High Energy Physics as a Global Enterprise: Report from ICHEP XXXVIII

Young-Kee Kim
The University of Chicago
Chair of ICHEP 2016
On behalf of the ICHEP 2016 organizing team

North American Particle Physics Conference
October 10, 2016

ICHEP
(International Conference on High Energy Physics)

a focal point of the field of particle physics,
bringing together experimentalists & theorists of the world
to share the latest advancements in the field

First held in 1950 (“Rochester Conference”)
biennial since 1960

38th ICHEP – Chicago: August 3 – 10, 2016

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THANK YOU !

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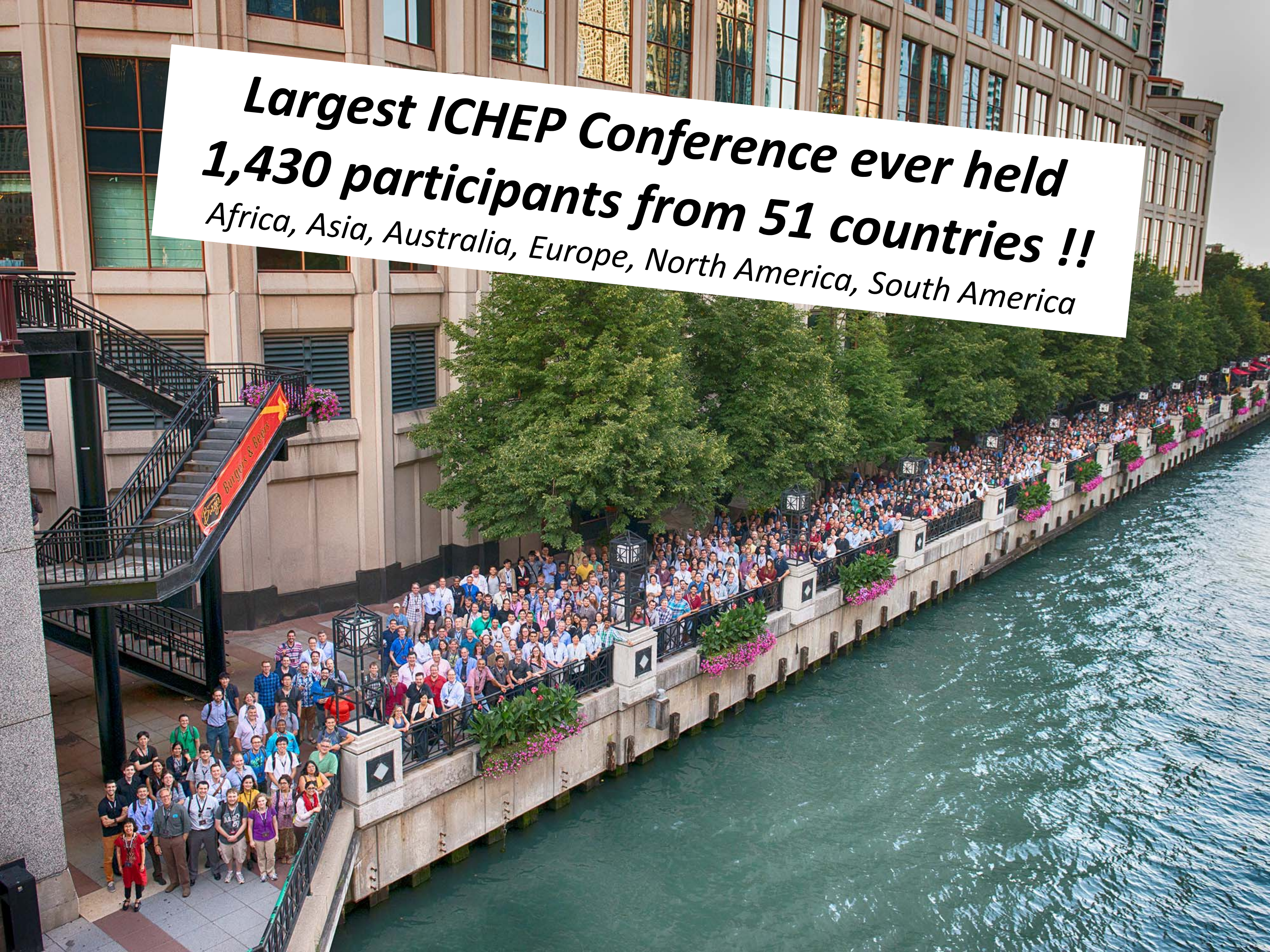
THANK YOU !

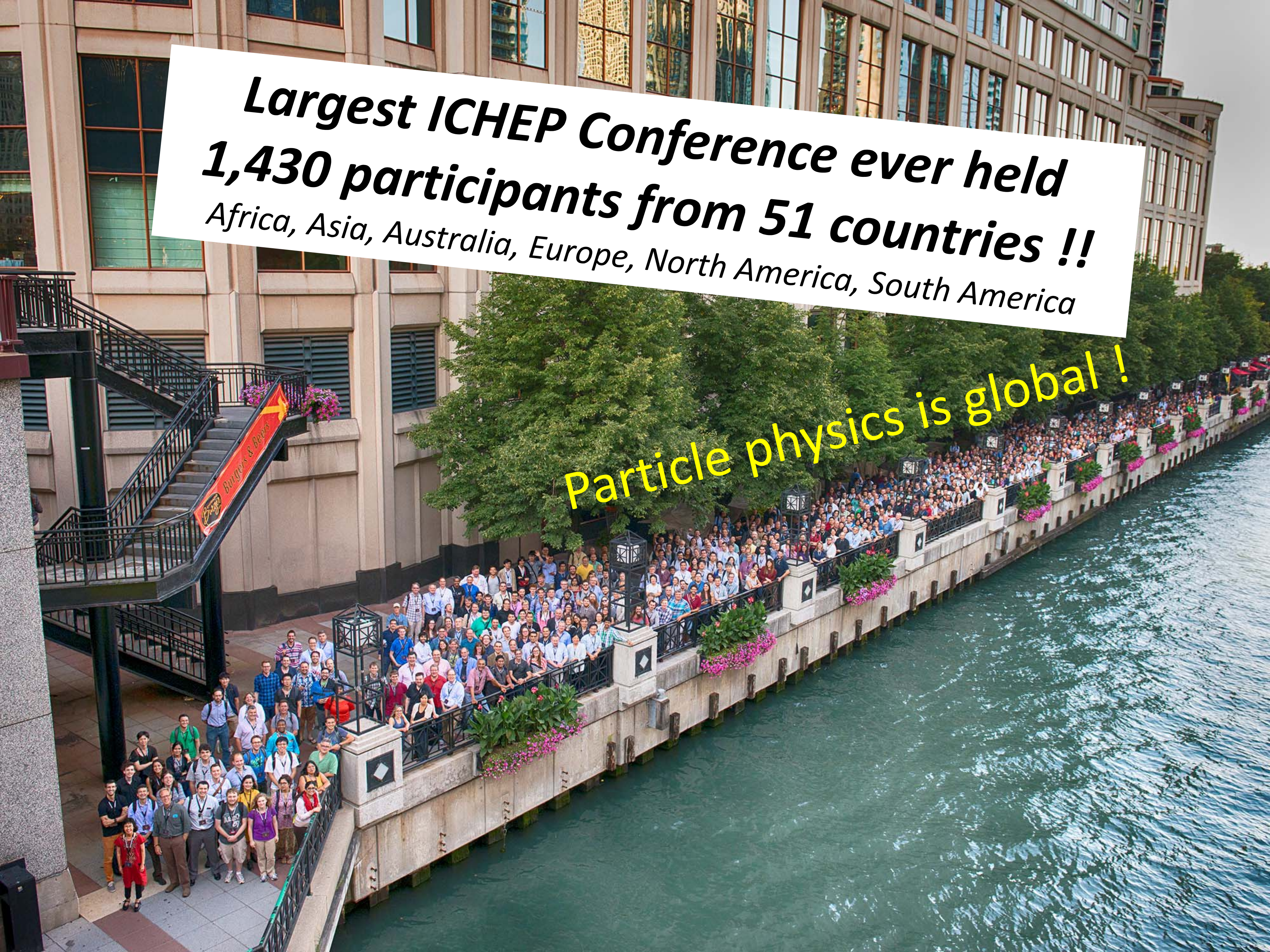

Burgers & Beers



Largest ICHEP Conference ever held

1,430 participants from 51 countries !!

Africa, Asia, Australia, Europe, North America, South America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1,430 participants from 51 countries !!
Africa, Asia, Australia, Europe, North America, South America
Particle physics is global !

1,600 abstracts submitted (16 parallel themes)

65 conveners from all continents

Program at a Glance

Registration	August 3 (Wednesday)
Parallel sessions (16 themes)	August 4 (Thursday)
	August 5 (Friday)
	August 6 (Saturday)
	Poster session #1 + reception
"Free day"	August 7 (Sunday)
Plenary sessions	August 8 (Monday)
	Poster session #2 + reception
	August 9 (Tuesday)
	August 10 (Wednesday)

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August 10 (Wednesday)

Outdoor concert at the Millenium park

ICHEP blankets, snacks

Program at a Glance

Registration August 3 (Wednesday)

Parallel sessions (16 themes)

August 4 (Thursday)
August 5 (Friday)
August 6 (Saturday)

Poster sessio

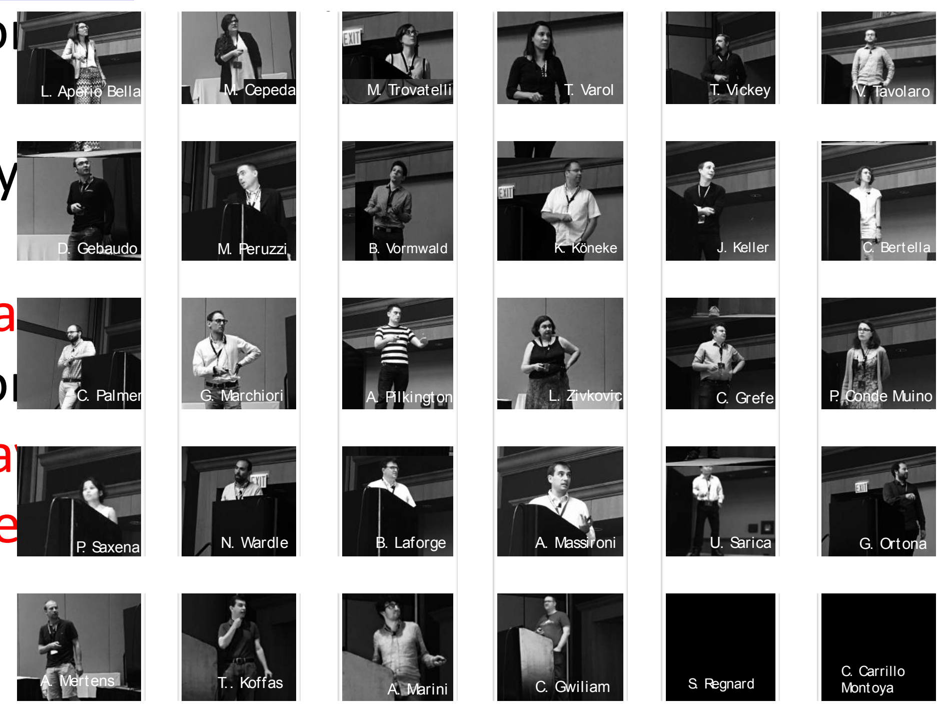
"Free day" August 7 (Sunday

Plenary sessions August 8 (Monda

Poster sessio

August 9 (Tuesda
August 10 (Wedne

600 parallel talks



Program at a Glance

Registration	August 3 (Wednesday)
Parallel sessions (16 themes)	August 4 (Thursday)
	August 5 (Friday)
	August 6 (Saturday)

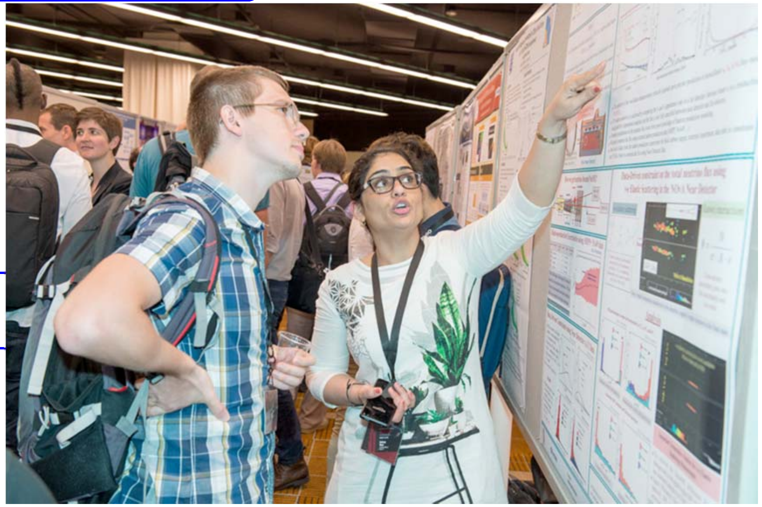
Poster session #1 + reception

500 posters

"Free day"	August 7 (Sunday)
Plenary sessions	August 8 (Monday)

Poster session #2 +

	August 9 (Tuesday)
	August 10 (Wednesday)



Program at a Glance

Registration August 3 (Wednesday)

Parallel sessions (16 themes)
August 4 (Thursday)
August 5 (Friday)
August 6 (Saturday)
Poster session #1 + reception

20 poster awards

"Free day" August 7 (Sund

Plenary sessions
August 8 (Mon
Poster sess
August 9 (Tues
August 10 (Wednesday)

+ online vote by ICHEP participants

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Registration August 3 (Wednesday)

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August 5 (Frid
August 6 (Satu
Poster ses

"Free day" August 7 (Sun

Plenary sessions August 8 (Monday)
Poster session #2 + reception
August 9 (Tuesday)
August 10 (Wednesday)

Sunday, August 7 (“Free Day”)

Time	Superior A	Superior B	Riverwalk A/B		Huron	Chicago Ballroom
09:00	Linear Collider Board					
10:00		China-Chicago Connection				
11:00			Saturday Poster Presenters: If you wish to keep your poster, please collect it during this time.	Tevatron Reunion		
12:00						
13:00		IUPAP-C11	Monday Poster Presenters: Please set up your poster during this time.		IBS, Korea Satellite Session	
14:00						
15:00	International Committee for Future Accelerators (ICFA)					Windy City Physics Slam ***Open to the public*** Seating is first-come, first served
16:00						
17:00						
18:00						
19:00						

Five physicists battle it out in a high-energy competition.

Moderator: Tom Skilling, WGN

Renée Hlozek, University of Toronto
Dan Hooper, University of Chicago/Fermilab
Chris Marshall, University of Rochester
Clara Nellist, LAL-Orsay/IN2P3/CNRS
Mariel Pettee, Yale University

- Satellite meetings
- Workshops
- Outreach activities

3

New Initiatives at ICHEP 2016

Broader Impacts

new initiatives
in communication, education, and outreach

Communication teams from around the world

Lunch time sessions

Aimed at ICHEP participants' skills
in outreach and communication through news and social media

Lunch & Learn: Engaging the public (Fri. Aug.4)

What makes a great physics news story (Mon. Aug.8)

Making science fun & exciting through social media (Tues.Aug.9)

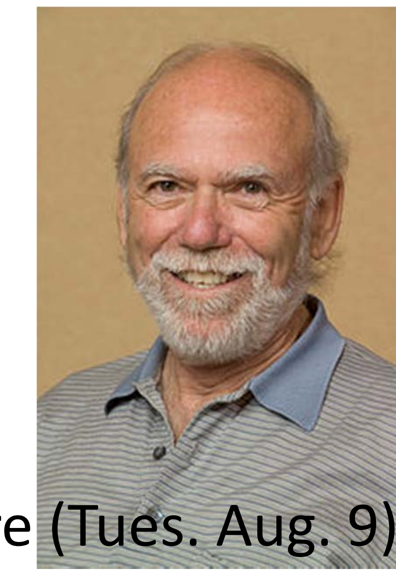
Arts and Sciences

Universe and Rhythm

Movement at Break
Inspired by physics equations

The Physics Slam
(Sun. Aug.7)

5 scientists competed to earn audience applause through presentations of their research

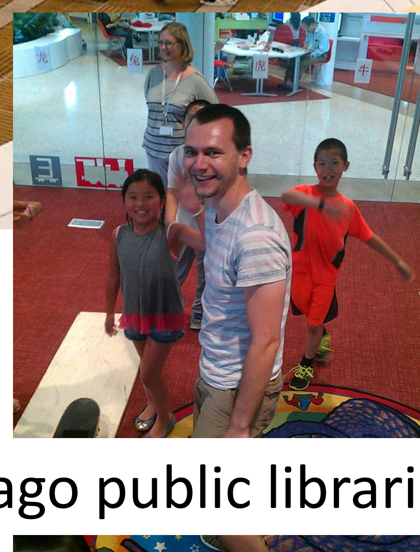


Public Lecture (Tues. Aug. 9)
Discovery of Gravitational Waves

Outreach programs at Chicago public libraries

(30 libraries by 60 ICHEP participants)

Training session



at Chicago public libraries

Tour of Fermilab and CERN

Tour of Fermilab and CERN

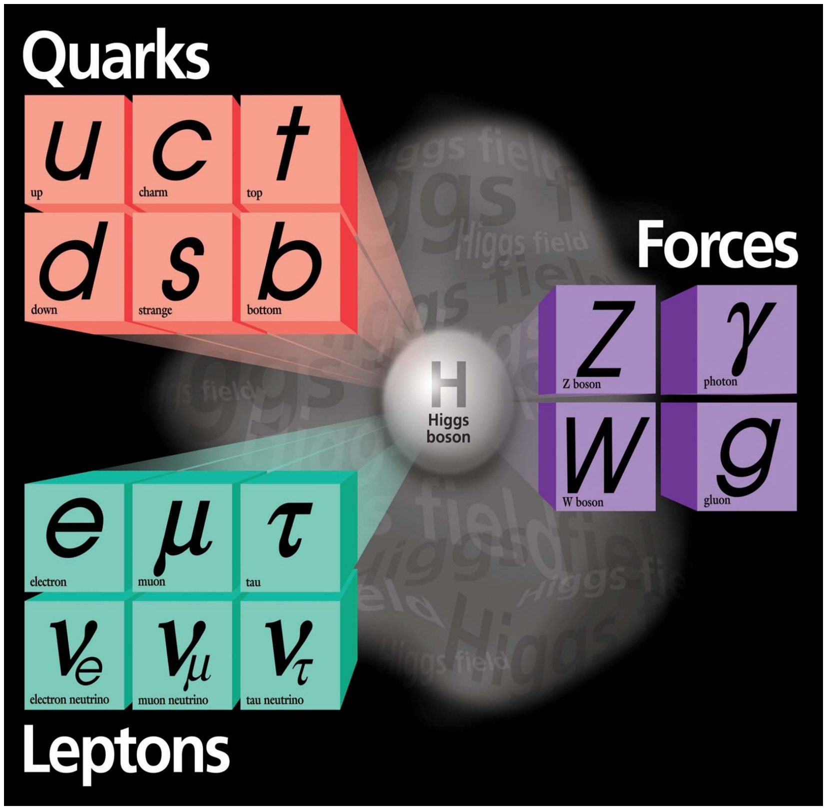
Industrial exhibit

To enhance technology developments ⟷ technology applications

Scientific Highlights

The triumphs……

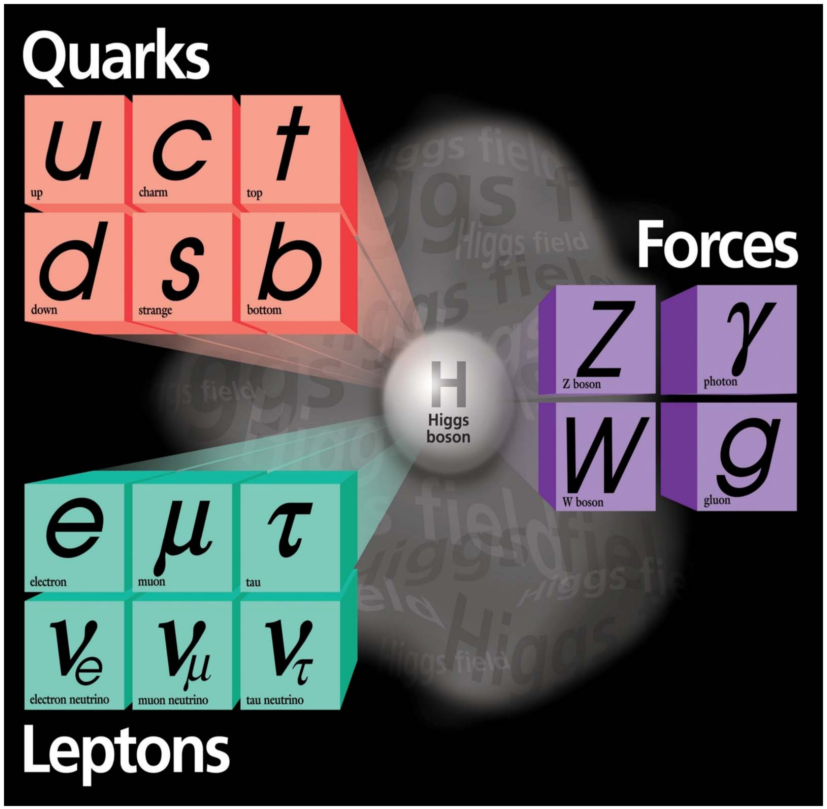
The Standard Model



- Remarkable intellectual construction
- Experimental results beautifully fit in this framework

