positron Sources (e-, e+)
- Damping Ring (DR)
- Ring to ML beam transport (RTML)
- Main Linac (ML) : SCRF Technology
- Beam Delivery System (BDS)

1.3 GHz Nb 9-cellCavities	16,024
Cryomodules	1,855
SC quadrupole pkg	673
10 MW MB Klystrons & modulators	436

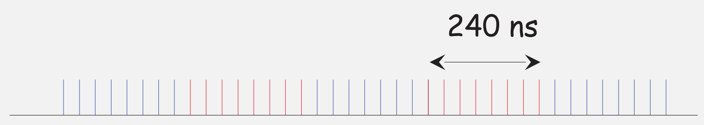
Production yield: 94 % at > 35+/-20%
Average gradient: 37.1 MV/m
> R&D goal of 35 MV/m reached (2012)



CLIC Layout at 3 TeV

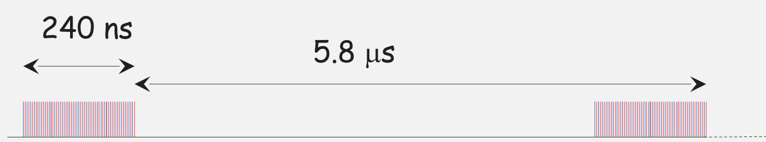
Drive Beam Generation

Drive beam time structure - initial

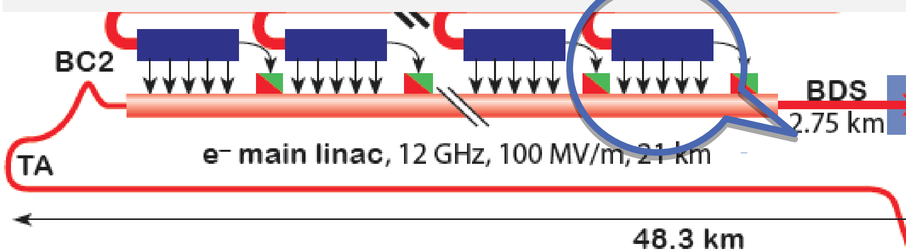


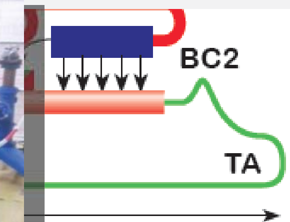
140 μs train length - 24 × 24 sub-pulses
4.2 A - 2.4 GeV – 60 cm between bunches

Drive beam time structure - final



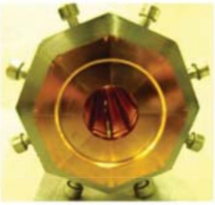
24 pulses – 101 A – 2.5 cm between bunches

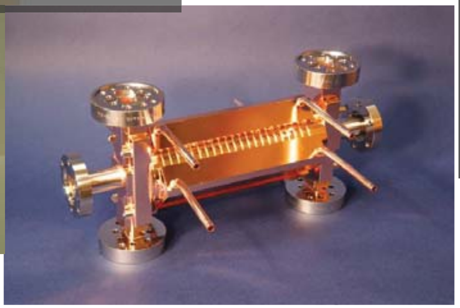


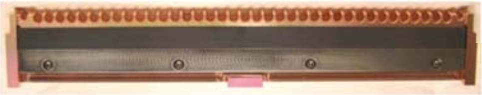


CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump

e⁻ injector, 2.86 GeV







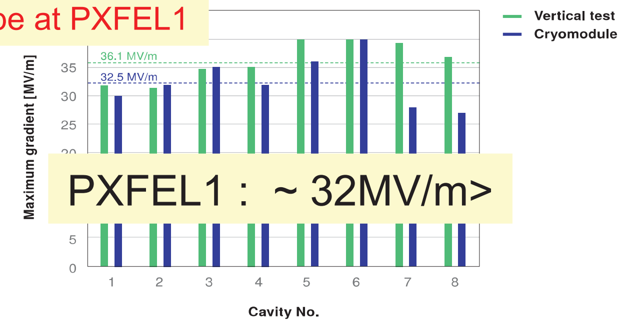
Main Beam Generation Complex

Cryomodule System Tests

DESY: FLASH

- 1.25 GeV linac (TESLA-Like tech.)
- ILC-like bunch trains:
- 600 ms, **9 mA** beam (2009); ← Demonstrated
  800 ms 4.5 mA (2012)
- RF-cryomodule string with beam → PXFEL1 operational at FLASH

XFEL Prototype at PXFEL1

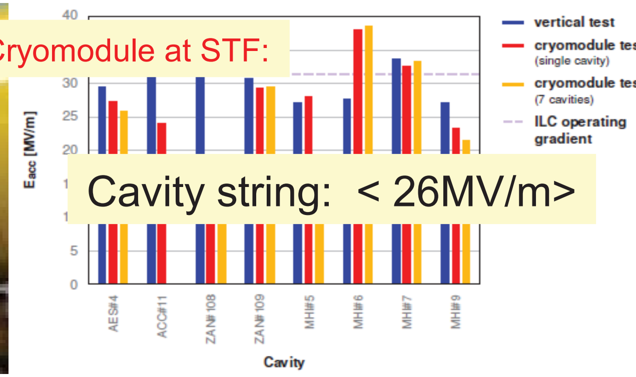


PXFEL1 : ~ 32MV/m>

KEK: STF/STF2

- S1-Global: completed (2010)
- Quantum Beam Accelerator (Inverse Llaser Compton): 6.7 mA, **1 ms** ← Demonstrated
- CM1 test with beam (2014 ~2015)
- STF-COI: Facility to demonstrate CM assembly/test in near future

S1 Global Cryomodule at STF:



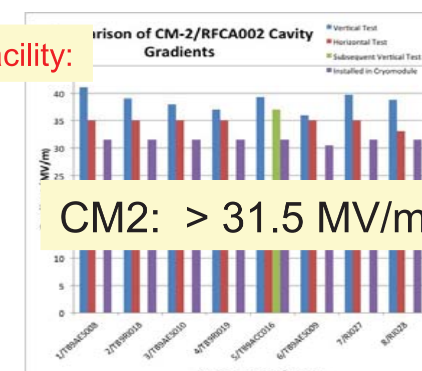
Cavity string: < 26MV/m>

FNAL: ASTA

(Advanced Superconducting Test Accelerator)

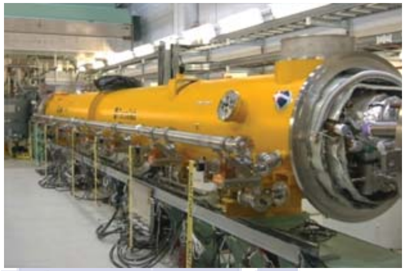
- CM1 test complete
- CM2 operation (2013)
- CM2 with beam (soon)

CM2 at NML Facility:

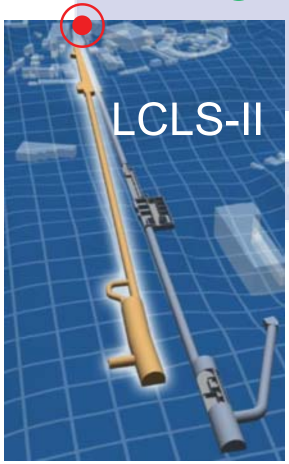


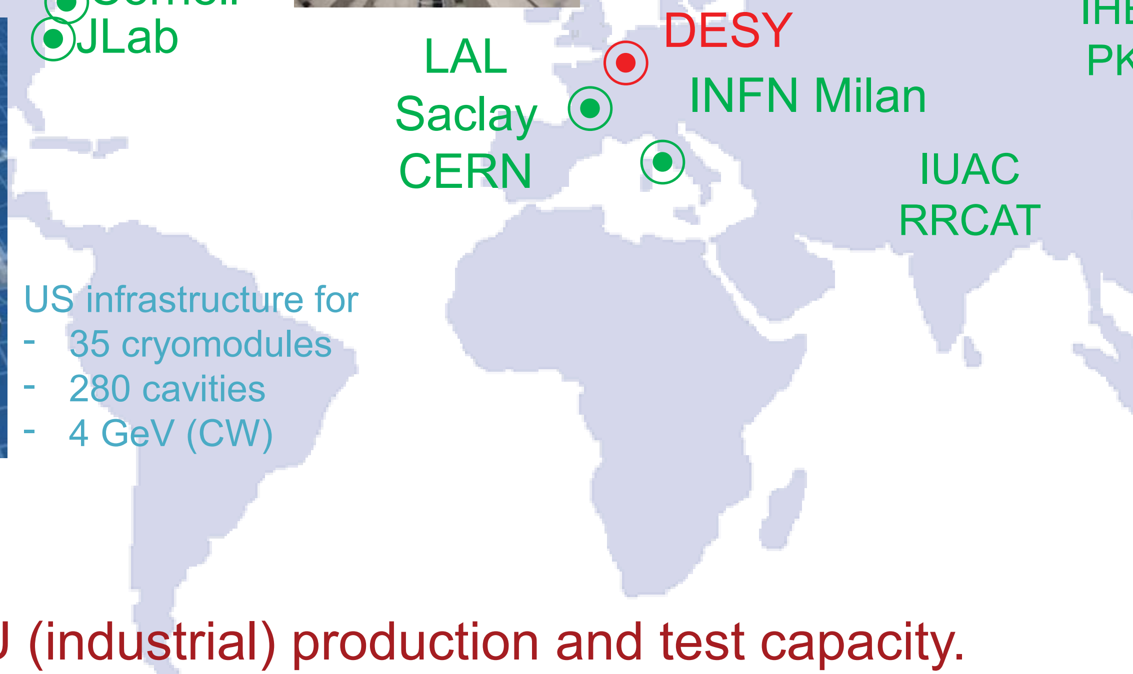
CM2: > 31.5 MV/m>

FEL and advanced linacs with SCRF modules



Largest deployment of this technology to date
- 100 cryomodules
- 800 cavities
- 17.5 GeV (pulsed)





US infrastructure for
- 35 cryomodules
- 280 cavities
- 4 GeV (CW)

US and EU (industrial) production and test capacity. Perfectly placed for start of ILC construction end of this decade.

ILC Recent progress of KEK-ATF

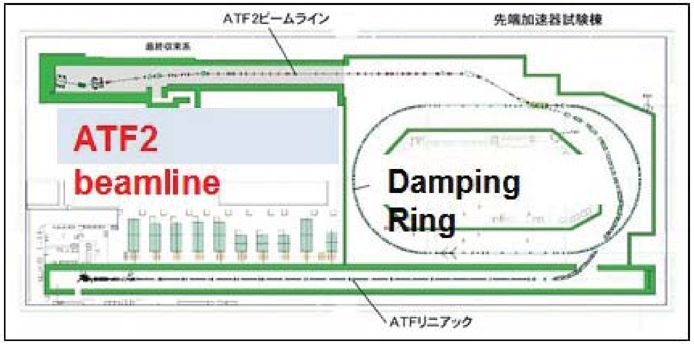
ATF2: Final focus Test beamline

Goal-1: Develop final focus system for ILC

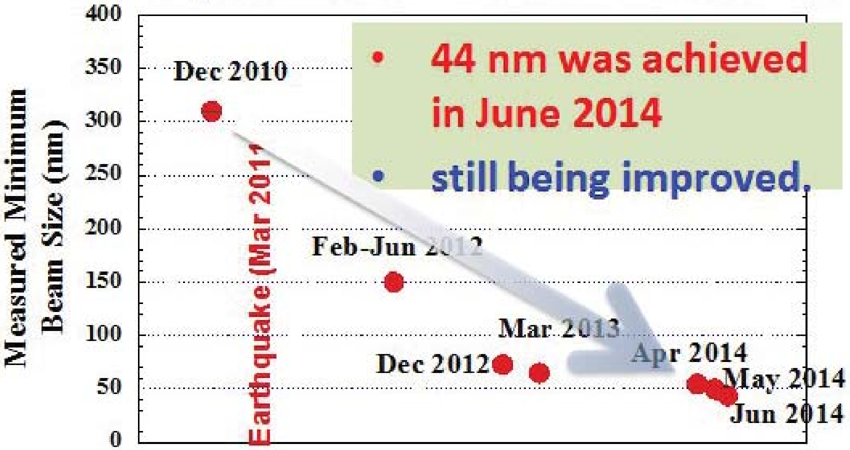
→ 37 nm vertical beam size at IP

Goal-2: Develop beam position stabilization in a few nm

→ Study of Intra-train feedback has been started.



