Concluding Remarks

Barry Barish - Caltech

"Summary" Talk

Van's message --

- *"Would you accept to give this important talk : the summary of the conference.*
- *It does not necessarily have to be a strict summary of all the talks at the conference. You may choose to cover the highlights (in your judgment), combined with your own vision/conclusions/ perspective"*

My talk will <u>not</u> even attempt to cover the rich set of ~ 100+ contributions over the next 60 minutes. Therefore, if you don't get your 30 seconds, so be it!

Rencontres du Vietnam

18 years ago: 1995

Rencontres du Vietnam

now: 2013

***ν** mass; Acceleration of Universe; **θ_{13}**; Higgs*

18 years into the future ~2031

"my vision/conclusions/perspective"

Gross

The Extreme Optimistic Scenario

- The Higgs(-like) boson ≠ SM Higgs
- Direct production of SUSY particles
- Detection of Dark Matter, in the sky, underground and at the LHC
- Strong guidance for the next steps!

ILC, CLIC, HL-LHC, VLHC, HHC, ...

Inquiry based science

1. How can we solve the mystery of dark energy?
2. Are there extra dimensions of space?
3. Do all the forces become one?
4. Why are there so many kinds of particles?
5. What is dark matter?

    How can we make it in the laboratory?

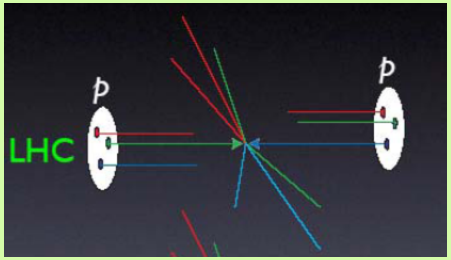
6. What are neutrinos telling us?
7. How did the universe come to be?
8. What happened to the antimatter?
9. Are there undiscovered principles of nature:

    New symmetries, new physical laws?

from the Quantum Universe

Experimental Probes

- High Energy pp Colliders
  - » Opening up a new energy frontier (~ 1 TeV scale)



- High Energy Lepton Colliders
  - » Precision Physics at the new energy frontier

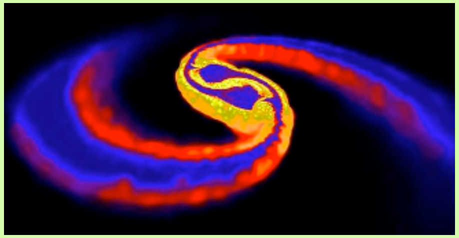
- Neutrinos
  - » Particle physics and astrophysics using a weakly interacting probe

- Particle Astrophysics/Cosmology
  - » Dark Matter; Cosmic Microwave, etc

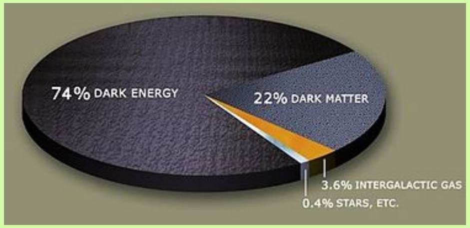
and more Experimental Probes

- **Precision Physics**
  - » SuperB factories
  - » Fermilab: g-2; μ → e; etc.

- **Gravity**
  - » Gravitational waves; quantum gravity



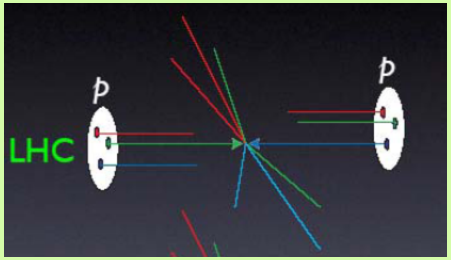
- **Dark Energy**
  - » Space missions



- **New Generations of Accelerators**
  - » Plasma/laser wakefield acceleration

Addressing the Questions

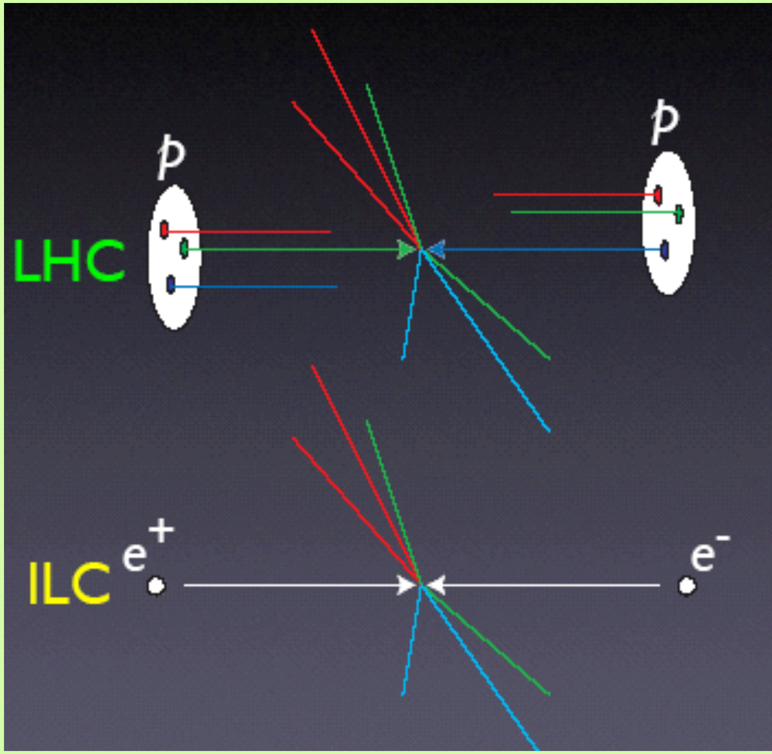
- **High Energy pp Colliders**
  - ➢ **Opening up a new energy frontier (~ 1 TeV scale)**



- **High Energy e^+e^- Colliders**
  - ➢ **Precision Physics at the new energy frontier**

Exploring the Terascale
the tools

- The LHC
  - It is leading the way and has large reach
  - Quark-quark, quark-gluon and gluon-gluon collisions at 0.5 - 5 TeV
  - Broadband initial state



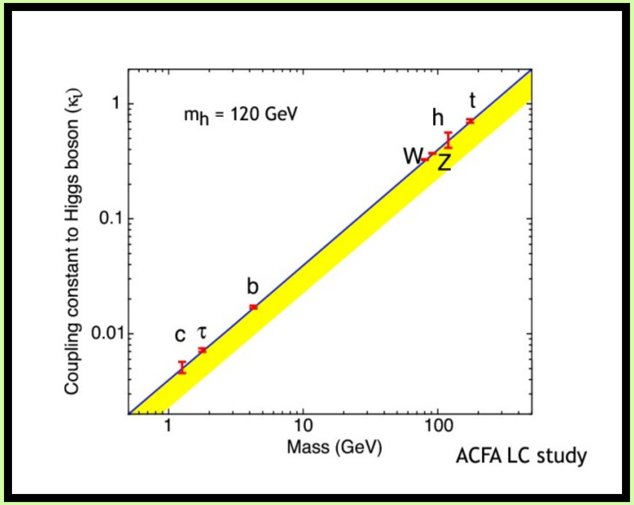
- A Lepton Collider (e.g. ILC or ?)
  - A second view with 'high precision'
  - Electron-positron collisions with fixed energies
  - Well defined initial state

- Together, these two types of accelerators are our tools for uncovering physics at the terascale

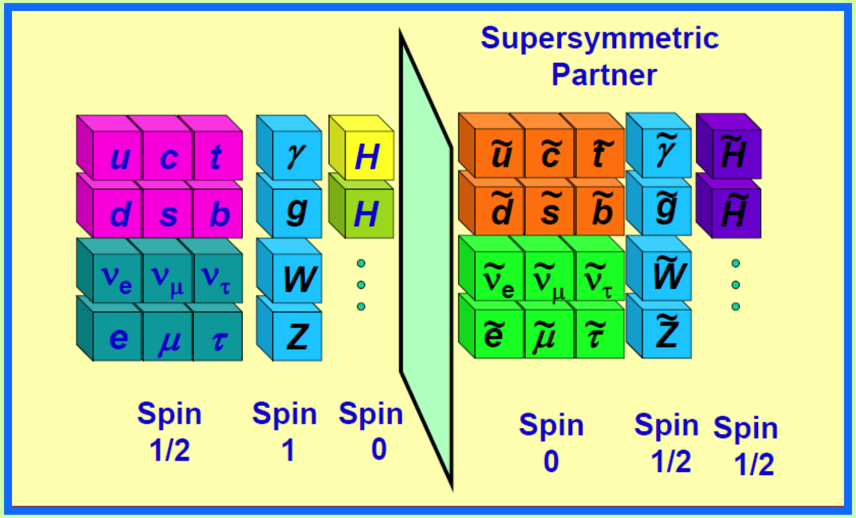
LHC

The Higgs has been discovered.
What about supersymmetry?

- **Higgs**



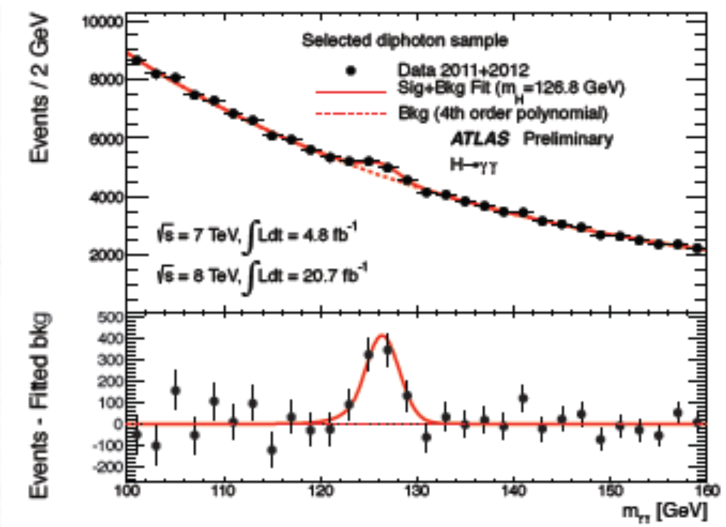
- **Supersymmetry**



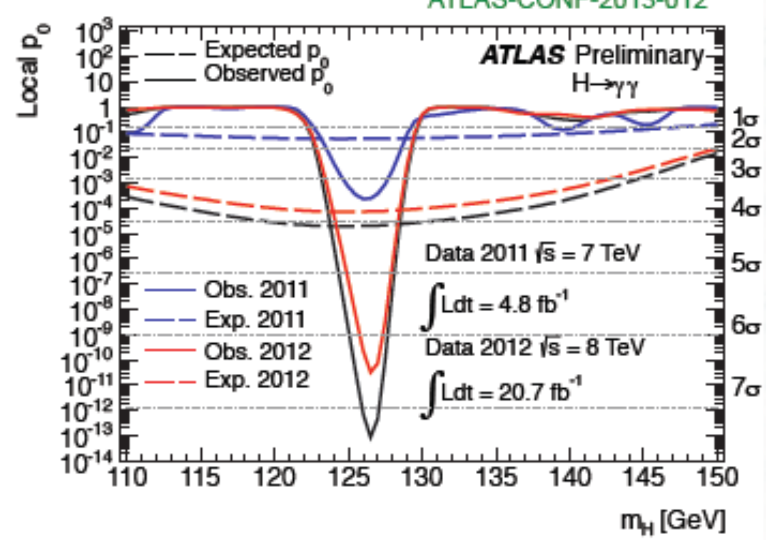
ATLAS: Higgs Evidence (γγ)

Result of the ATLAS search for H → γγ

Full dataset ATLAS-CONF-2013-012



ATLAS-CONF-2013-012



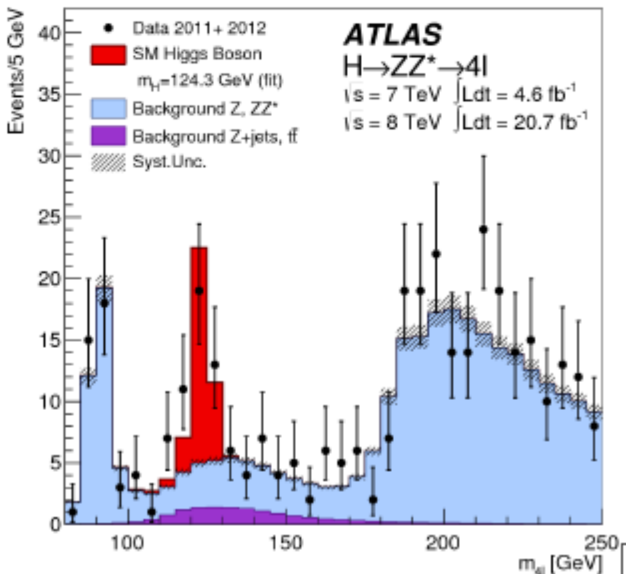
- p_0 value for consistency of data with background-only: $\sim 10^{-13}$ (7.4σ observed) for the combined 7 TeV and 8 TeV data; (4.3σ expected) (minimum found at $m_{\gamma\gamma}$ = 126.5 GeV)
- Establishes the discovery of the new particle in the γγ channel alone

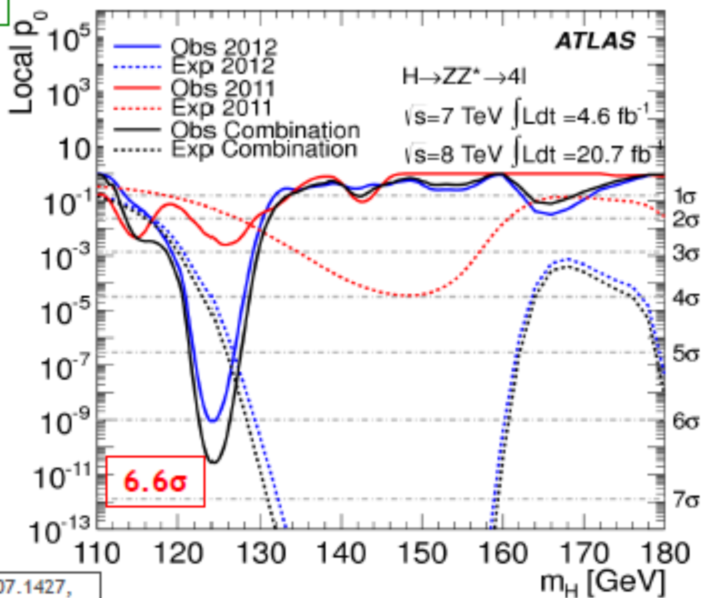
ATLAS: Higgs Evidence (4 leptons)

$H \to 4\ell^{\pm}$

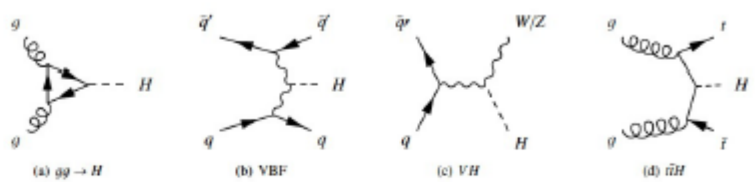
"Golden" channel, high S/B, excellent mass resolution, but low statistics

Signal significance 6.6σ, expected 4.4σ (SM)





arXiv:1307.1427, accepted by PLB

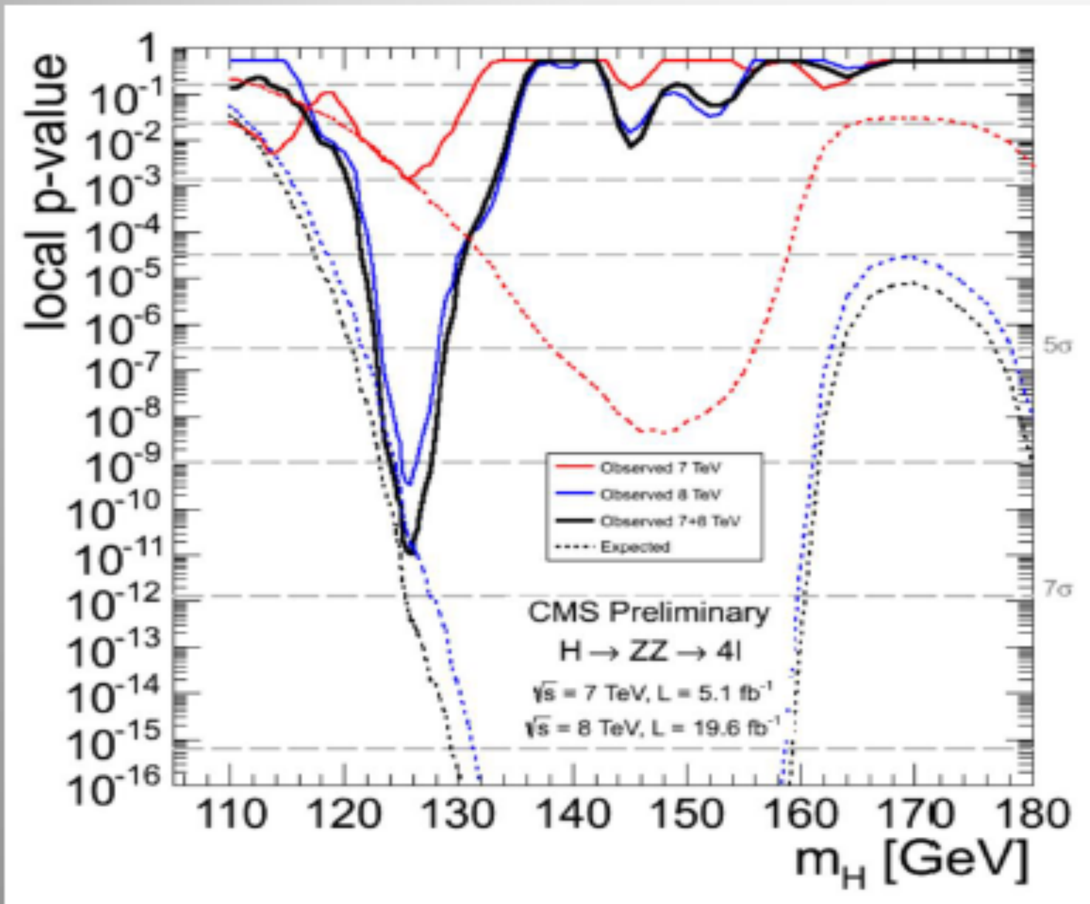


Again, categorisation of events to enhance VBF and VH sensitivity

Combining $H \to \gamma\gamma$ and $H \to 4\ell$, obtain

$$m_H = 125.5 \pm 0.2 \pm ^{0.5}_{0.6} \text{ GeV}$$

CMS: Higgs Evidence (ZZ → 4 l)



p-value: Expected: 7.1σ

Observed: 6.7σ

LHC/CMS: 5 Main Higgs Channels

For a mass of m_H = 125.7 GeV

CMS-PAS-HIG-13-005

Decay	Expected	Observed
ZZ	7.1 σ	6.7 σ
γγ	3.9 σ	3.2 σ
WW	5.3 σ	3.9 σ
bb	2.2 σ	2.1 σ
ττ	2.6 σ	2.8 σ

bb and ττ: 3.4 σ combined!

bb: includes VH and VBF
WW: includes ggF, VH, VBF

How about the other Higgs characteristics?