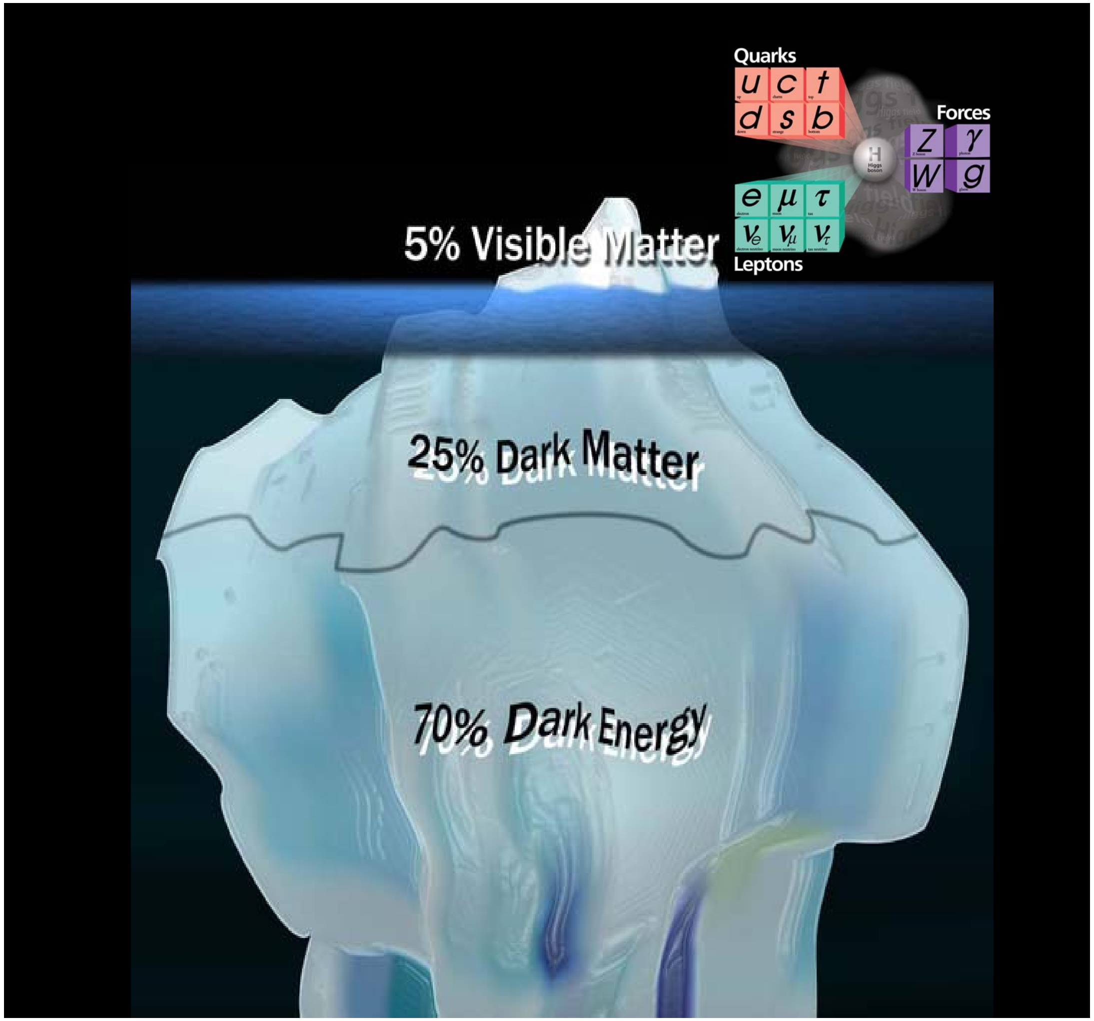
…… the mysteries

Physics Beyond
The Standard Model



- WHY ?
  - mass
  - 6 quarks
  - 3 families
  - neutrinos
  - forces
  - anti-matter

…… the mysteries



Scientific Drivers

U.S. Strategic Plan (Snowmass + P5, June 2014)

Five intertwined scientific Drivers were distilled from the results of a yearlong community-wide study:

- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles

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ICHEP2016

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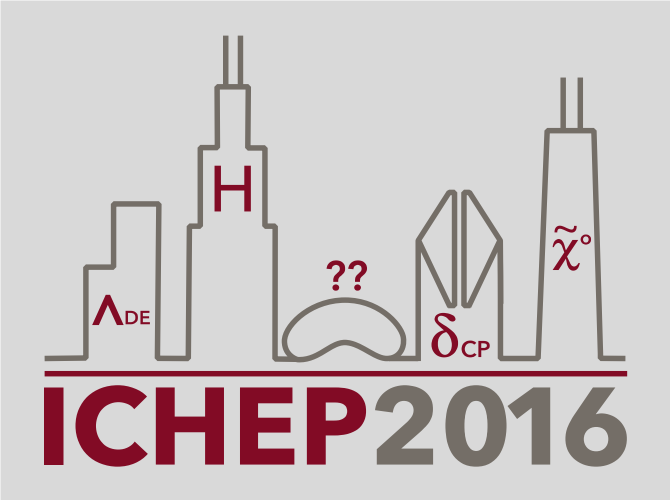
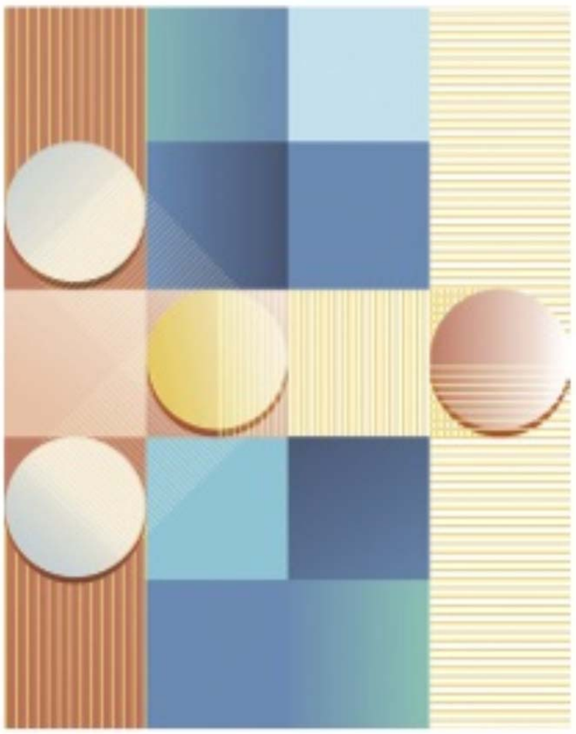


- Compelling, difficult, intertwined questions
- Require multiple approaches
- Only possible thanks to strong advancements in accelerators, detectors. & computing technologies

Higgs

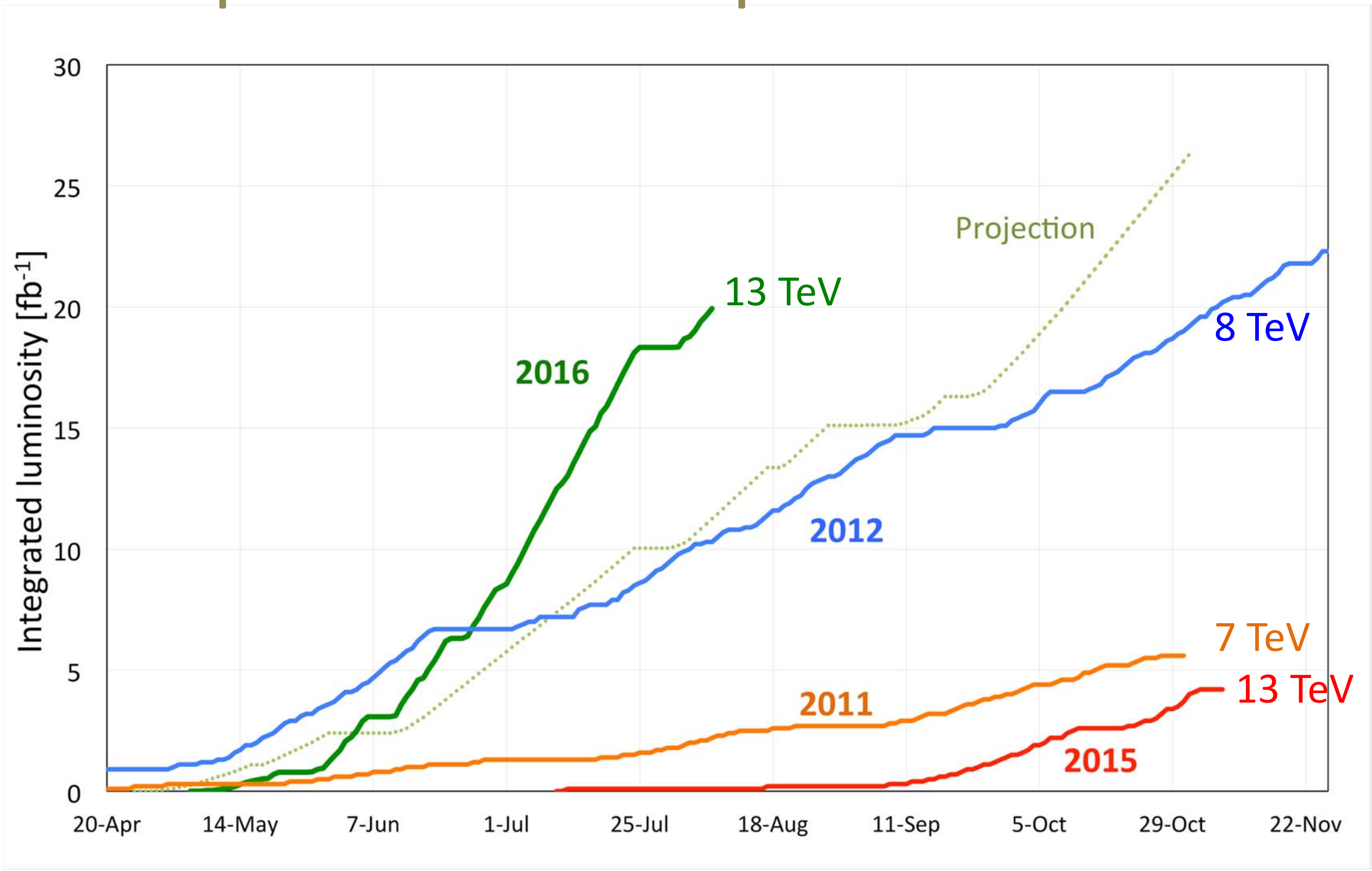
from the discovery of a Higgs-like particle to measurements and a new tool for discovery



NAPAC, October 10, 2016

Young-Kee Kim, University of Chicago

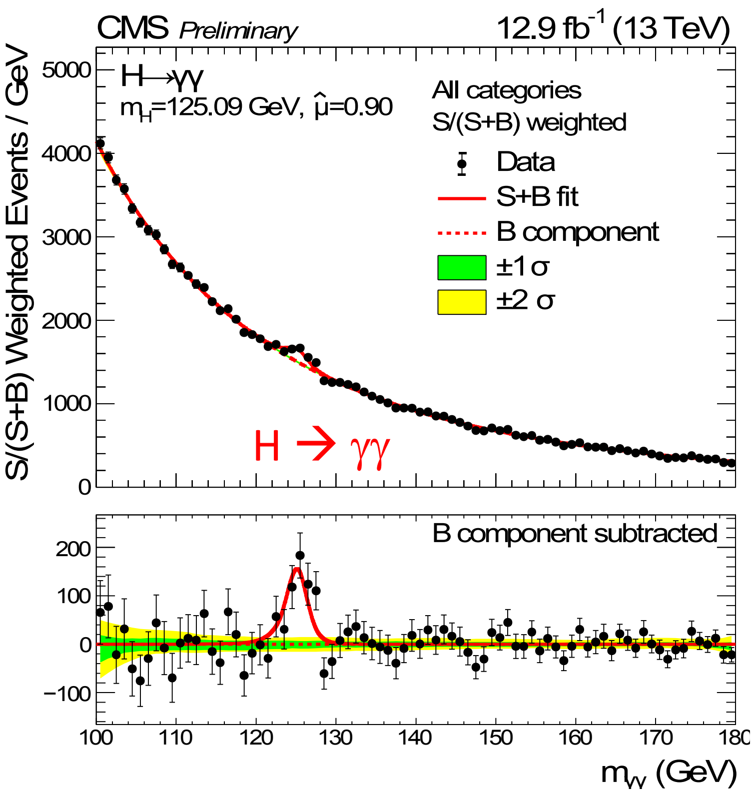
Spectacular LHC performance!

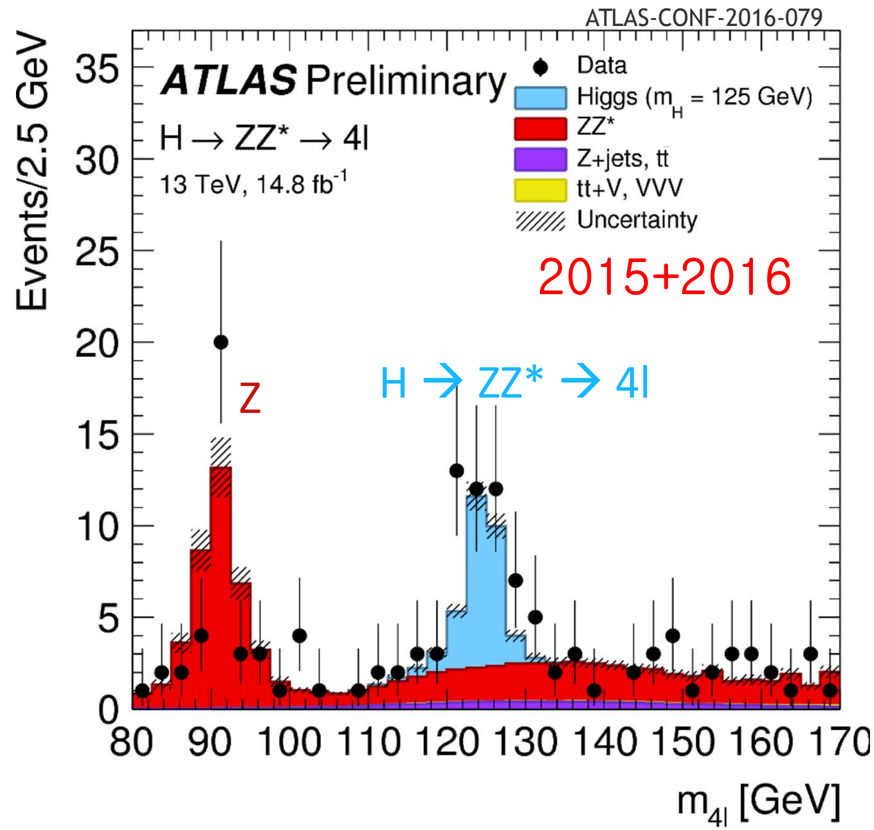


"No one is more surprised than we are" Mike Lamont @ ICHEP

Results shown at ICHEP 2016: 1% ~ 10% of Run 2 (2015-2018)

Rediscovering Higgs at 13 TeV





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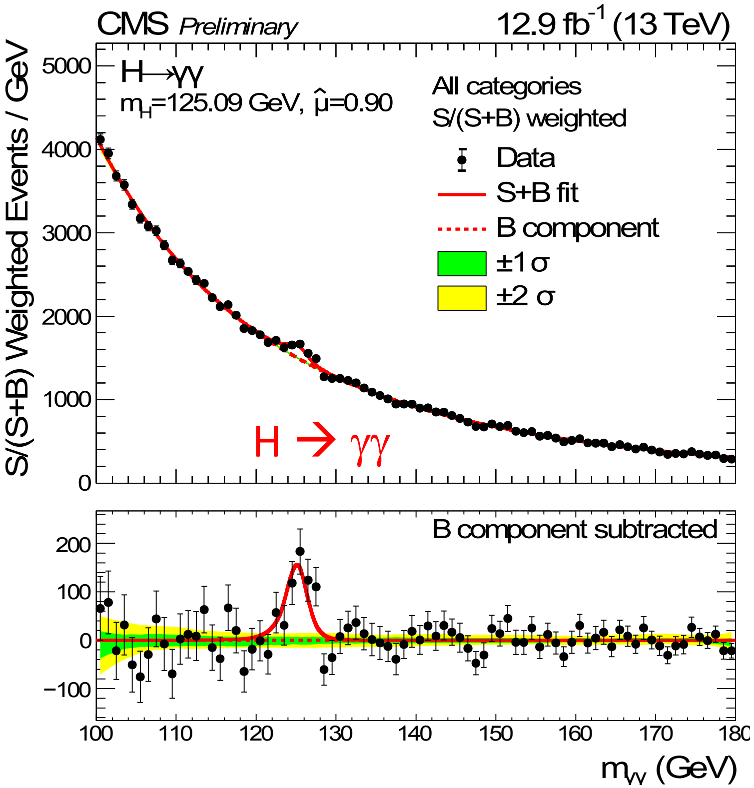
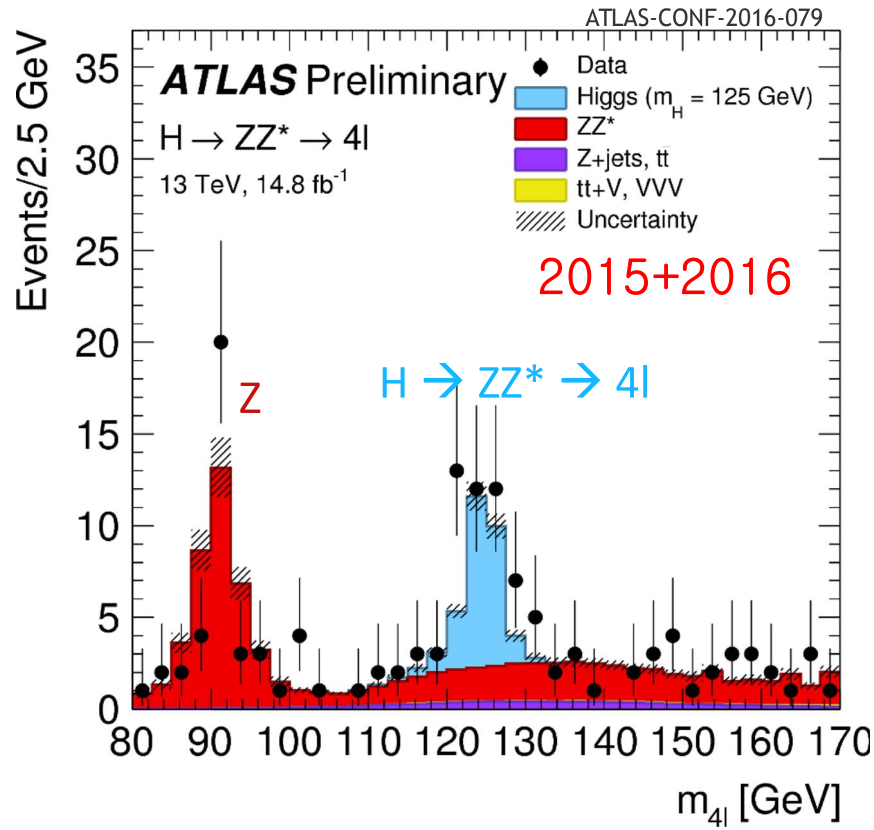
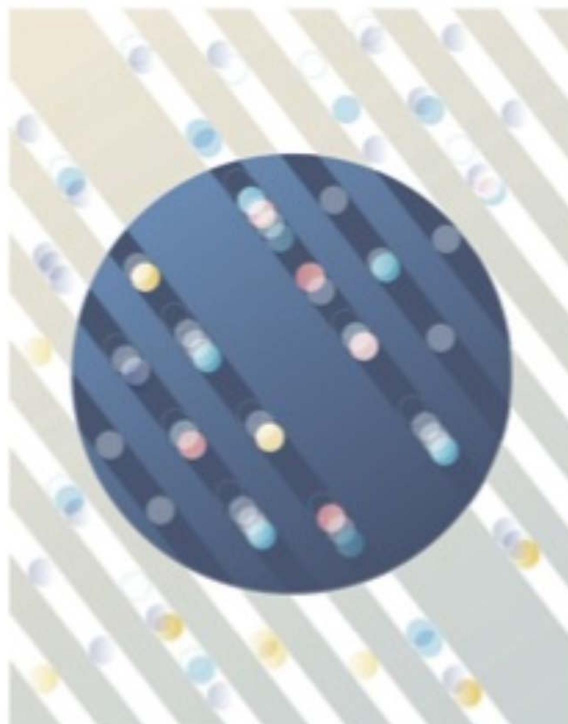




- Higgs seems to behave just as the SM predicts.
- Higgs as a new tool for discovery: heavier cousins / exotic decays
    - no signals emerged yet, but increasing sensitivity in the future

neutrinos



Neutrinos

- Among the most interesting objects to study to look for signs of new physics

- Many aspects of neutrino physics are puzzling:

  – What are the origin of neutrino mass?
  – What are the masses?
  – How are the masses ordered (mass hierarchy)?
  – Do neutrinos and antineutrinos oscillate differently? ($\cancel{CP}$)
  – Are there additional neutrino types or interactions?
  – Are neutrinos their own antiparticles?

Accelerator-based neutrinos

<u>Long baseline</u>

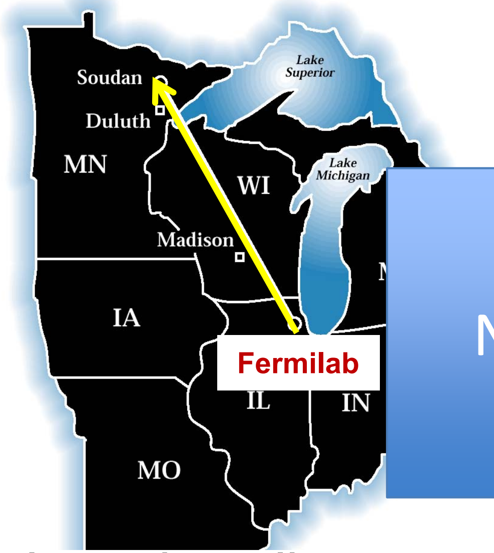
Fermilab → NOνA (810km), MINOS (735km)

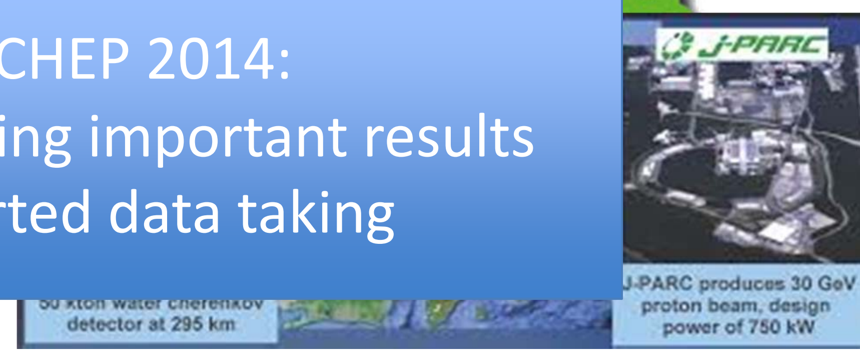
J-PARC → T2K (295km)

<u>Short baseline</u>

T600 – MicroBooNE – SBND

Accelerator-based neutrinos





News since ICHEP 2014:
NO νA started, producing important results
MicroBooNE started data taking

<u>Long baseline</u>

Fermilab → NO νA (810km), MINOS (735km)

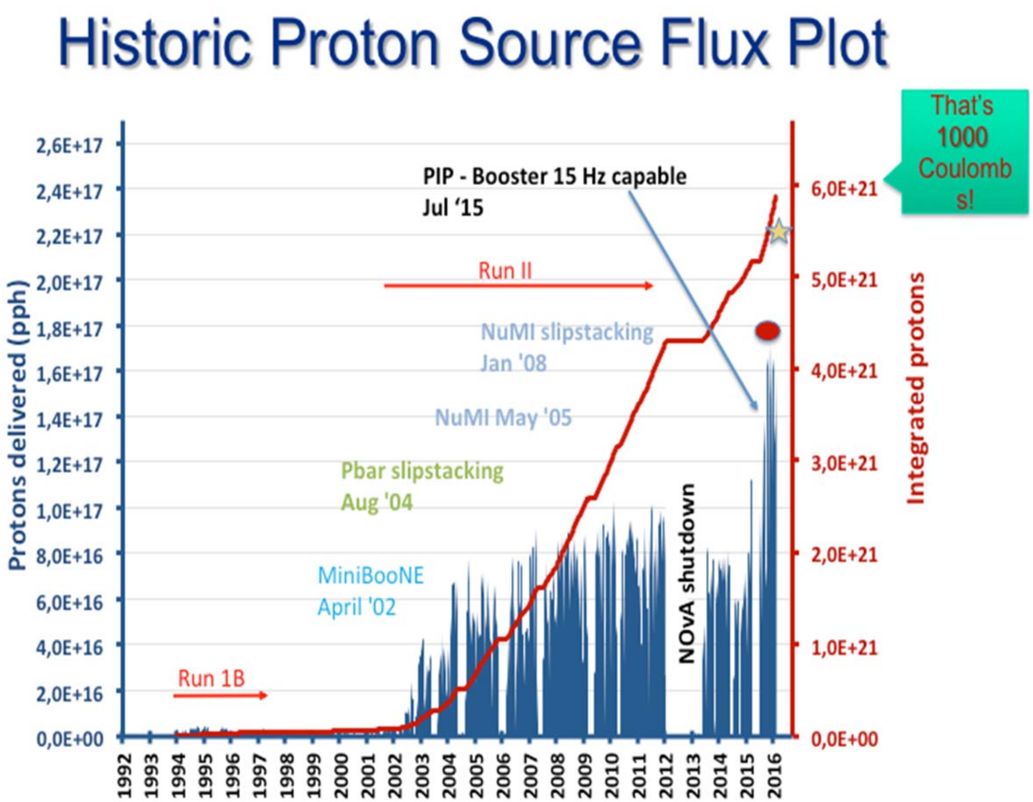
J-PARC → T2K (295km)