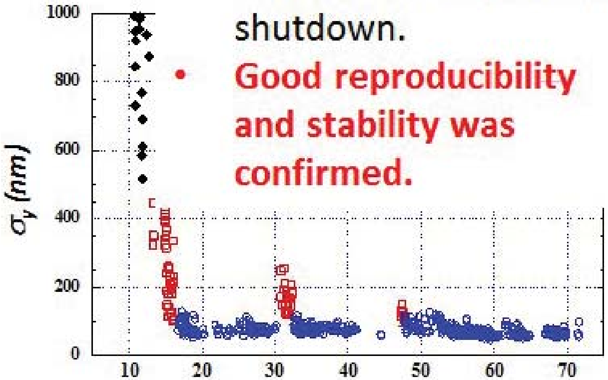
History of measured minimum beam size



- 44 nm was achieved in June 2014
- still being improved.

Presented by K.Kubo at IPAC2014

- Small beam size (<50 nm) was recovered in a day from an accelerator shutdown.
- Good reproducibility and stability was confirmed.

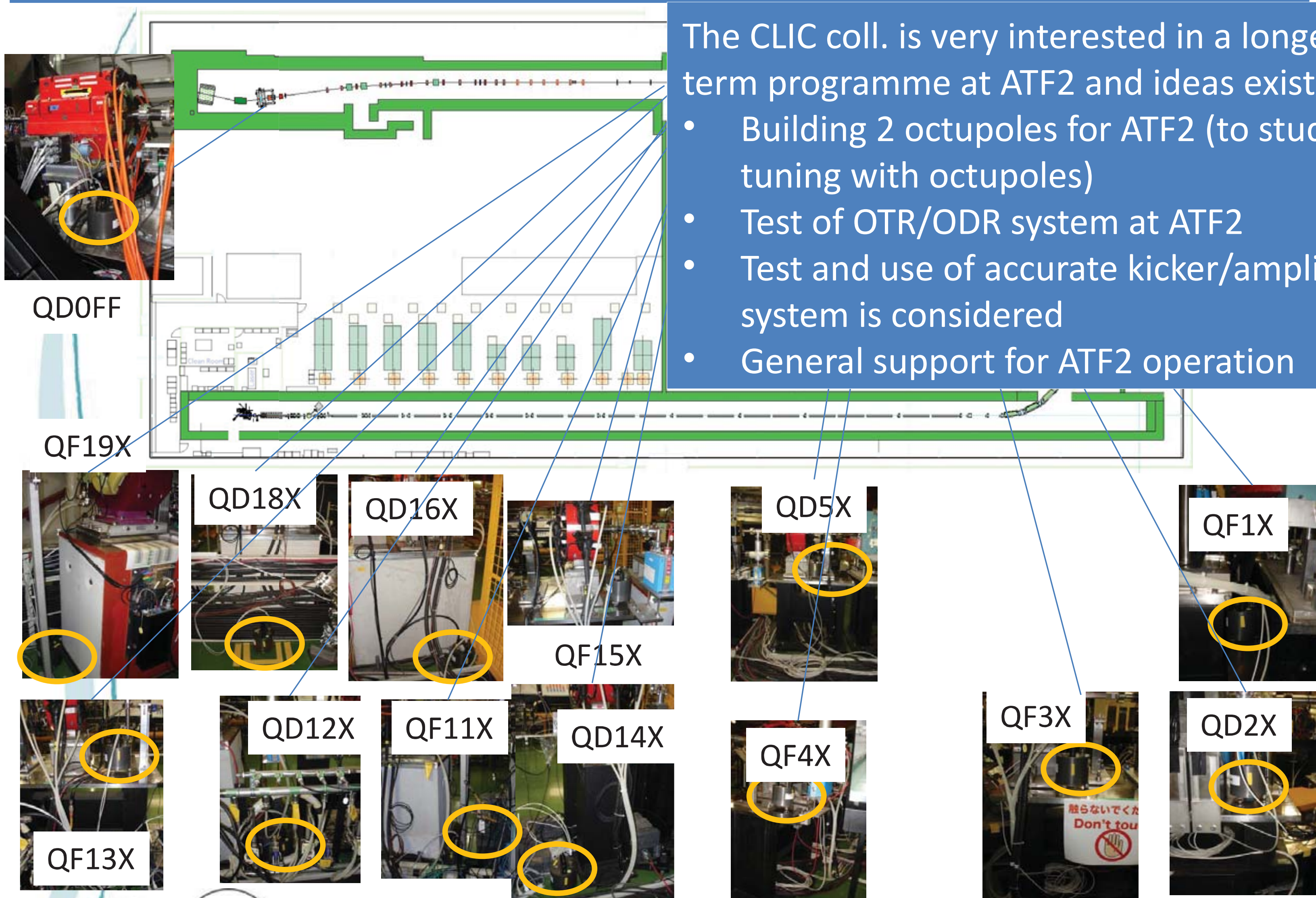


- **Small beam tuning** (All members; IHEP, KNU, KEK, Tokyo, Hiroshima,…)
- **Studies on multipole field error and Wake field** (IHEP, KEK,…)
- **Low-Q IP BPMs (KNU) High resolution BPM electronics (KNU, KEK)**

ATF2: Stabilisation Experiment

The CLIC coll. is very interested in a longer term programme at ATF2 and ideas exist for:

- Building 2 octupoles for ATF2 (to study FFS tuning with octupoles)
- Test of OTR/ODR system at ATF2
- Test and use of accurate kicker/amplifier system is considered
- General support for ATF2 operation



#1 Question for the World HEP Community

LHC – does it stand for:

- *Large Hadron Collider*

or

- *Last Hadron Collider?*

This was an old question. It was raised again and again after the demise of the SSC, e.g., Snowmass 1996, Snowmass 2001. But after Snowmass 2005, this question was put aside as our community decided to go full steam ahead for the ILC.

Why the Renewed Interest?

- A trigger was the discovery of the Higgs. As its mass is low, a circular *e+e-* collider can serve as a Higgs factory. But the ring size must be big in order to combat synchrotron radiation. Such a big ring will be ideal for a future *pp* collider.
- CERN
  - Has established a 20-year plan for the LHC and HL-LHC, can now afford to study a post-LHC machine
  - CLIC is on the table. However, an energy frontier big circular *pp* collider is no doubt the ultimate goal.
- China
  - A "*new kid on the block*" for large size circular colliders, bringing in much needed fresh blood
  - Encouraged by the recent achievements in neutrino physics, powered by the nation's economic strength, eager to take on "big things"
  - Team is young, but enthusiastic and optimistic about the future of our field
- US
  - P5 report:

    "Recommendation 24: Participate in global conceptual design studies and critical path R&D for future very high-energy proton-proton colliders. Continue to play a leadership role in superconducting magnet technology focused on the dual goals of increasing performance and decreasing costs."

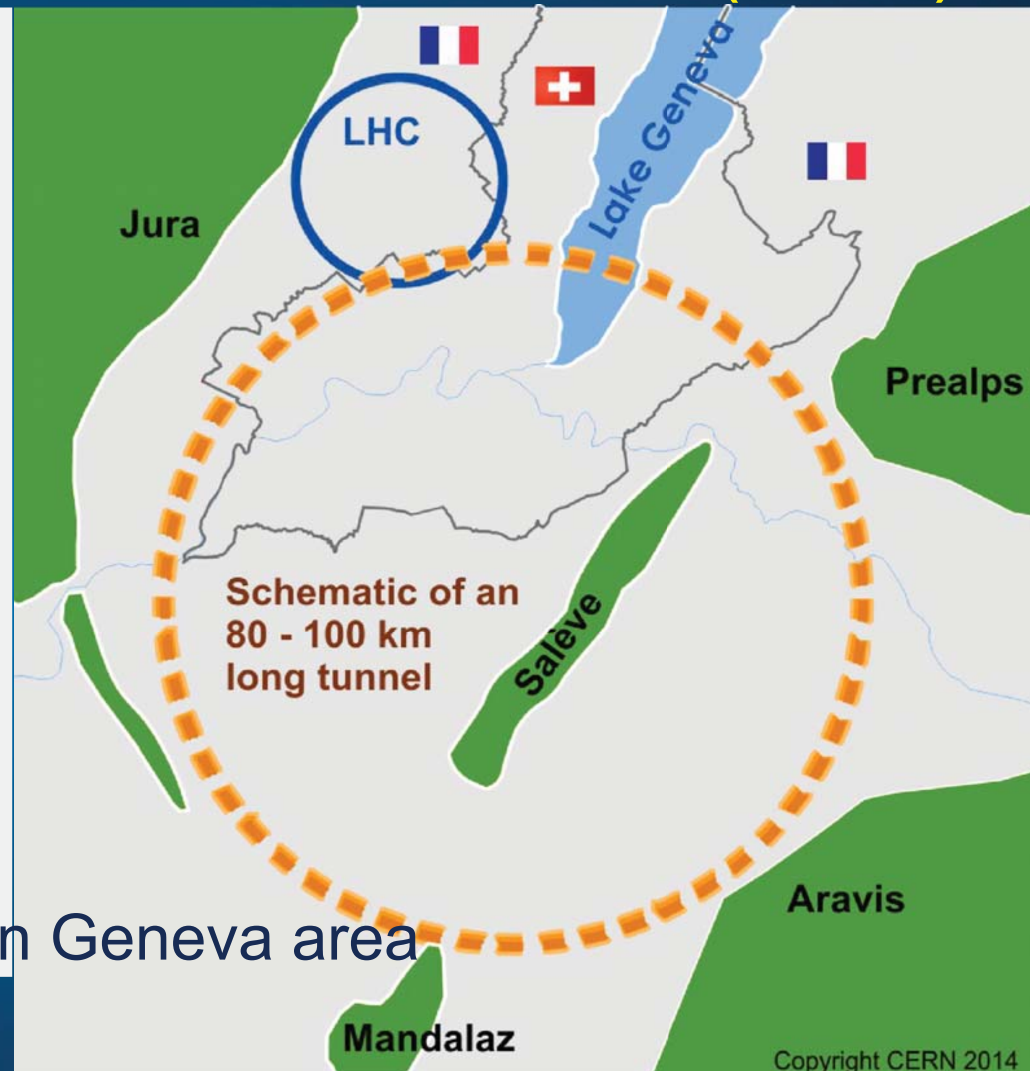
Future Circular Collider Study - SCOPE
CDR and cost review for the next ESU (2018)