- Spin (must be spin 0)
- Coupling (couples to mass)
- Are there more Higgs particles?
- What is the self-coupling
- etc

These questions will be a major focus of the LHC program after the upgrade; but so far, LHC results are consistent with a simple Higgs

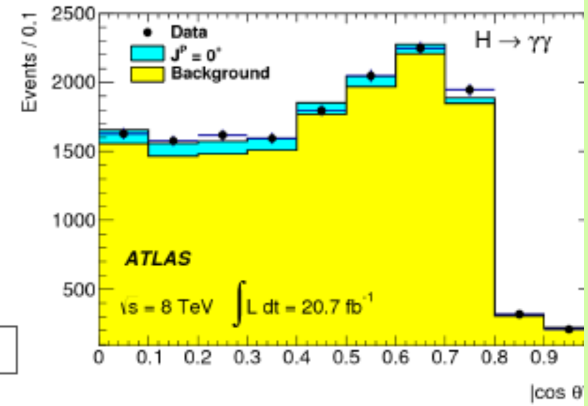
ATLAS: Spin 0?

Spin-parity

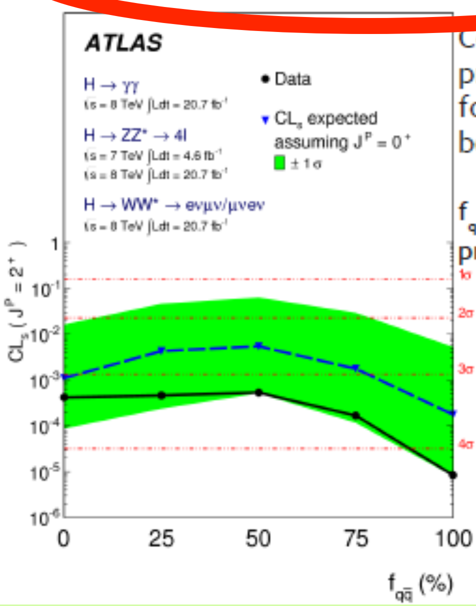
Use $H\to\gamma\gamma$, $H\to 4\ell$, $H\to WW\to \ell\nu\ell\nu$
Variables sensitive to decay angles

Make pairwise hypothesis tests J^P vs 0^+

arXiv:1307.1432
accepted by PLB



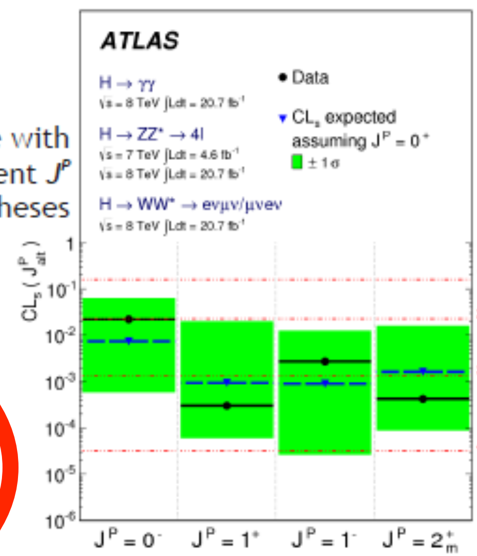
Data are consistent with 0^+ on every test



Compare with a range of production hypotheses for a spin-2 graviton-like boson

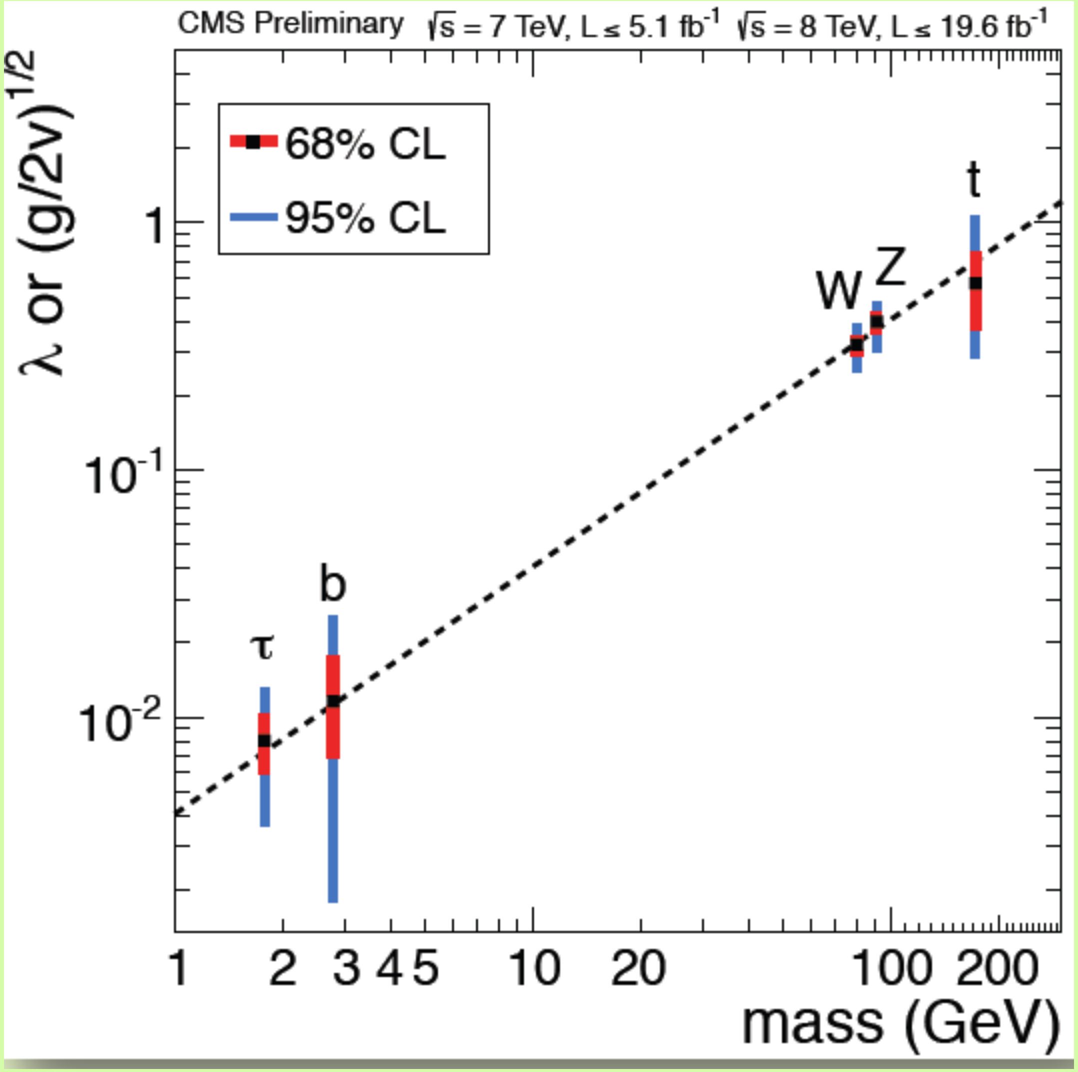
f_{qq} = fraction of qq production (rather than gg)

Compare with different J^P hypotheses



All alternative hypotheses disfavoured at >97.8% CL

CMS: Higgs coupling vs mass



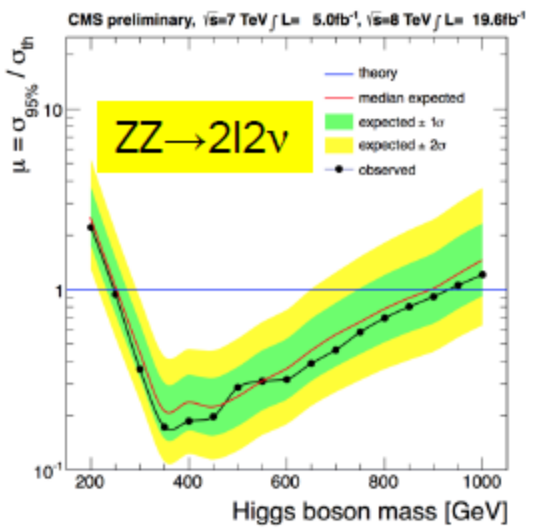
Is there a high mass Higgs?

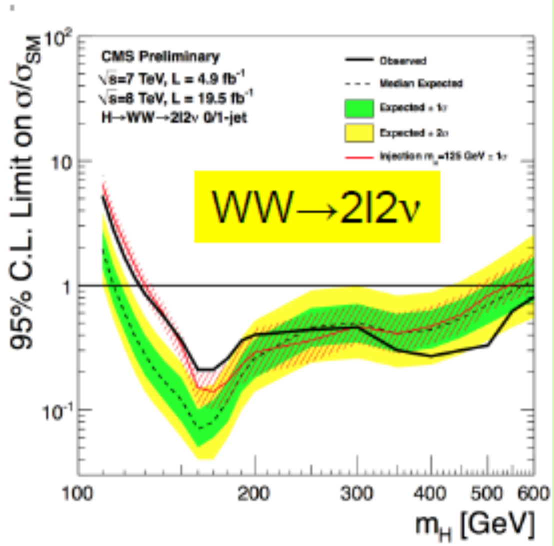
High Mass Higgs Searches

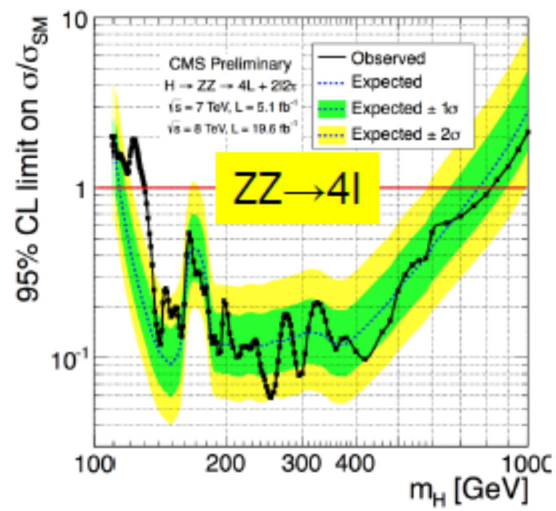
High mass Higgs searches with SM channels WW, ZZ updated with 2012 Statistics

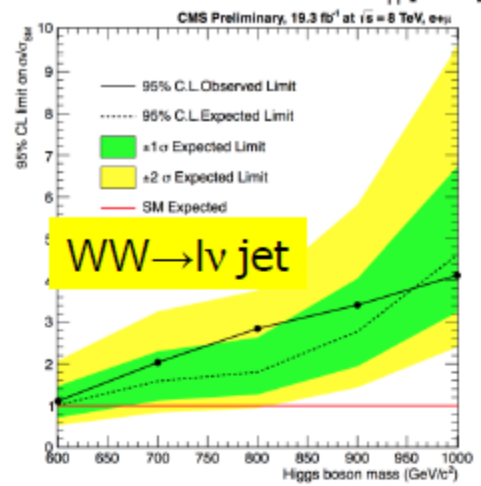
Sensitivity reaches now up to ~ 1 TeV

Interpretation of the data in eg EW-singlet models; Benchmark models proposed by the LHC XS WG:
See CMS-PAS-13-008
CMS-PAS-13-014

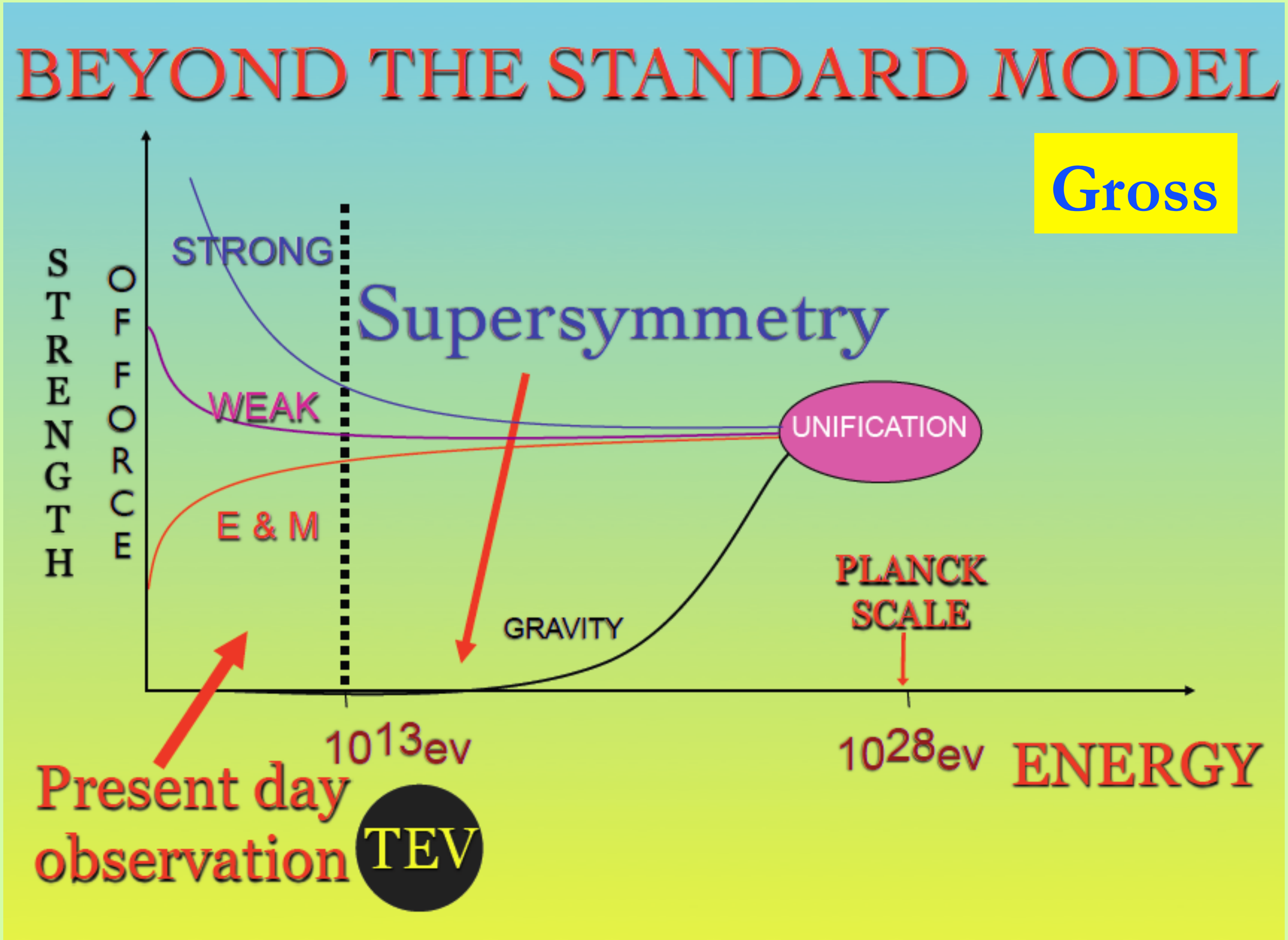






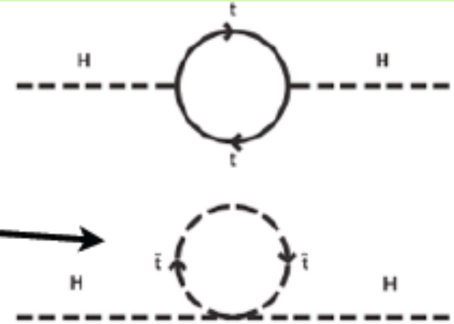


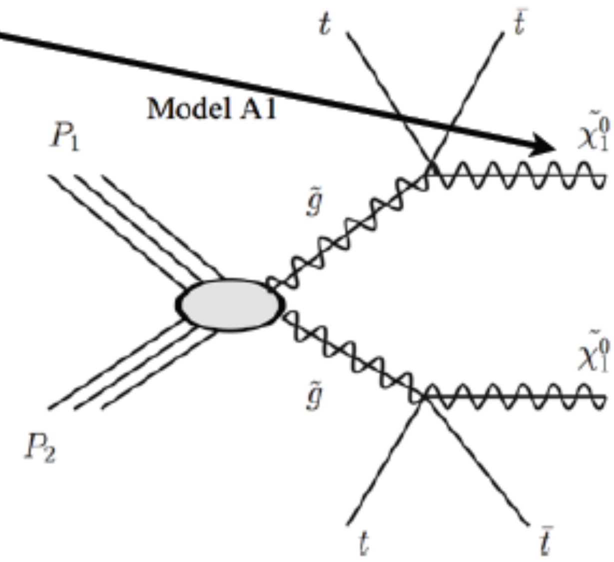
What about supersymmetry?