<u>Short baseline</u>

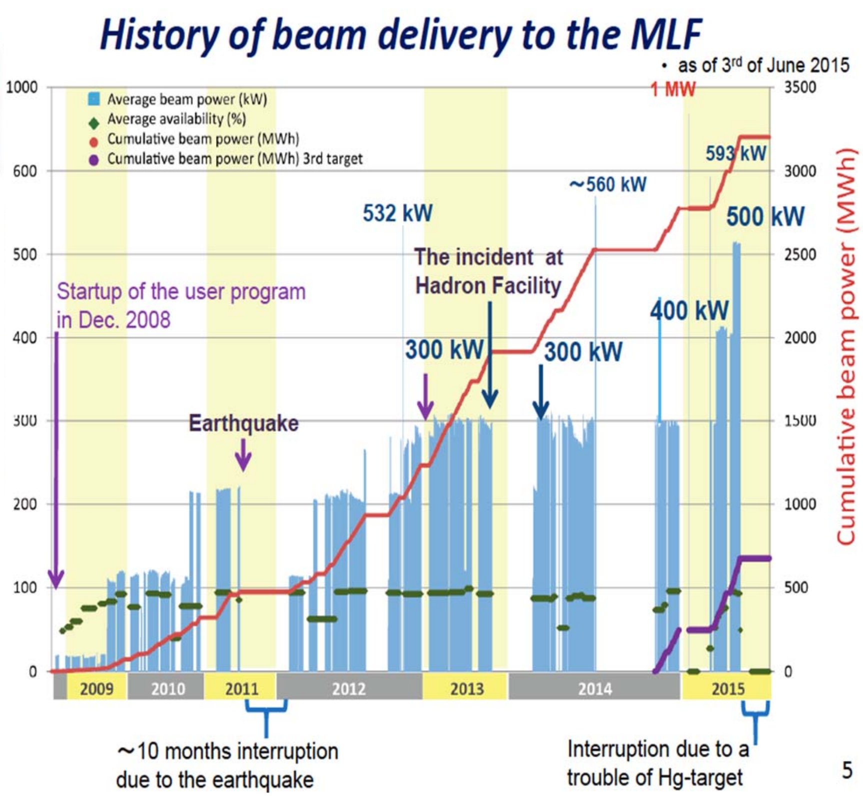
T600 – MicroBooNE – SBND

Intensity Frontier Accelerators

Fermilab

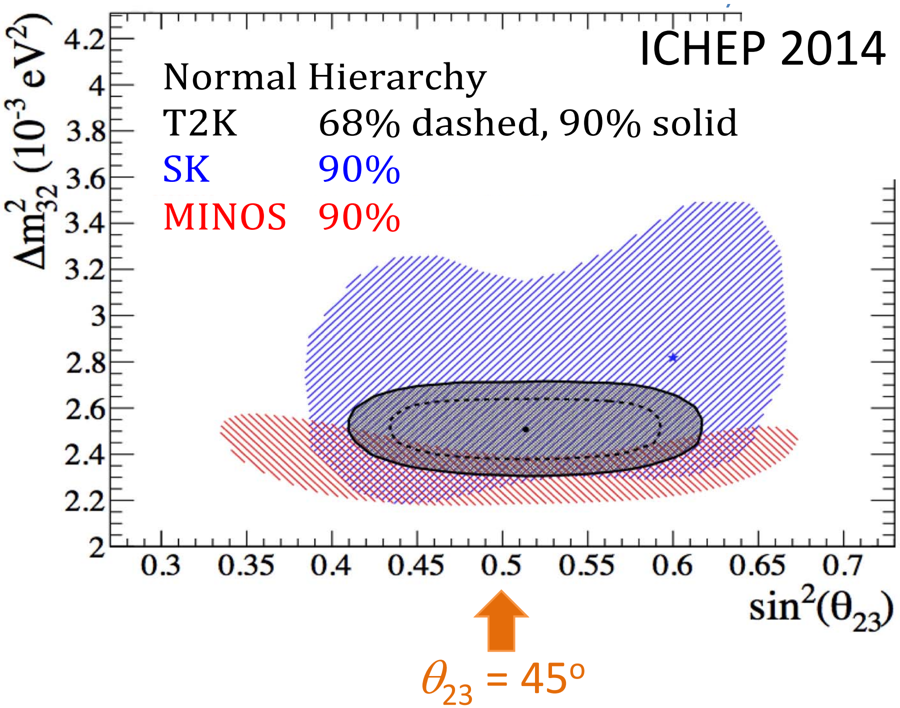


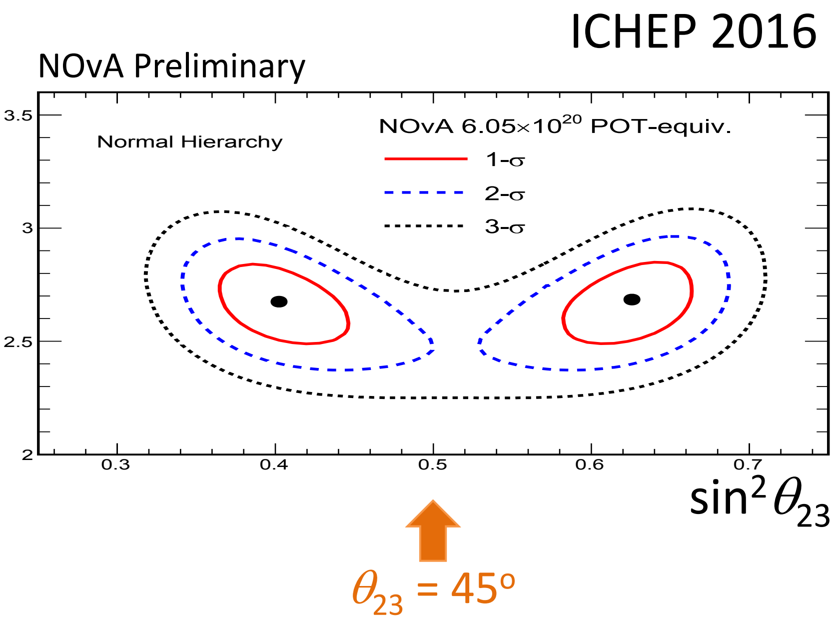
J-PARC



NOνA disfavors maximal mixing of ν_2 and ν_3

Test of a new symmetry that underlies maximal mixing





NOνA's electron ν appearance results exclude maximum mixing at 2.5σ

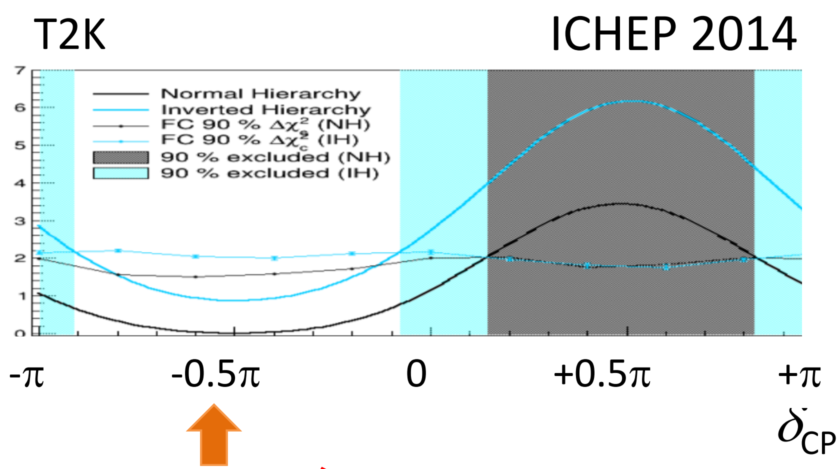
NOvA observes hints of non maximal mixing

T2K favors the idea of CP violation in neutrinos

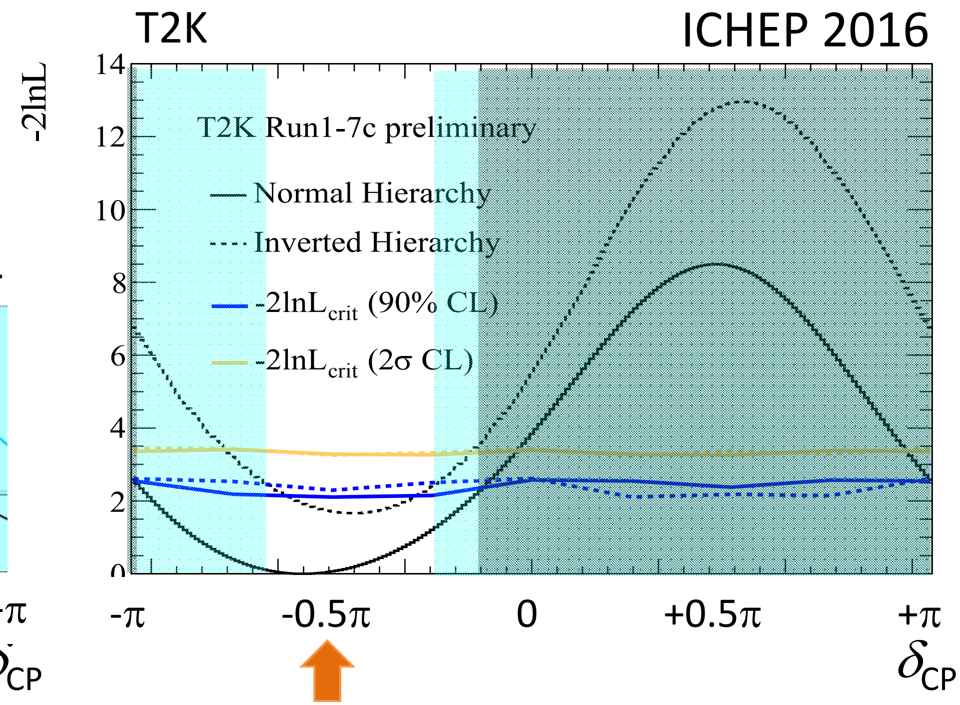
Favoring δ_{CP} ~ -0.5π (= 1.5π)
Lucky spot!!

χ^2

Better Fit



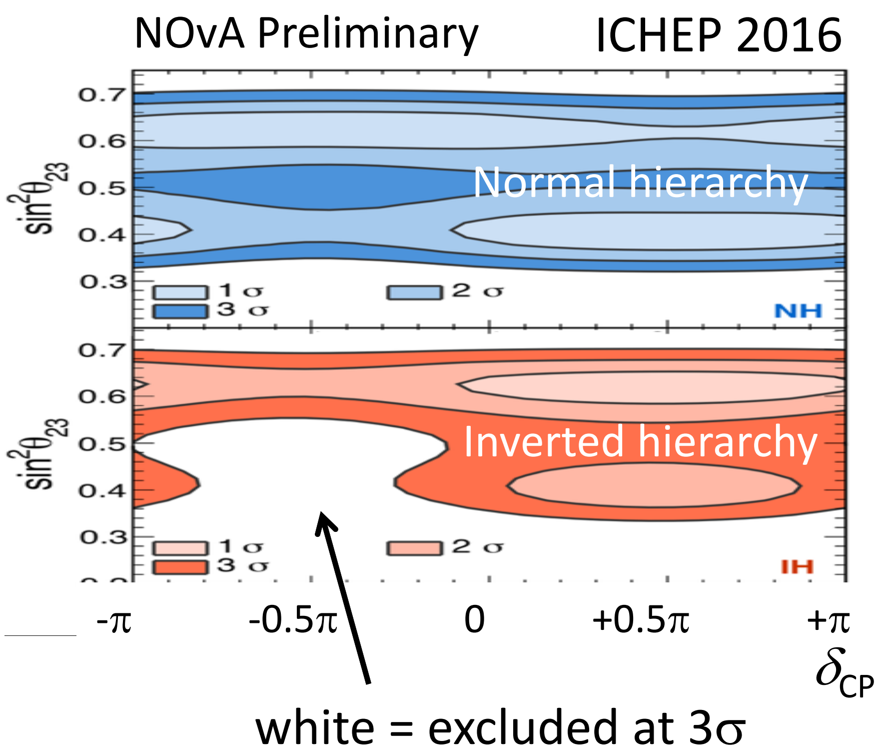
Maximal ~~CP~~

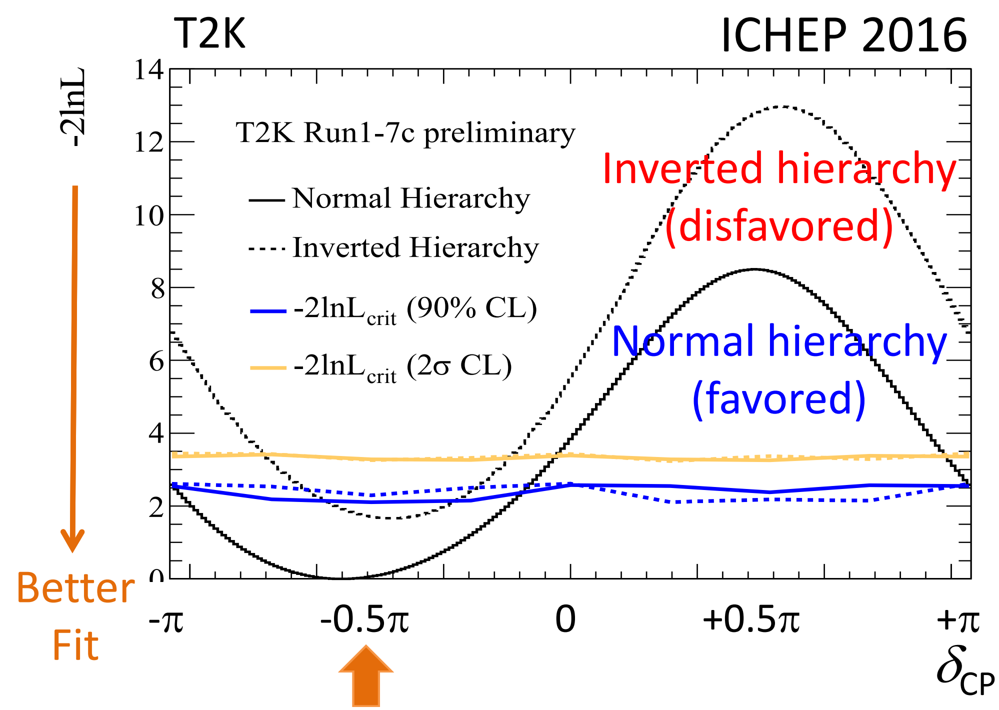


Maximal ~~CP~~

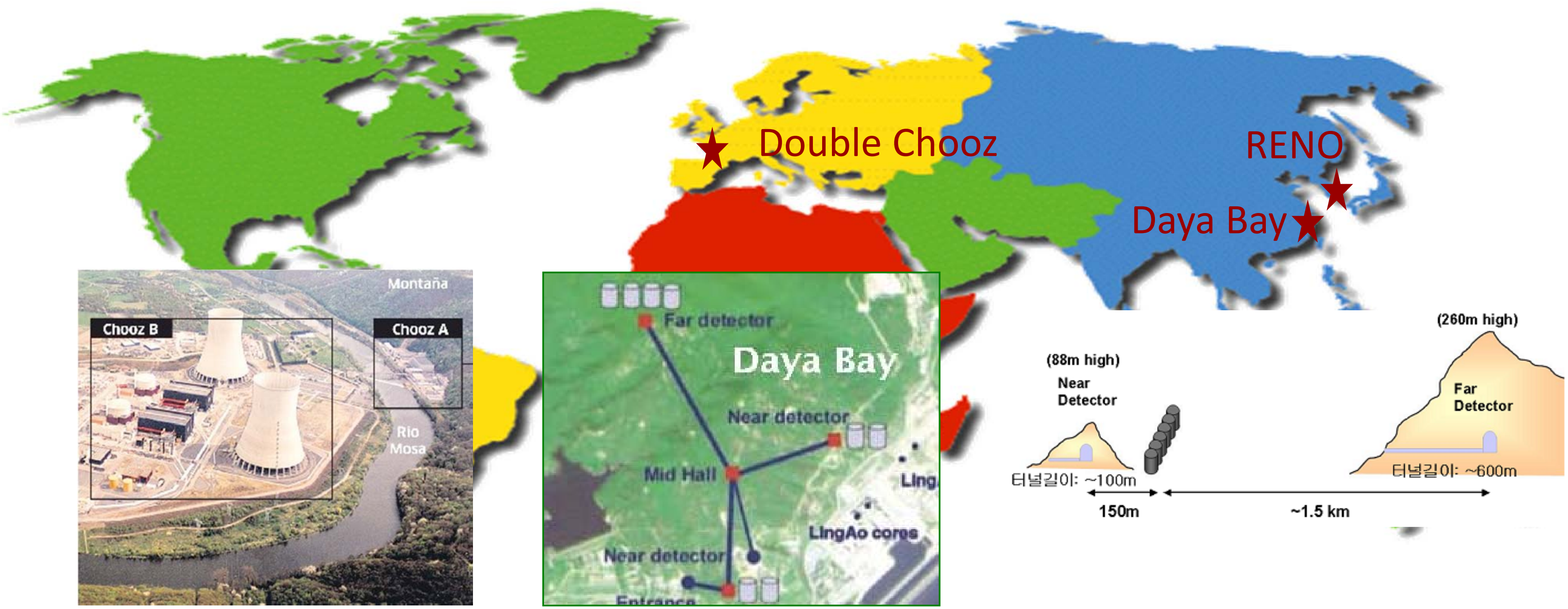
T2K further favors δ_{CP} ~ -0.5π,
excluding CP Conservation (δ_{CP} = 0 and π) at 90% CL

NOνA and T2K favor normal mass hierarchy





Reactor-based neutrinos



Double Chooz in France

Daya Bay in China

RENO in South Korea

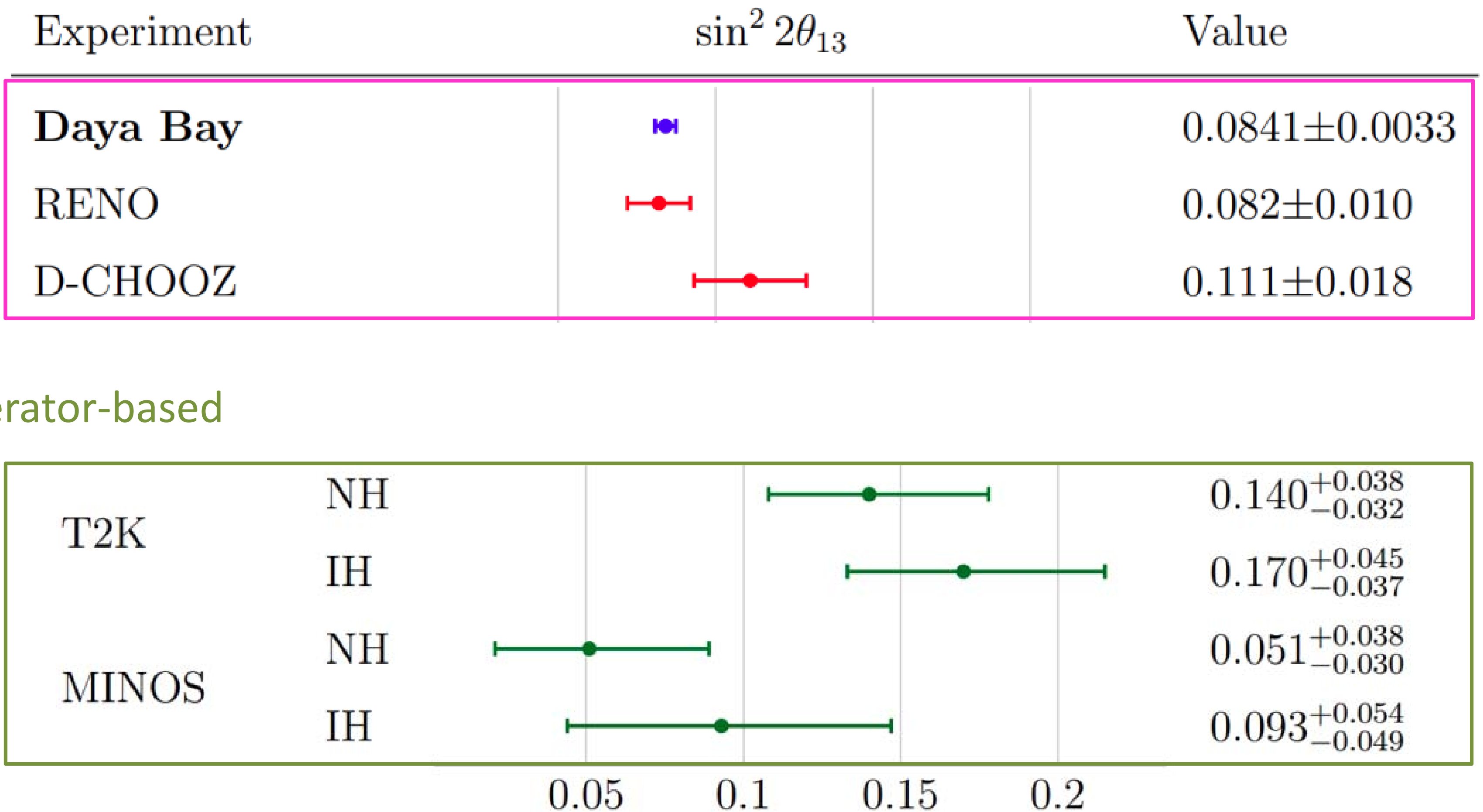
Next generation experiments: JUNO

RENO50

Impressive progress on θ_{13} (mixing of ν_1 and ν_3)