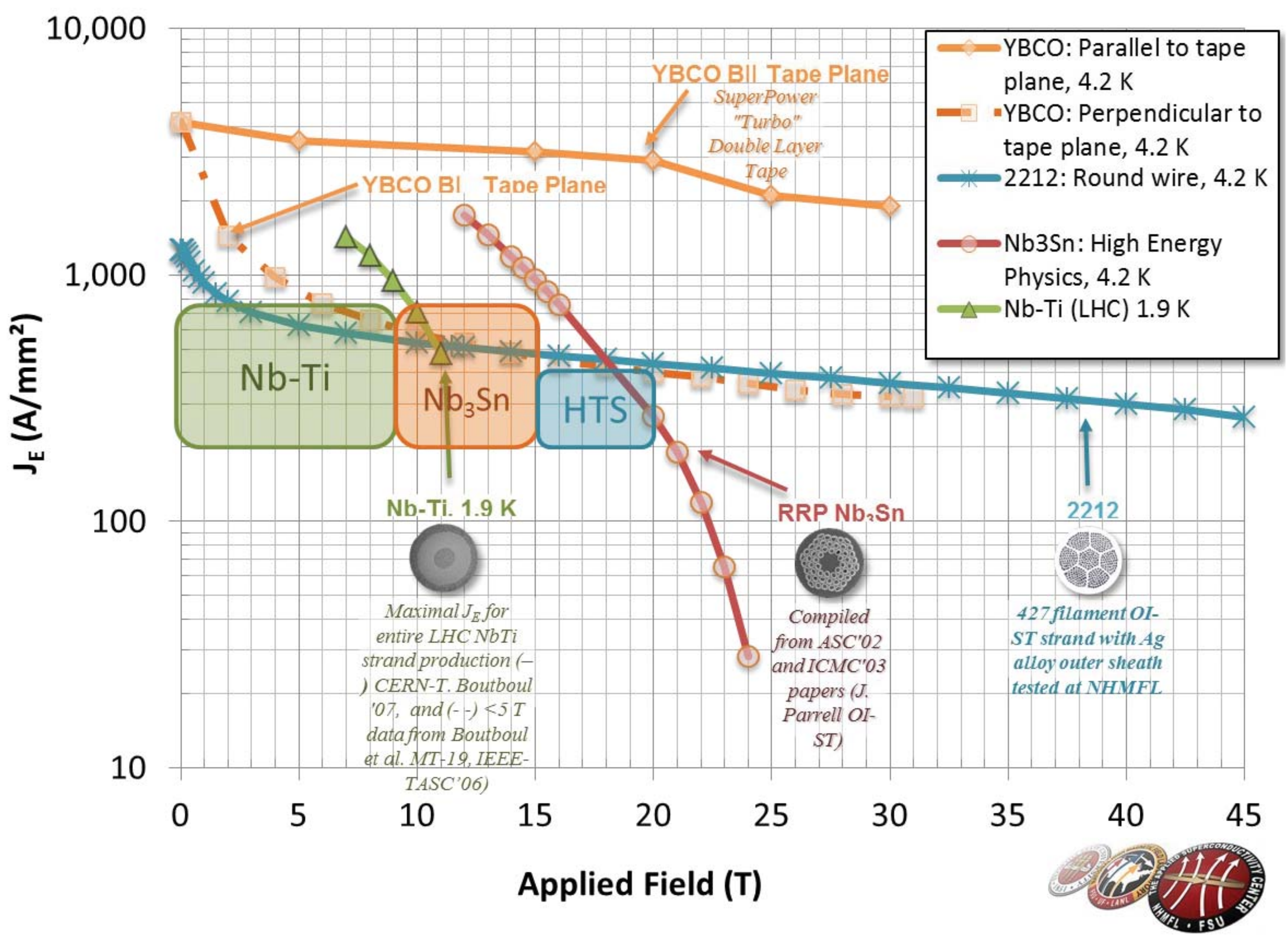
Forming an international collaboration to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

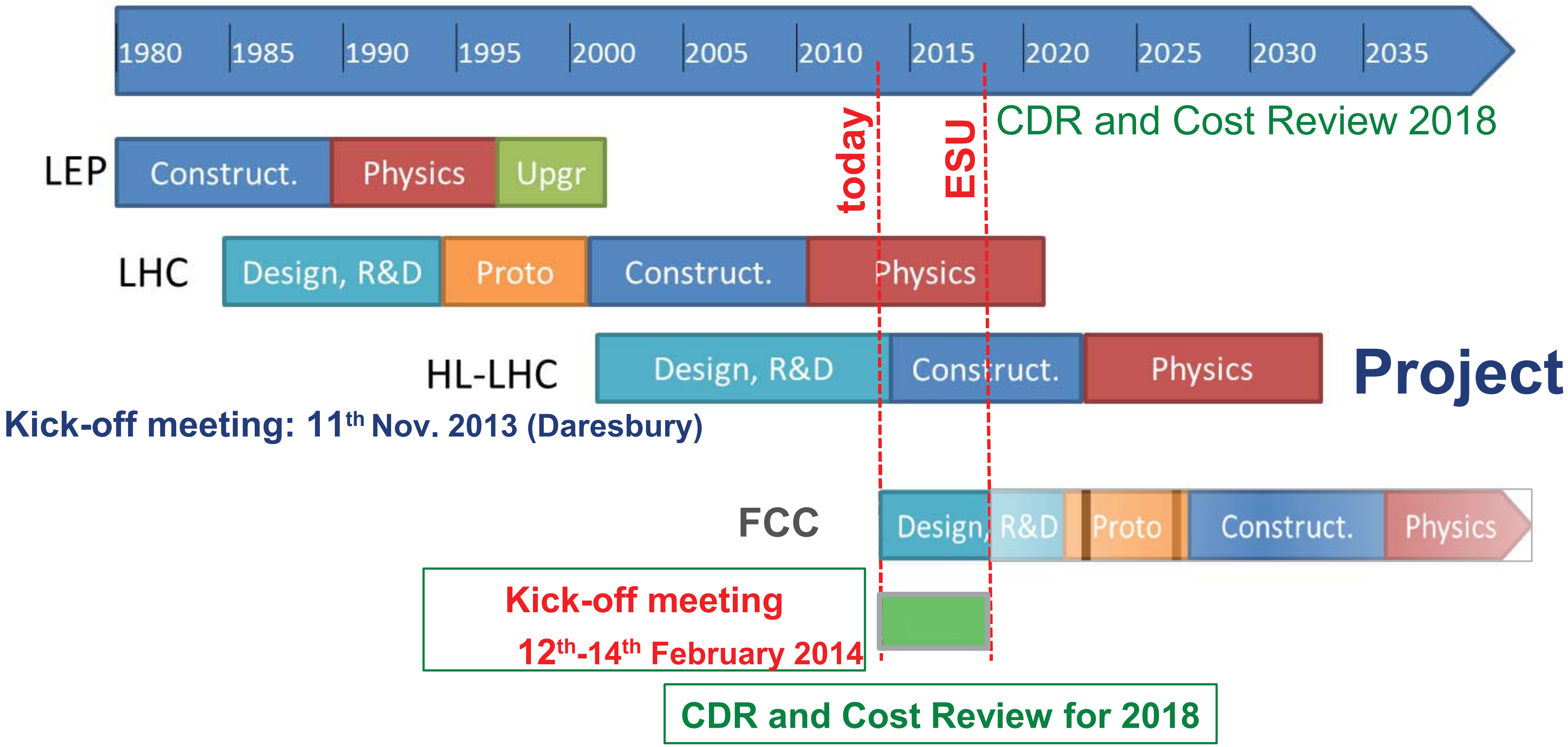
- **e^+e^- collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area





(courtesy of Peter Lee, Applied SC Center of FSU)

FCC study milestones



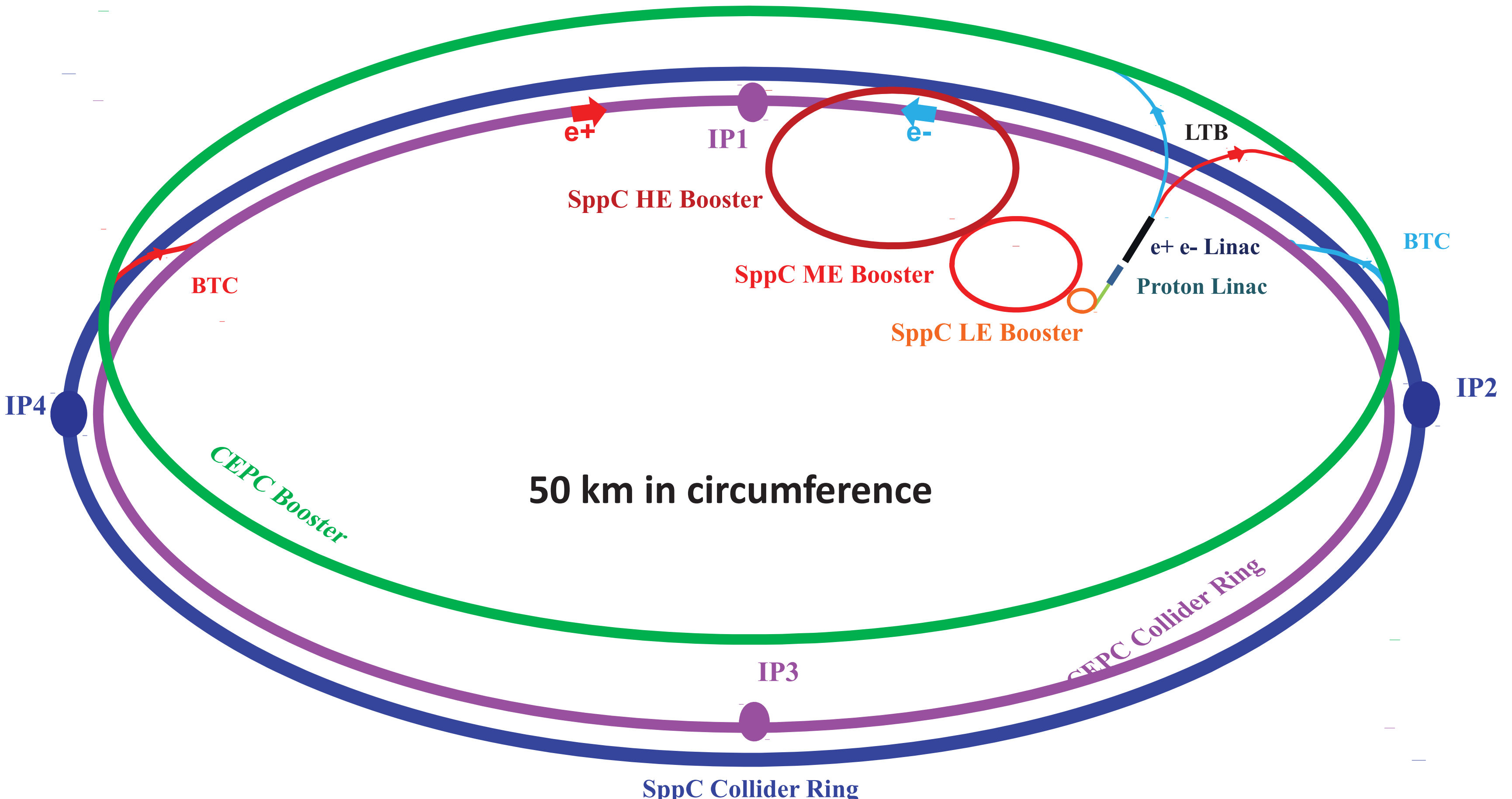
FCC Kick-off Meeting

The CEPC-SppC Kick-off Meeting in Beijing

- The Chinese CEPC+SPPC Study Group kick-off meeting took place Sept. 13-14 in Beijing
- Participation by over 120 physicists from 19 domestic institutes
- Domestic accelerator, theoretical and experimental physicists were organized