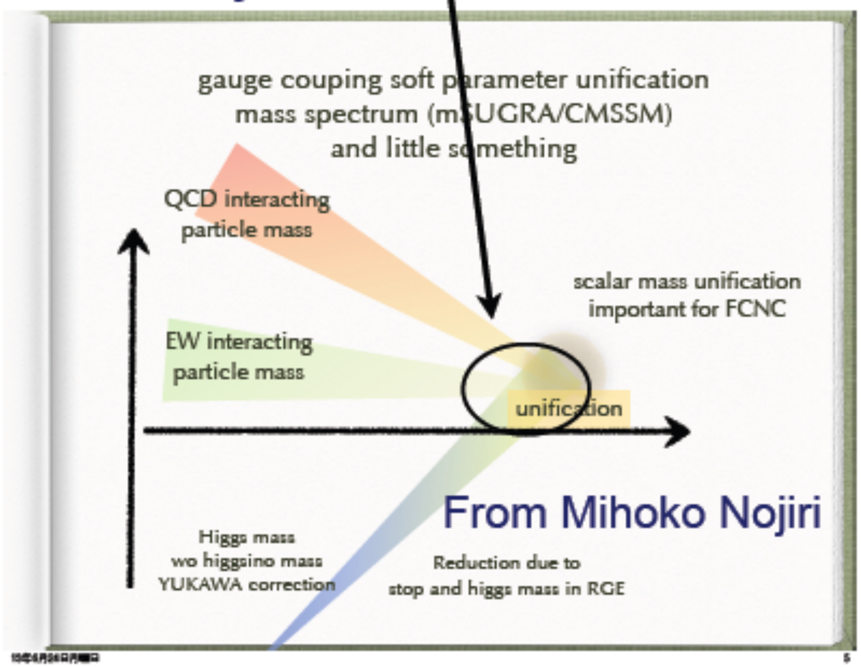


Are there Supersymmetric Particles?

- SUSY can solve a lot of problems "at once"
  - Hierarchy problem
  - Dark matter candidate
  - Forces unify more nicely?

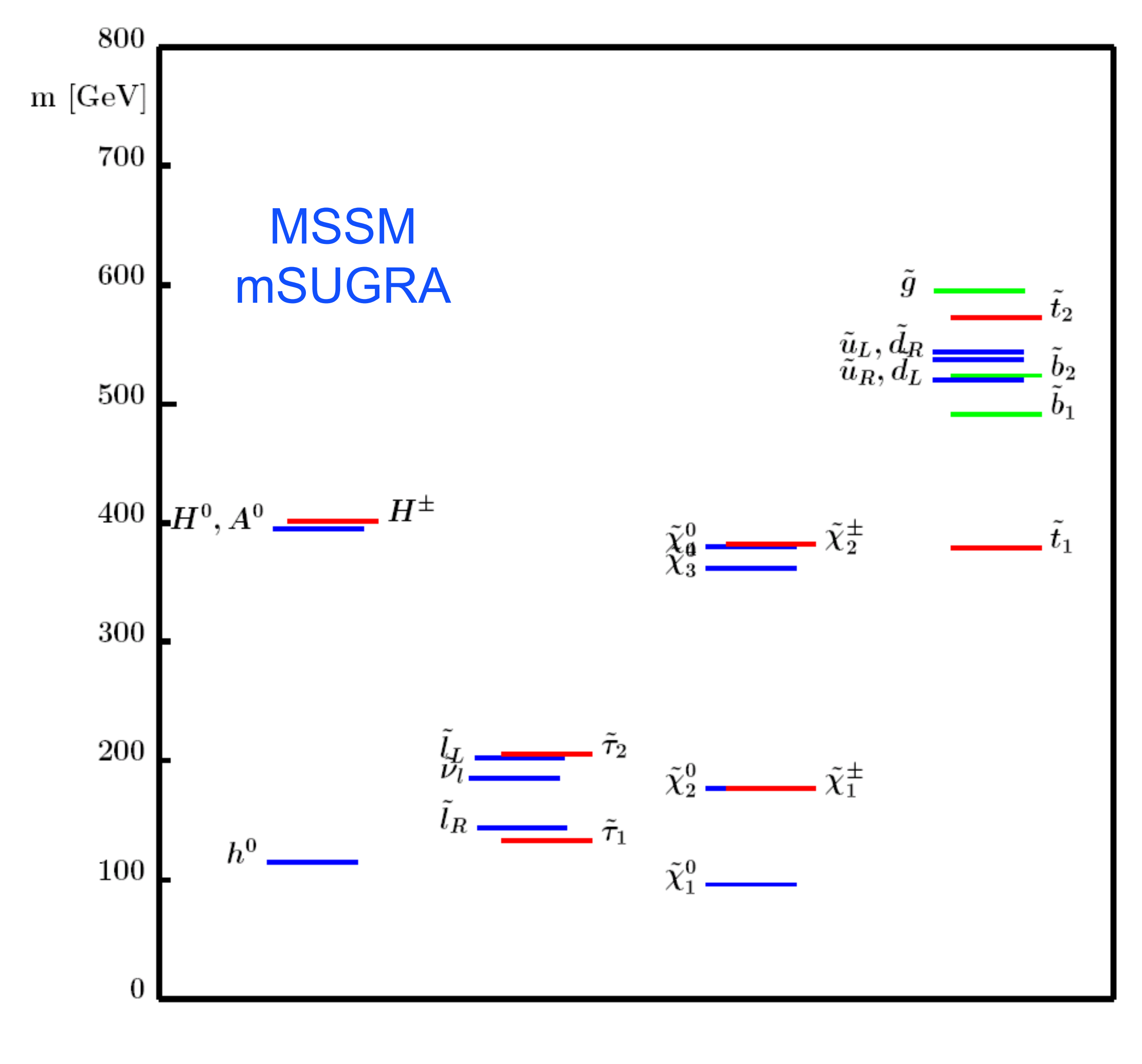






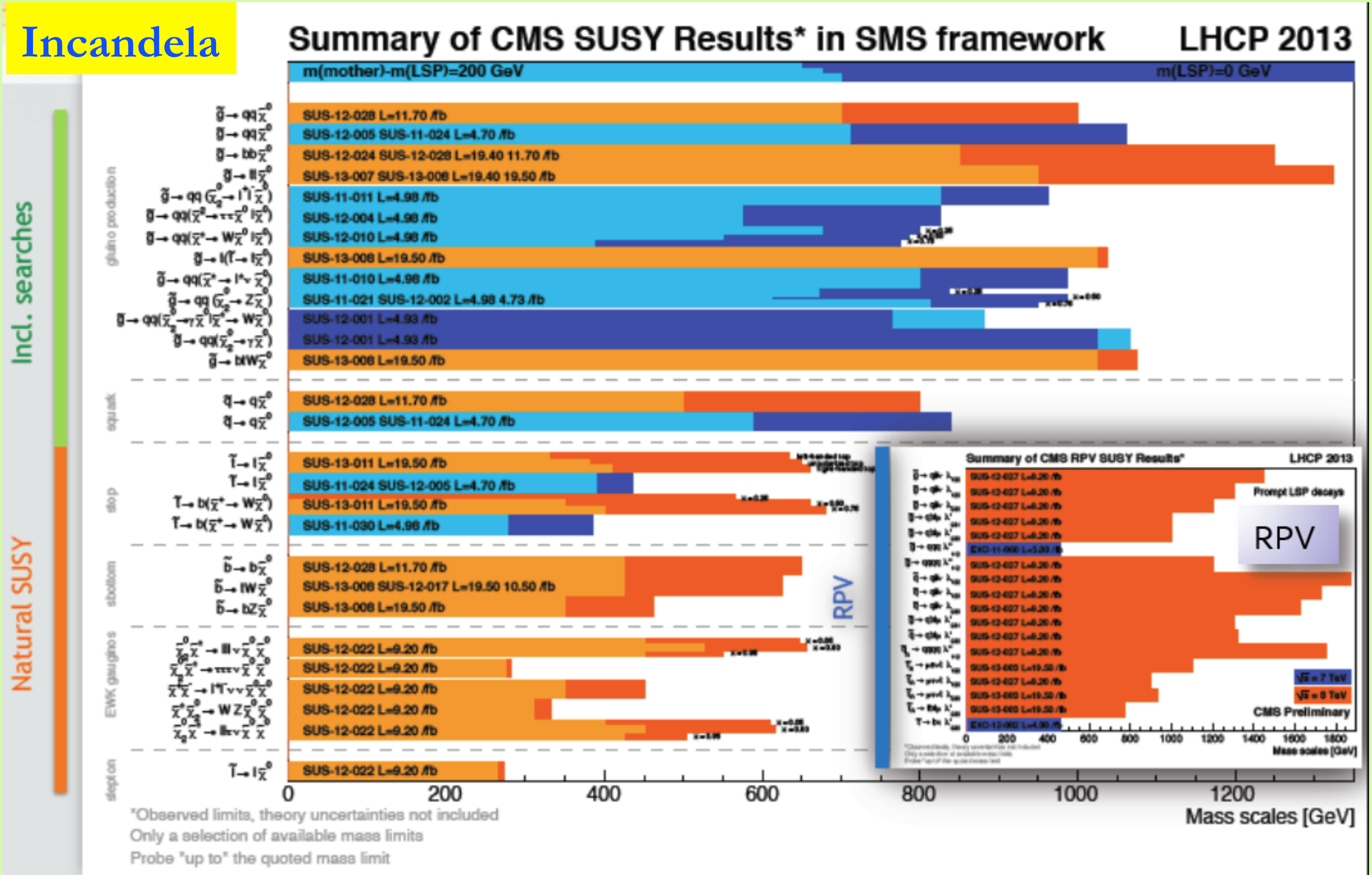
Rappoccio – LP2013

We expect a rich spectrum of new particle

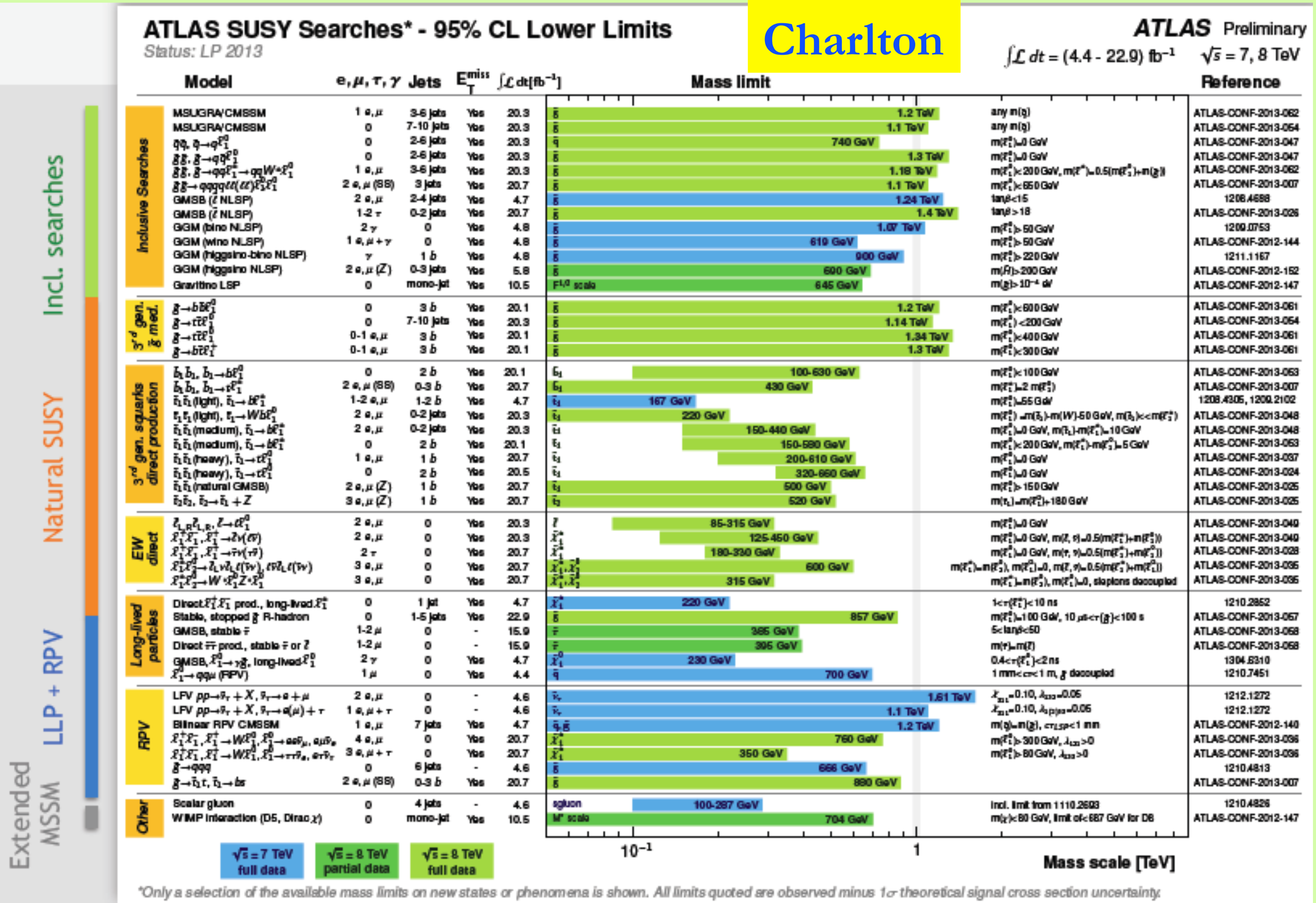


squarks and sgluons heavy yielding long decay chains ending with LSP neutrilino

CMS: Supersymmetric Particles

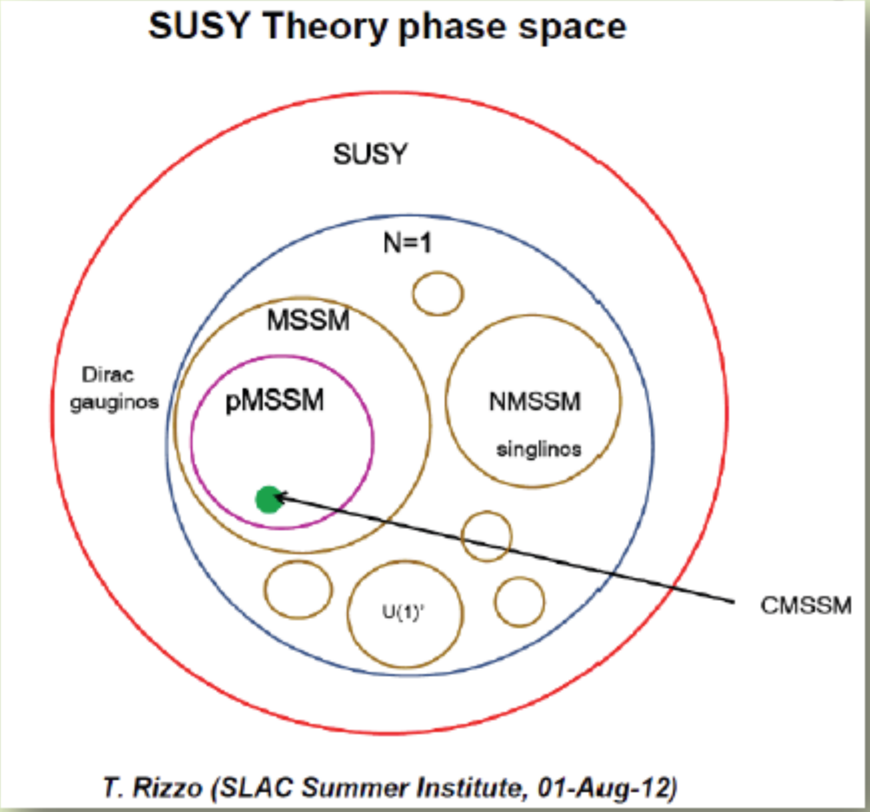


ATLAS: Supersymmetric Particles



Supersymmetric Particles **NOT** ruled out

CMSSM in context

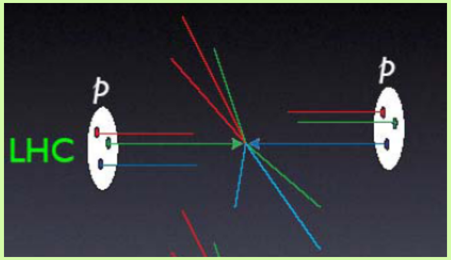


- LHC excludes squarks and gluinos > 1 TeV and > 1.8 TeV respectively in the CMSSM
  - But, this is only really probing a tiny part of a large parameter space

Incandela

Addressing the Questions

- High Energy pp Colliders
  - Opening up a new energy frontier (~ 1 TeV scale)



- High Energy e^+e^- Colliders
  - Precision Physics at the new energy frontier

Glashow - International Collaboration

International Scientific Cooperation

A Paradigm for Peace among Nations

Basic scientific research is among the few areas wherein nations of the world cooperate. Modern science emerged as an multinational endeavor: Copernicus (a Pole), Tycho Brahe (a Dane), Kepler (a German), Galileo (an Italian) and Newton (an Englishman) taught us our place in the heavens. Whilst these were all white, Christian, European men, today everyone can contribute to the Scientific Adventure regardless of nationality, religion, race or sex. Among many international collaborations:

- Alpha Magnetic Spectrometer: 16 nations
- International Space Station: 15 nations
- International Linear Collider: 19 nations
- ITER (Thermonuclear Research): EU + six nations
- CERN: Scientists from over 100 nations

A Global Initiative for an ILC

International Committee for Future Accelerators (ICFA) representing major particle physics laboratories worldwide.