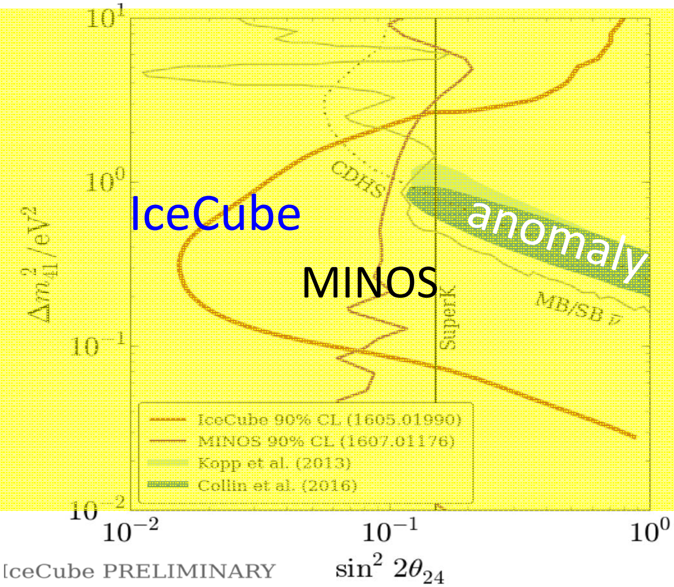
reactor-based

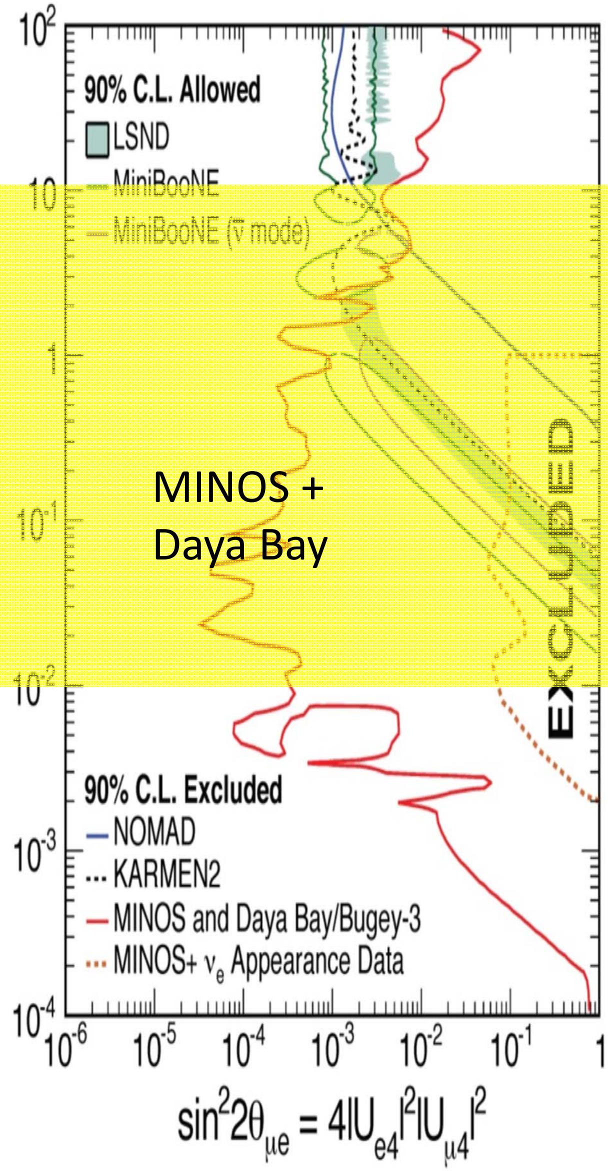
accelerator-based

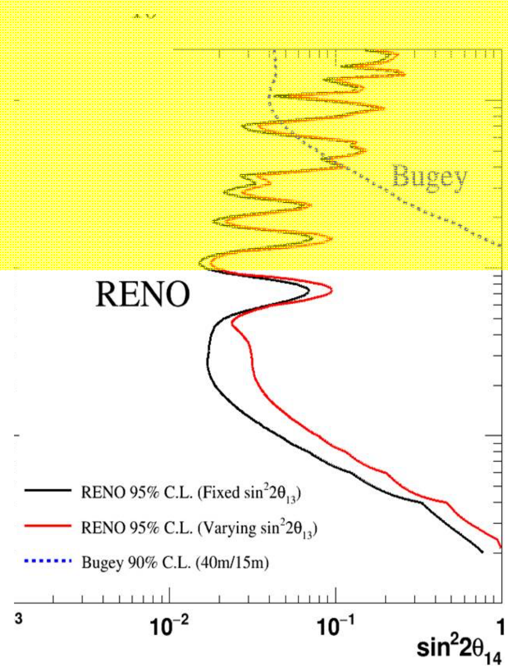


Long simmering issue of sterile neutrinos

No evidence



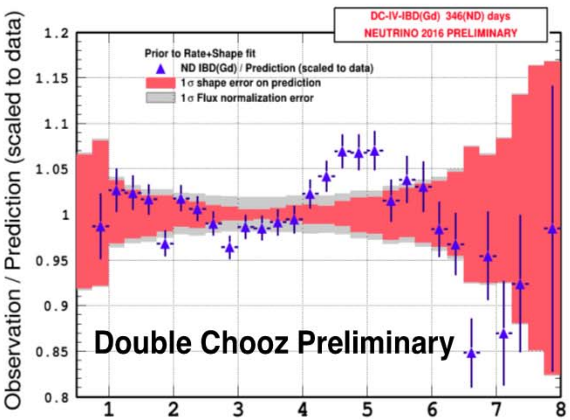




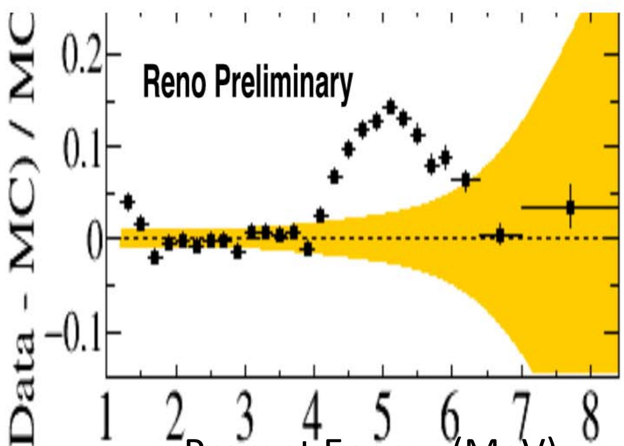
Long simmering issue of sterile neutrinos

Reactor neutrino flux is lower than prediction by latest models:
Sterile neutrinos could explain this discrepancy

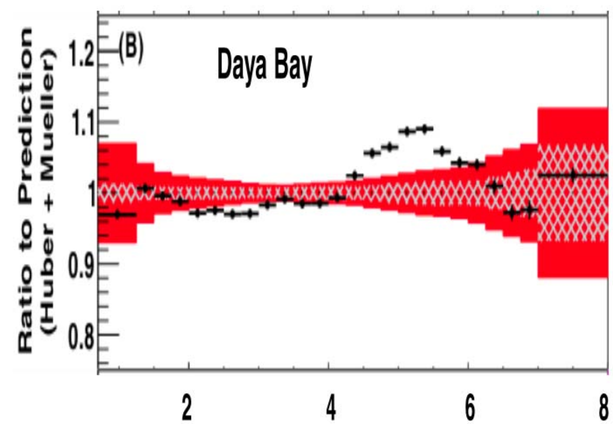
These models failed to predict the 5 MeV bump



Visible Energy (MeV)



Prompt Energy (MeV)



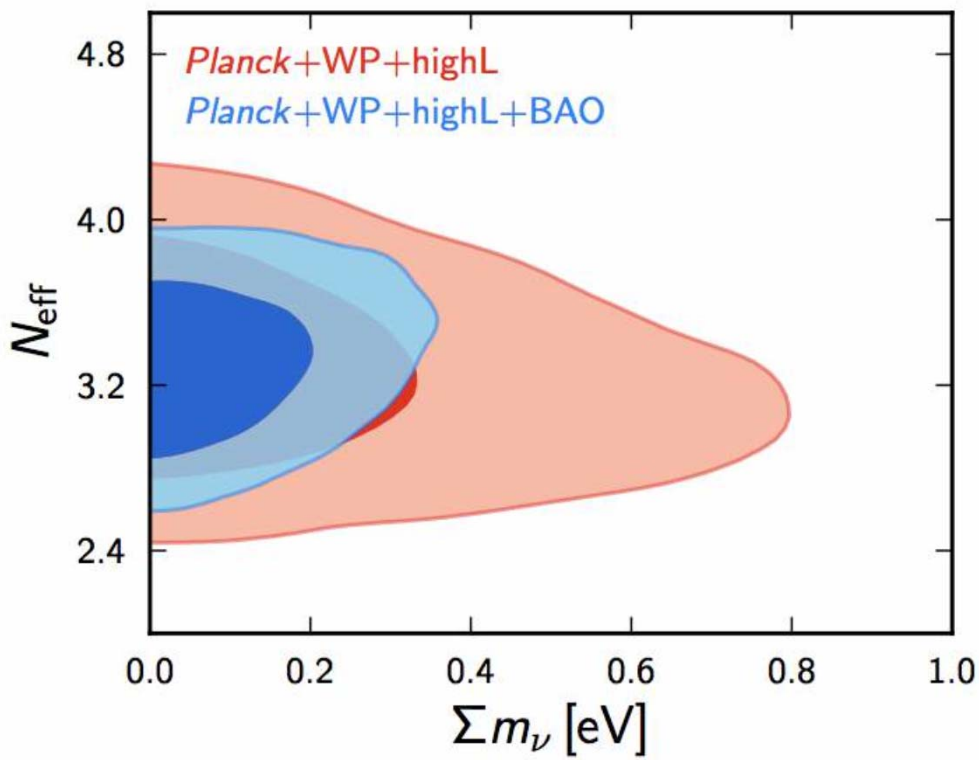
Energy (MeV)

Need an influx of theorists to make better calculations

Neutrino mass

Cosmic Microwave Background experiments

Planck Collaboration (plot 2013; constraints 2015)



$\Sigma m_\nu < 0.23$ eV @95%, $N_\nu^{eff} = 3.15 \pm 0.23$

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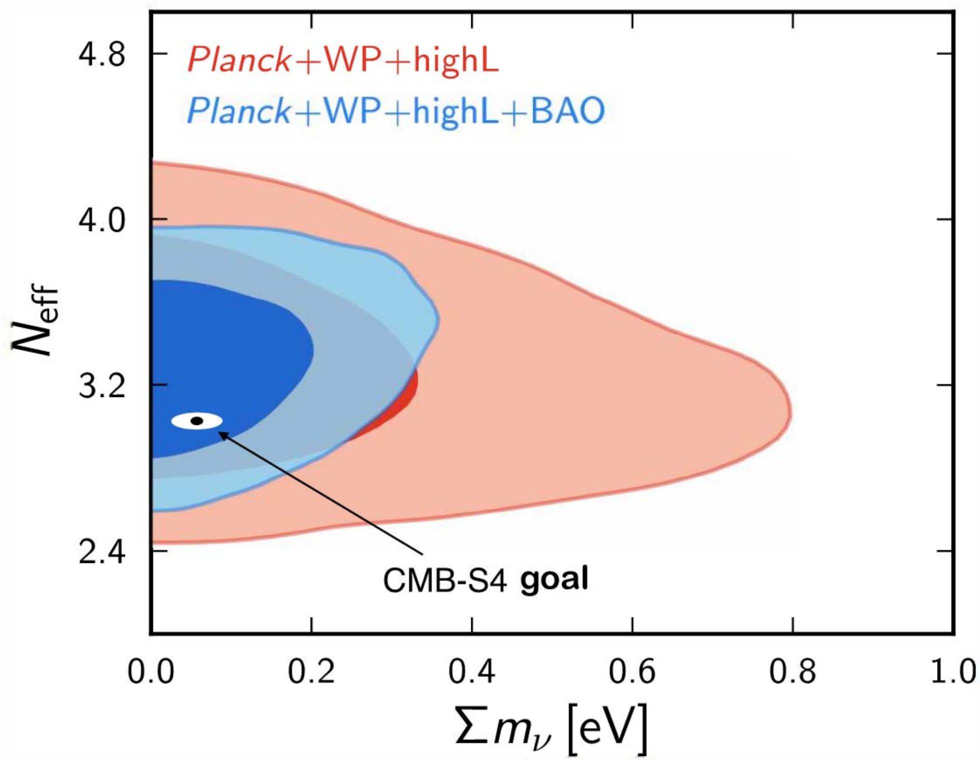

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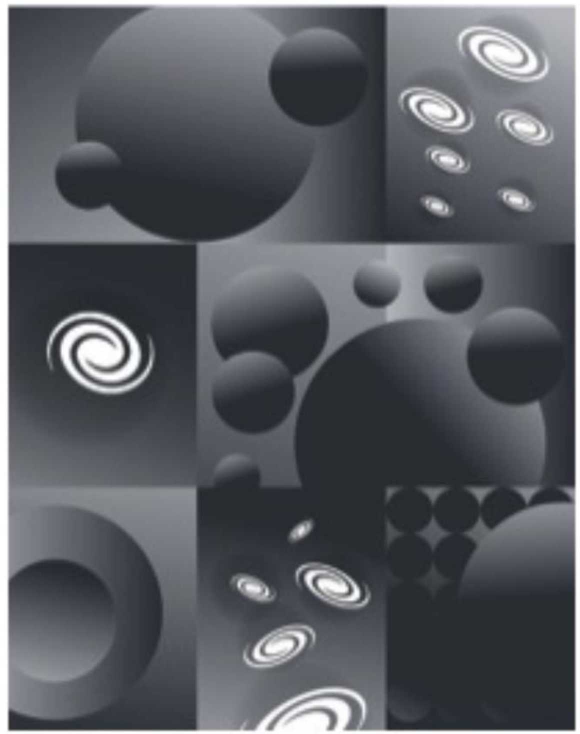
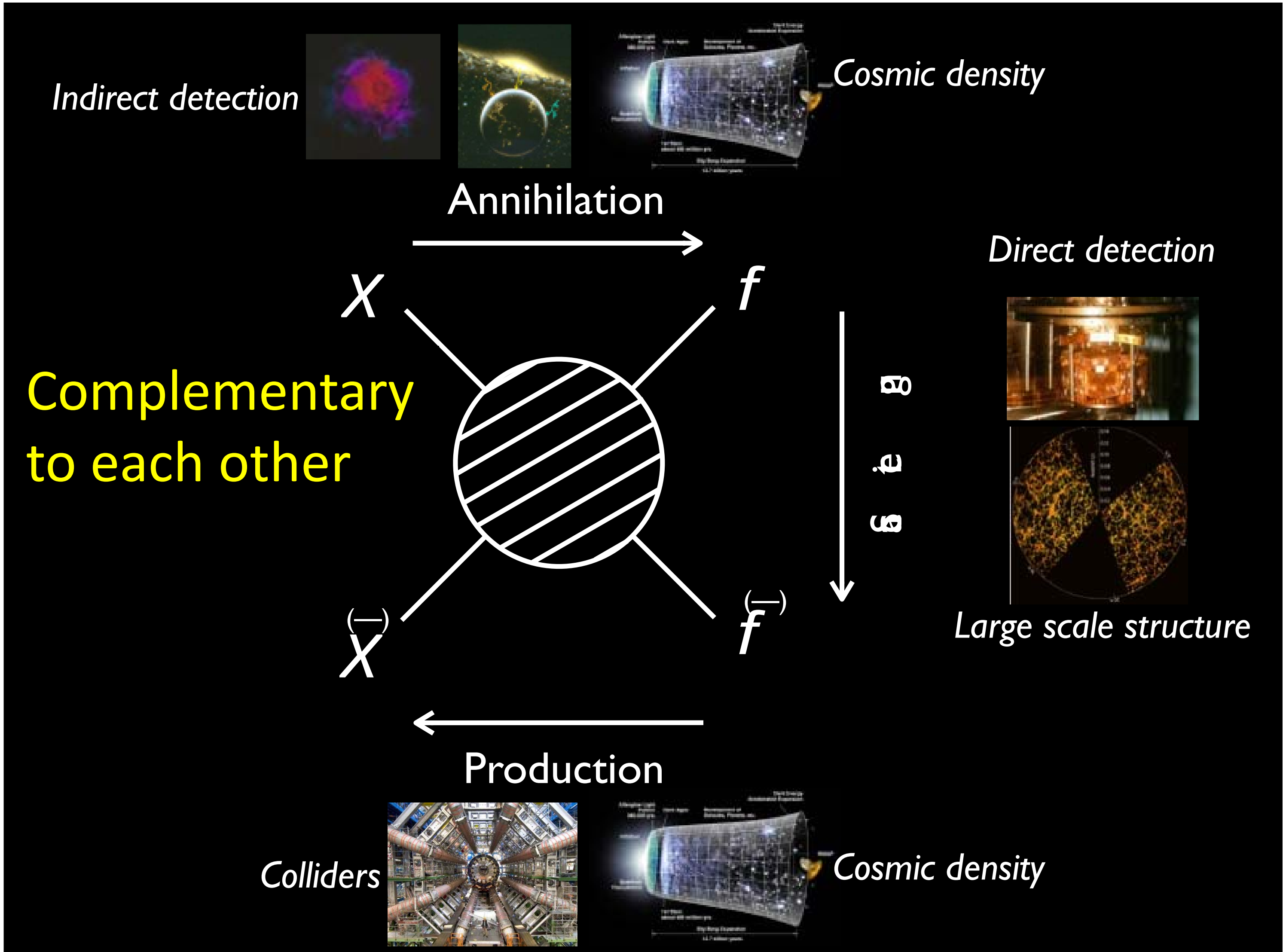
Dark Matter



dominates the universe, but its identity is still mysterious

Experimental approaches



The field is as vibrant as ever!

Direct searches: underground facilities are also for ν's, proton decays

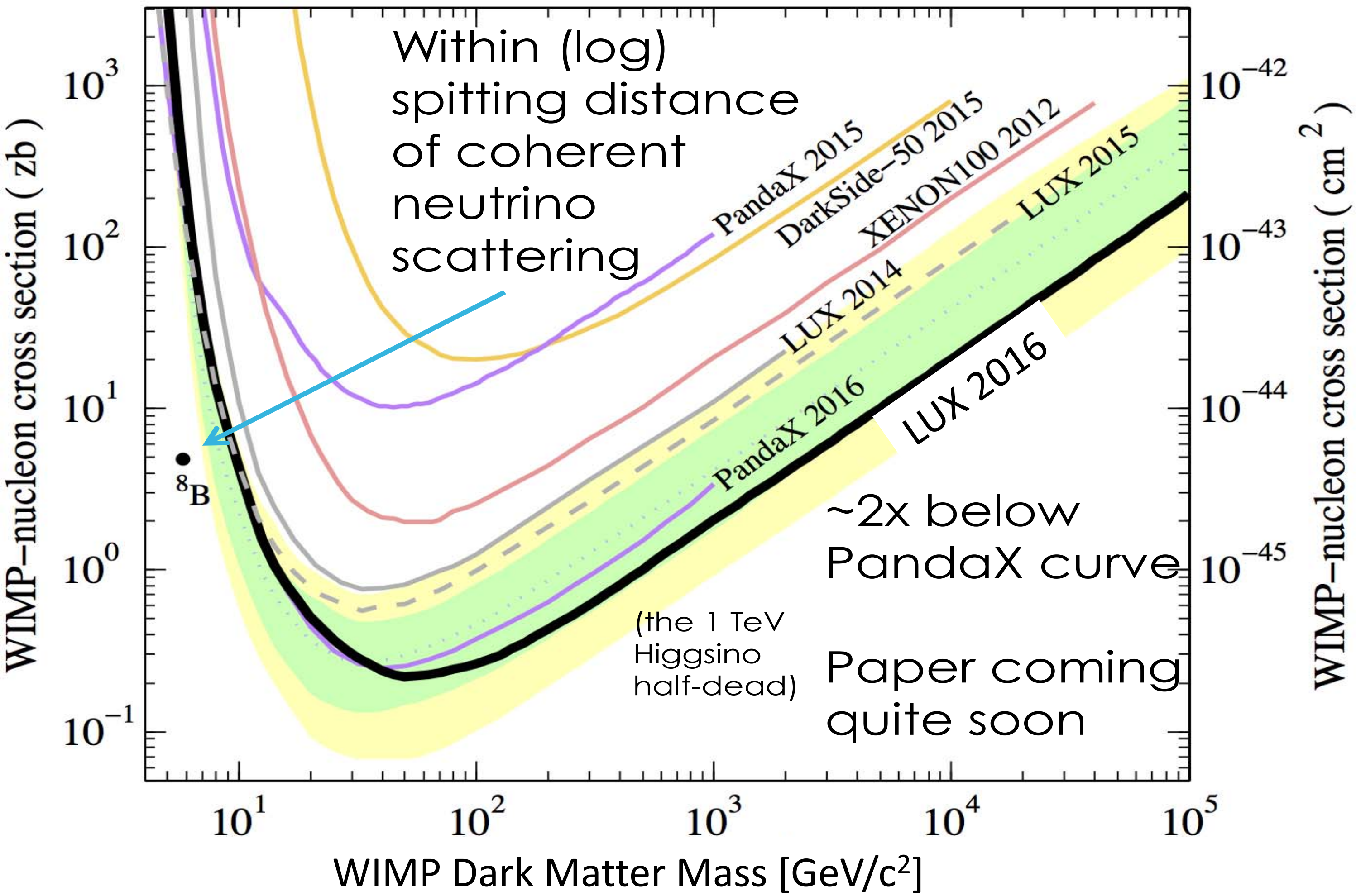
- XMASS (800 kg LXe, Kamioka, 2011-)
- SuperCDMS (25kg Ge, Soudan, 2012-)
- LUX (350 kg LXe, Homestake, 2012-)
- DarkSide (50 kg LAr, Gran Sasso, 2012-)
- COUPP (60 kg CF_3I, SNOLab, 2012-)
- XENON-1T (1 ton LXe, Gran Sasso, 2014-)
- EURECA, DARWIN, ……

The field is as vibrant as ever!