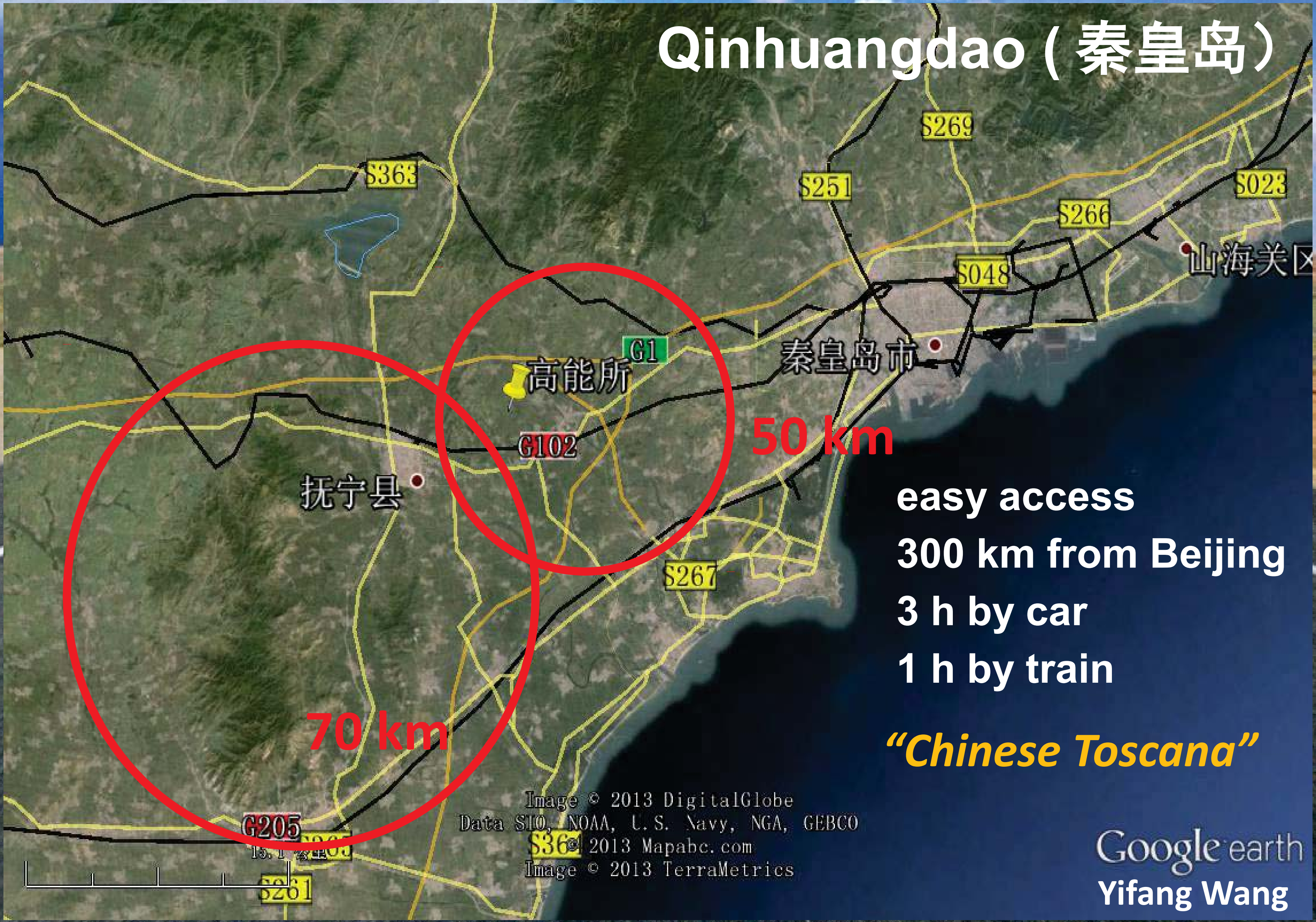
CEPC-SppC

CEPC is an 240 GeV Circular Electron Positron Collider, proposed to carry out high precision study on Higgs bosons, which can be upgraded to a 70 TeV or higher pp collider SppC, to study the new physics beyond the Standard Model.



CepC/SppC study (CAS-IHEP)

e^+e^- collisions; then *pp* collisions



CEPC-SppC Project Timeline (dream)

CEPC

2015 — 2020 — 2025 — 2030 — 2035

- Pre-studies (2013-2015)
- R&D Engineering Design (2016-2020)
- Construction (2021-2027)
- Data taking (2028-2035)

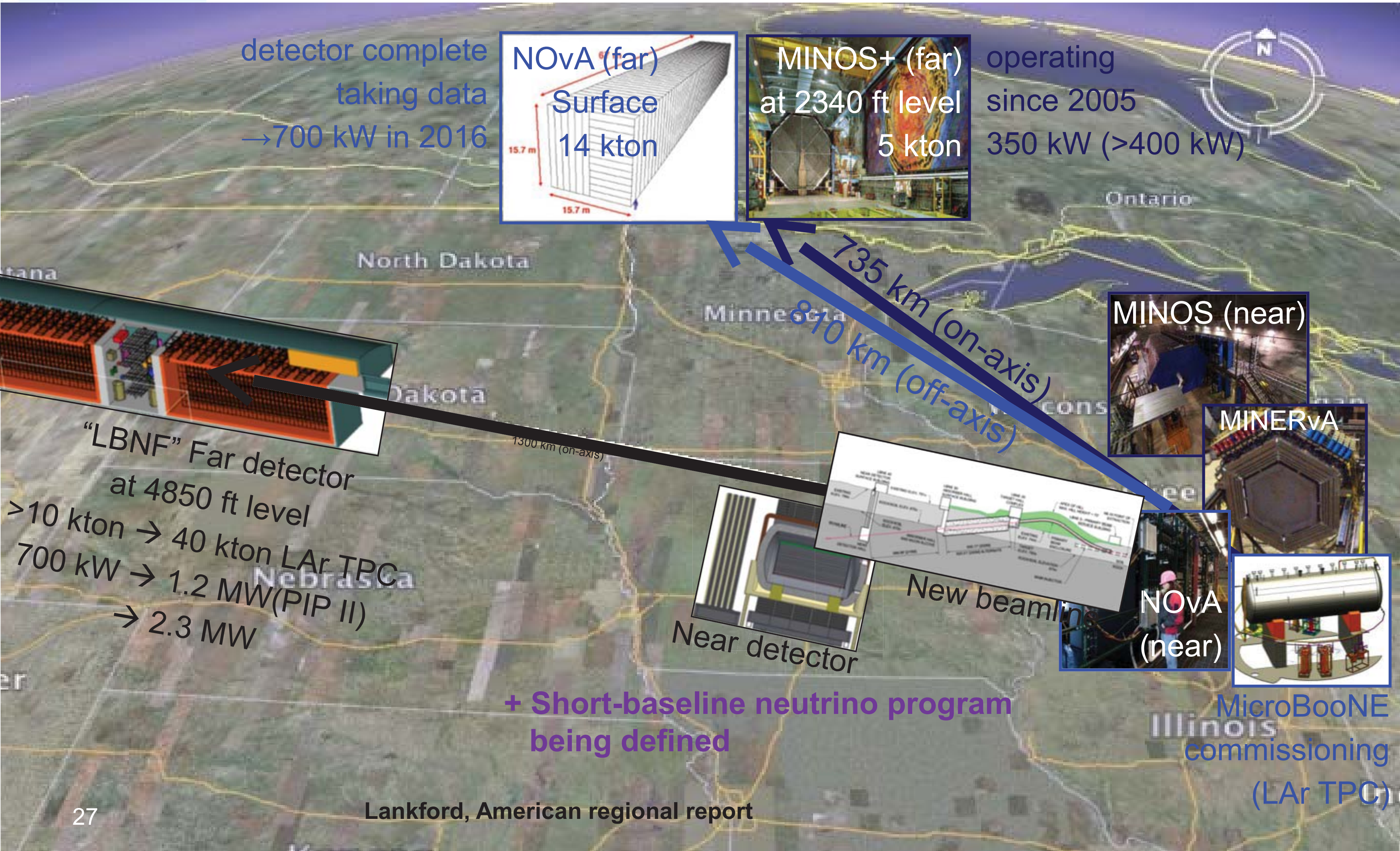
1st Milestone: pre-CDR (by the end of 2014)
→ R&D funding request to Chinese government in 2015 (China's 13th Five-Year Plan 2016-2020)

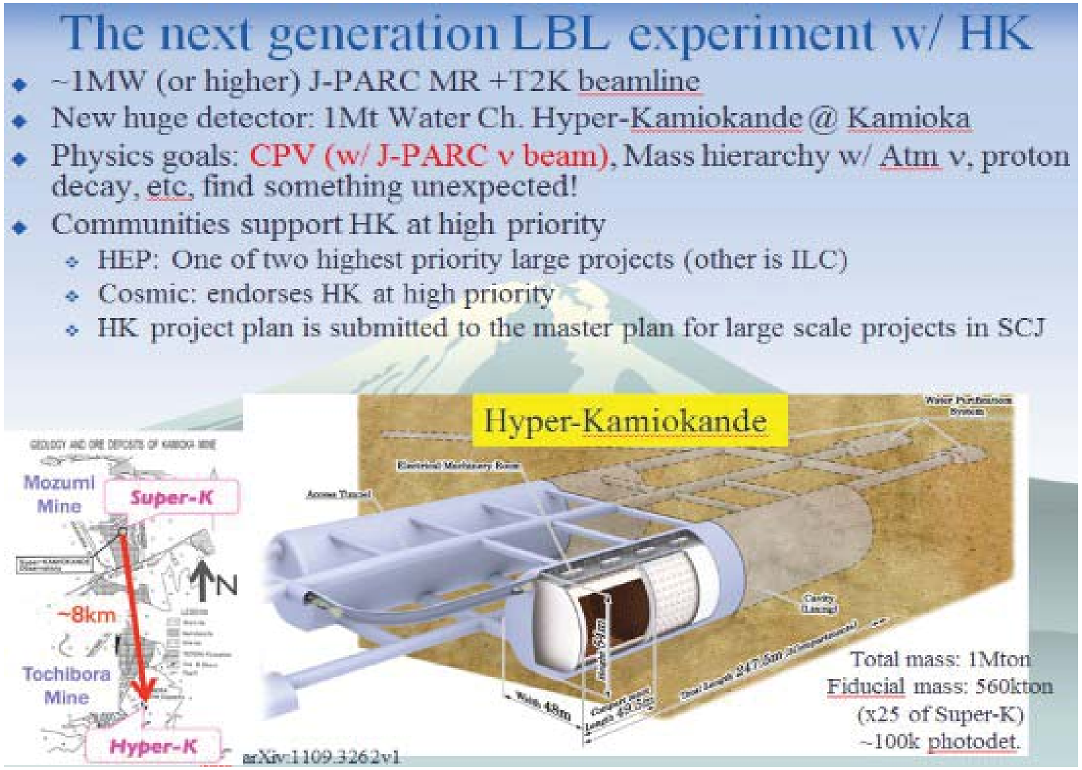
SppC

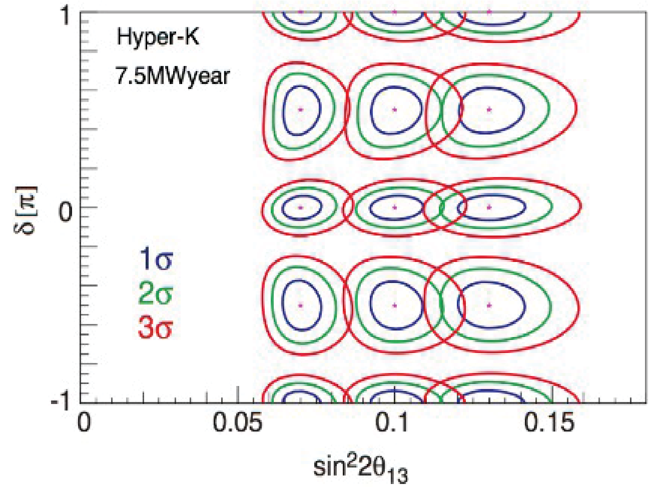
2020 — 2030 — 2040

- R&D (2014-2030)
- Engineering Design (2030-2035)
- Construction (2035-2042)
- Data taking (2042-2055)

Evolution of Fermilab Neutrino Experiments







Requirement : joint proposal of HK and J-PARC upgrade

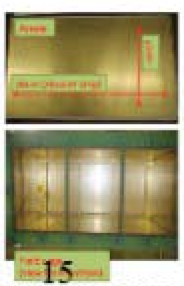
Liquid Ar TPC Activity in Japan

Experimental assessment of detector performance such as dE/dx measurement is performed with 250L set up