- Chose ILC accelerator technology (SCRF)
- Determined ILC physics design parameters
- Formed Global Design Effort and Mandate (TDR)

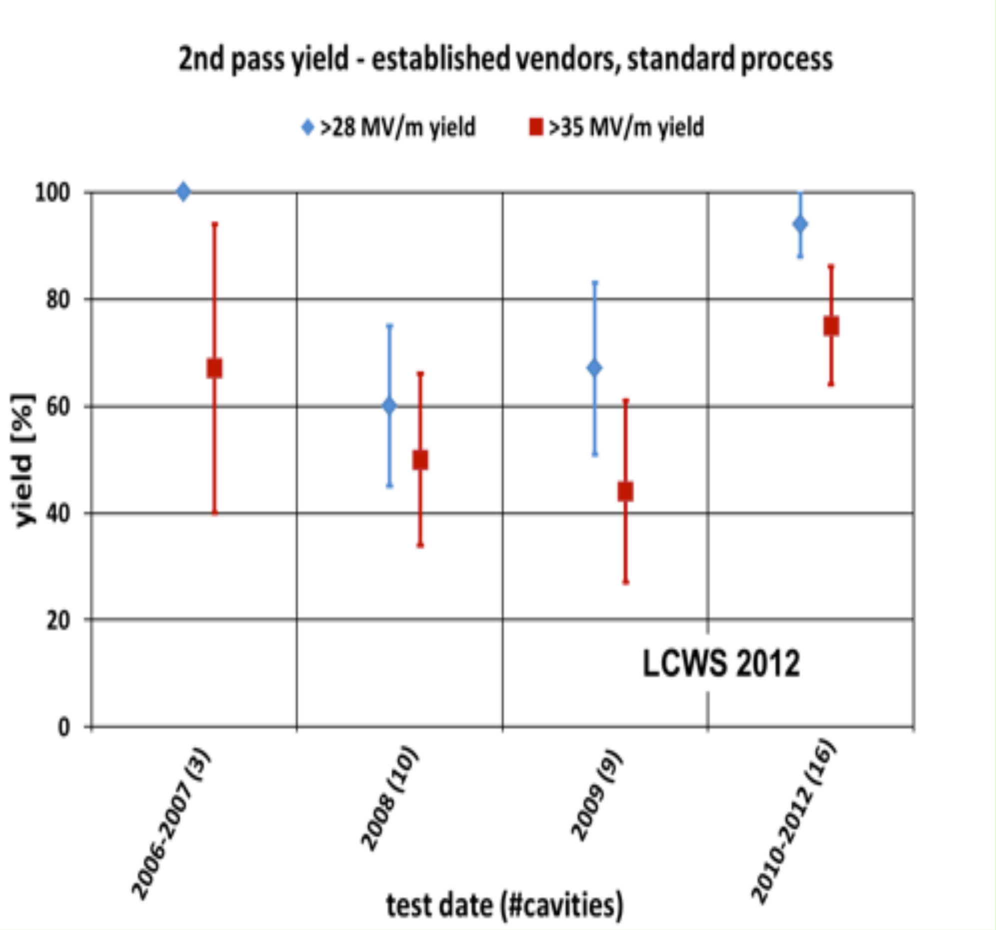
Globally Coordinated SCRF R&D

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective, etc

- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

Progress in Cavity Gradient Yield



Production yield:
94 % at > 28 MV/m,

Average gradient:
37.1 MV/m

ILCSC/ICFA Parameters Studies

physics driven input

Key Parameters

» Luminosity → $\int L dt = 500\ fb^{-1}$ in 4 years

» E_{cm} adjustable from 200 – 500 GeV

» Ability to scan between 200 and 500 GeV

» Energy stability and precision below 0.1%

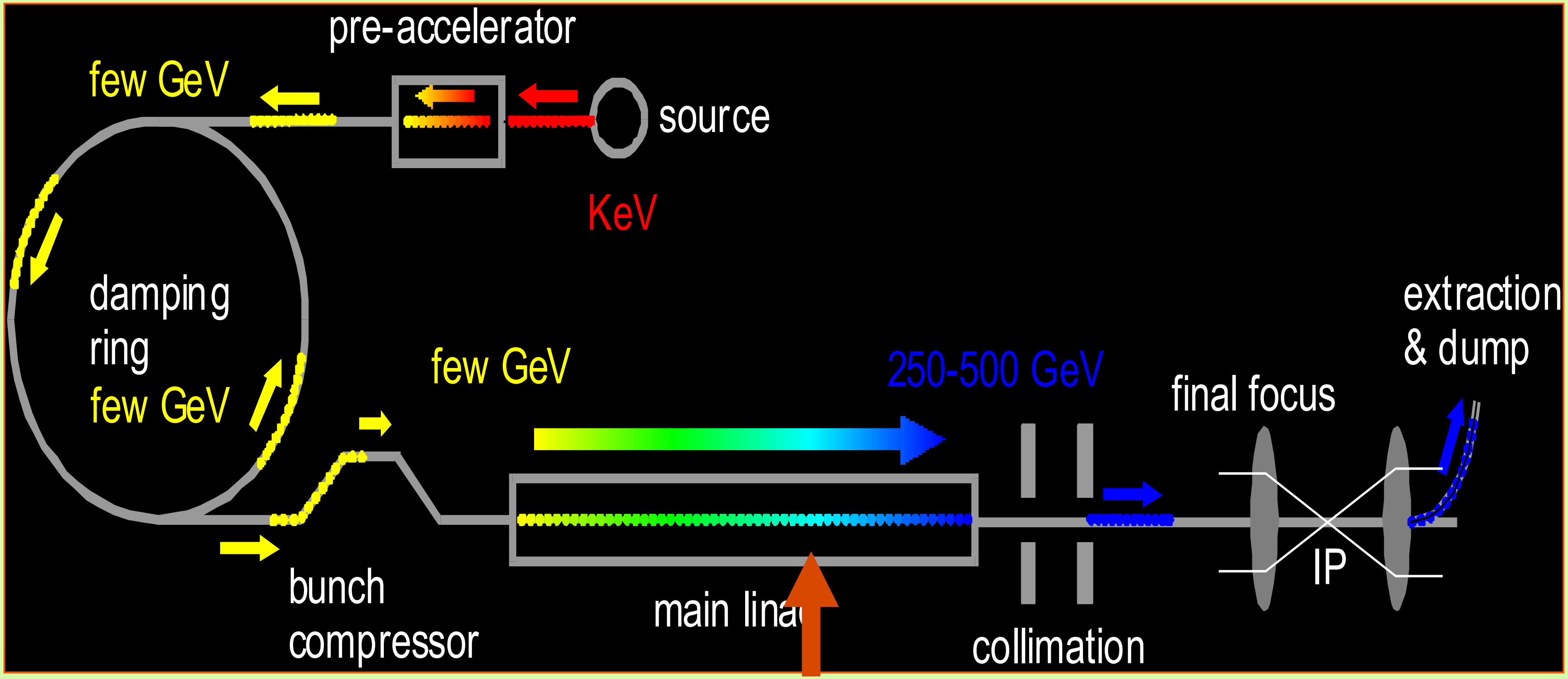
» Electron polarization of at least 80%

Options

– The machine must be upgradeable to 1 TeV

– Positron polarization desirable as an upgrade

GDE -- Design a Linear Collider



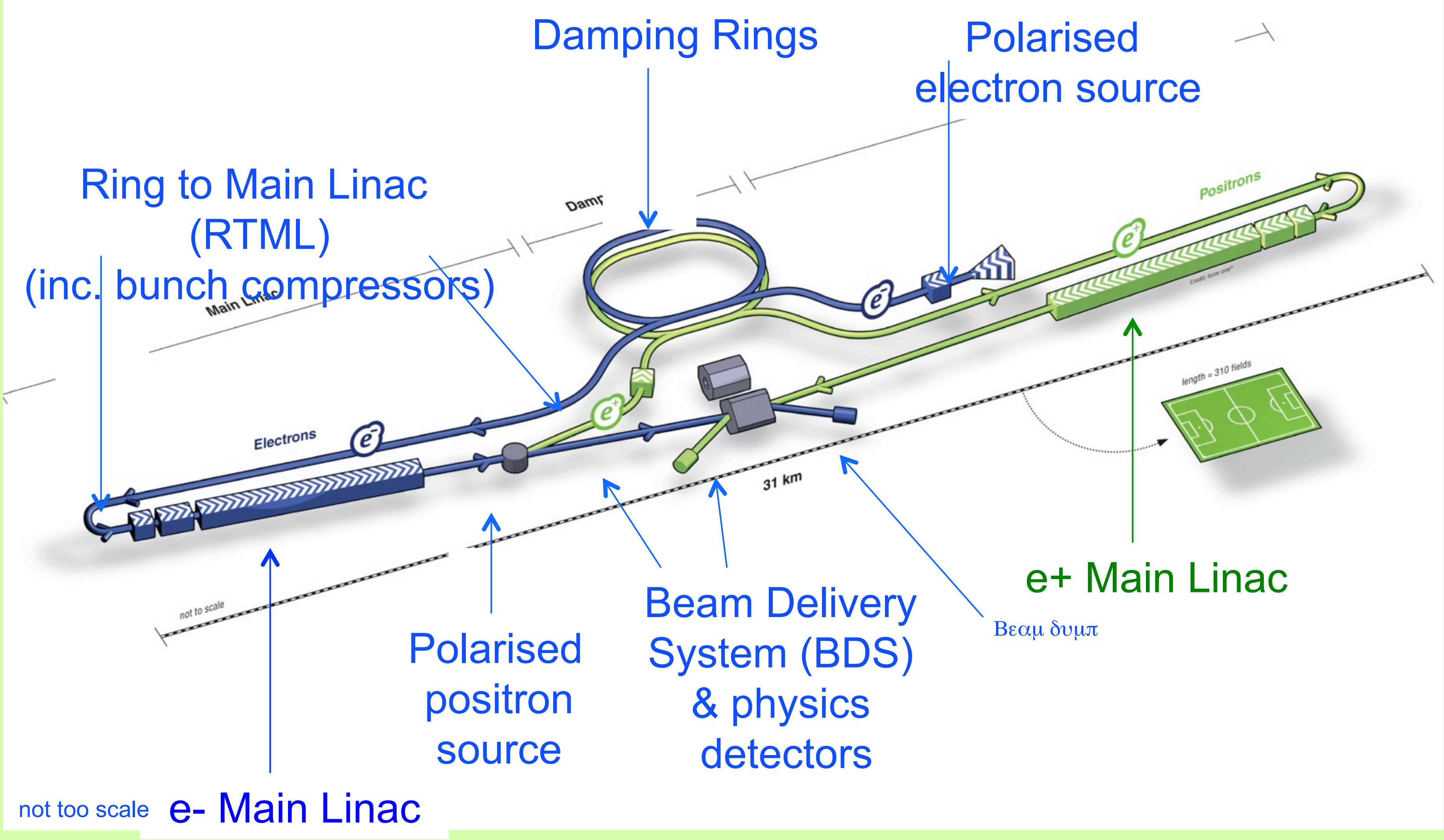
Superconducting RF
Main Linac

33

RDR Design Parameters

Max. Center-of-mass energy	500	GeV
Peak Luminosity	~$2x10^{34}$	$1/cm^2s$
Beam Current	9.0	mA
Repetition rate	5	Hz
Average accelerating gradient	31.5	MV/m
Beam pulse length	0.95	ms
Total Site Length	31	km
Total AC Power Consumption	~230	MW

ILC Technical Design Report Layout

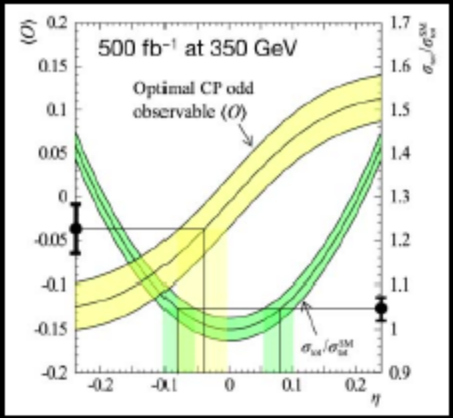


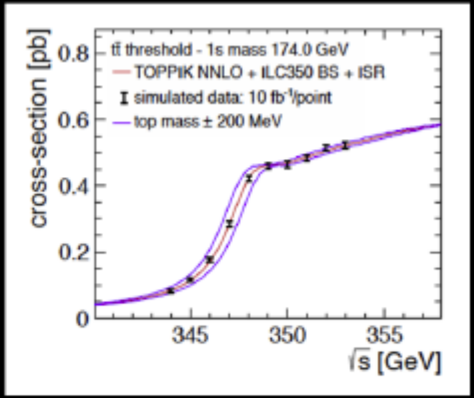
ILC Physics Potential

Yamamoto

ILC 250~500 GeV

- Higgs
  - Generate ~30K Higgs every year (w/ pol)
    - 5 σ Higgs discovery sensitivity in ~ 1 day
  - Higgs Brs (table later)
    - H → cc, invisible; & model independent
  - Γ_{tot} to 5%
    - Br(H → WW) & g(HWW) by e+e- → ννH
    - Br(H → ZZ) & g(HZZ) by e+e- → HZ
  - CP to 3~4% (on mixing coeff)
- top
  - m_t(msbar) to 100 MeV
  - Anomalous ttZ, tbW, ttg coupl
- New physics through SM
  - Composite Higgs scale to 45 TeV
  - Anomalous WWV coupl
- New unexpected particles!

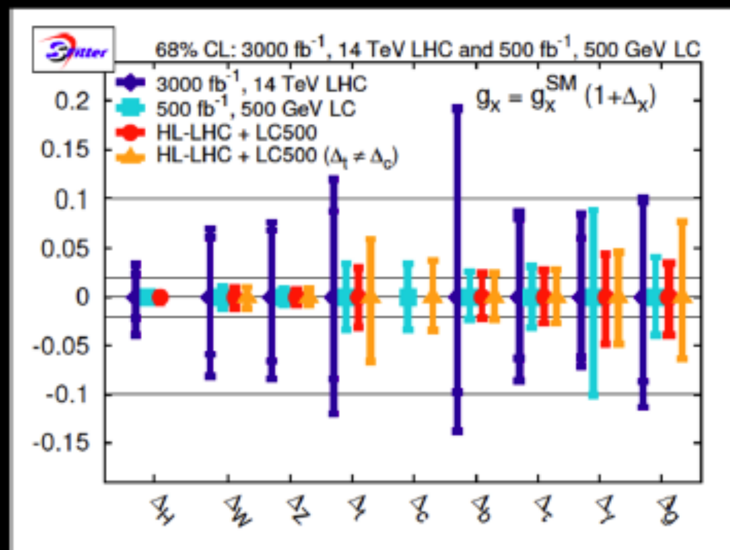




ILC Physics Potential

Measurement errors of Higgs couplings

LHC 14 TeV 3000 fb-1 and ILC 500 GeV 500 fb-1



Klute et al
arXiv:1301/1322v2

500 fb^{-1} of ILC@500 GeV
1.8 E34/cm^{2}s : ~3 years
(1 yr = 1E7 s)

Apart from γ, ILC errors are 1/3~1/10 of LHC
(statistical equivalent: 1~2 orders of magnitude more- at about the same cost)

- LHC may improve systematics (both theoretical and experimental)
- ILC by full simulation with bkgs. May improve analysis methods

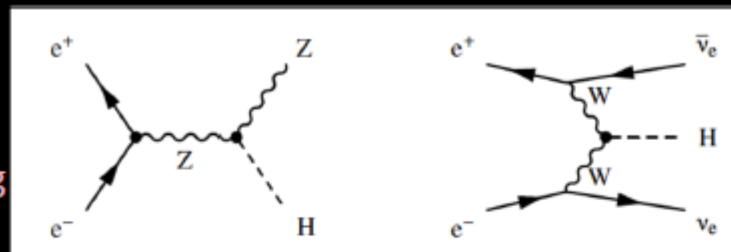
Great prospect for HEP : ILC and LHC running in parallel!