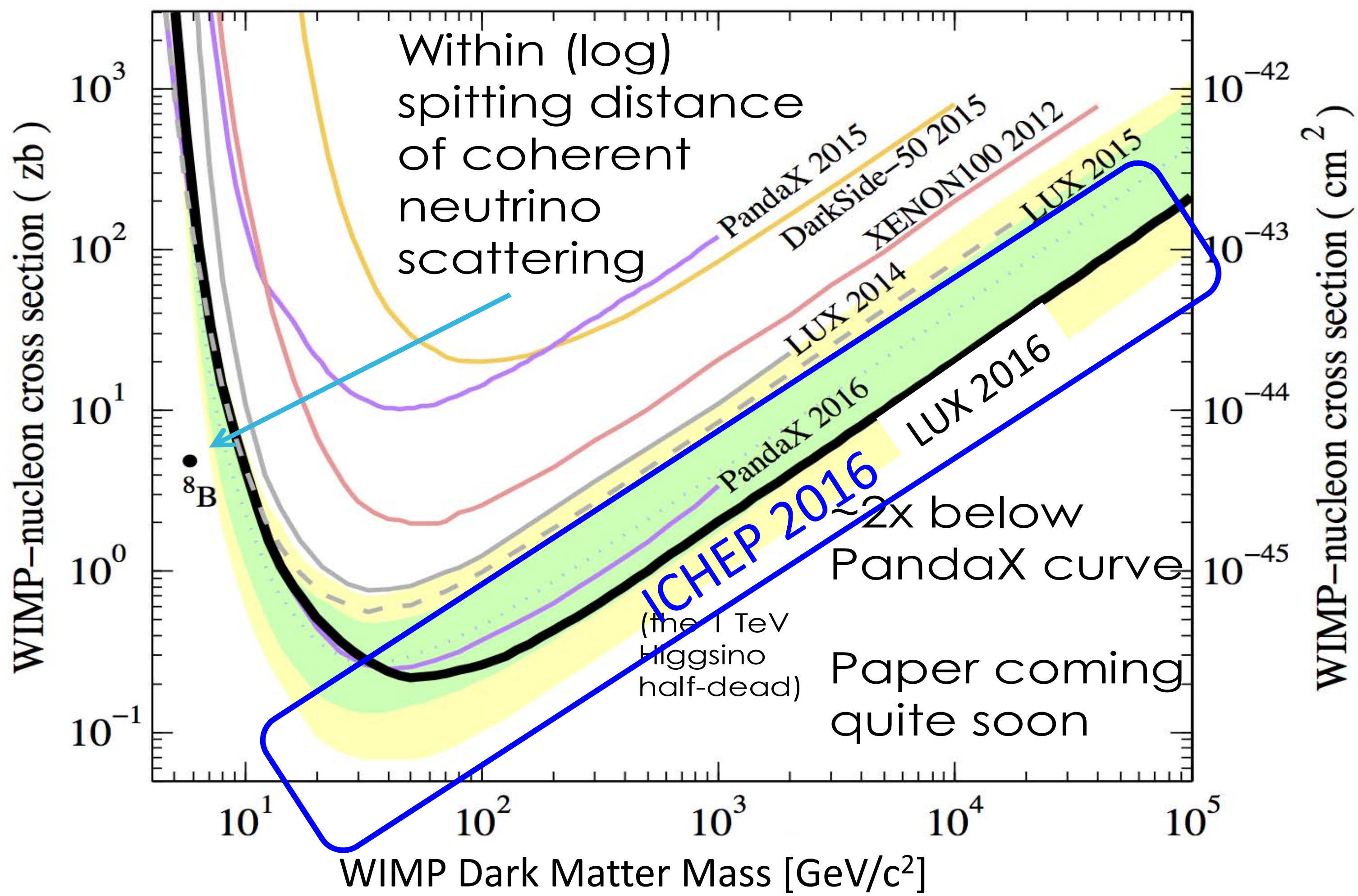
Direct searches: underground facilities are also for ν's, proton decays

- XMASS (800 kg LXe, Kamioka, 2011-)
- SuperCDMS (25kg Ge, Soudan, 2012-)
- LUX (350 kg LXe, Homestake, 2012-)
- DarkSide (50 kg LAr, Gran Sasso, 2012-)
- COUPP (60 kg CF_3I, SNOLab, 2012-)
- XENON-1T (1 ton LXe, Gran Sasso, 2014-)
- EURECA, DARWIN, ……

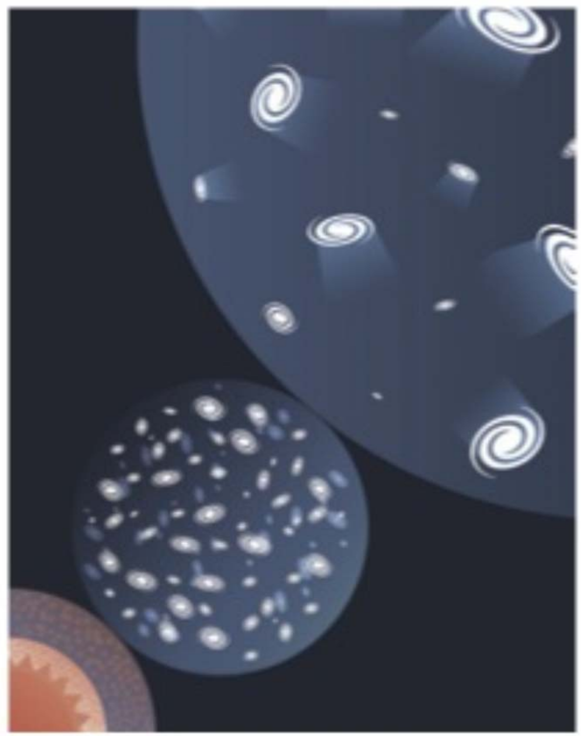
Direct WIMP searches: Spin independent



Direct WIMP searches: Spin independent

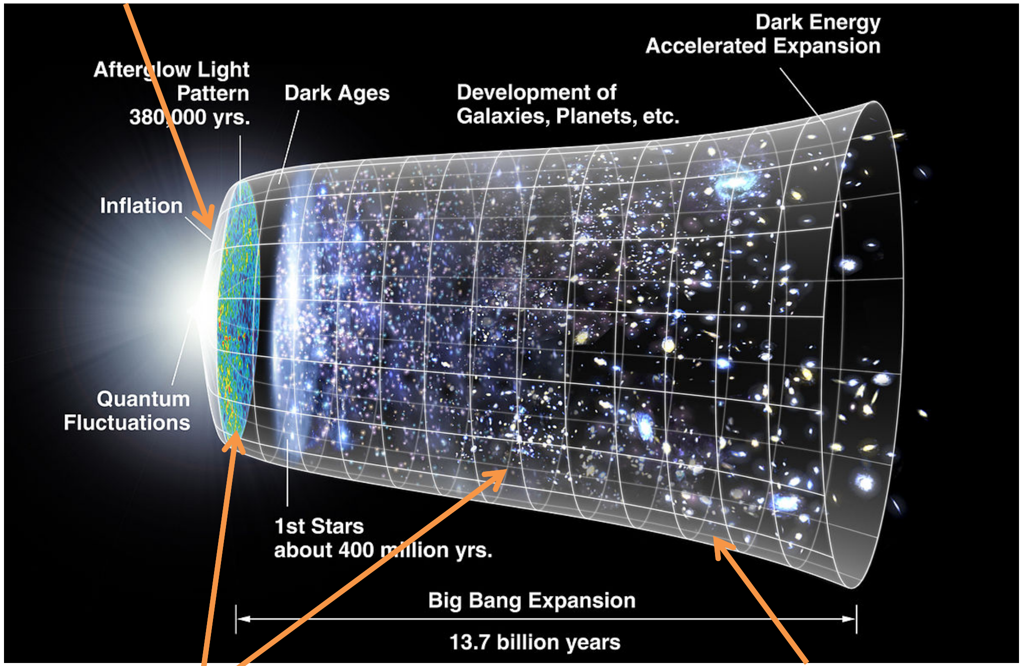


Dark Energy and Inflation



Accelerated expansion of the universe

1st epoch: Inflation, a primordial epoch of acceleration

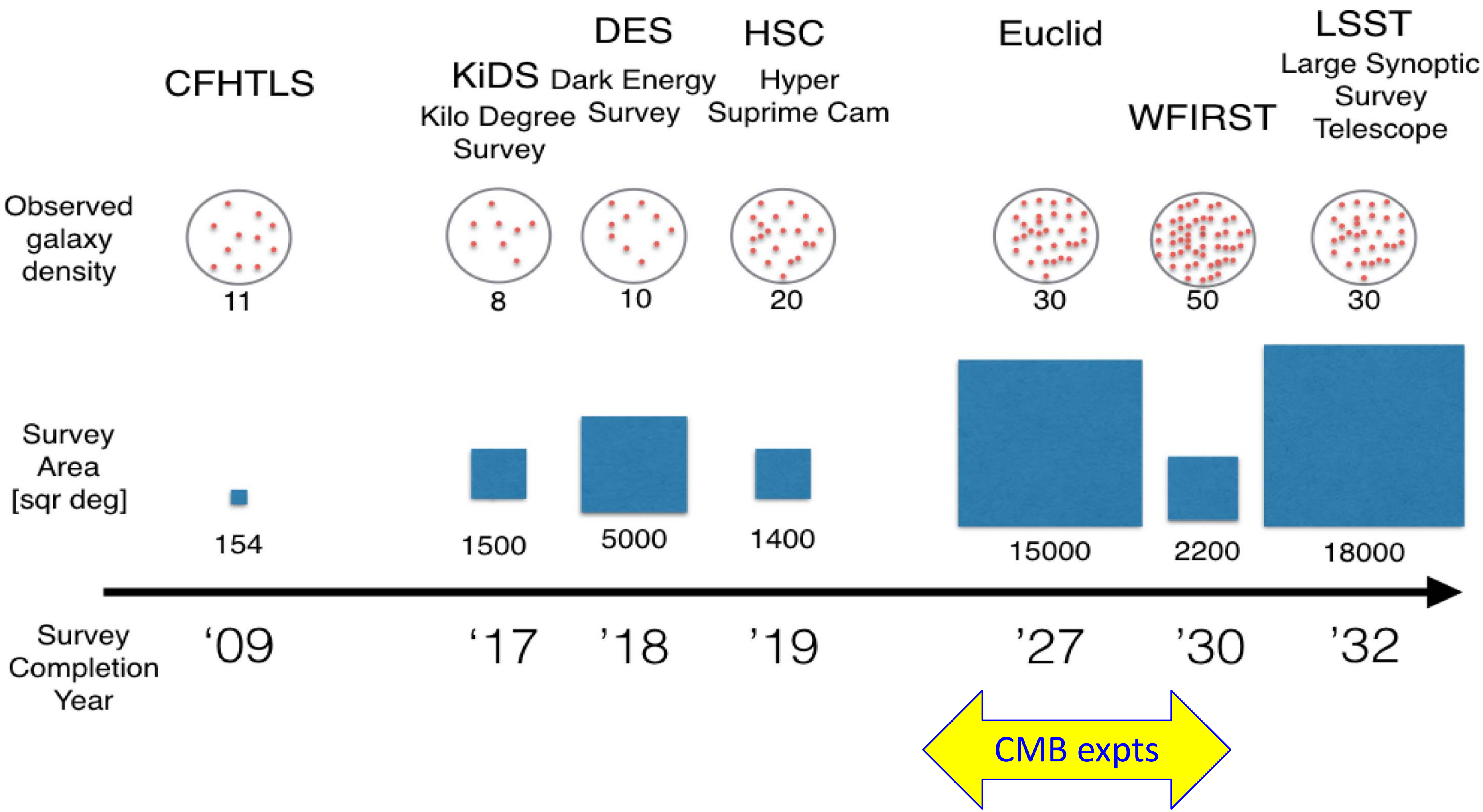


2nd epoch:
began recently, continues today
Driven by dark energy?

Σm_ν impacts
growth of structure

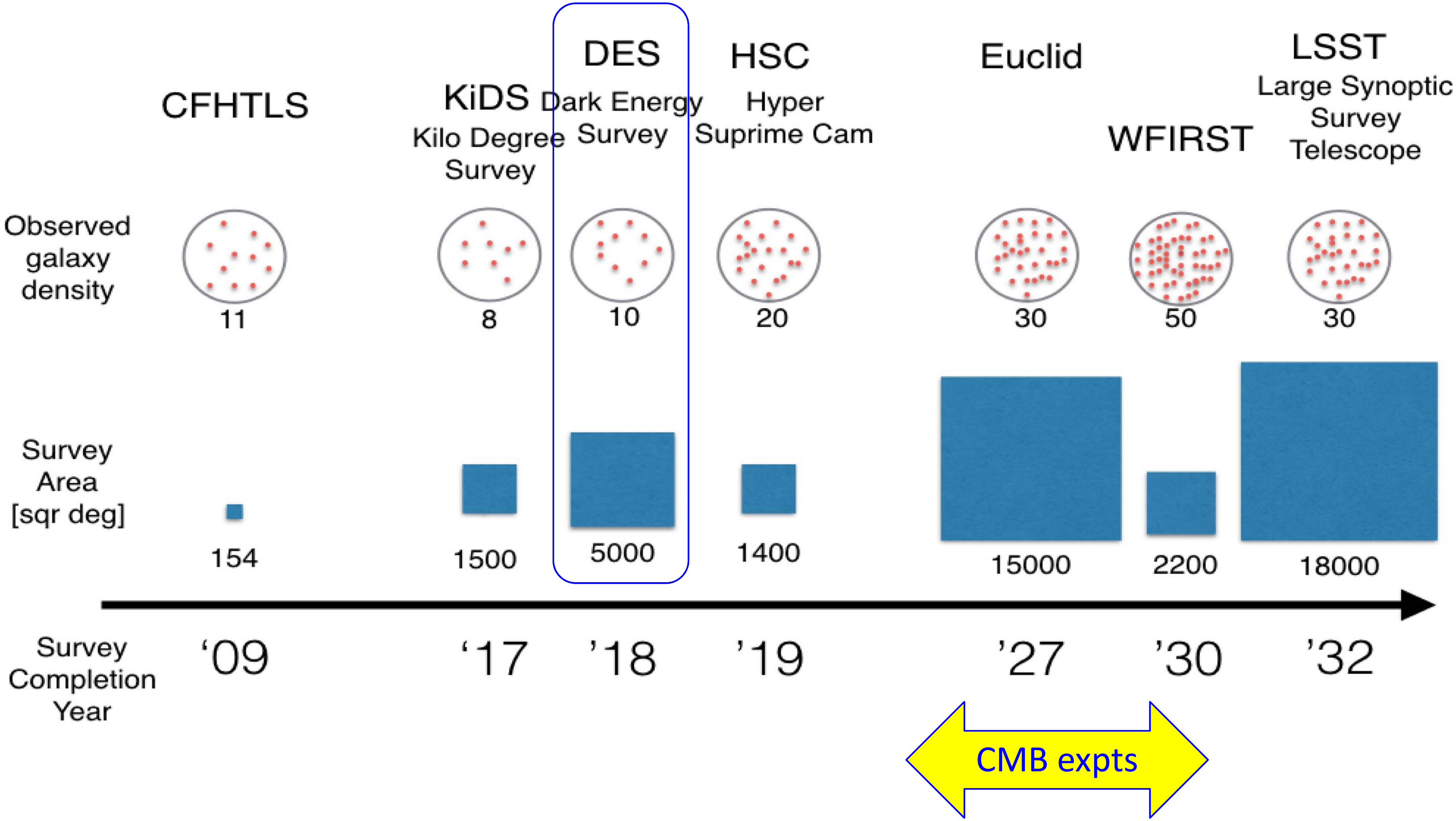
Complementary strengths of ground and space experiments

Photometric Dark Energy Surveys



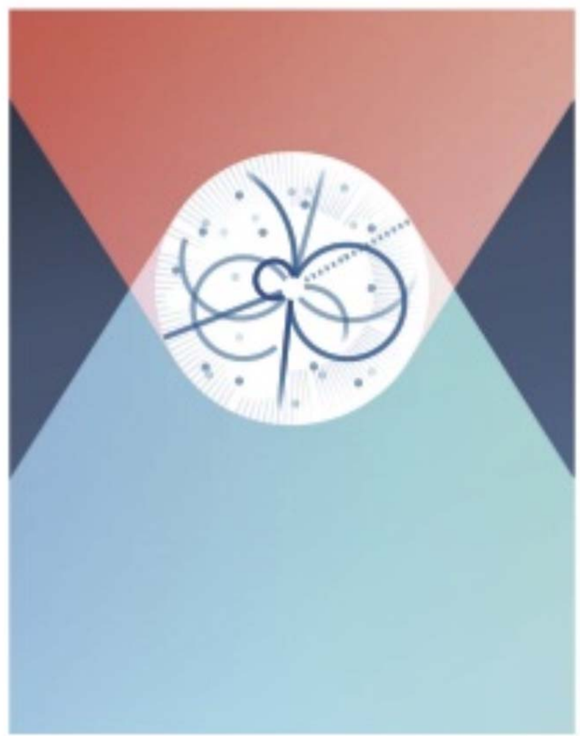
PIXIE (~2023), LiteBIRD (~2025), LiteCORE (~2026-2030), CMB-S4

Photometric Dark Energy Surveys

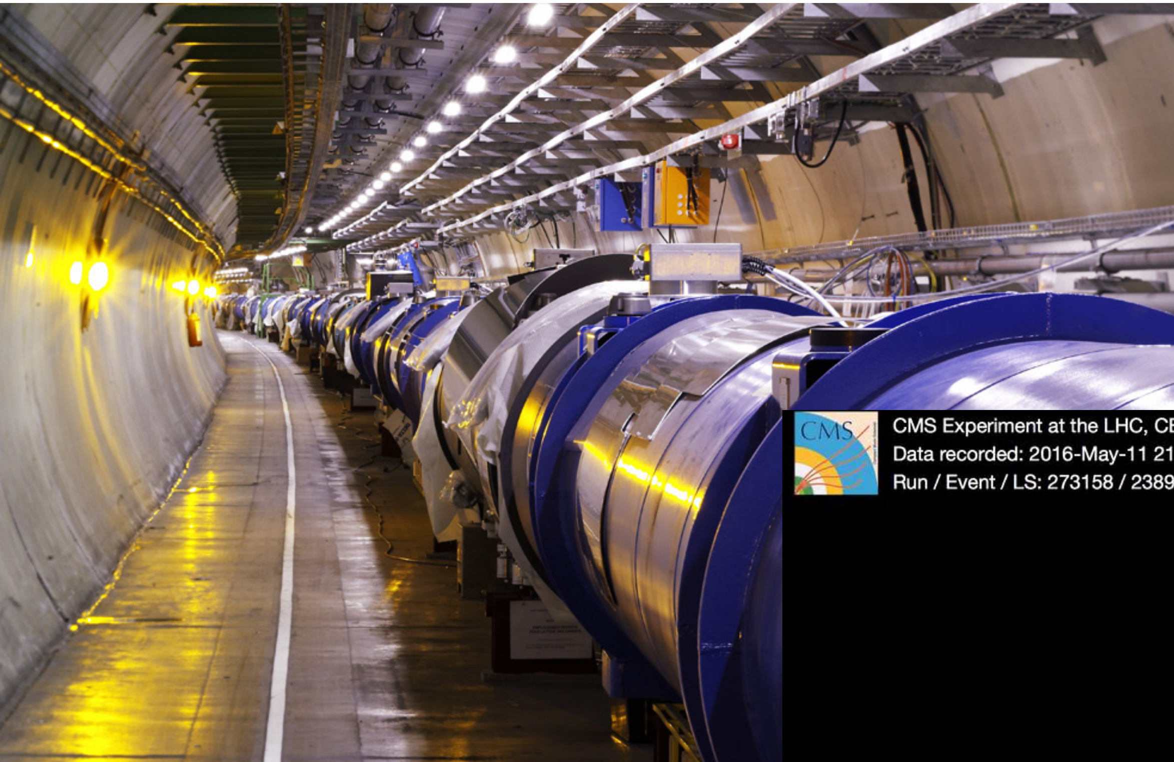


PIXIE (~2023), LiteBIRD (~2025), LiteCORE (~2026-2030), CMB-S4

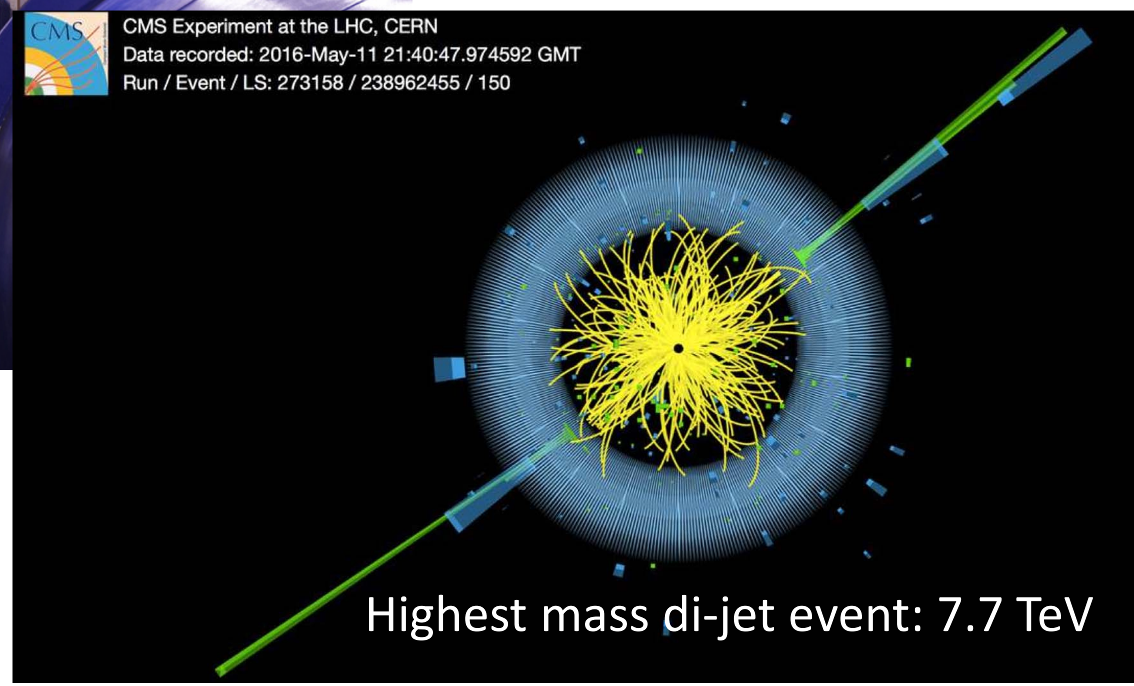
Explore the unknowns:
new particles, interactions, physical principles



Producing new particles?