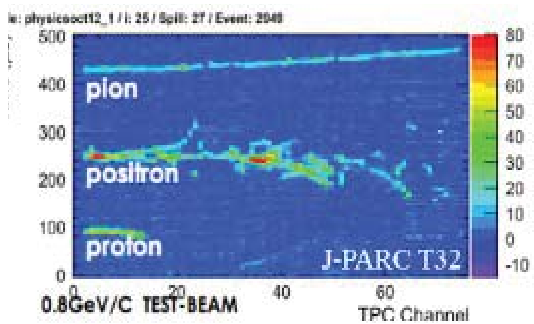
Single phase 2D charge readout plane

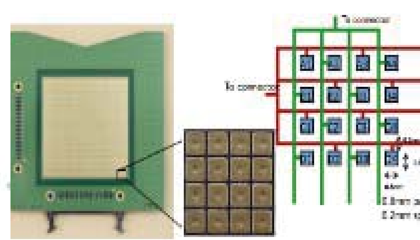
Economical low noise readout electronics with ASIC technology eventually applicable in cold environment

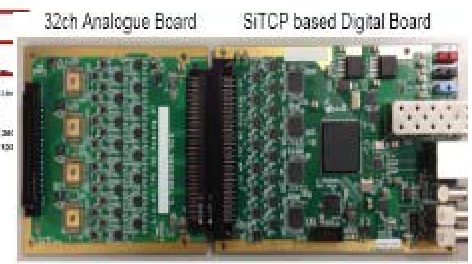
250L set up



TPC for 250L







Experiment@LBNF and Hyper-Kamiokande

	Experiment@LBNF	Hyper-Kamiokande
Beam Energy	120 GeV (60 – 120 GeV)	30 GeV
Beam Power	≥ 1.2 MW	≥ 750 kW
Beam Configuration	On-axis, Wide-band	Off-axis (2.5^{o}), Narrow-band
Baseline	1300 km (default)	300 km
Detector Technology	Liquid Ar	Water Cherenkov
Far detector F.V.	35 kt (LBNE) → 40 kt (P5)	560 kt
Near Detector	Yes	Yes
Estimated Cost (to be re-evaluated)	~$1.5B* (Full Costing* for beamline, near and far detectors)	~$800M (only for far detector)
Proposal Status	DOE CD1 approval (in the process of reformulation)	In discussion w/ MEXT (See M. Shiozawa's talk)

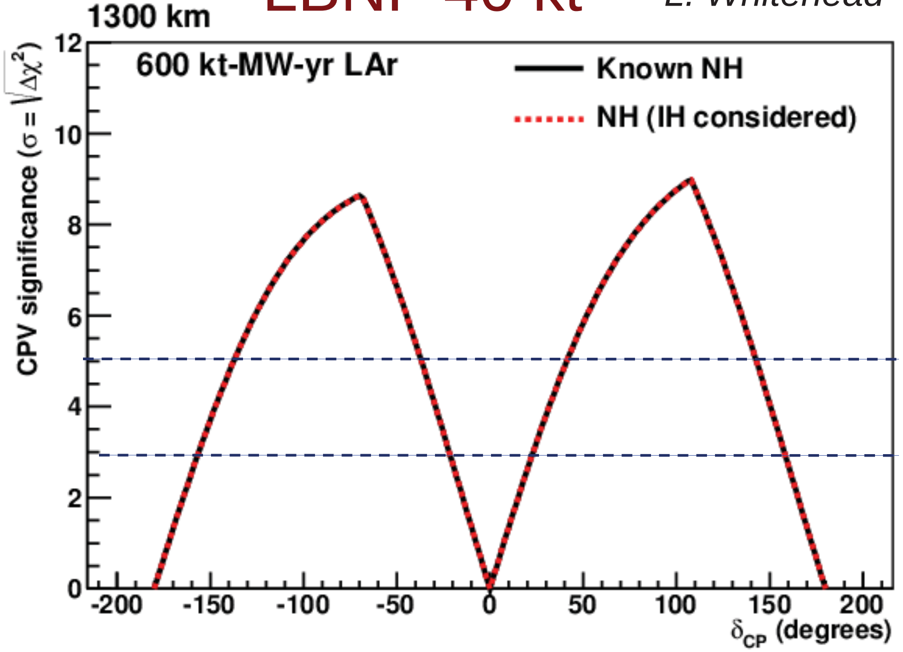
(* includes: project management, contingency and escalation)

These two proposed experiments are complementary to each other in many aspects. However, the science goals of each experiment must be compelling on its own. And in my opinion they are.

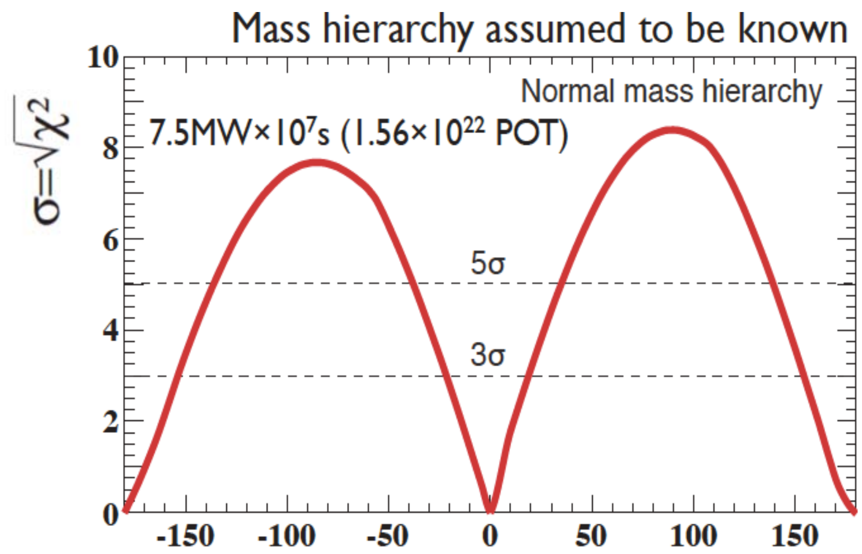
LBNE and HyperK Sensitivities to CPV

LBNF 40 kt

L. Whitehead



HyperK



Exposure of
600 kt-MW-yr
(~ 40 kt x 1.2MW x 12.5 yrs)

>3σ CPV sensitivity for 75% of δ

>5σ CPV sensitivity for 56% of δ

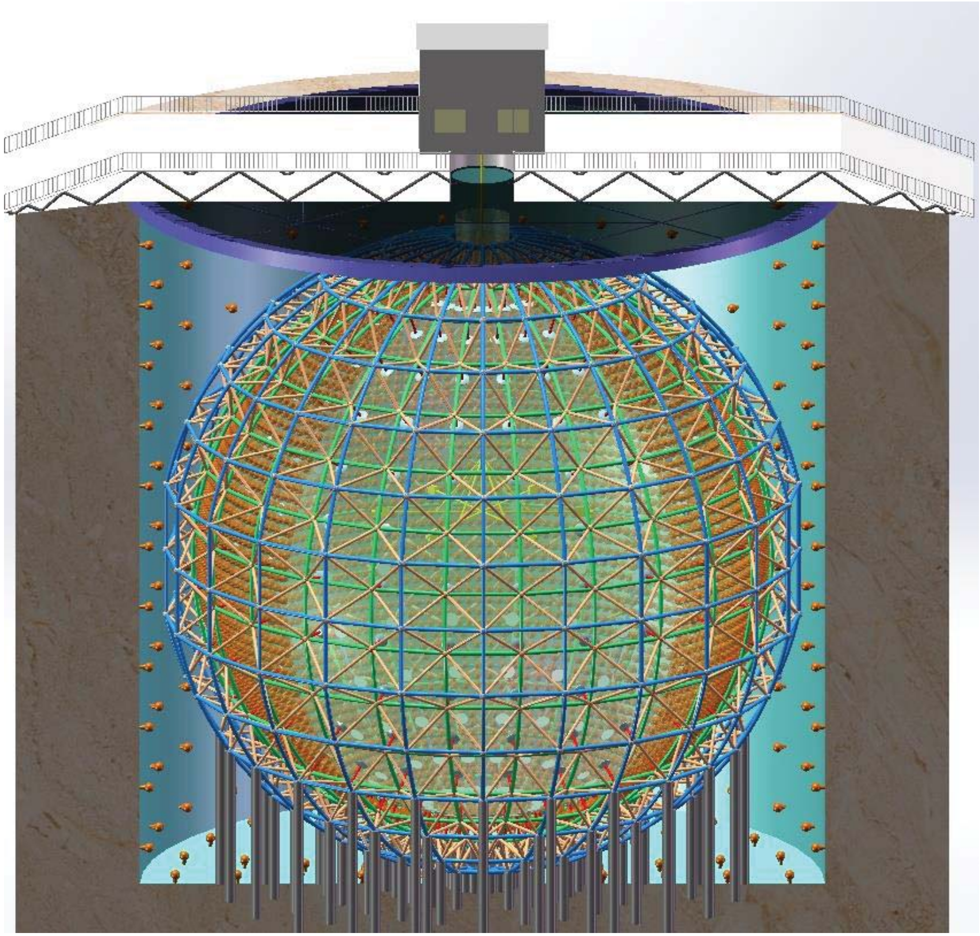
Exposure of
7.5 MW x 10^7 s (~ 750 kW x 10 yr)
w/ 560 kt F.V. allows:

>3σ CPV sensitivity for 76% of δ

>5σ CPV sensitivity for 58% of δ

The JUNO Experiment

- Jiangmen Underground Neutrino Observatory, a multiple-purpose neutrino experiment, approved in Feb. 2013. ~ 300 M$.



- 20 kton LS detector
- 3% energy resolution
- 700 m underground
- Rich physics possibilities
  - Reactor neutrino for Mass hierarchy and precision measurement of oscillation parameters
  - Supernovae neutrino
  - Geoneutrino
  - Solar neutrino
  - Atmospheric neutrino
  - Exotic searches

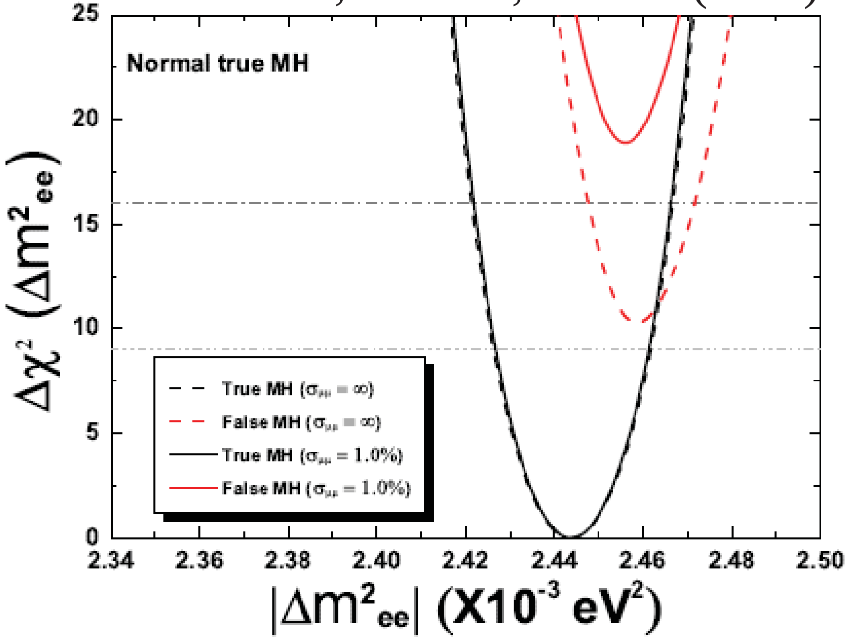
Talk by Y.F. Wang at ICFA seminar 2008, Neutel 2011; by J. Cao at Nutel 2009, NuTurn 2012 ; Paper by L. Zhan, Y.F. Wang, J. Cao, L.J. Wen, PRD78:111103, 2008; PRD79:073007,2009