ILC Physics Potential

Yamamoto

ILC @1 TeV

Higgsstrahlung



W fusion

	250 GeV	350 GeV	500 GeV	1 TeV
$\sigma(e^+e^- \to ZH)$	240 fb	129 fb	57 fb	13 fb
$\sigma(e^+e^- \to H\nu_e\bar{\nu}_e)$	8 fb	30 fb	75 fb	210 fb
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}	500 fb^{-1}	1000 fb^{-1}
# ZH events	60,000	45,500	28,500	13,000
# $H\nu_e\bar{\nu}_e$ events	2,000	10,500	37,500	210,000

Luminosity
each energy for ~3 years

- At higher Ecm
  - W fusion dominant
  - More Higgs
  - New particles !
- Good for Higgs self coupling

  $e^+e^- \to \nu\nu HH$
  - Effect of irreducible diagrams less important

  $\delta\lambda/\lambda = 0.76\ \delta\sigma/\sigma$ @ 1 TeV

  ($\delta\lambda/\lambda = 1.66\ \delta\sigma/\sigma$ @500 GeV)

  □ $\delta\lambda/\lambda = 17\%$ (2 ab^{-1} @ 1 TeV)

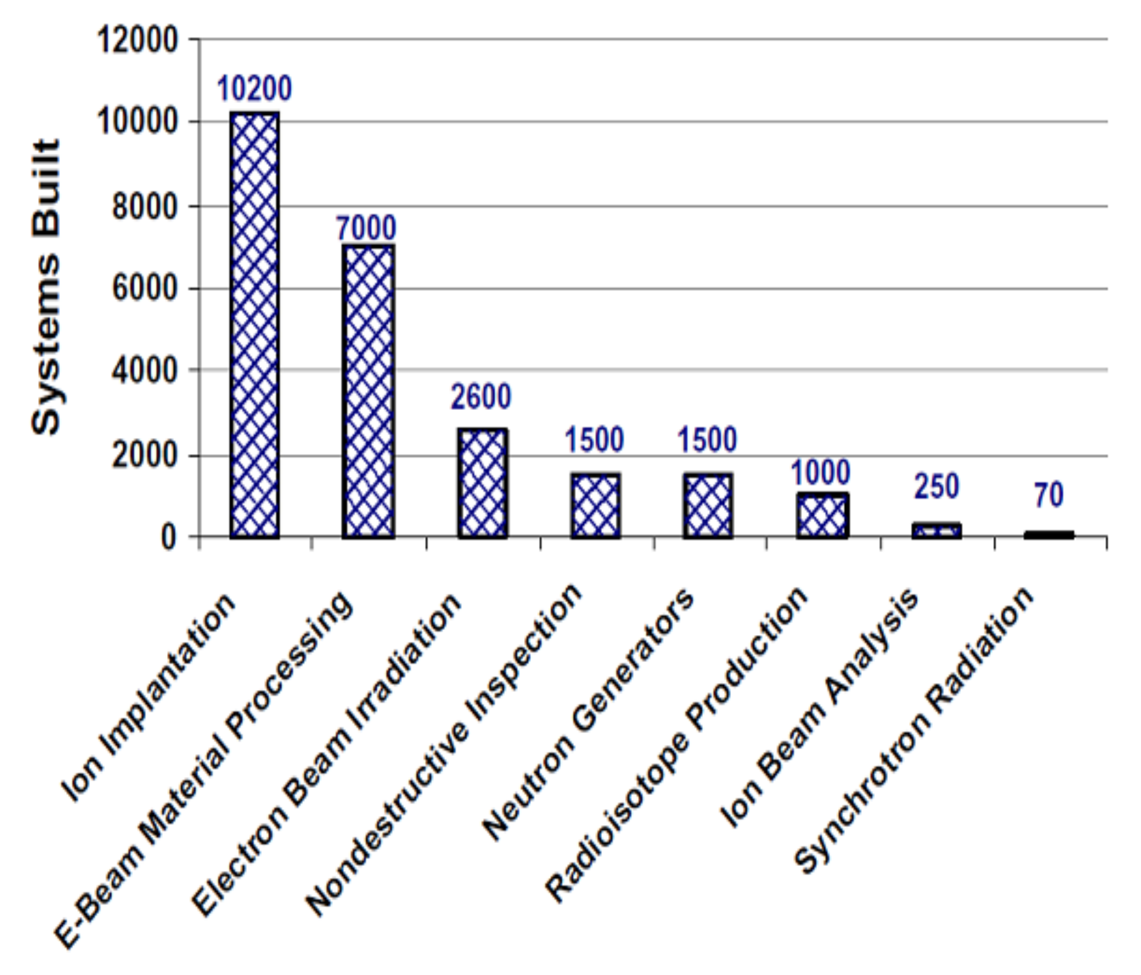
Glashow - Accelerators

How 'Atom Smashers' Became Big Business

Cyclotrons were created for pure research: to study the basic building blocks of matter. But these and other particle accelerators contribute directly to wealth creation and human welfare. Some 30,000 accelerators operate today. Very few do fundamental research. Mostly they are used for industry and medicine: Ion Implantation, Material Processing, Particle Beam Therapy, Medical Isotope Production, Food Irradiation, Nondestructive Inspection etc.

Energy loss due to 'synchrotron radiation,' once a problem at electron accelerators, has become a multi-billion dollar bounty. Synchrotron light is useful for many basic sciences, medicine and industry. About 70 of these large, expensive and sophisticated light sources are deployed in 20 countries. Far more powerful 'Fourth Generation' light sources are on the horizon.

Accelerators: Economic Impact



- Total built to date >24 000, with >18 000 in operation
- Sales increasing ~10% per year
- Presently >70 accelerator vendors worldwide
- Vendors primarily in US, Europe and Japan, but growing in China, Russia and India
- Equipment sales ~$3B per year worldwide

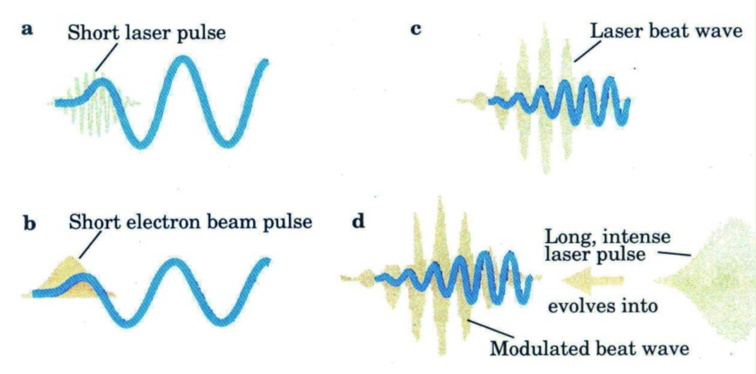
All the products that are processed, treated or inspected by particle beams have an annual value exceeding $500B

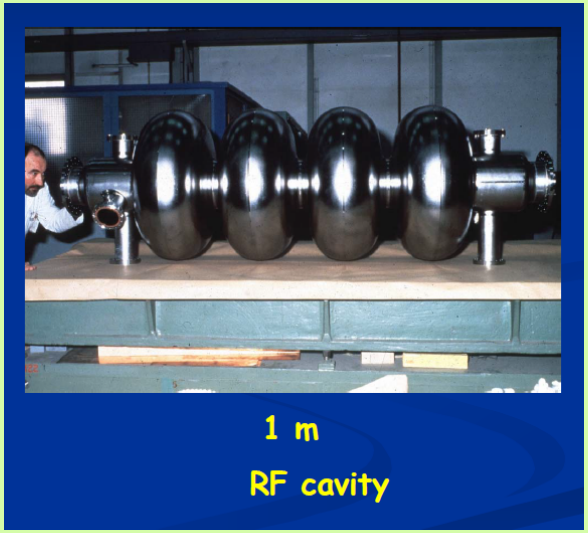
Future of Accelerator Based Particle Physics?

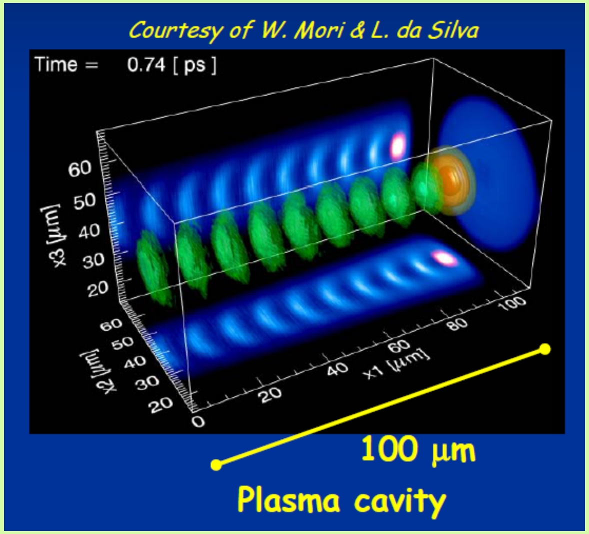
Future of Accelerators (eliminate materials!)

Plasma/Laser

Wakefield Acceleration



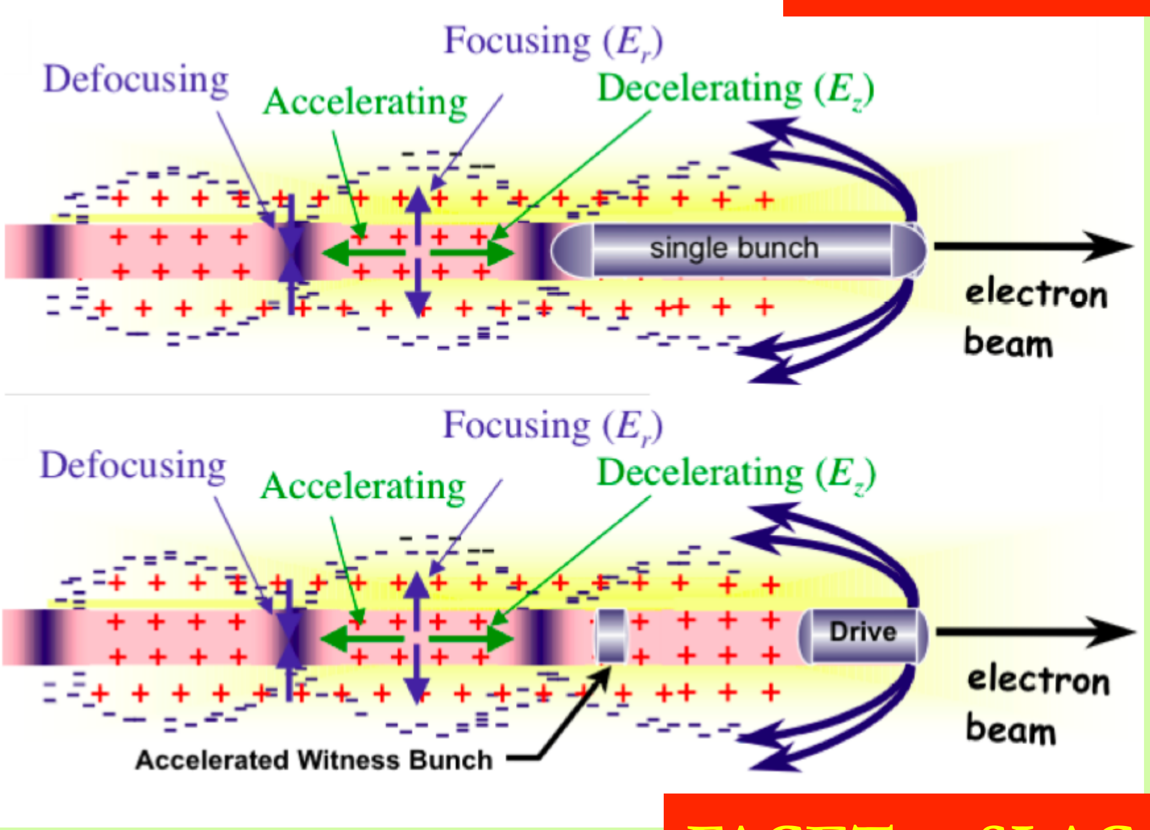




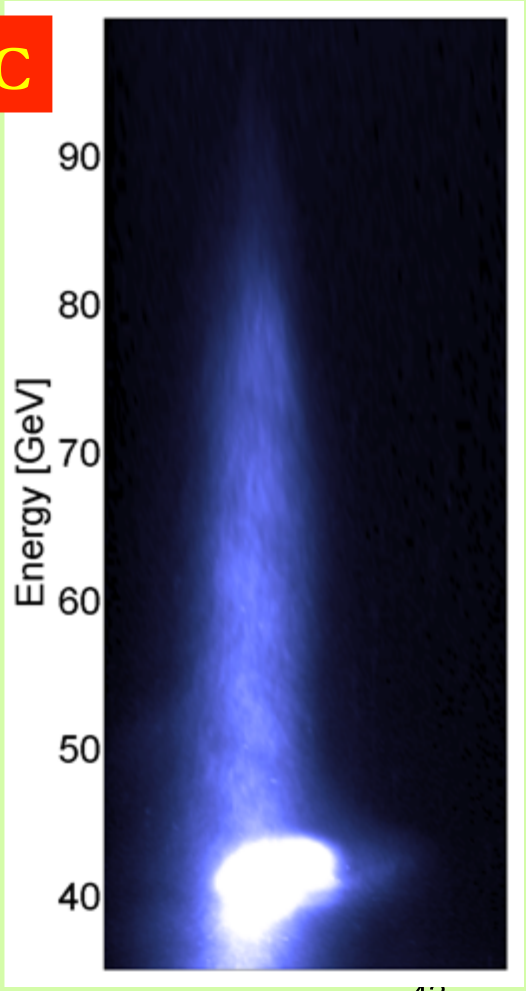
Compact Acceleration

50 GeV/meter has been achieved

FFTB at SLAC

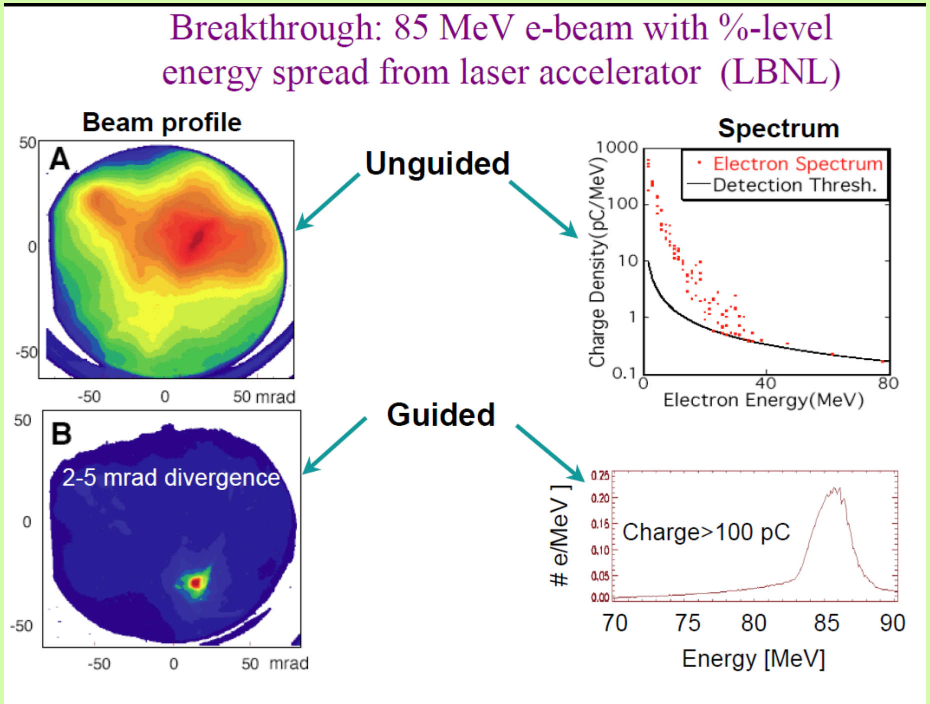


FACET at SLAC

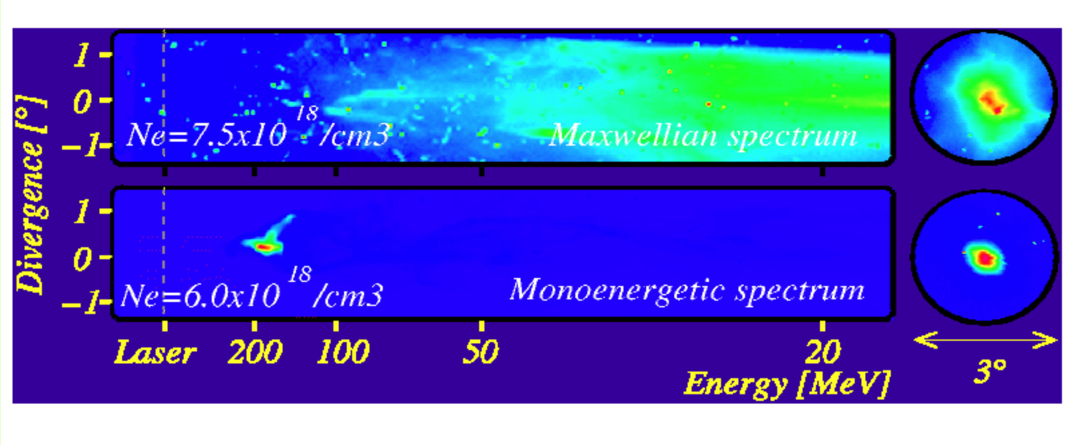


Controlling the beams

LBNL



Reducing energy spread to ~ percent level



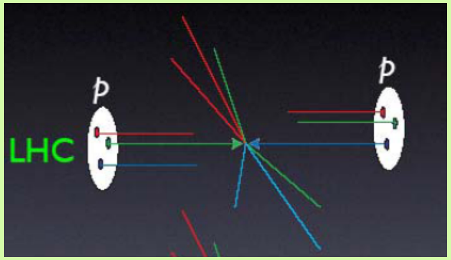
Reducing angular divergence (< 1 degree)