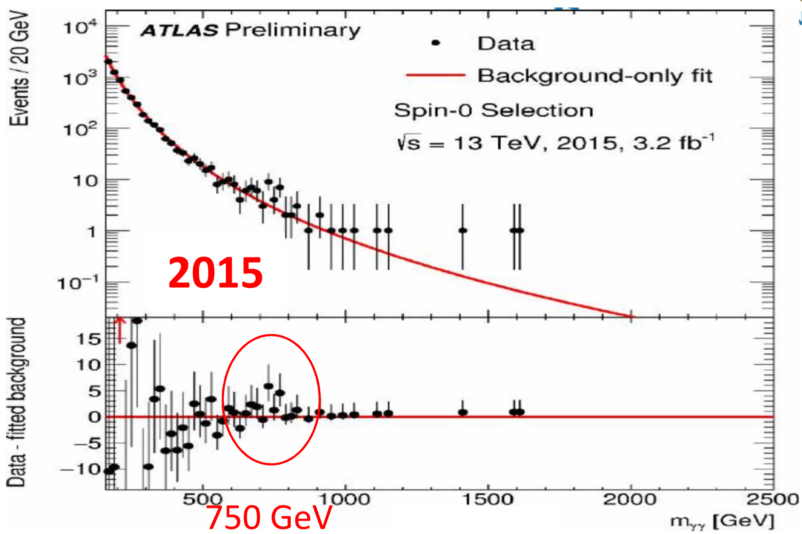


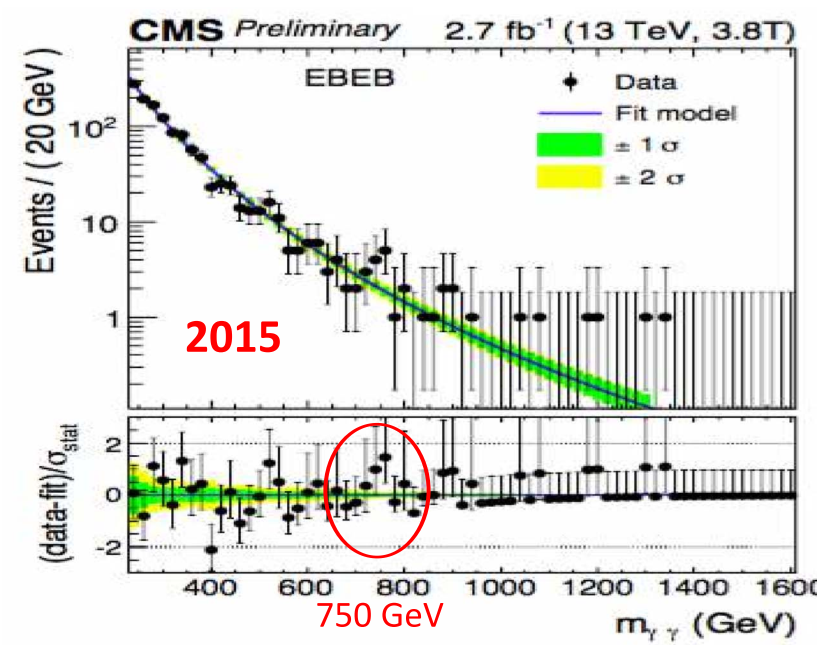
Exploring the unknown
at unexplored energies
with unprecedented rates



Update on 750 GeV $\gamma\gamma$ resonance:

the most highly anticipated





Update on 750 GeV $\gamma\gamma$ resonance:

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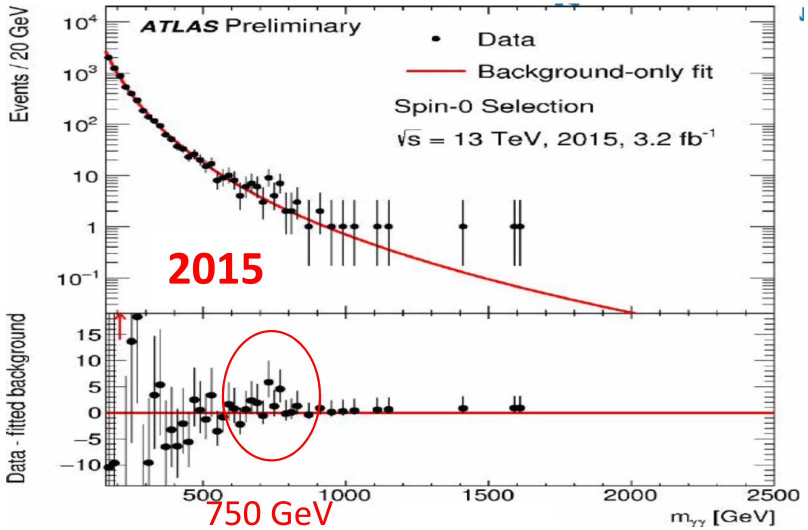
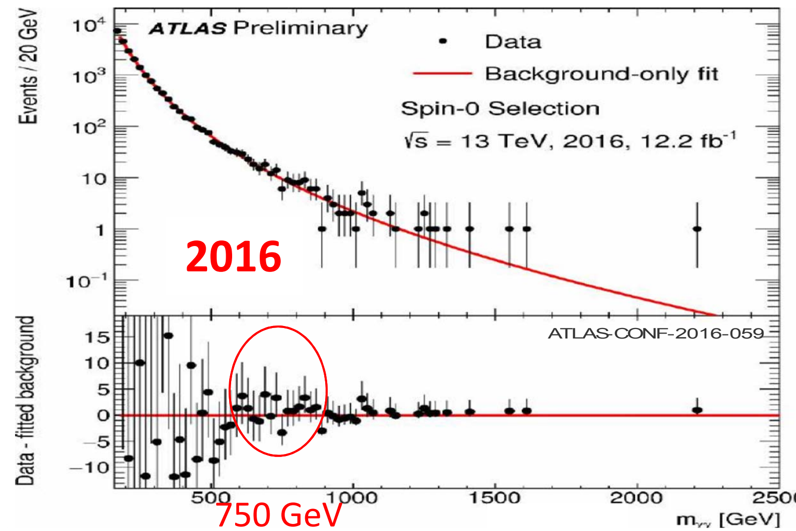
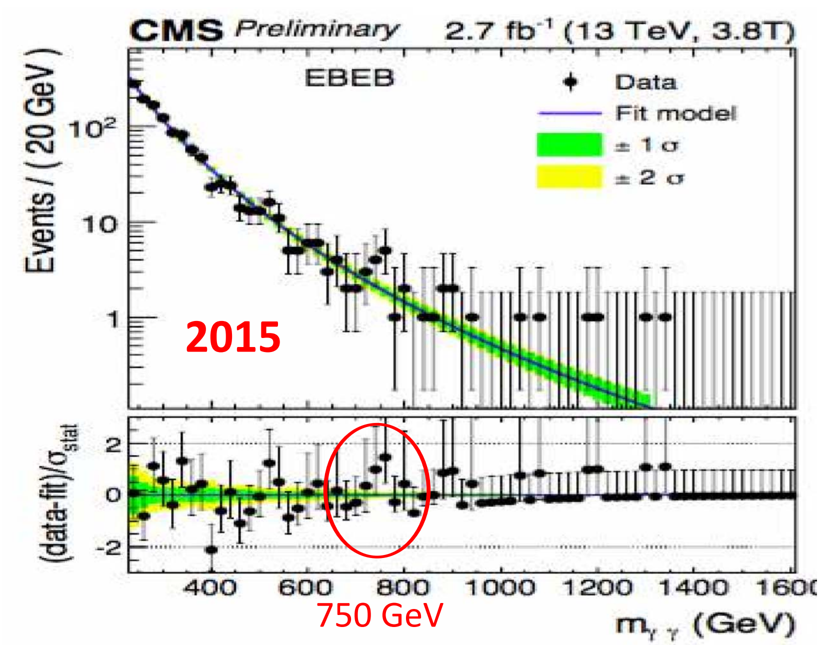
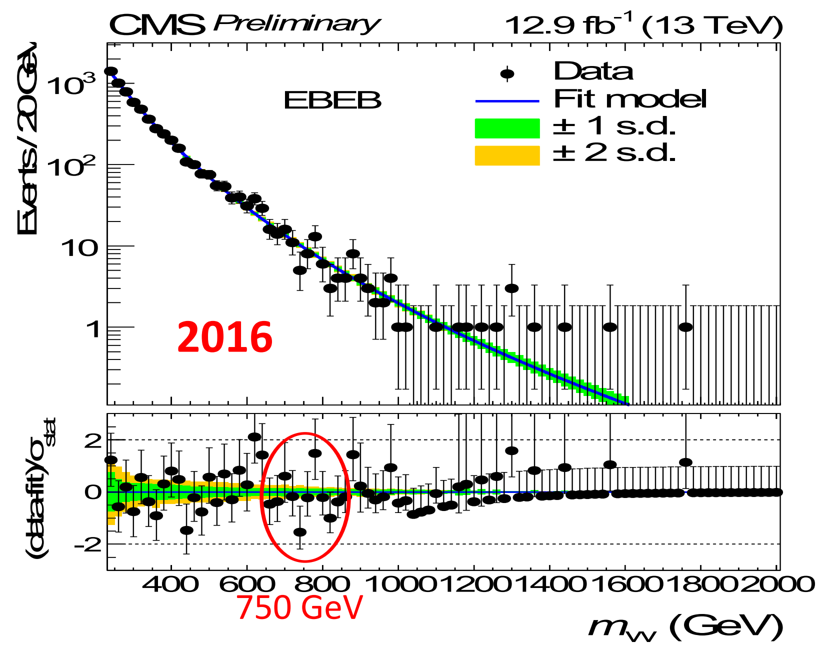
ICHEP 2016









Update on 750 GeV $\gamma\gamma$ resonance:

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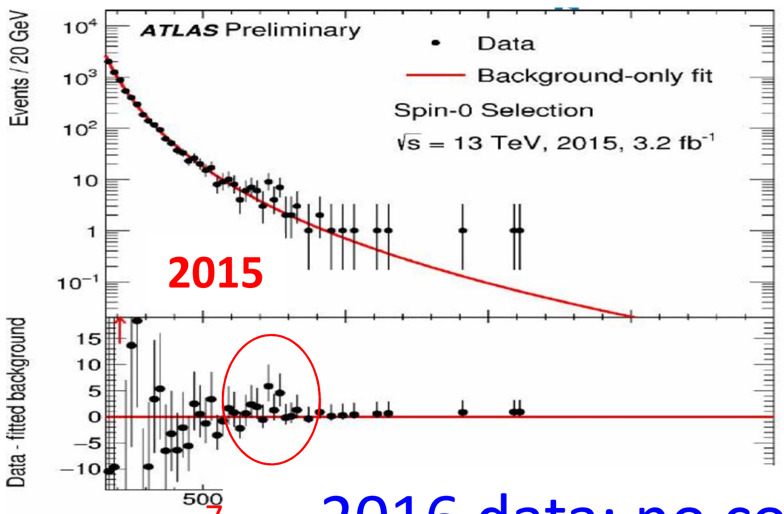
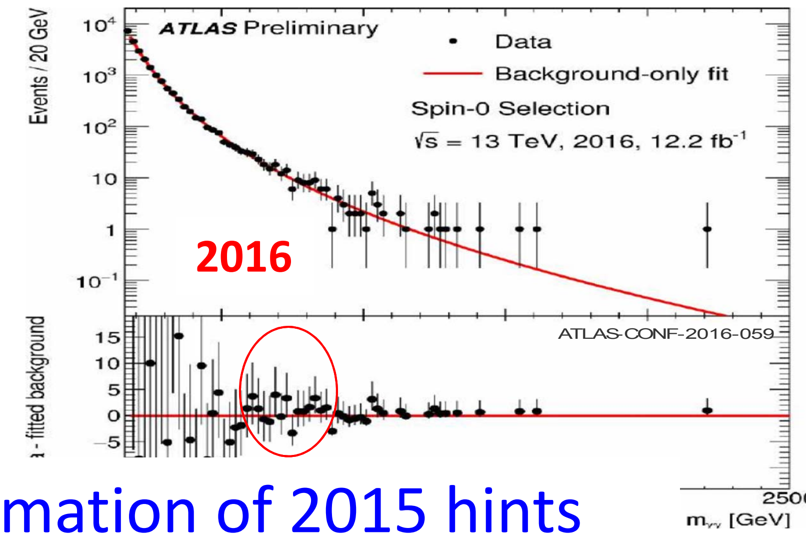
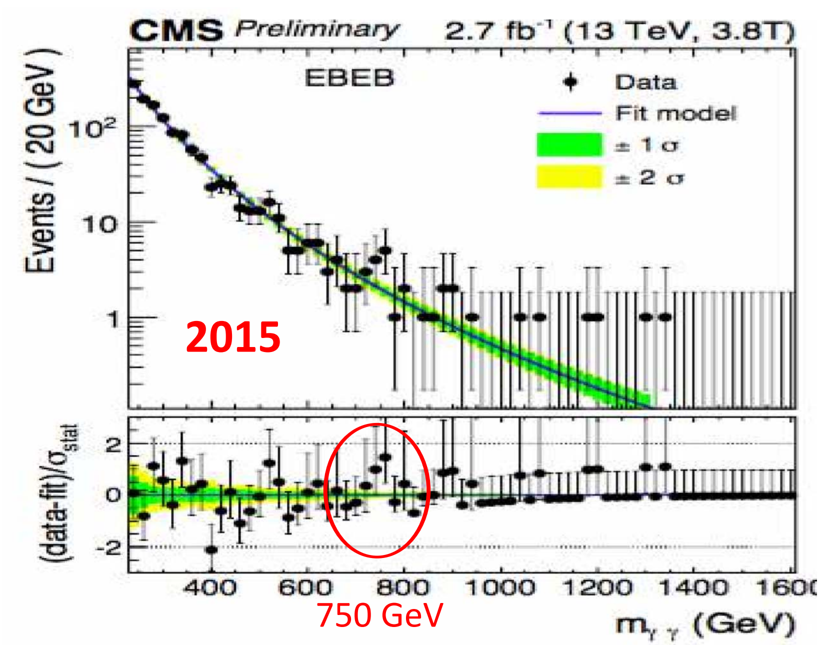
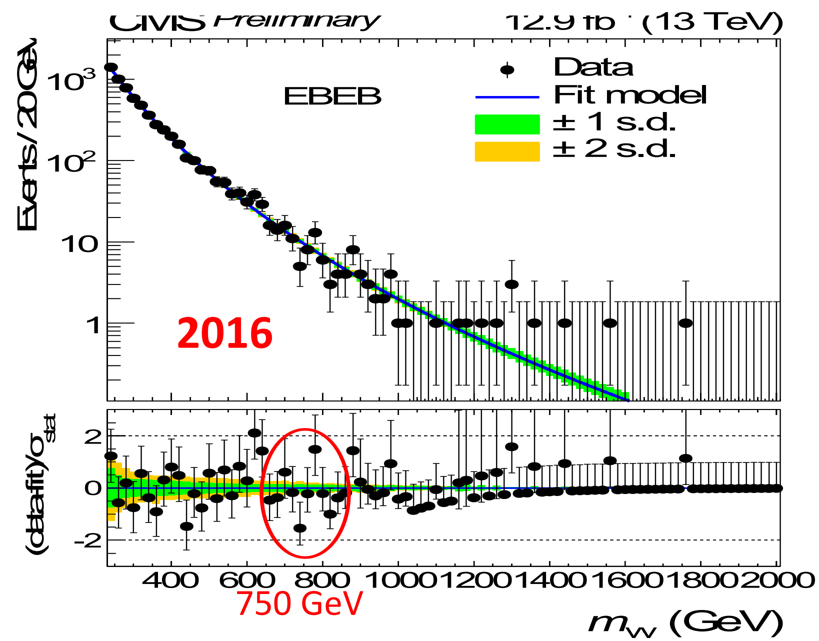
ICHEP 2016



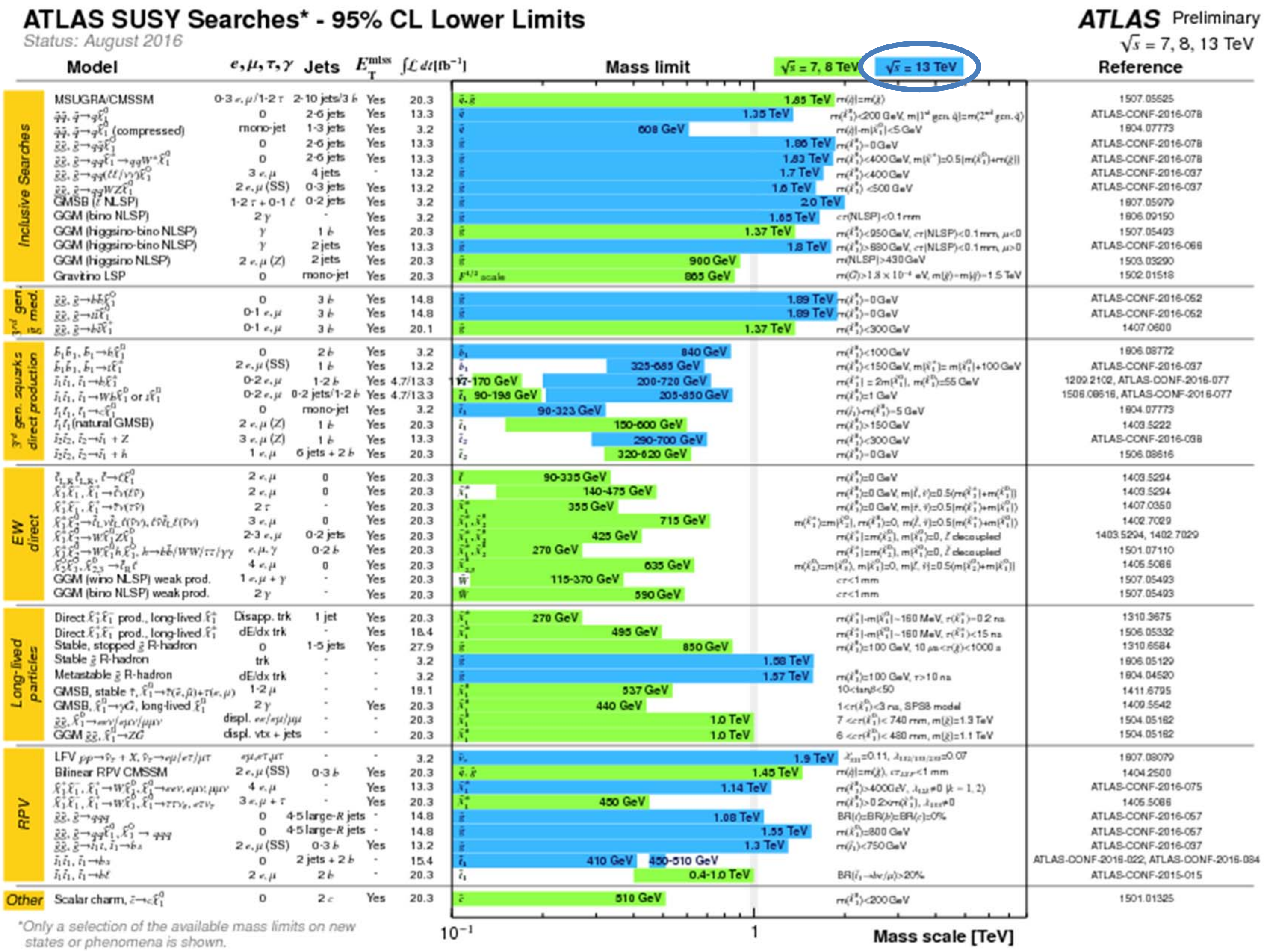


2016 data: no confirmation of 2015 hints

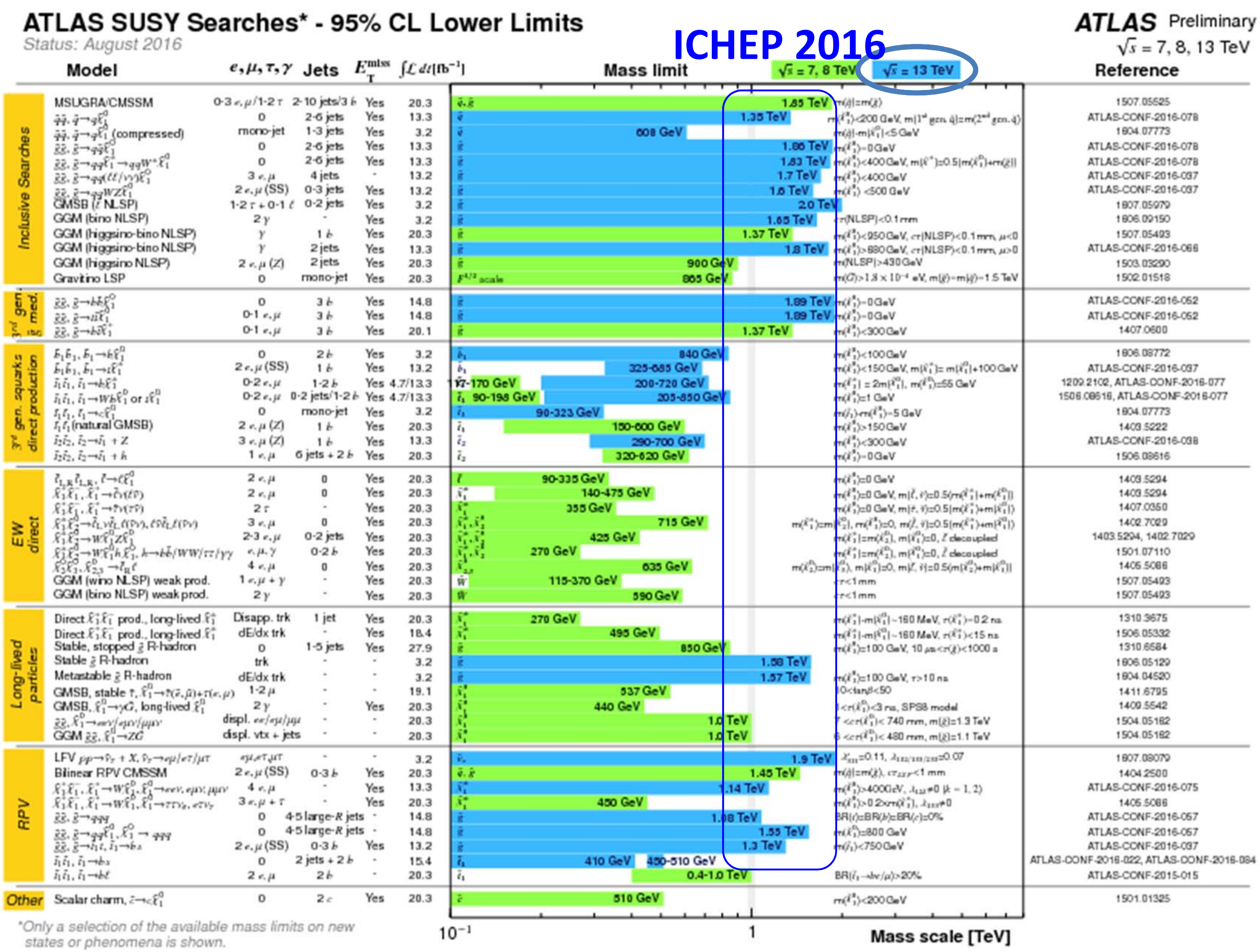




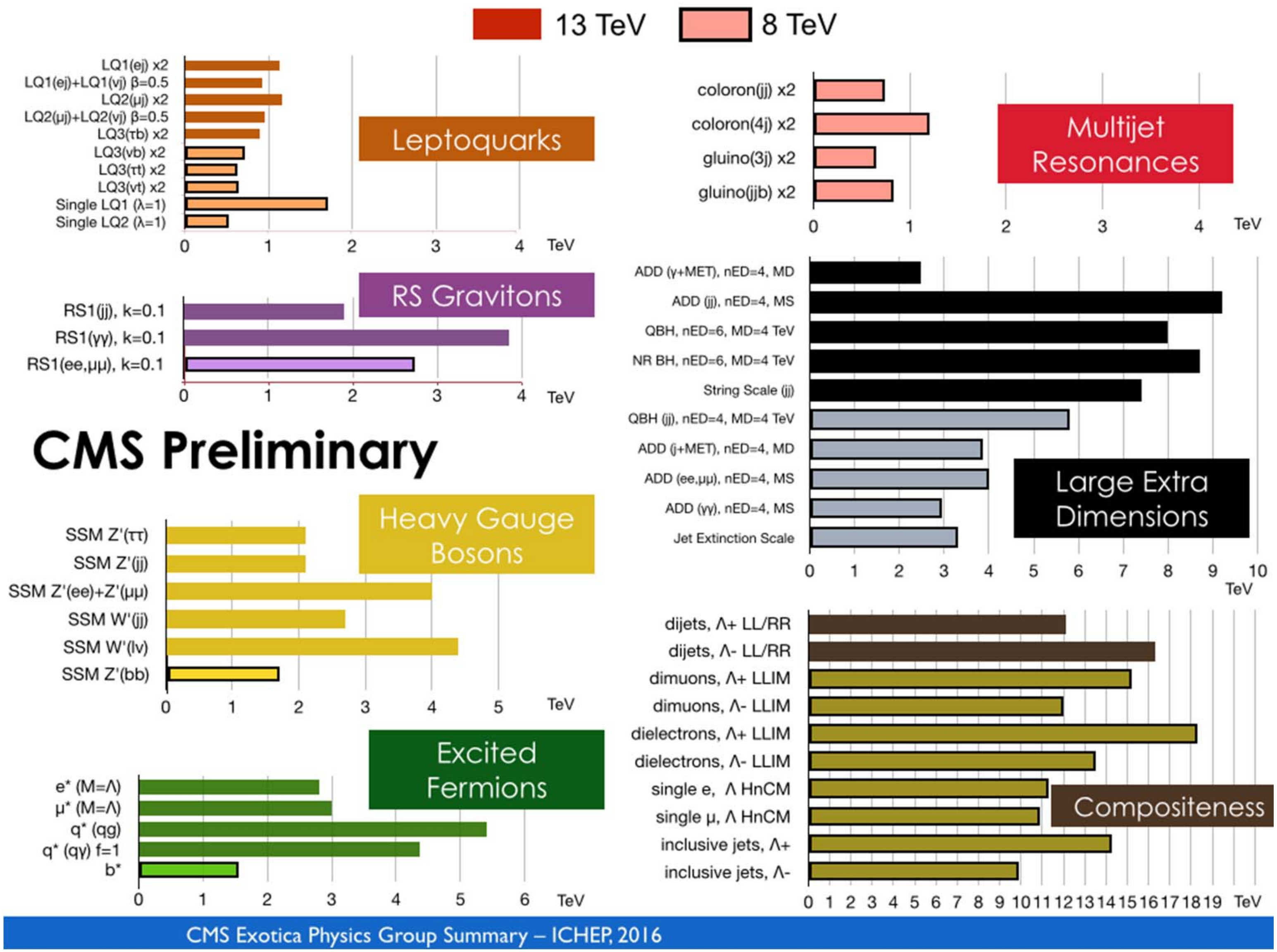
Beyond the Standard Model: SUSY Searches