Physics Reach

Thanks to a large θ_{13}

- Mass hierarchy
- Precision measurement of mixing parameters
- Supernova neutrinos
- Geoneutrinos
- Solar & atmospheric neutrinos
- Sterile neutrinos

Y.F. Li et al, PRD 88, 013008 (2013)

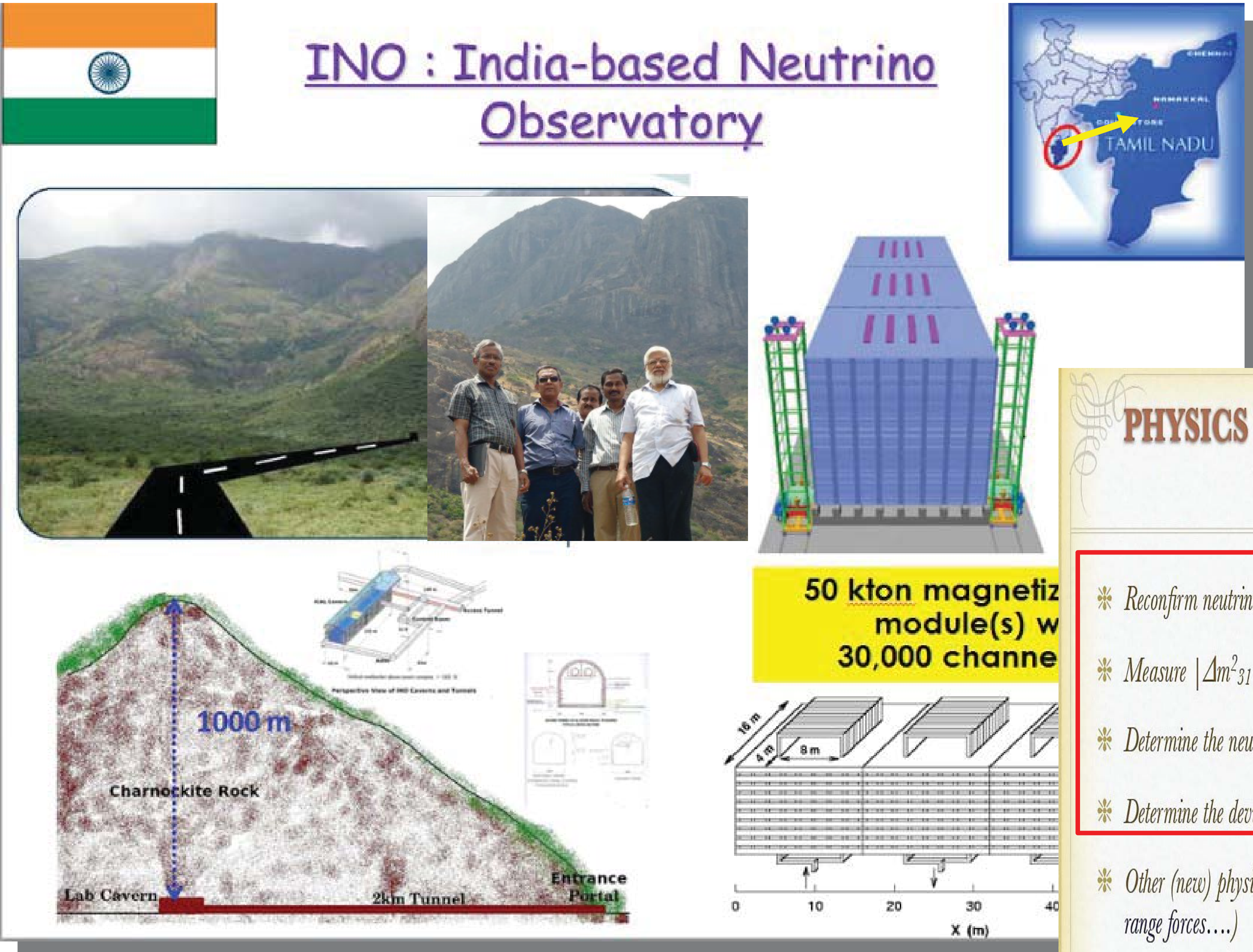


	Current	JUNO
Δm^2_{12}	4%	0.6%
Δm^2_{23}	5%	0.6%
$\sin^2\theta_{12}$	5%	0.7%
$\sin^2\theta_{23}$	10%	N/A
$\sin^2\theta_{13}$	6% ➔ 3%	~ 15%

For 6 years, mass hierarchy can be determined at 4σ level, if $\Delta m^2_{\mu\mu}$ can be determined at 1% level

Detector size: 20kt
Energy resolution: 3%/√E
Thermal power: 36 GW

5. Underground Project in India

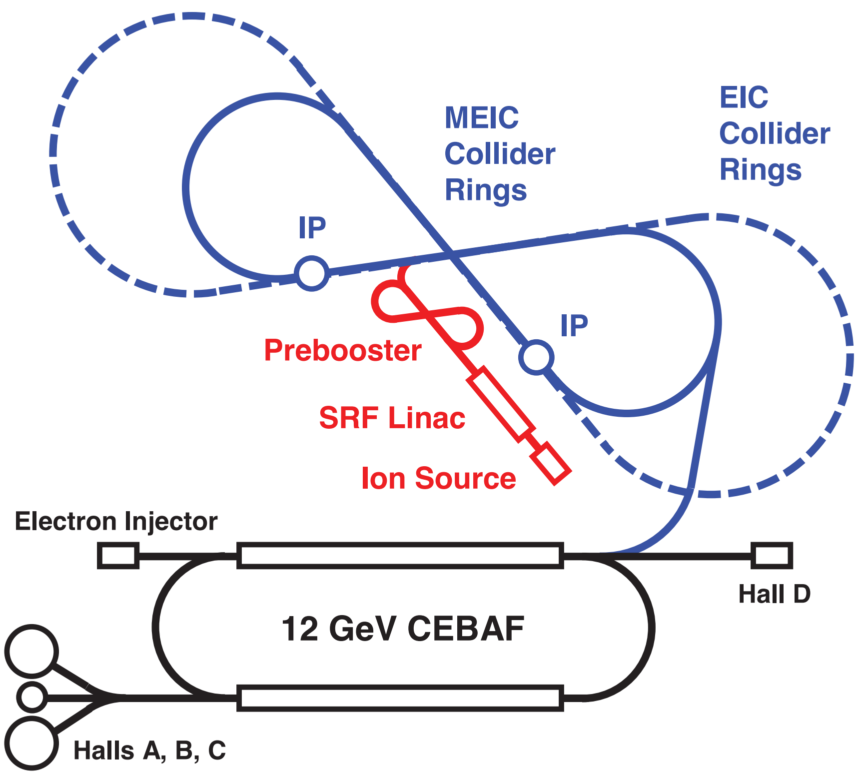


PHYSICS WITH ATMOSPHERIC NEUTRINOS

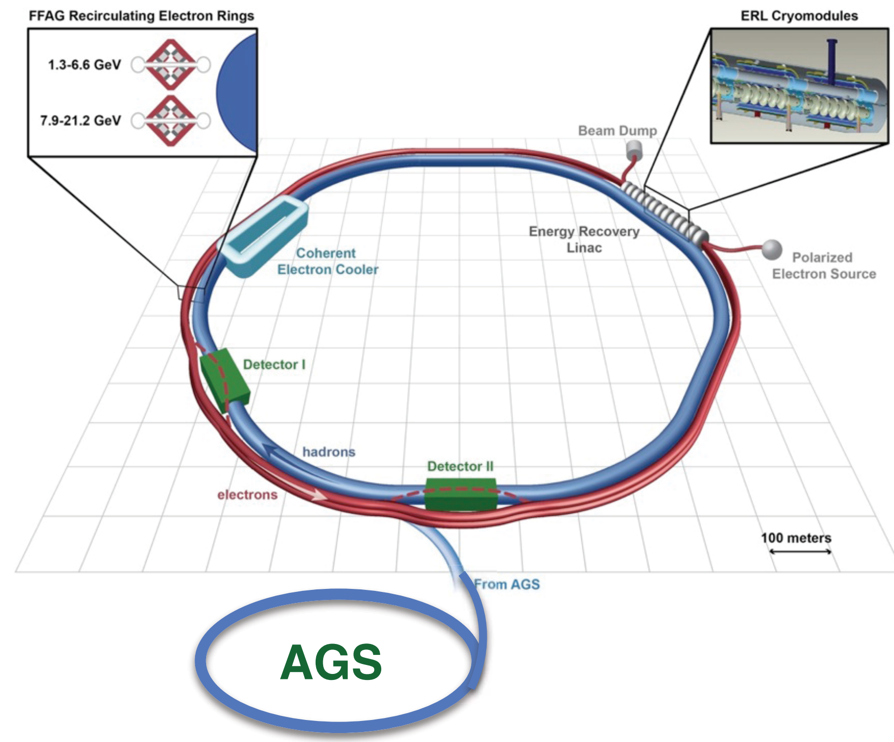
- *Reconfirm neutrino oscillations from distortion in L/E*
- *Measure* $|\Delta m^2_{31}|$ *and* $\sin^2 2\theta_{23}$
- *Determine the neutrino mass hierarchy*
- *Determine the deviation of* θ_{23} *from* 45° *and its octant*
- *Other (new) physics (sterile neutrinos, NSI, CPTV, LIV, Long range forces….)*
- *Very high energy neutrinos and muons*

U.S.-based EICs – the Machines

MEIC (JLab)



eRHIC (BNL)



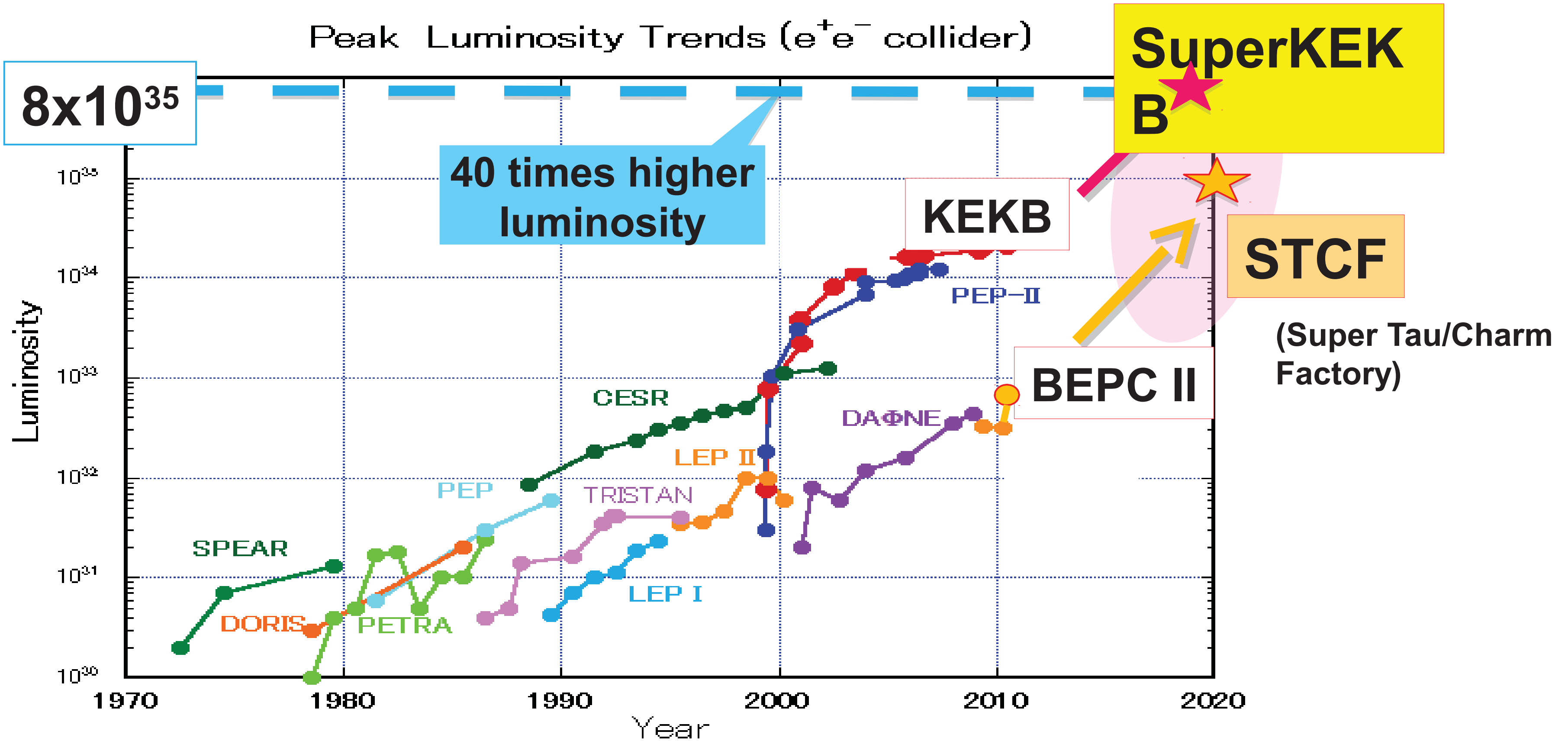
✧ **First polarized electron-proton/light ions collider in the world**