Advanced Accelerator R&D projects

FACET	BELLA
SLAC National Accelerator Laboratory	Lawrence Berkeley National Lab
Creates electron wake using an electron beam in a plasma	Creates electron wake using a laser beam in a plasma
Based on previous experiments that doubled the energies of a few electrons—from 42 billion to 85 billion electron volts—in 84 centimeters	Based on previous experiments that accelerated tightly packed electron bunches—the kind needed for physics experiments—from zero to 1 billion electron volts in 3 centimeters
Stimulus funds: $14.5 million	Stimulus funds: $20 million
Next step/midterm goal: is to create tighter electron bunches and accelerate them from 23 billion to 46 billion electron volts in 40 centimeters	Next step/midterm goal: is to accelerate already-tight electron bunches to higher energies, from zero to 10 billion electron volts in 80 centimeters

Experimental Probes

- High Energy pp Colliders
  - » Opening up a new energy frontier (~ 1 TeV scale)



- High Energy Lepton Colliders
  - » Precision Physics at the new energy frontier

- Neutrinos
  - » Particle physics and astrophysics using a weakly interacting probe

- Particle Astrophysics/Cosmology
  - » Dark Matter; Cosmic Microwave, etc

Experimental Probes

- **Neutrinos**
  - » **Particle physics and astrophysics using a weakly interacting probe**

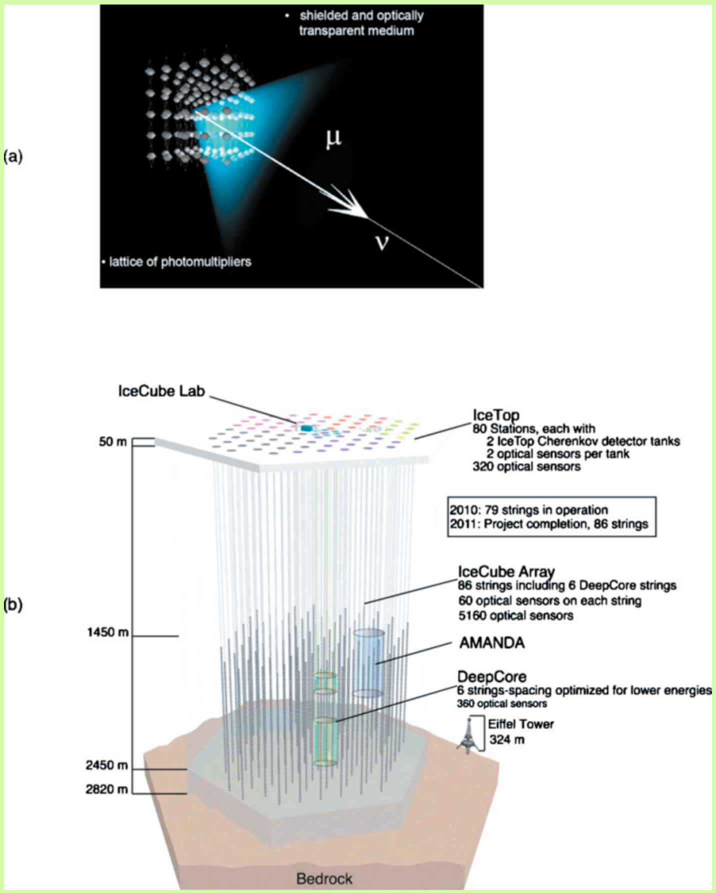
- **Particle Astrophysics/Cosmology**
  - » **Dark Matter; Cosmic Microwave, etc**

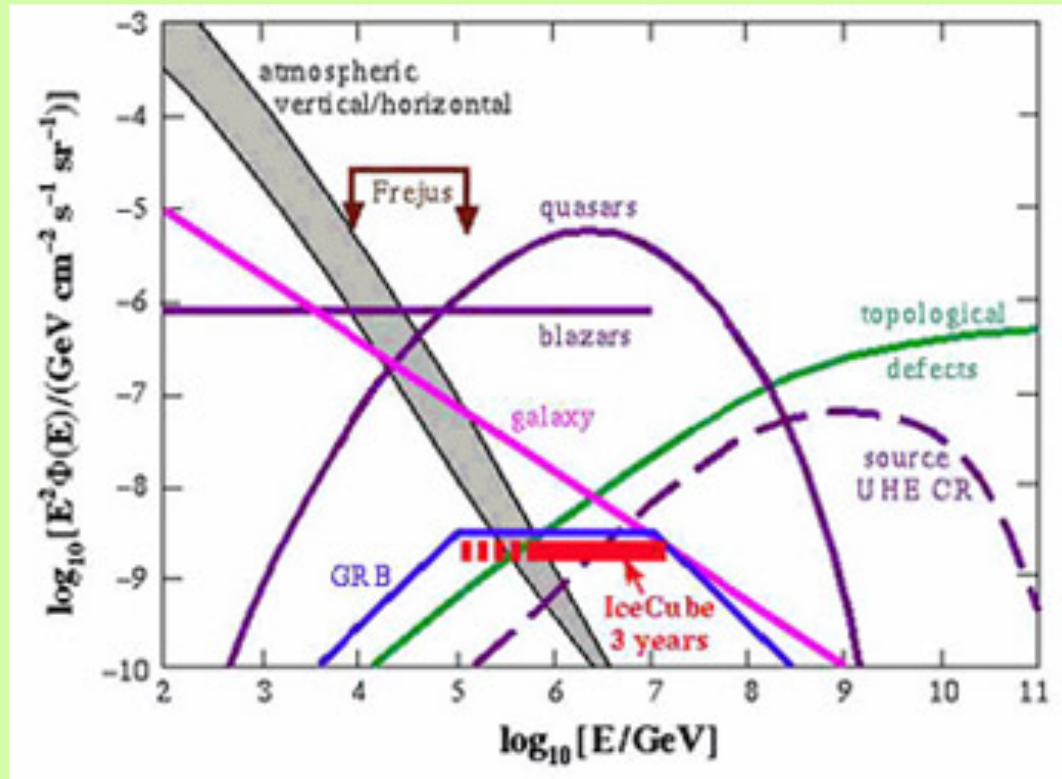
Neutrinos – Broad field; Specialized Expts

- **Neutrino Properties**
  - » Why are neutrino masses so small and what is their mass scale?
  - » Separation and ordering of neutrino masses?
  - » Are neutrinos their own antiparticles?
- **Neutrinos in Astrophysics**
  - » Astrophysical sources of neutrinos, and their contribution to the dark matter?
- **Neutrinos and Fundamental Particle Physics**
  - » CP violation in neutrinos, leptogenesis, possible role in the early universe and in understanding the particle antiparticle asymmetry in nature?

Ice Cube: Neutrino Astronomy

- **Neutrino Astrophysics – Investigating astrophysical sources emitting ultra high energy neutrinos**

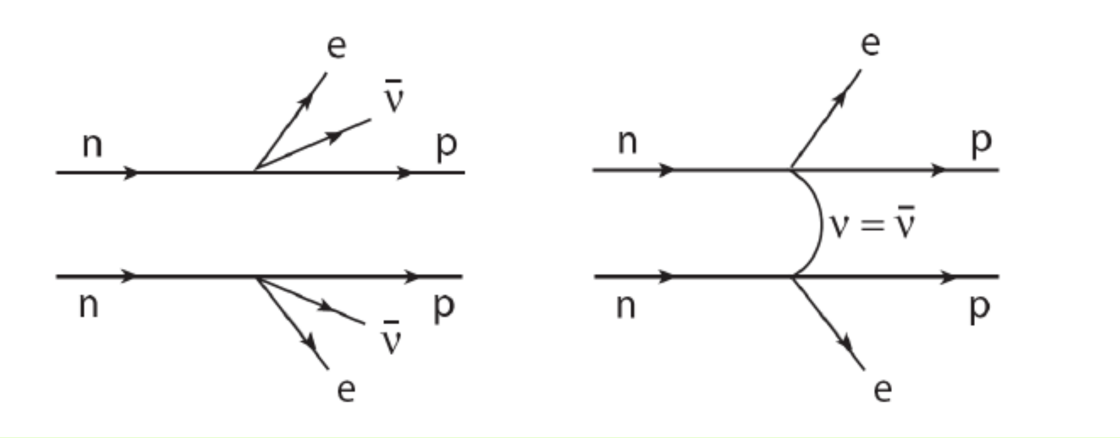




South Pole

Is the neutrino its own antiparticle?

- **Neutrinoless Double Beta Decay**

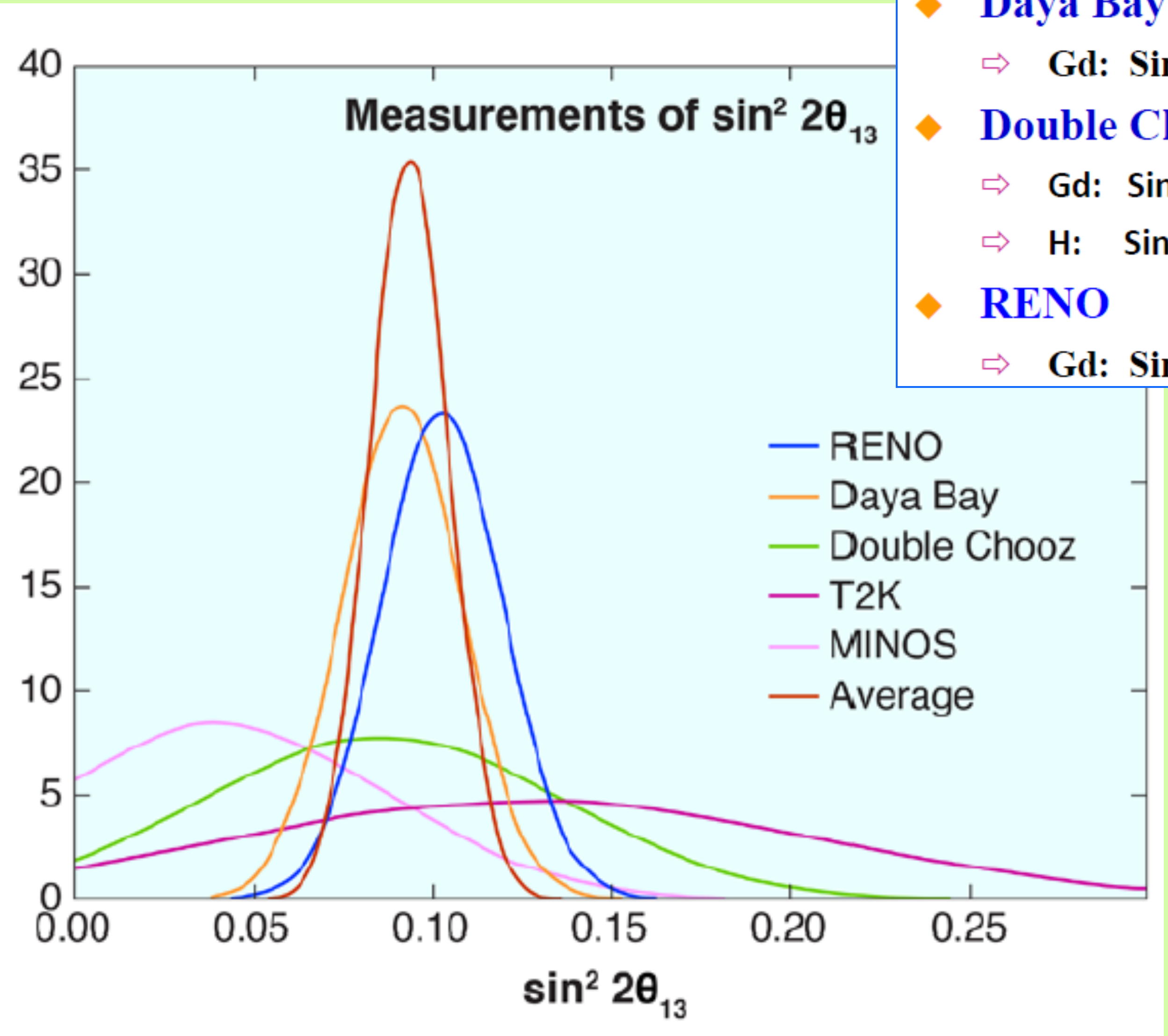


- **If neutrino is a Majorana particle (own antiparticle)**
  - » Determine neutrino mass scale
  - » Importance for Grand Unification
  - » Lepton number violation
  - » Implications for leptogenesis

Neutrinoless Double Beta Decay

- Experimental Challenges – What technique?
  - » Isotopes decaying to monochromatic electrons over continuum background. No obvious best isotope? Therefore, several large-scale experiments are likely needed.
  - » Which technique scales to the needed mass (Xenon, Germanium, ???)
- Experimental Challenges – Scale required
  - » Present experiments – 10 kg → sensitivity to $m_\nu < 1$ eV
  - » Need ~ 1 ton detectors to reach atmospheric m_ν ~50 meV
  - » Need ~ 50 tons to reach solar m_ν ~ 1 meV scale
- Other issues: Low background environment; costs; etc

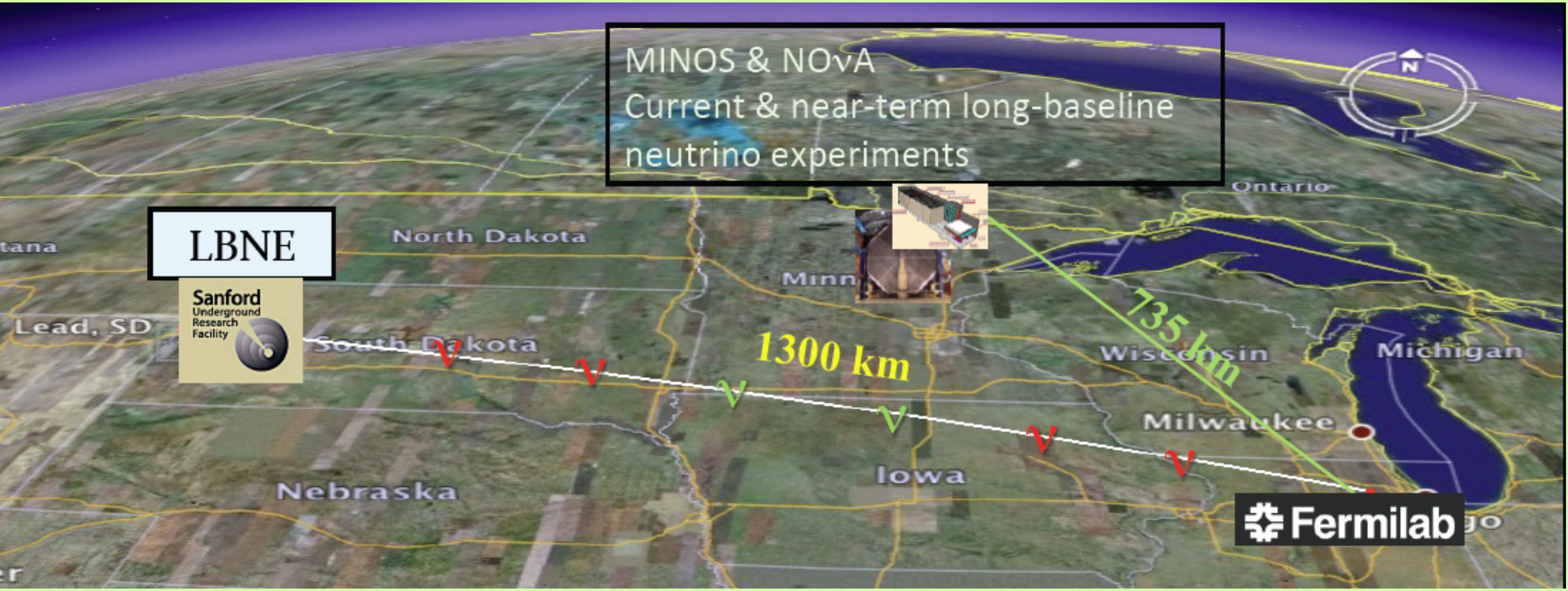
Reactors –ν oscillation results for $Sin^2 2\theta_{13}$



- **Daya Bay**
  - ⇨ Gd: $Sin^2 2\theta_{13} = 0.089 \pm 0.010^{stat} \pm 0.005^{syst}$
- **Double Chooz**
  - ⇨ Gd: $Sin^2(2\theta_{13}) = 0.109 \pm 0.030^{stat} \pm 0.025^{syst}$
  - ⇨ H: $Sin^2(2\theta_{13}) = 0.097 \pm 0.034^{stat} \pm 0.034^{syst}$
- **RENO**
  - ⇨ Gd: $Sin^2 2\theta_{13} = 0.113 \pm 0.013^{stat} \pm 0.019^{syst}$