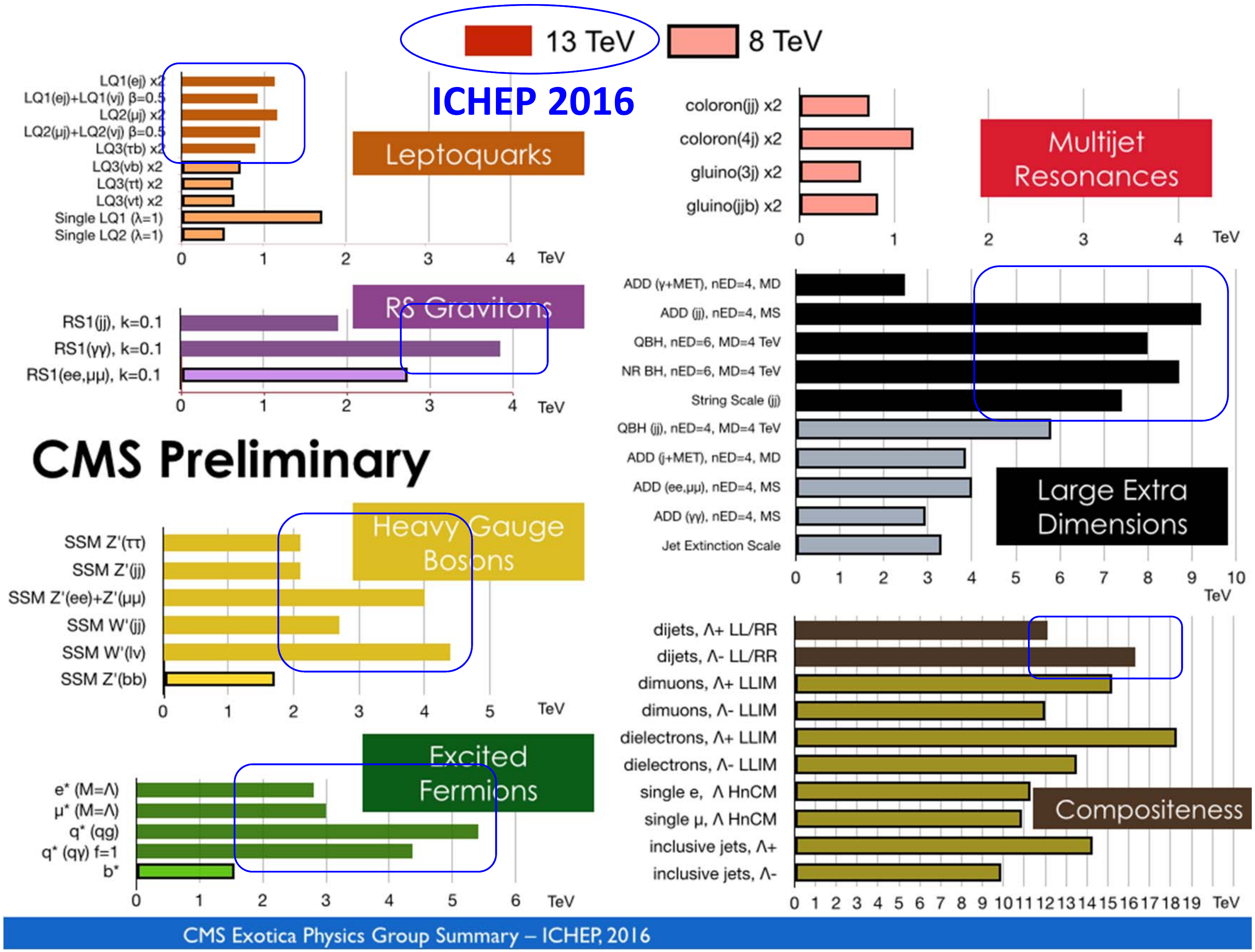
Beyond the Standard Model: SUSY Searches



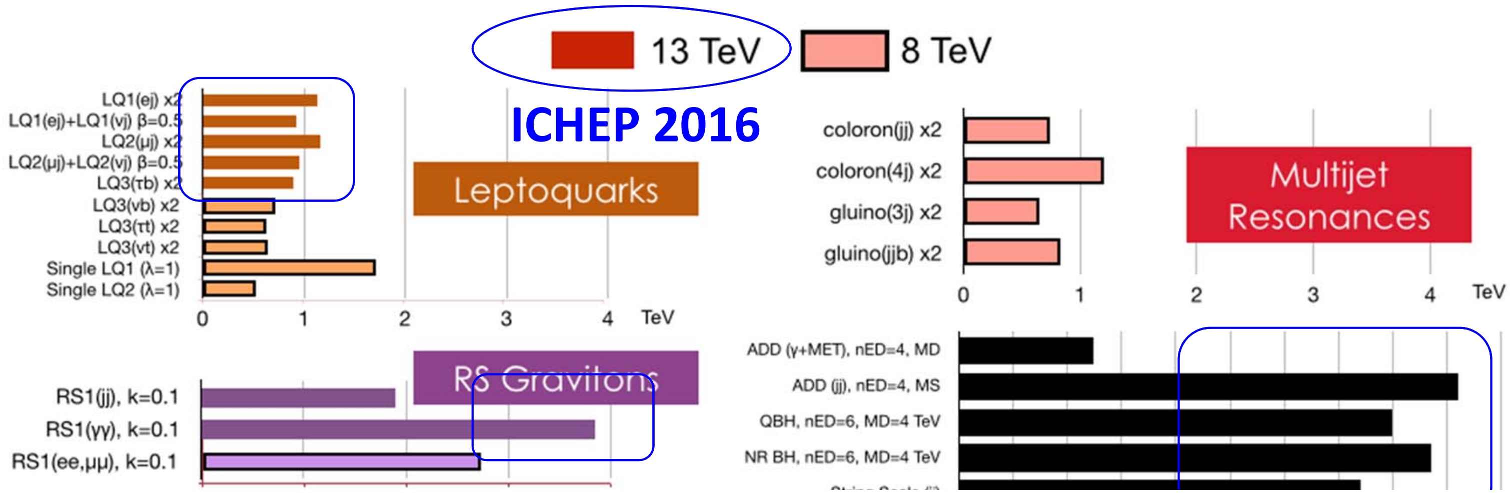
Beyond the Standard Model: Exotics Searches



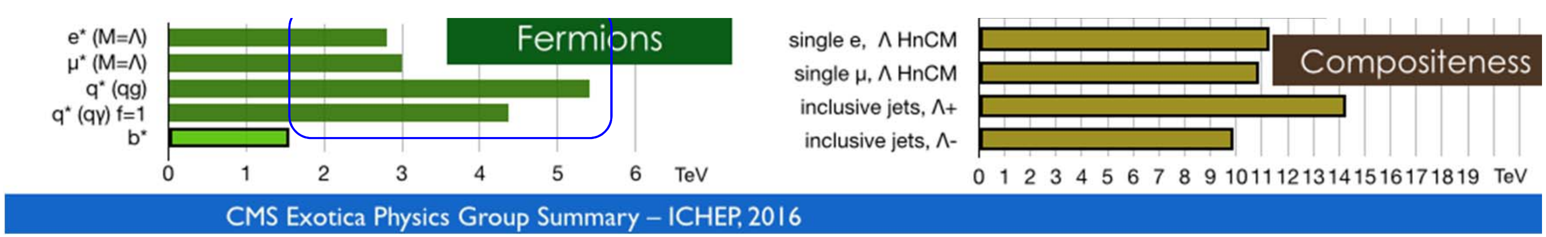
Beyond the Standard Model: Exotics Searches



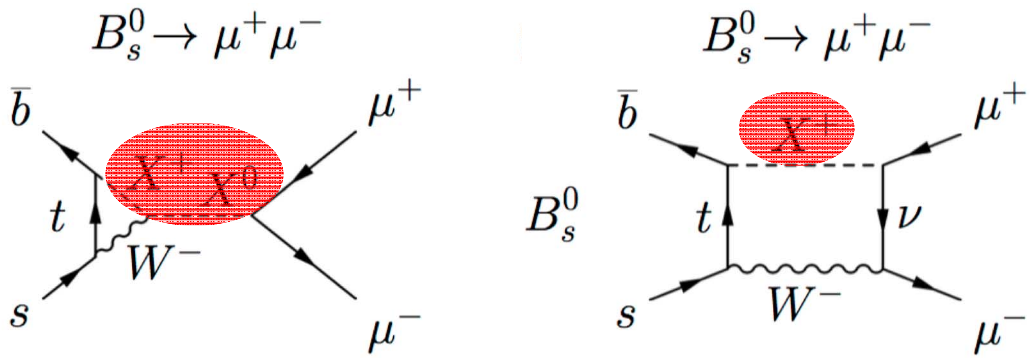
Beyond the Standard Model: Exotics Searches



- Unfortunately the hints from Run 1 and 2015 data were not confirmed in 2016.
- However, the limits set significantly extend the Run 1 results, thus further constraining various models.



Detecting the quantum influence of new particles



- Questions
  - Why 3 families?
  - Why so many?
  - Masses and mixing
    - Why quark mixing so different from neutrino mixing?
  - CP violation in the leptonic sector
  - Matter and antimatter asymmetry
  - Baryon and charged lepton number violation
  - ….

Many experimental results from

ATLAS, CMS, ALICE, LHCb, LHCf, COMPASS, PHENIX, CDF, DZero, BaBar, Belle, BES-III, NA62, KOTO, MEG, KLOE, Muon g-2, DeeMe, Mu2e, COMET, H1, ZEUS, SND, CMD-3, …

Many experimental results from

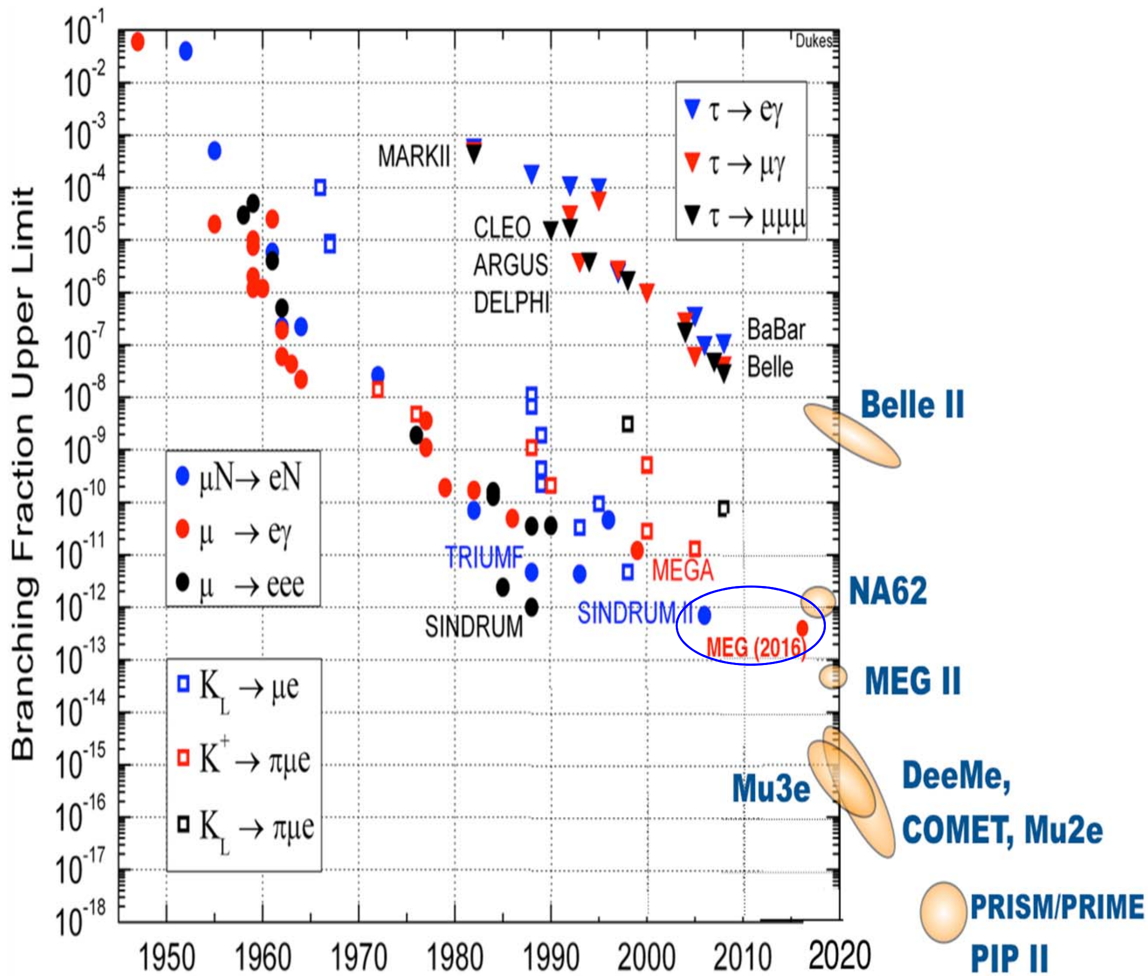
ATLAS, CMS, ALICE, LHCb, LHCf, COMPASS, PHENIX, CDF, DZero, BaBar, Belle, BES-III, NA62, KOTO, MEG, KLOE, Muon g-2, DeeMe, Mu2e, COMET, H1, ZEUS, SND, CMD-3, …

News since ICHEP 2014:
NA62 at CERN (charged kaon) started taking data
KOTO at J-PARC (neutral kaon) resumed data taking
Muon g-2 at Fermilab will be soon running
Super KEKB at KEK good progress made

Charged lepton flavor violation ($\mu \rightarrow e$)

Observation → a clear signature of new physics

- $\mu^+ \rightarrow e^+\gamma$
  - MEG at PSI
    - $< 4.2 \times 10^{-13}$ @90% CL
  - MEG II: x10 sensitivity
    - End 2017
- $\mu \rightarrow eee$
  - Mu3e at PSI
    - Stage 1: 2018-2020
    - Stage 2: > 2020
- μ to e conversion
  - Mu2e at Fermilab
    - ~2021
  - COMET at J-PARC
    - Phase I: 2018-2019
    - Phase II: ~2021



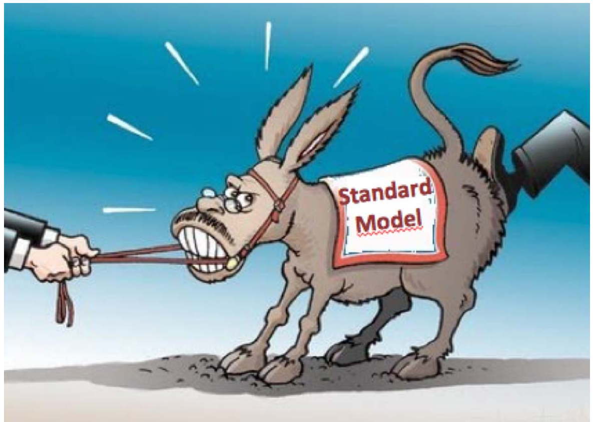
Developments on theory

- Tremendous developments in
  - theoretical calculations and new physics models
- Recent lattice QCD calculations play a key role
  - reliable theoretical predictions are needed on same time scale as measurements with commensurate uncertainties

Decay constants, form factors,
& mixing parameters

Results presented at ICHEP 2016

- Many new results
- But no new physics observed



The Standard Model is a
stubborn animal, indeed!

- Some interesting excesses worth keeping an eye on as more data become available

- A vast number of scientific opportunities on offer now and in the future

Enabling Technologies

One of the most popular parallel-session themes, ~400 abstracts submitted

Detectors (277 abstracts)
Accelerators (58 abstracts)
Computing (52 abstracts)

Particle physics is global

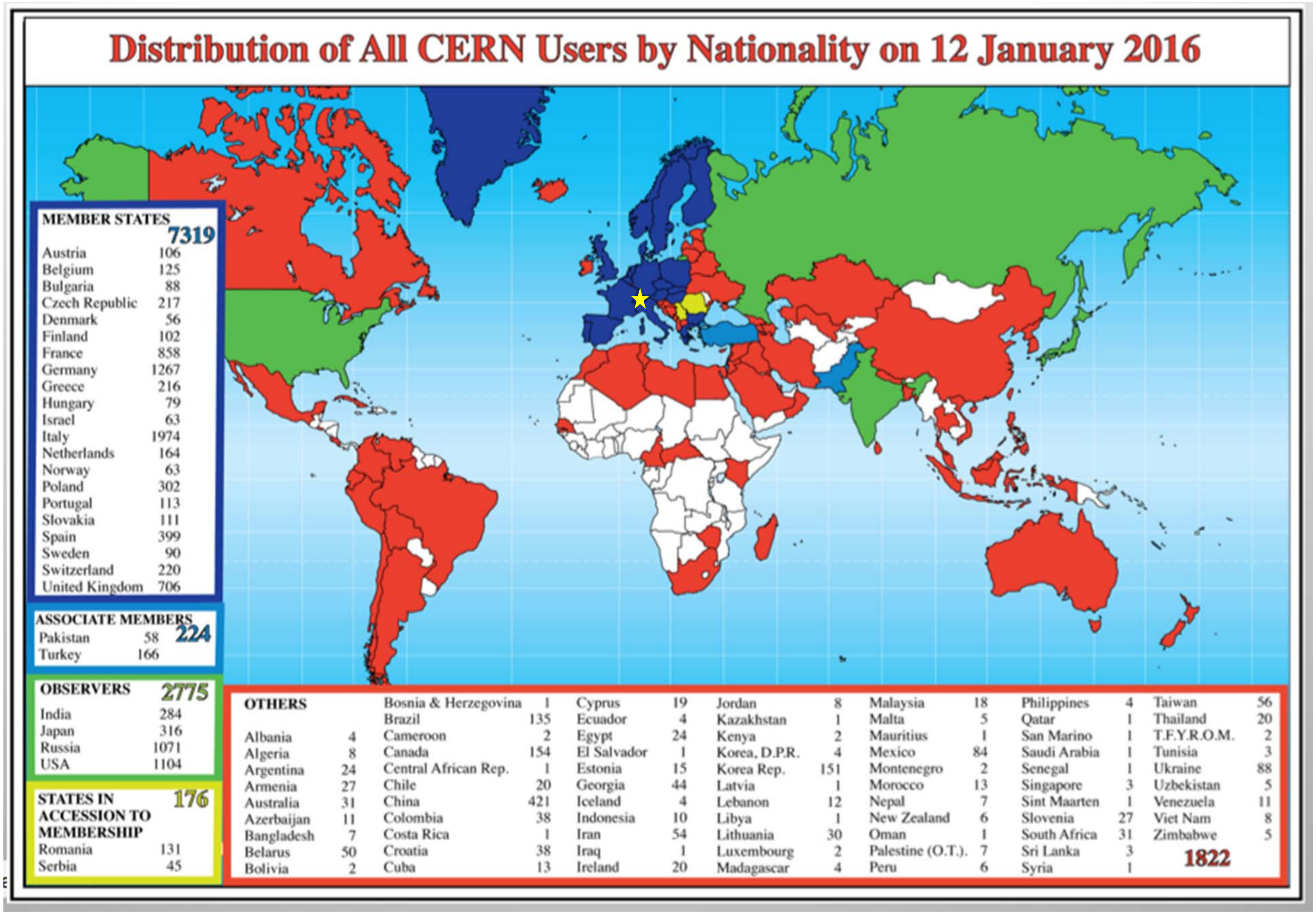
- The world community updates their vision regularly
  - Regional planning, executable over ~10 years, in the context of a 20-year global vision
    - 2012 Japan
    - 2013 European
    - 2014 U.S.
    - Canada, China, …
- Next planning
  - In the next couple of years

- Together, the community continues to develop the strategy of particle physics.