✧ **First electron-nucleus (various species) collider in the world**

✧ **Both cases make use of existing facilities** (H. Montgomery, Oct 29)

Heavy Flavor Physics

- Livingston plot for luminosity:



- Great opportunities at
  - Belle II (SuperKEKB)
  - upgraded LHCb
- and at
  - STFC

HEP Cosmic Frontier Program Experiments

October 2014

Experiment	Location	Description	Current Status	# Collaborators (# US, HEP)	# Institutions (# US, HEP)	# Countries
Baryon Oscillation Spectrosopic Survey (BOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	operations ended in FY14	230 (150 US, 40 HEP)	(22 US, 8 HEP)	7
Dark Energy Survey (DES)	CTIO in Chile	dark energy stage III (imaging)	operations started Sept. 2013	300	25 (13 US, 9 HEP)	6
Large Synoptic Survey Telescope (LSST) - Dark Energy Science Collaboration (DESC)	Cerro Pachon in Chile	dark energy stage IV (imaging)	science studies, planning	232 (200 US, 134 HEP)	53 (41 US, 16 HEP)	3
Large Synoptic Survey Telescope (LSST) - LSSTcam Project	Cerro Pachon in Chile	dark energy stage IV (imaging)	CD3a approved; FY14 Fabrication start; CD2 review Nov. 2014	142 (111 US, 111 HEP)	17 (11 US, 11 HEP)	2
Dark Energy Spectroscopic Instrument (DESI)	KPNO in AZ (plan)	dark energy stage IV (spectroscopic)	CD0 approved Sept 2012; CD1 review Sept 2014	180 (95 US, 72 HEP)	42 (23 US, 18 HEP)	13
DM-G1: Axion Dark Matter eXperiment (ADMX-IIa)	Univ Washington	dark matter - axion search	operating	24 (20 US, 17 HEP)	7 (6 US, 3 HEP)	2
DM-G1: Chicagoland Observatory for Underground Particle Physics (COUPP-60); now PICO	SNOLab in Canada	dark matter - WIMP search	operating	60 (26 US, 8 HEP)	14 (6 US, 1 HEP)	5
DM-G1: DarkSide-50	LNGS in Italy	dark matter - WIMP search	operating	122 (66 US, 12 HEP)	26 (12 US, 3 HEP)	7
Large Underground Xenon (LUX)	SURF in South Dakota	dark matter - WIMP search	operating	102 (86 US, 64 HEP)	18 (15 US, 13 HEP)	3
Super Cryogenic Dark Matter Search (SuperCDMS-Soudan)	Soudan in Minnesota	dark matter - WIMP search	operating	83 (72 US, 44 HEP)	20 (17 US, 7 HEP)	3
DM-G2: ADMX-G2	Univ Washington	dark matter - axion search	Selected July 2014; Moving to fabrication phase in FY15	31 (29 US, 20 HEP)	8 (7 US, 4 HEP)	2
DM-G2: SuperCDMS-SNOLAB	SNOLab in Canada	dark matter - WIMP search	Selected July 2014; planning CD1 in FY15	94 (83 US, 54 HEP)	20 (17 US, 7 HEP)	4
DM-G2: LZ	SURF in South Dakota	dark matter - WIMP search	Selected July 2014; planning CD1 review in Jan. 2015	154 (118 US, 107 HEP)	28 (18 US, 17 HEP)	3
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	FLWO in AZ	gamma-ray survey	operating	92 (74 US, 32 HEP)	20 (15 US, 5 HEP)	4
Pierre Auger Observatory	Argentina	cosmic-ray	operating	463 (51 US, 12 HEP)	100 (20 US, 5 HEP)	18
Fermi Gamma-ray Space Telescope (FGST) Large Area Telescope (LAT)	space-based	gamma-ray survey	June 2008 launch; operating	319 (157 US, 73 HEP)	49 (14 US, 3 HEP)	9
Alpha Magnetic Spectrometer (AMS-02)	space-based (on ISS)	cosmic-ray	May 2011 launch; operating	600	60 (6 US, 2 HEP)	16
High Altitude Water Cherenkov (HAWC)	Mexico	gamma-ray survey	Operations started in 2014	111 (54 US, 8 HEP)	31 (16 US, 2 HEP)	2

Global strategy

Science Drivers & Research Frontiers

Science drivers identify the scientific motivation, while the Research Frontiers provide a useful categorization of experimental techniques

	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●		●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

Future (large, global) HEP Facilities

My compilation of large facilities with a global scope

- **LHC, incl. HL-LHC**
- **Very High Energy Hadron Collider**
  - **include ee and ep options**
- **Electron-Positron Collider**
  - **ILC, CLIC**
- **LBNF: long baseline neutrino facility**

Global Strategy

- Regional strategies in Particle Physics
  - Japan
  - Europe: update approved by CERN Council
  - US: P5

- US P5 Strategy: Science Drivers
  - Higgs boson
  - Neutrino mass
  - Dark matter
  - Cosmic acceleration
  - Explore the unknown

  → Facilities: LHC, LBNF, ILC, …

- Japan, February 2012
  - if there is a Higgs → ILC
  - If theta_13 is large → large neutrino experiment

- Europe, May 2013
  - LHC incl. HL-LHC
  - Accelerator R&D (CLIC, high field magnets)
  - ILC in Japan
  - participation in long-baseline neutrino experiment(s)

- Different flavors in different regions, but large overlap!
- Emerging global strategy

Setting the Future Stage…it will be Global

- Europe is looking to lead the FCC
- China is looking to lead at the CEPC-SPPC
- Japan is looking to lead the ILC

- The US focus on neutrinos now and R&D to help FCC/SPPC

- Plan: Start together and develop technology together
- Plan: Reduce the cost per country?....more countries helps but technology breakthroughs will be cost driver

Global HEP Strategy

ICFA statement in February, 2014 at DESY

ICFA encouraged the two studies (FCC and CEPC-SPPC) to work as close together as possible, with the following statement:

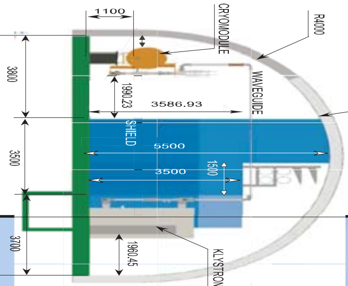
ICFA supports studies of energy frontier circular colliders and encourages global coordination.

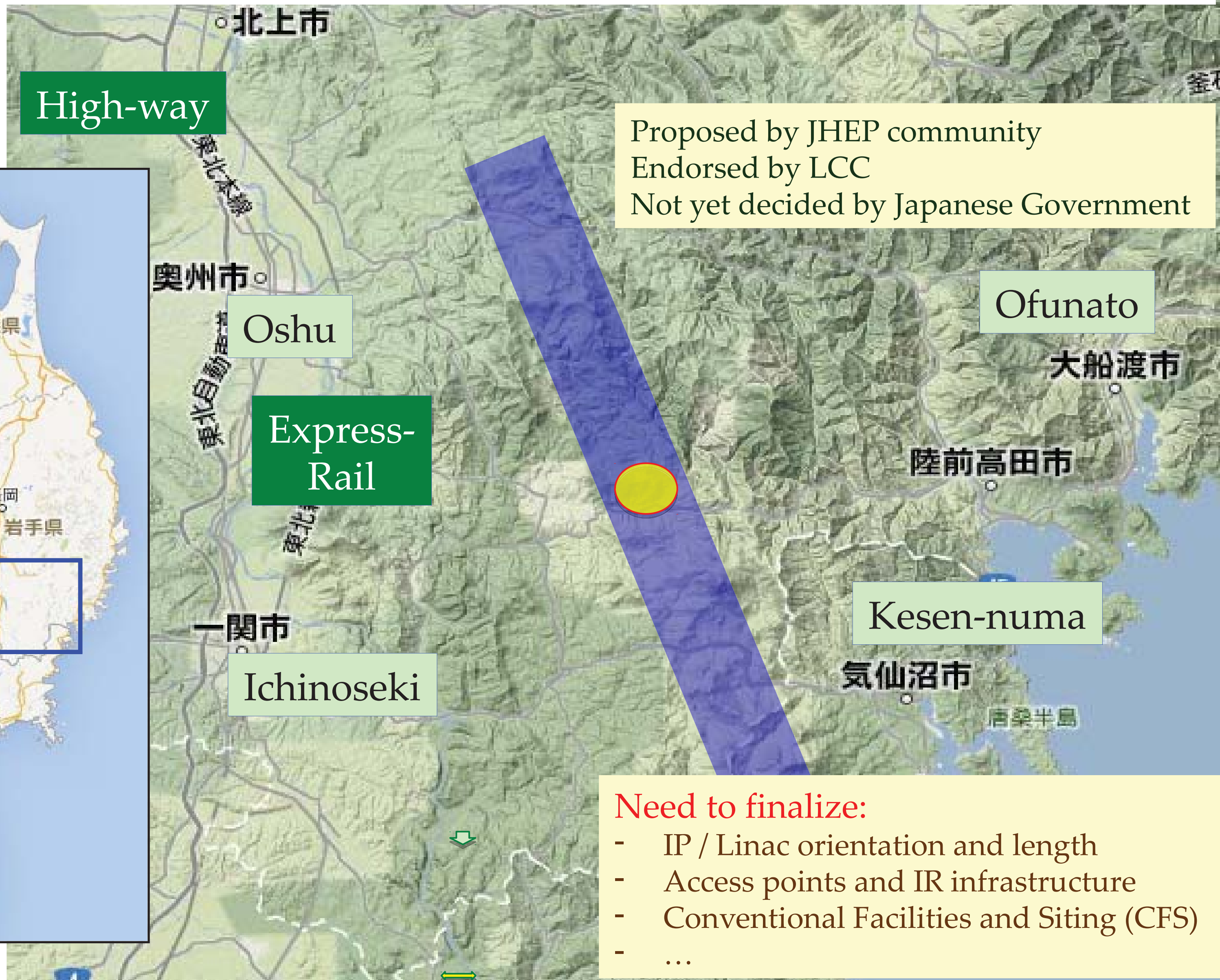
ICFA statement in July, 2014 at Valencia

ICFA endorses the particle physics strategic plans produced in Europe, Asia and the United States and the globally aligned priorities contained therein. Here, ICFA reaffirms its support of the ILC, which is in a mature state of technical development and offers unprecedented opportunities for precision studies of the newly discovered Higgs boson. In addition, ICFA continues to encourage international studies of circular colliders, with an ultimate goal of proton-proton collisions at energies much higher than those of the LHC.