Long baseline neutrinos - LBNE

- Mass hierarcy
- CP violation



Scholberg

LBNE – Cost / Schedule

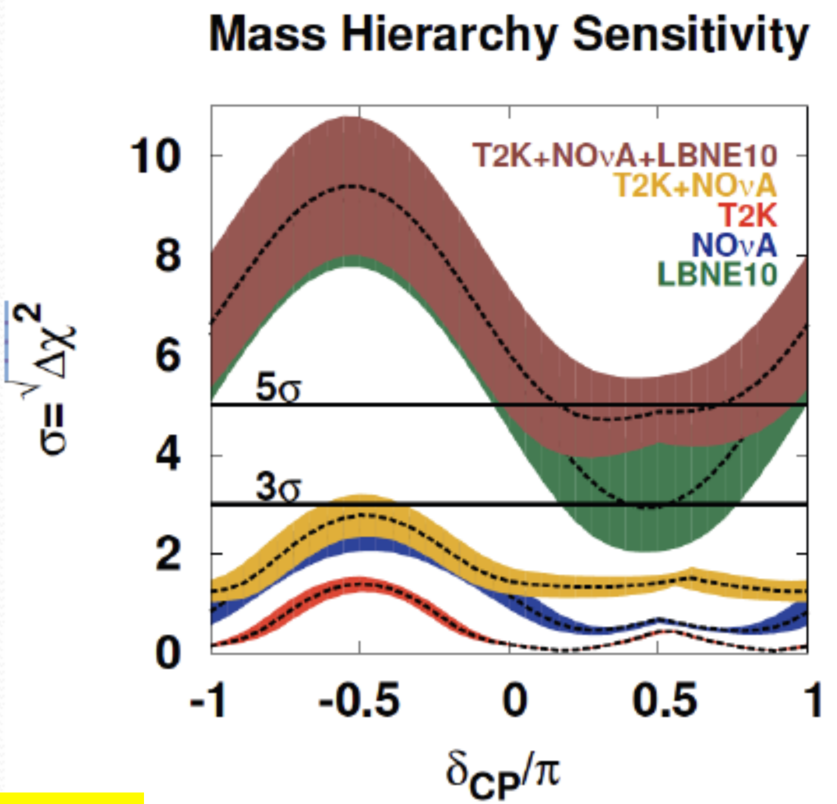
Scope	Cost (TPC)
LBNE 34 kTon@4850L and near detector	$1.440B
LBNE Phase I, 10 kTon surface	$0.789B
+Place Underground	$0.924B
+ Near Detector	$1.054B

DOE Critical Decisions

- CD-0 ("Mission Need") approves the need for the project. — Jan 2010
- CD-1 ("Alternative Selection and Cost Range") approves overall design, cost and schedule. — Dec 2012 *(for phase 1)*
- CD-2 ("Performance Baseline") approves the precise technical design, cost and schedule. — *Early 2017*
- CD-3A ("Approve Long-Lead Item Procurements") approves early start of selected parts of the project. — *Early 2016*
- CD-3 ("Start of Construction") approves the start of construction. — *Late 2017*
- CD-4 ("Project Completion") approves transition to operations. — *2023*

LBNE – mass hierarchy

- 700 kW beam
- 10 kton detector on the surface
- 10 yrs running (5 yr ν + 5 yr *vbar*)



T2K 750 kW x 5 yr ($7.8\mathrm{x}10^{21}$pot) ν

NOνA 700 kW x (3 yr ν + 3 yr $\bar{\nu}$) (3.8 $\mathrm{x}10^{21}$pot)

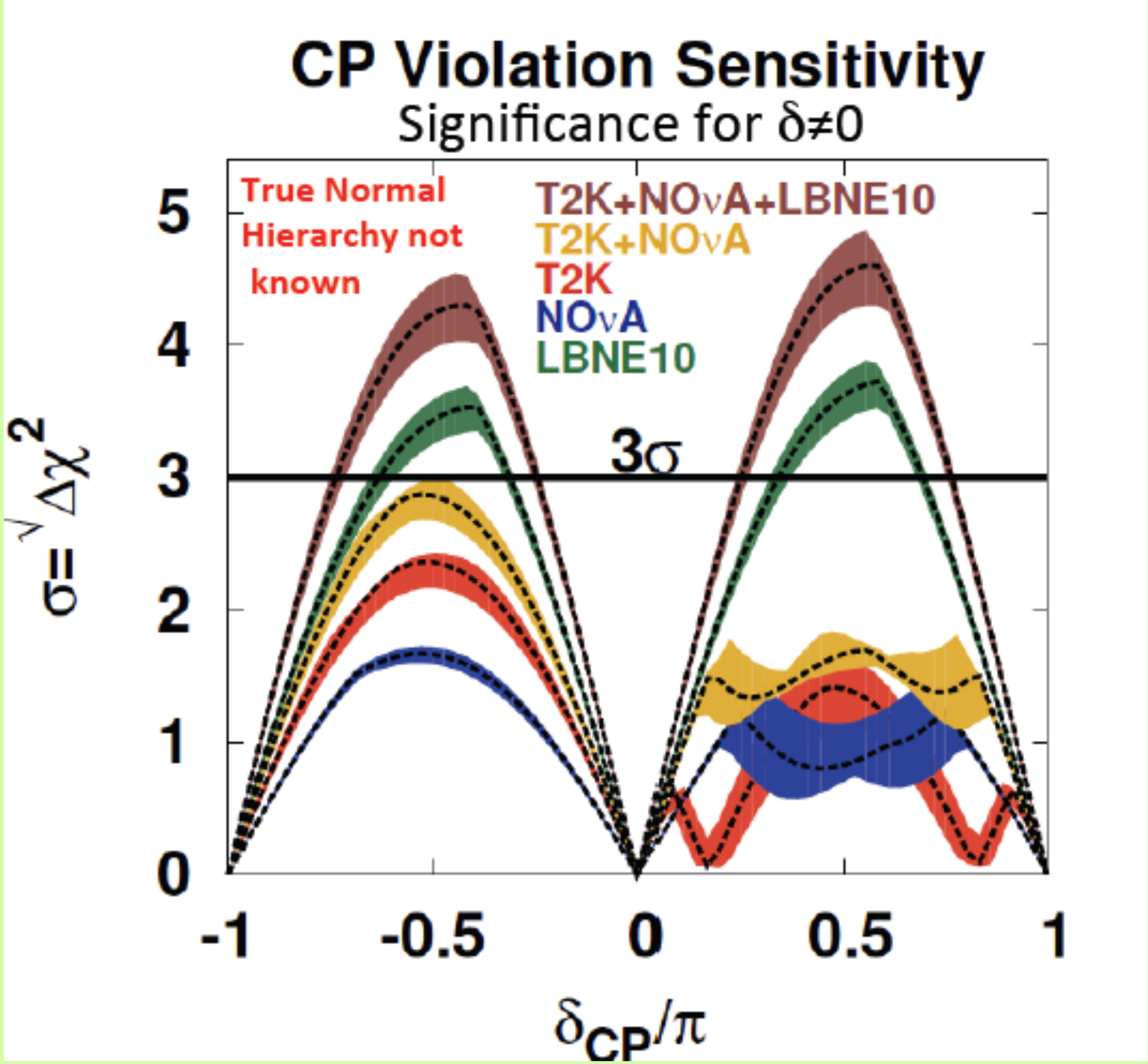
LBNE10 (80 GeV*) 700 kW x (5 yr ν + 5 yr $\bar{\nu}$)

*Improved over CDR 2012 120 GeV MI proton beam

Bands: 1σ variations of θ_{13}, θ_{23}, Δm_{31}^2
(Fogli et al. arXiv:1205.5254v3)

Scholberg

LBNE – CP violation sensitivity

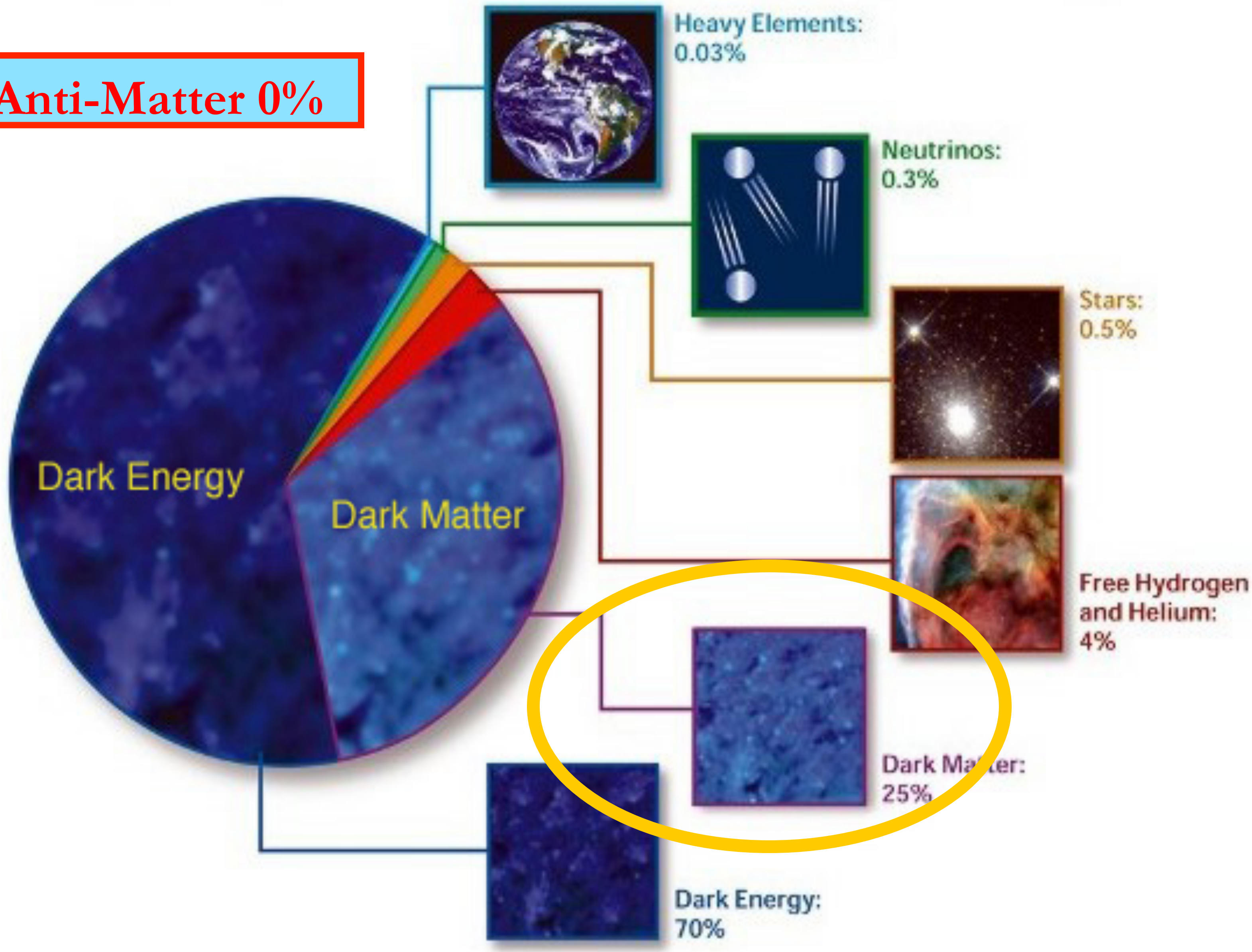


Approaches

- **Particle Astrophysics/Cosmology**
  - » **Dark Matter; Cosmic Microwave, etc**

The Energy Budget of the Universe

Anti-Matter 0%

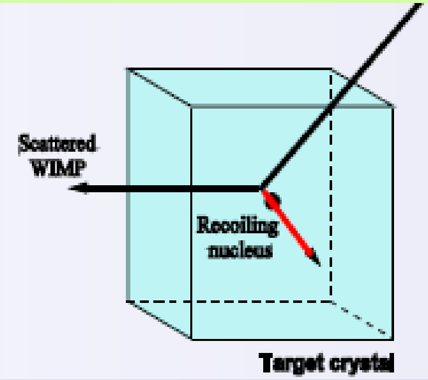


Searching for WIMP Dark Matter

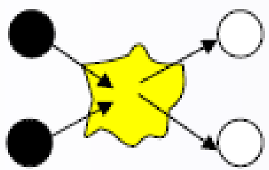
Underground

- Direct Detection:

Look for the elastic scattering of dark matter with nuclei



In Space



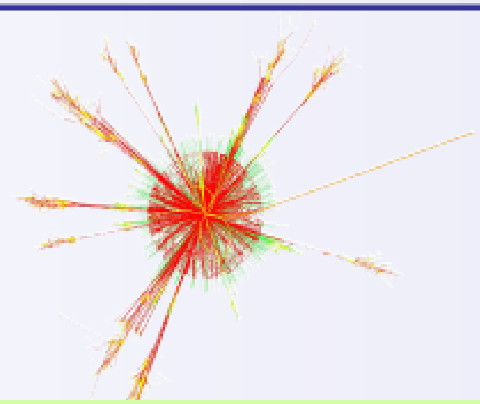
- Neutrinos
- Photons
- Electron-Positron, Antimatter

- Indirect Detection:

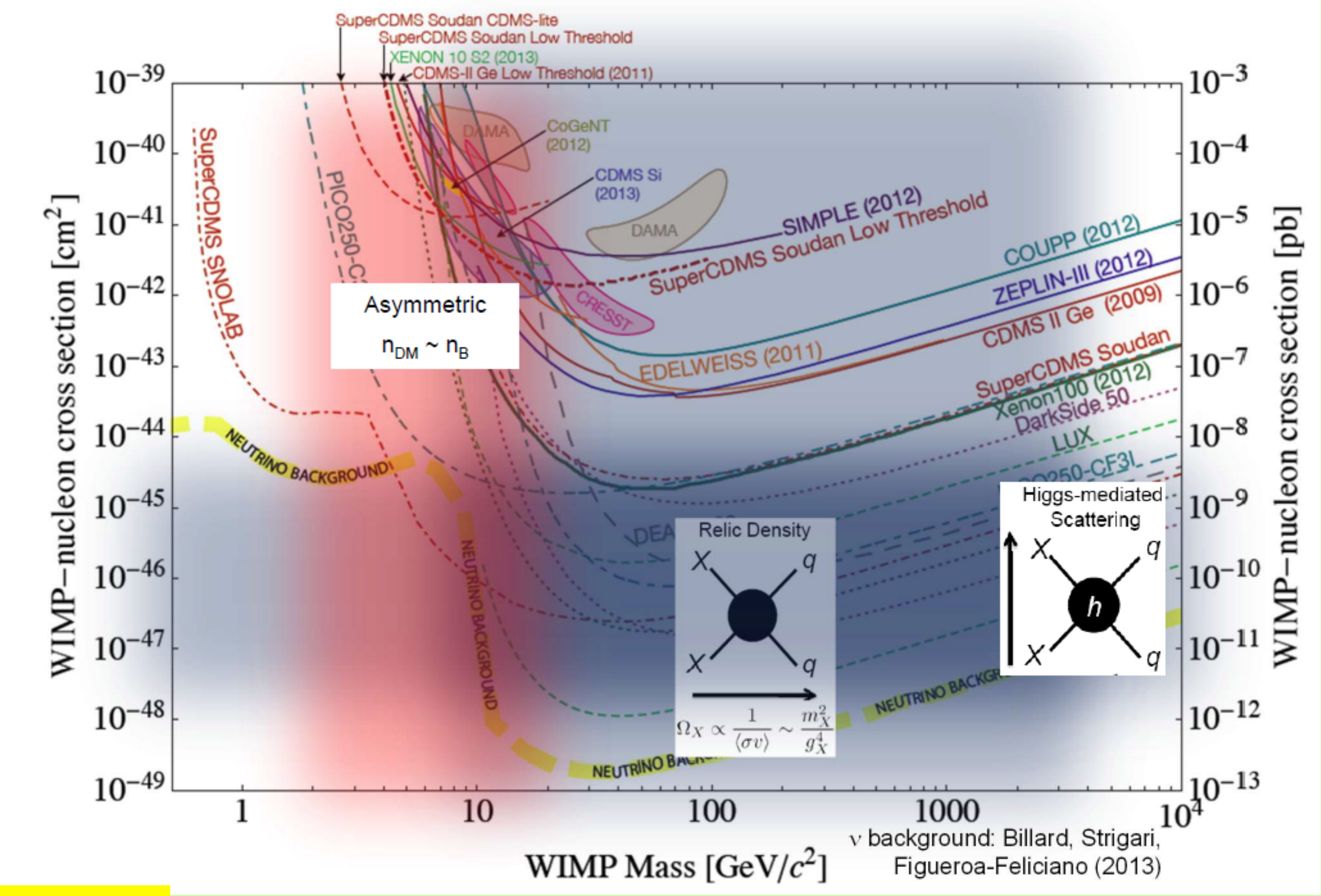
Look for the annihilation products

On Accelerators

Look for signals of new physics



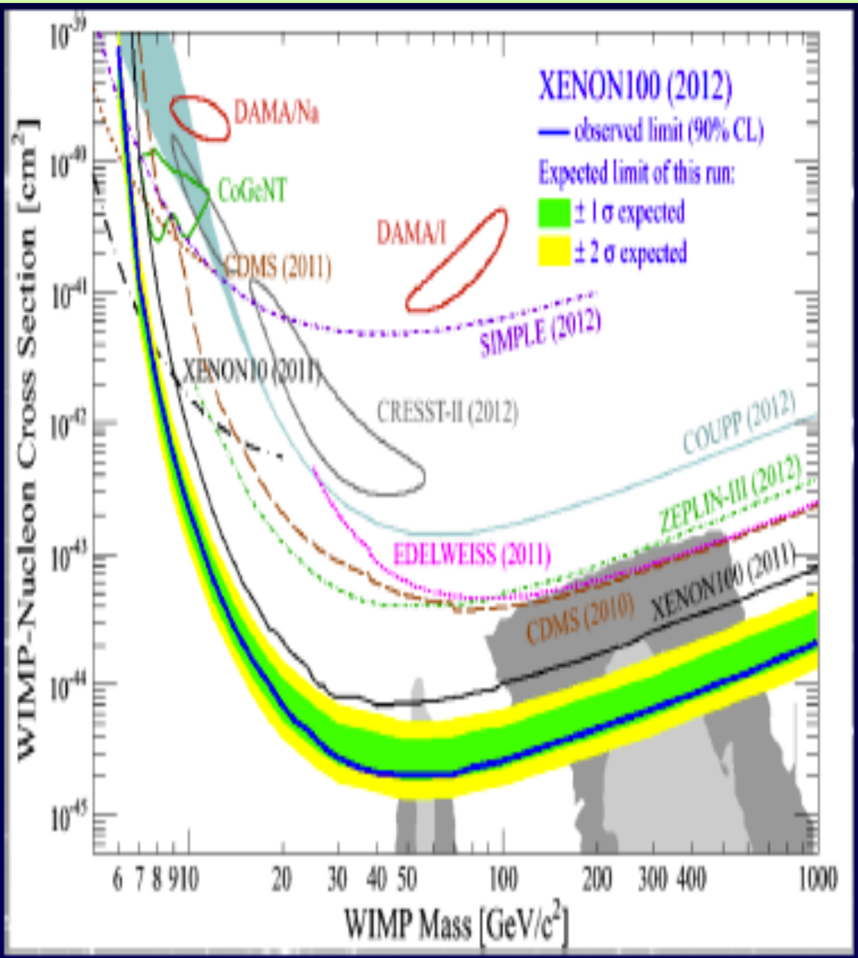
Searching for Dark Matter



Sadoulet

Searching for Dark Matter: Xenon100

- Data taken between February 2011 and March 2012 (reduced background)
- 2 events observed with a background expectation of 1 ± 0.2
- $\sigma_{SI} = 2.0 \times 10^{-45} cm^2$ for a 50 GeV WIMP (90% CL)