U.S. P5 Report (2014)

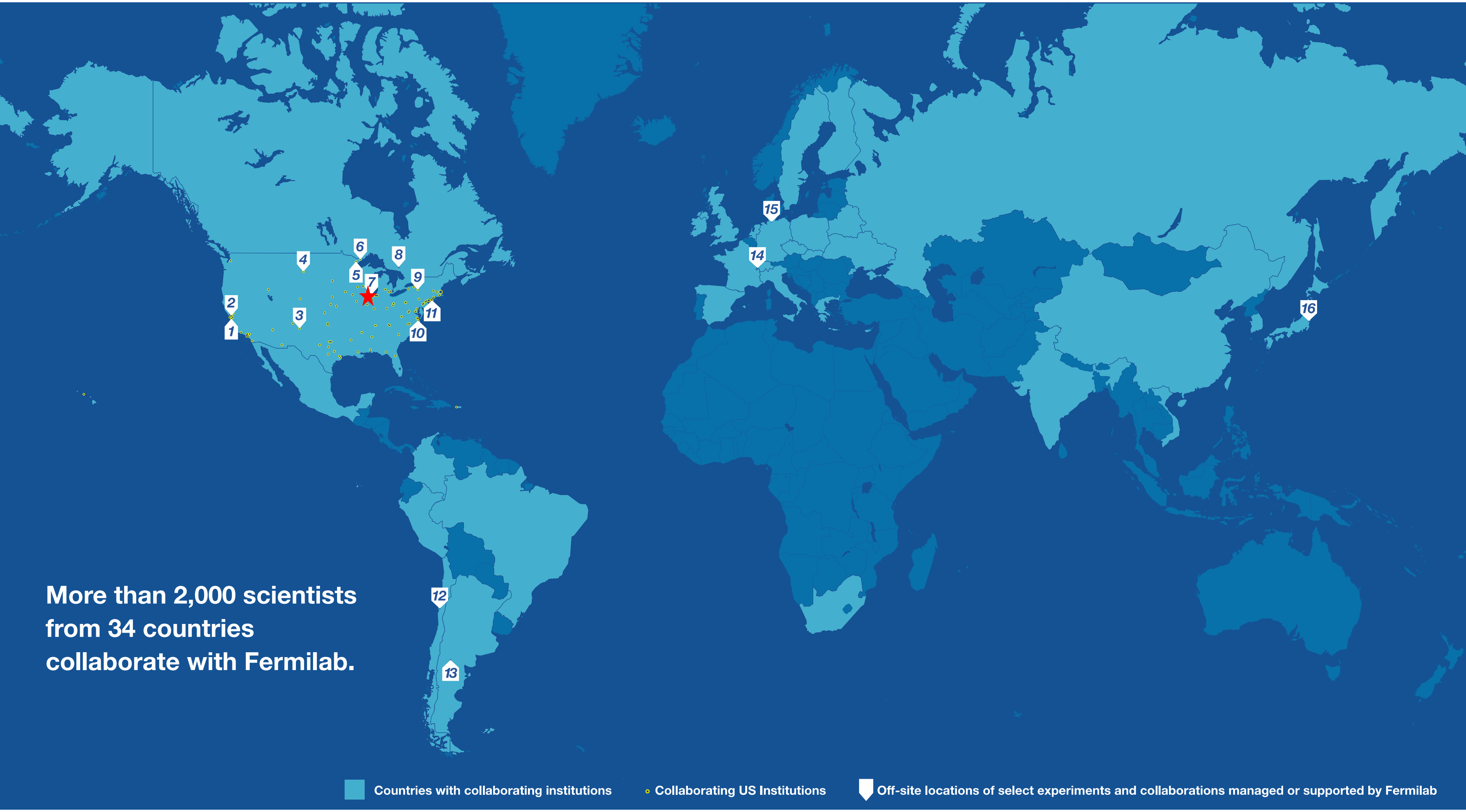
"Particle physics is global. The United States and major players in other regions can together address the full breadth of the field's most urgent scientific questions if each hosts a unique world-class facility at home and partners in high-priority facilities hosted elsewhere. Strong foundations of international cooperation exist, with the Large Hadron Collider (LHC) at CERN serving as an example of a successful large international science project. Reliable partnerships are essential for the success of international projects. Building further international cooperation is an important theme of this report, and this perspective is finding worldwide resonance in an intensely compatitive field."

CERN Users

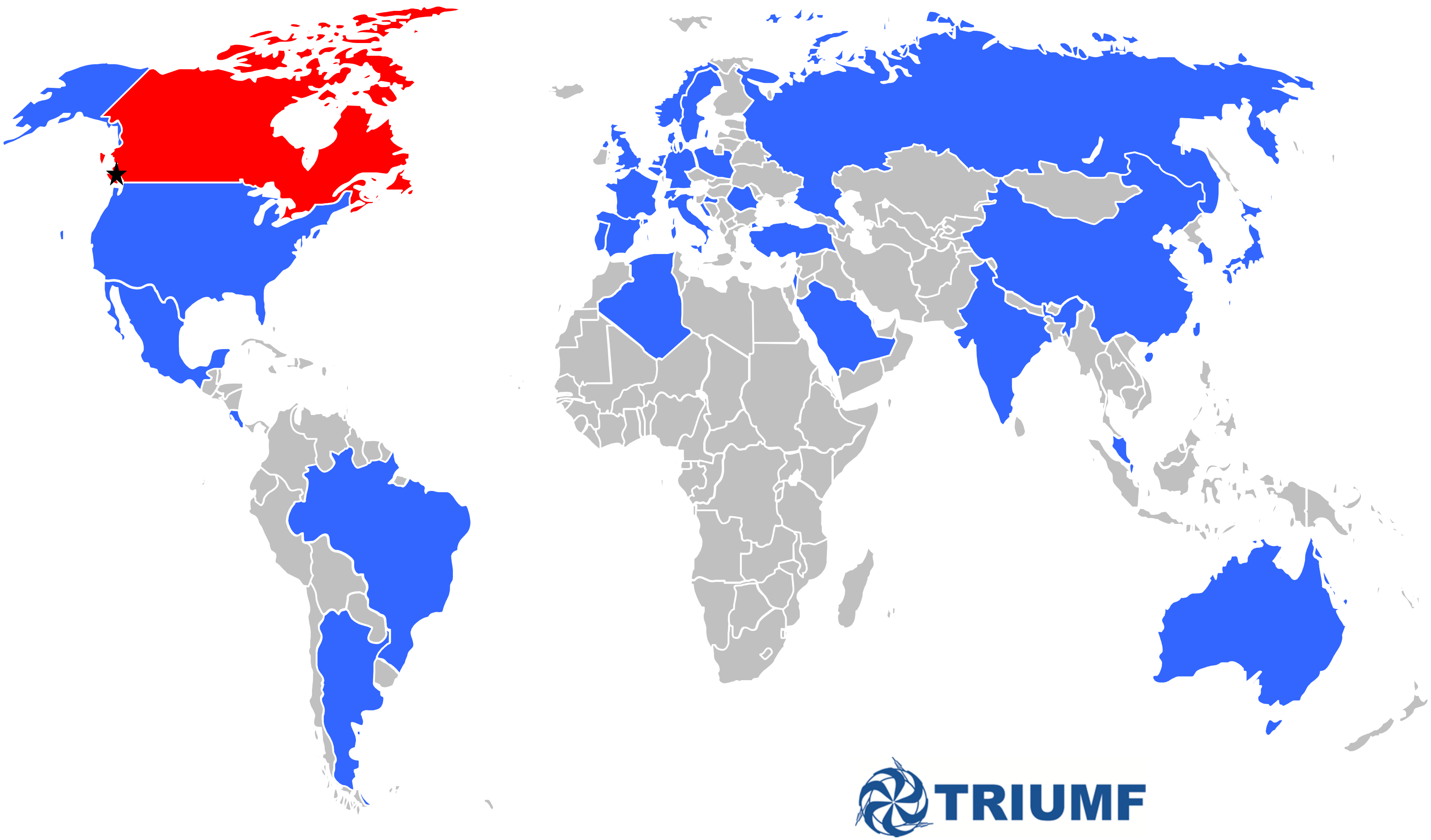

Distribution of All CERN Users by Nationality on 12 January 2016
MEMBER STATES 7319
Austria 106
Belgium 125
Bulgaria 88
Czech Republic 217
Denmark 56
Finland 102
France 858
Germany 1267
Greece 216
Hungary 79
Israel 63
Italy 1974
Netherlands 164
Norway 63
Poland 302
Portugal 113
Slovakia 111
Spain 399
Sweden 90
Switzerland 220
United Kingdom 706
ASSOCIATE MEMBERS 224
Pakistan 58
Turkey 166
OBSERVERS 2775
India 284
Japan 316
Russia 1071
USA 1104
STATES IN ACCESSION TO MEMBERSHIP 176
Romania 131
Serbia 45
OTHERS
Albania 4
Algeria 8
Argentina 24
Armenia 27
Australia 31
Azerbaijan 11
Bangladesh 7
Belarus 50
Bolivia 2
Bosnia & Herzegovina 1
Brazil 135
Cameroon 2
Canada 154
Central African Rep. 1
Chile 20
China 421
Colombia 38
Costa Rica 1
Croatia 38
Cuba 13
Cyprus 19
Ecuador 4
Egypt 24
El Salvador 1
Estonia 15
Georgia 44
Iceland 4
Indonesia 10
Iran 54
Iraq 1
Ireland 20
Jordan 8
Kazakhstan 1
Kenya 2
Korea, D.P.R. 4
Korea Rep. 151
Latvia 1
Lebanon 12
Libya 1
Lithuania 30
Luxembourg 2
Madagascar 4
Malaysia 18
Malta 5
Mauritius 1
Mexico 84
Montenegro 2
Morocco 13
Nepal 7
New Zealand 6
Oman 1
Palestine (O.T.). 7
Peru 6
Philippines 4
Qatar 1
San Marino 1
Saudi Arabia 1
Senegal 1
Singapore 3
Sint Maarten 1
Slovenia 27
South Africa 31
Sri Lanka 3
Syria 1
Taiwan 56
Thailand 20
T.F.Y.R.O.M. 2
Tunisia 3
Ukraine 88
Uzbekistan 5
Venezuela 11
Viet Nam 8
Zimbabwe 5
1822

KEK Users

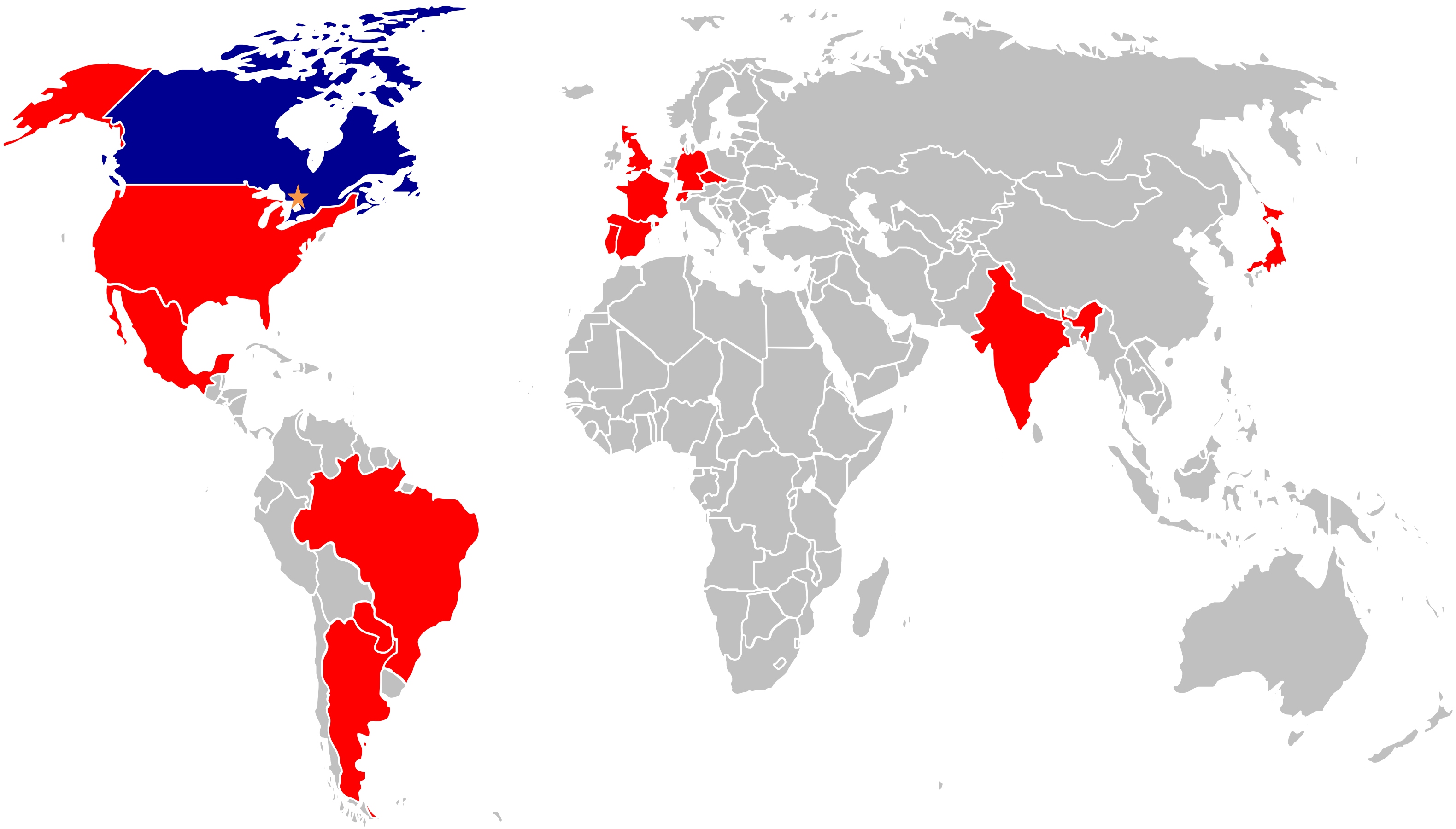
Fermilab Users



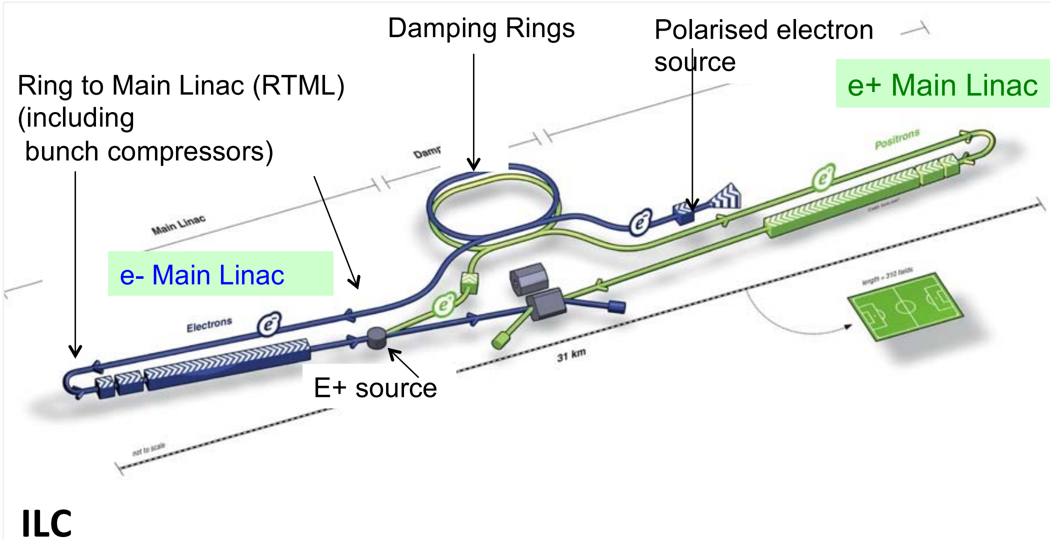
TRIUMF Users

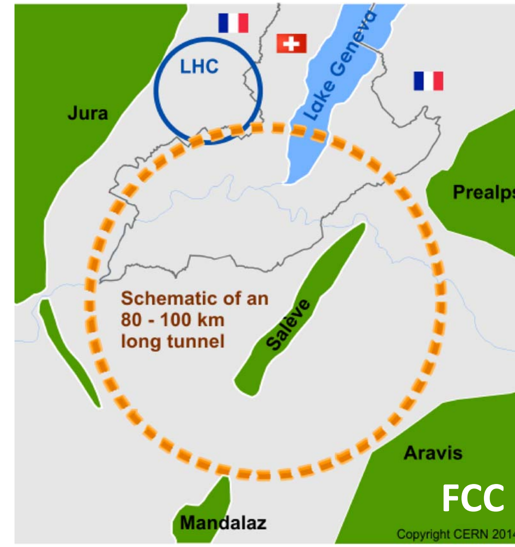


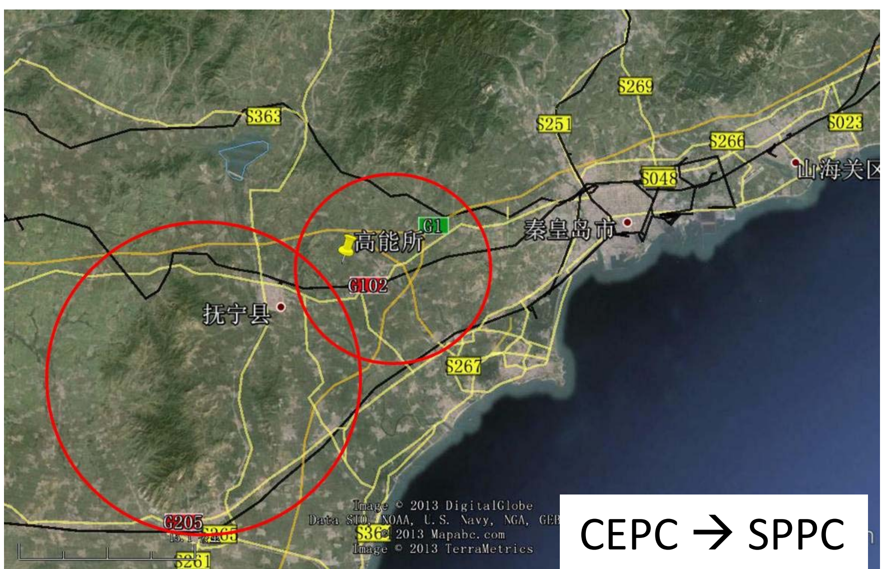
SNOLab Users

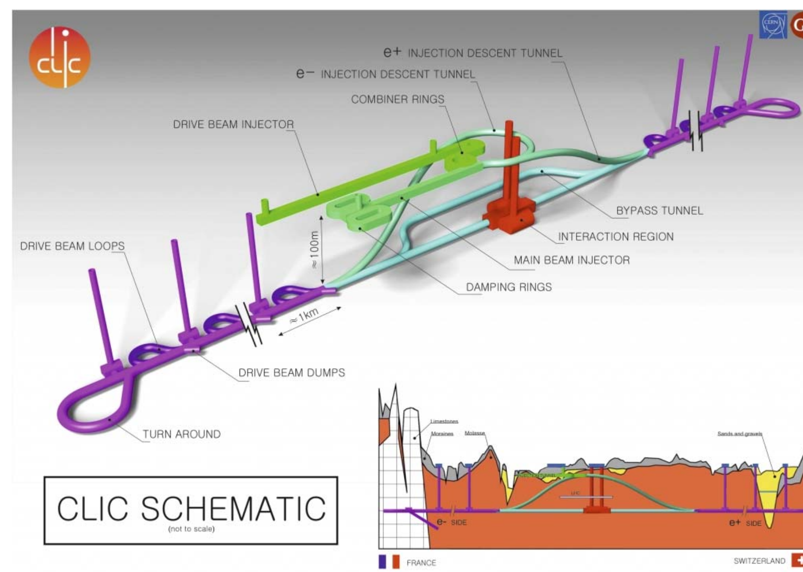


Next Global Projects: Energy Frontier

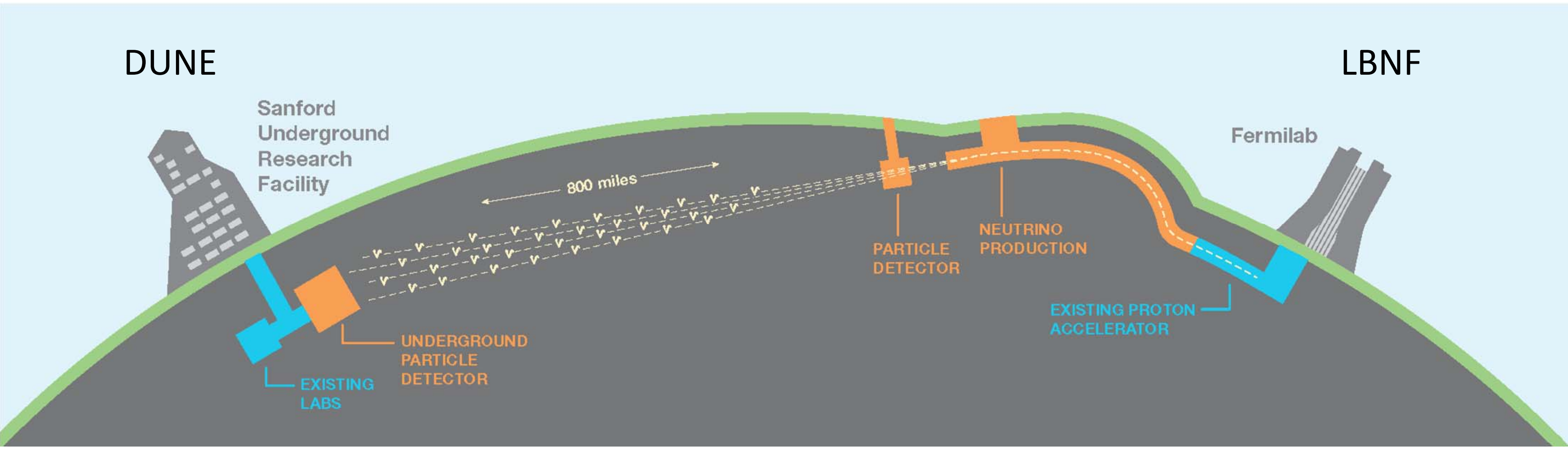


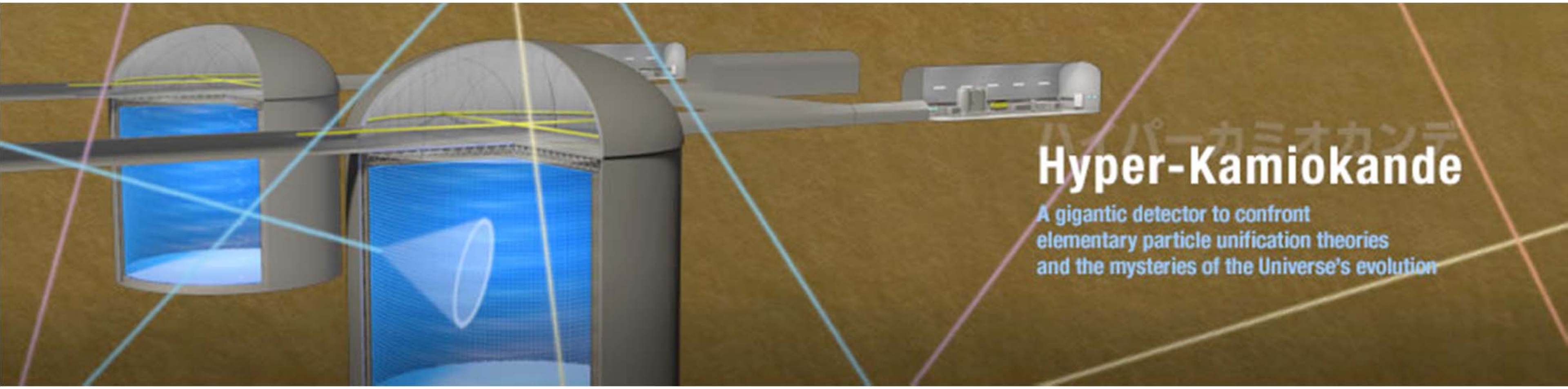






Next Global Projects: Intensity Frontier





Future Global Facilities Session at ICHEP 2016

online questions – strong participation by young scientists

Who said this?

ICHEP is a good gig

Conclusion slide by Ian Shipsey
“Vision and Outlook:
Where do we go from here?”

Chicago is cool

ICHEP is a good platform to bring the community together. lets get the community together more often than once every two years!

What I have heard at ICHEP makes me all the more enthusiastic about having a career as particle physicist

ICHEP makes me wish I was a physicist

Answer:

Attendees at this meeting