Site specific studies

Establish a site-specific Civil Engineering Design - map the (site independent) TDR baseline onto the preferred site - assuming “Kitakami” as a primary candidate



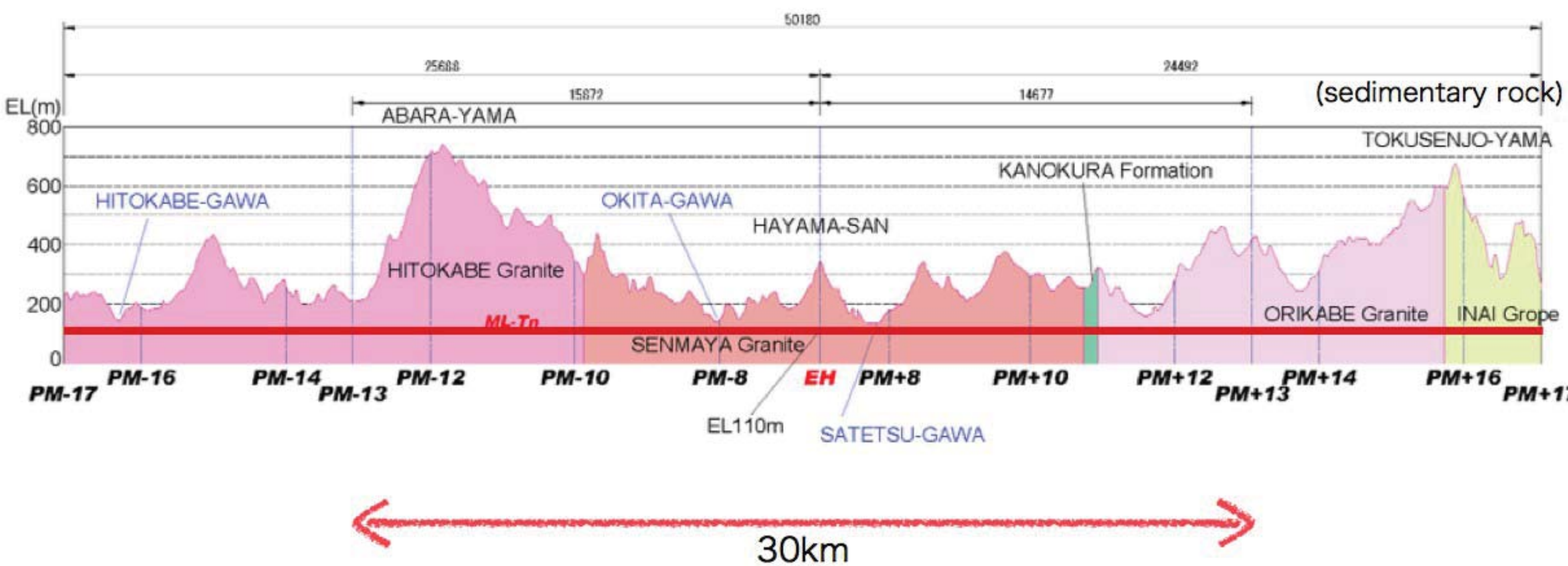


Proposed by JHEP community
Endorsed by LCC
Not yet decided by Japanese Government

Need to finalize:

- IP / Linac orientation and length
- Access points and IR infrastructure
- Conventional Facilities and Siting (CFS)
- …

ILC preferred site - Kitakami



al

Japan: Academic Expert Committee

- MEXT has requested $0.5M for investigatory study which was approved on Dec 24, 2013.
  - Not a fund request by a researcher, but by MEXT.
  - Approved by the ministry of finance and then by an official cabinet decision.
  - Will be doubled next year (i.e. ~1M$)

- An expert committee was established under MEXT
  - 13 members (could increase)
    - A few particle physicists included
    - No 'ILC proponents'
  - Kickoff meeting held on May 8, 2014
  - Report to be completed by FY2015 (i.e. end of March 2016)

- The outcome is critically important for the ILC

Discussion

We are not well coordinated as a field...

It is vital to have competition.
Wiser to have collaboration and coordination.

We have to collaborate closely for different studies.
And start to compete when projects start...

We need to have global vision,
in particular regarding human resources.
Accelerator physicists are rare species!..

Discussion

We do need more than one project for the future.
Some competition is vital...

CEPC vs ILC:
- We absolutly need both of them!
- Very much complementary.
- We should try to convince our governments...
- In the past we talked about ILC with 2 experiments.
  What about 2 accelerators with 1 detector each?
  Abandoning push-pull would be welcomed by many people...

(Yifang Wang, director of IHEP)

Discussion

HEP funding per researcher per year comparable with
other branches of science

Aviability of funding depends on being able to convince
society (voters)

Laboratories need to produce ideas for the public each week

Politicians are easy to be confused...

ICFA should play more active role to set the strategy...

Conclusions

Accelerators in Europe

A vibrant activity in the construction of accelerator based facilities:

- XFEL, SWISSFEL
- ESS
- FAIR
- Synchrotron Light Accelerators Upgrades
- ....

It is fundamental to retain the skills in the field and to increase the networking among the European Research infrastructures

It is an asset in the exploration of New Physics

Despite their impact on science, most accelerators that have been built are used for other purposes

- About 30,000 accelerators are in use world wide
  - Sales of accelerators > $ 2 B /yr and growing
  - Accelerators touch over $ 500B/yr in products
  - Major Impact on our economy, health, and well being

- Some Products:

Our message needs to be

- Basic research like particle physics and astronomy is not a luxury
- In fact it is **key to our future economic competitiveness** in a globalising, knowledge based economy

Why?

- Because
  - **It attracts young people into science and trains them for the 21st century**
  - **It drives technological innovation**

Science & Technology Facilities Council

Future?


The future will be exicting
The future will & must be (even more) global

"Those who ignore history are condemned to repeat it."

Next ICFA Seminar

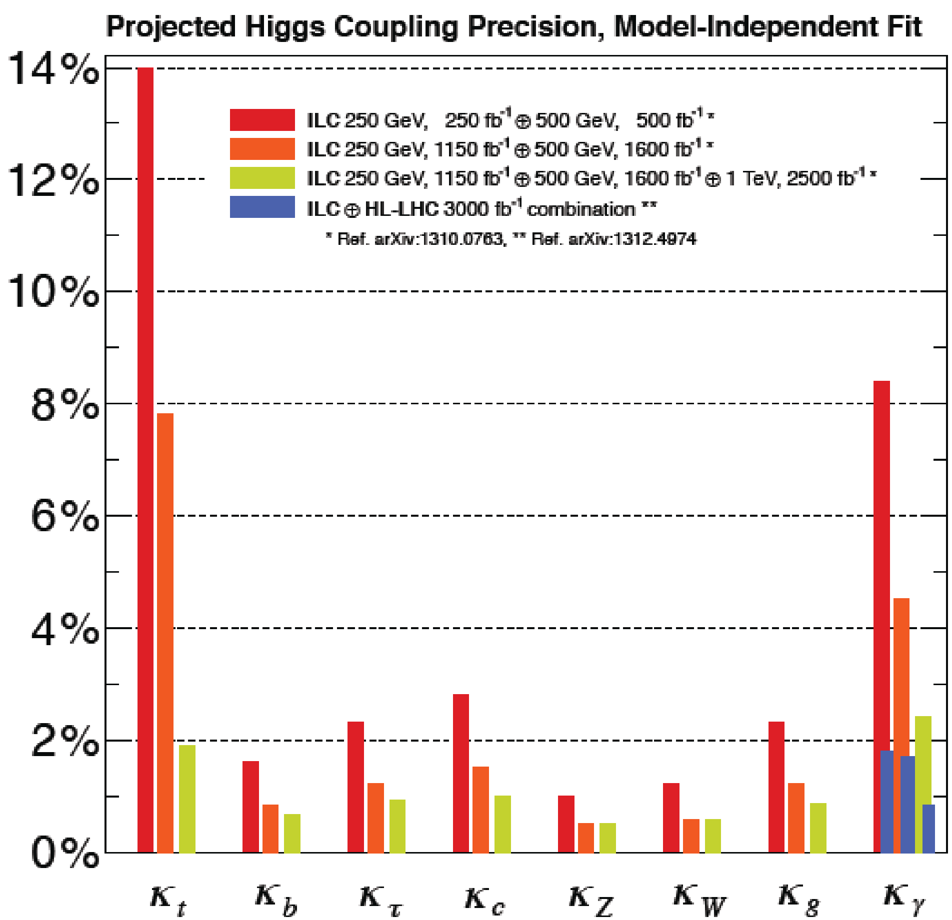
Vancouver, fall 2017

ICFA web page: http://www.fnal.gov/directorate/icfa/

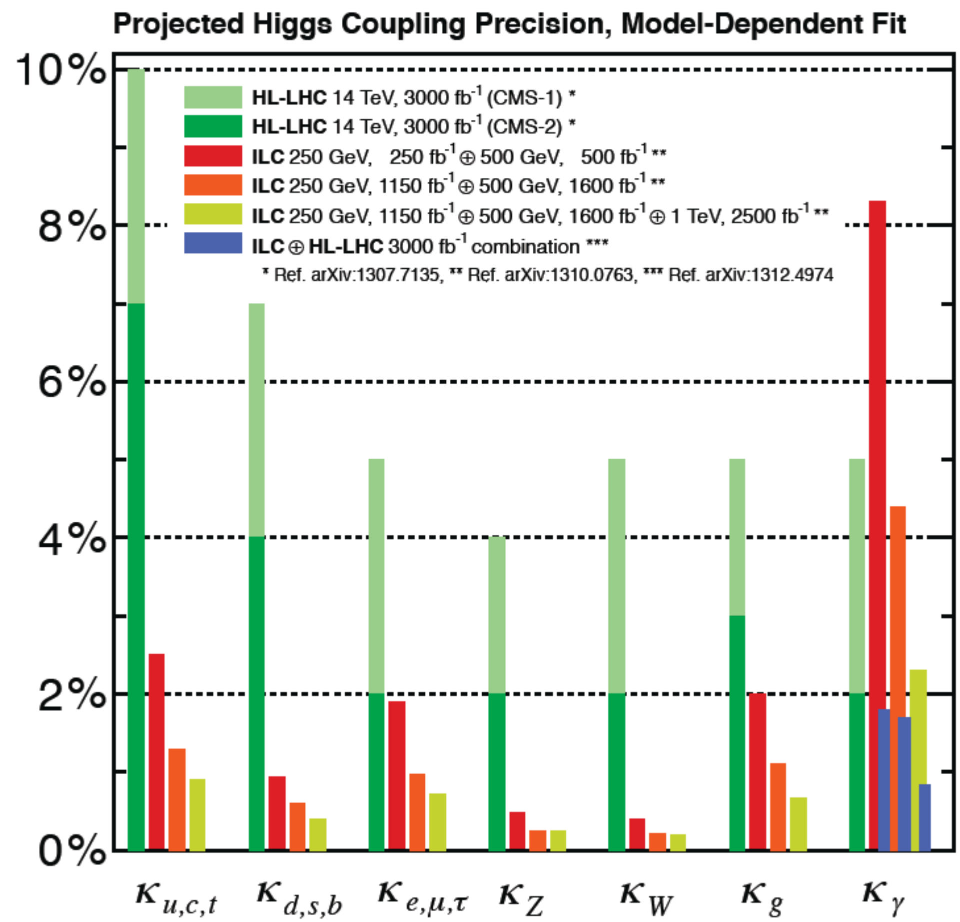

Thank you !
谢 谢

Combined Higgs results (ILC)

See talk of Kerstin Tackmann yesterday (Higgs – decays and properties)



Fully model-independent



LHC-like fits, assuming SM decay modes only