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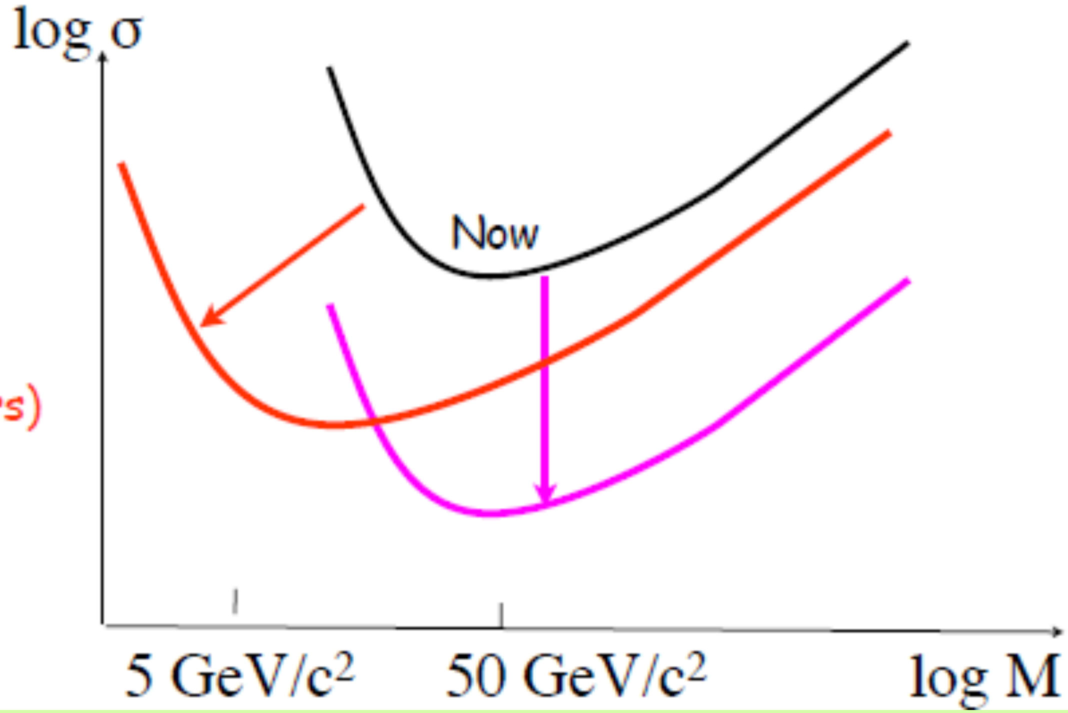
The future: experimental strategy

2 directions

1. Improve sensitivity at large mass (e.g., liquid noble)
2. Improve sensitivity at small mass

(low temperature detectors)

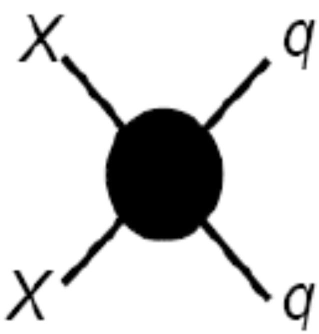


Combination of liquid Xe/Ar + low temperature detectors can approach fundamental neutrino limit +⁸Be detection

Sadoulet

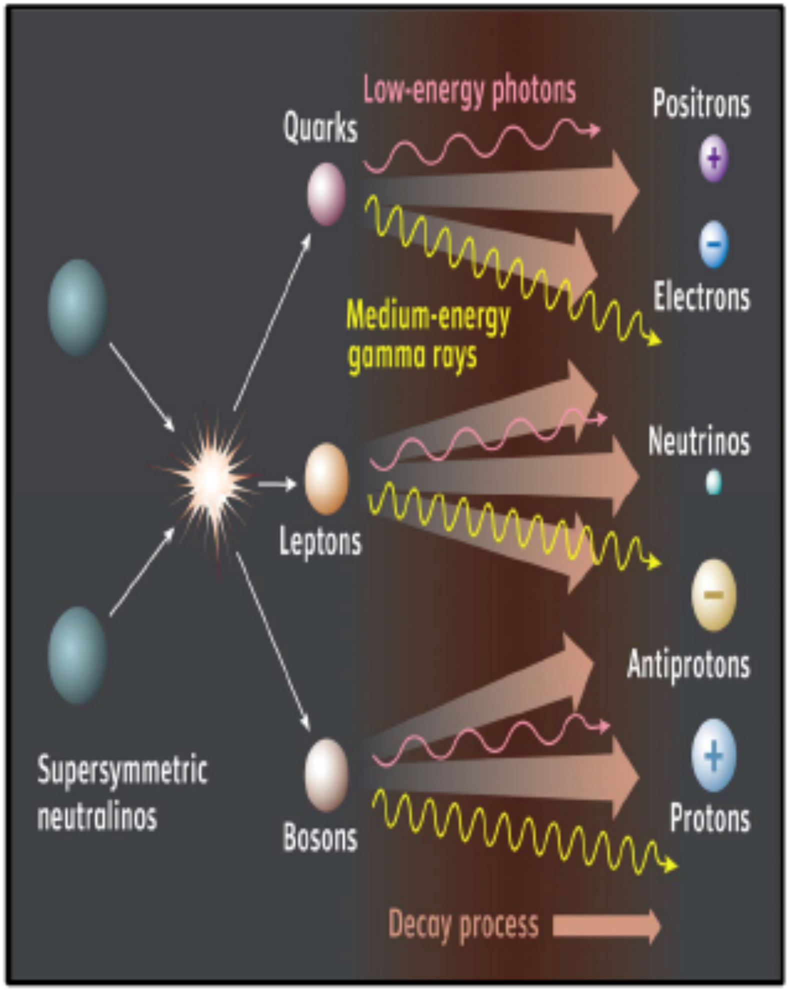
Indirect searches for dark matter

- Dark matter may pair annihilate in our galactic neighborhood to
  - Photons
  - Neutrinos
  - Positrons
  - Antiprotons
  - Antideuterons



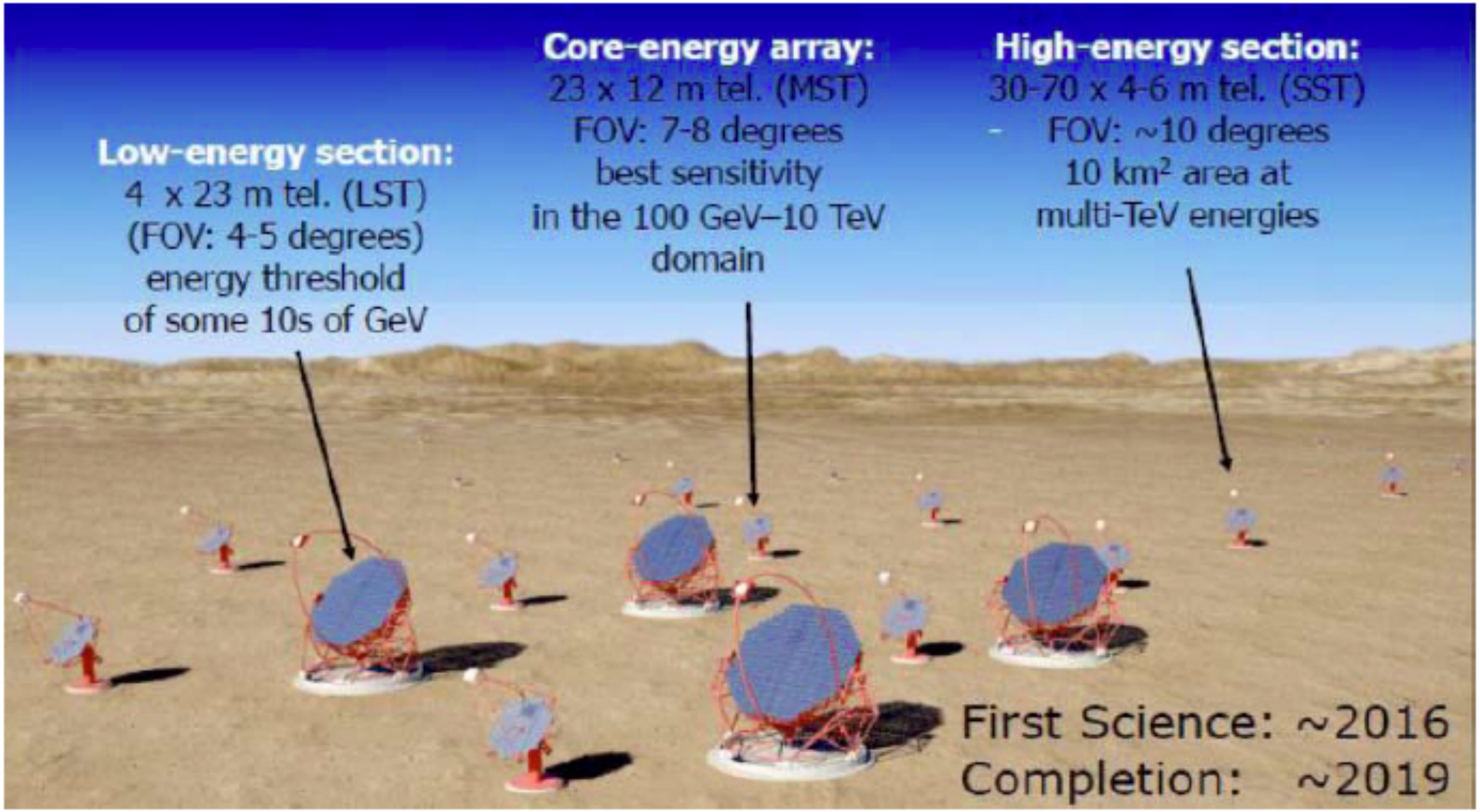
- The relic density provides a target annihilation cross section

$$\langle \sigma_A v \rangle \sim 3 \times 10^{-26}\ \mathrm{cm^3/s}$$

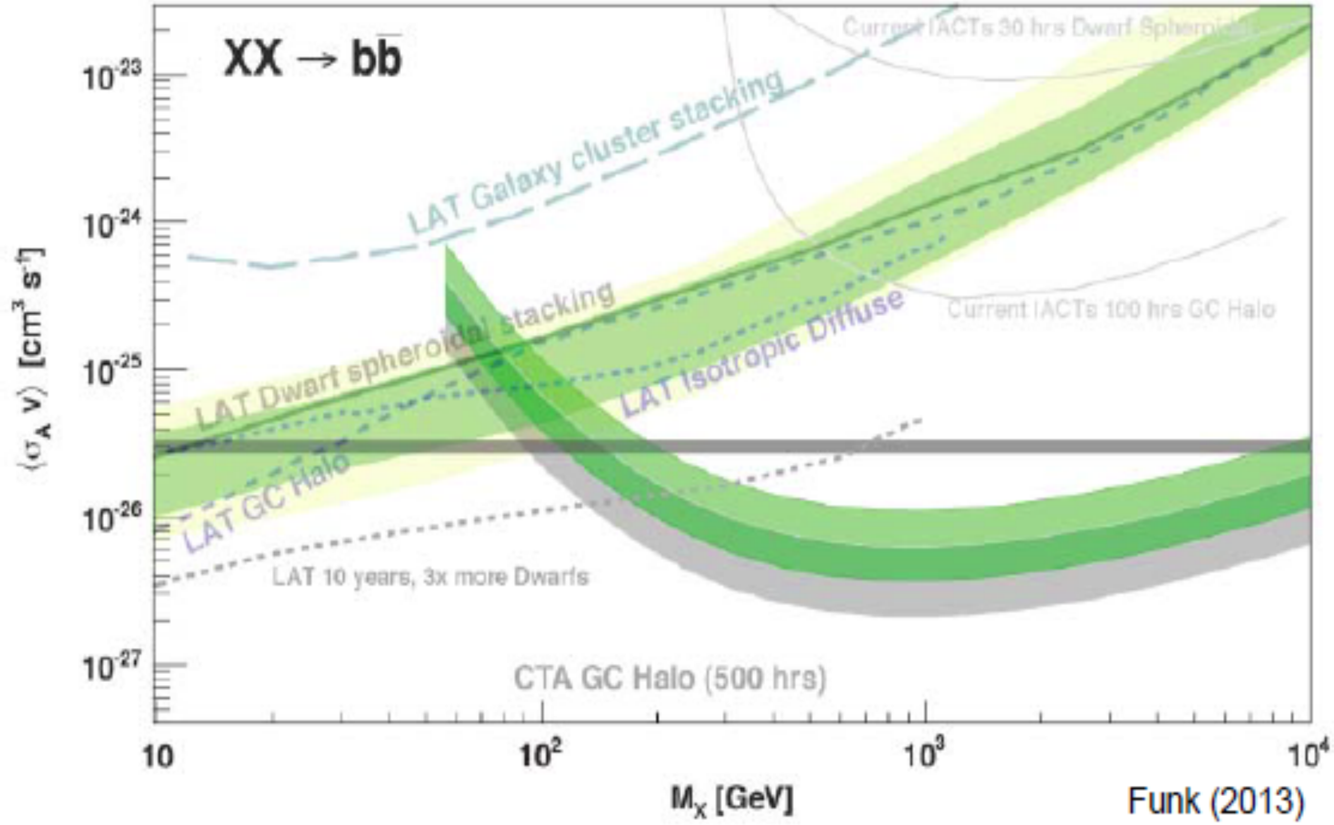


Indirect searches: photons

Future: Cerenkov Telescope Array



Indirect searches: photons

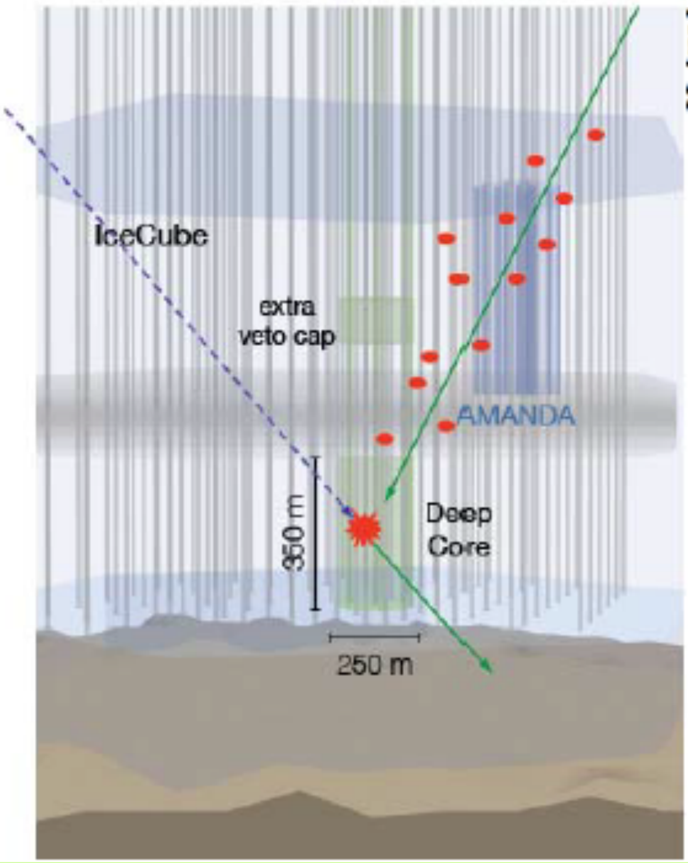


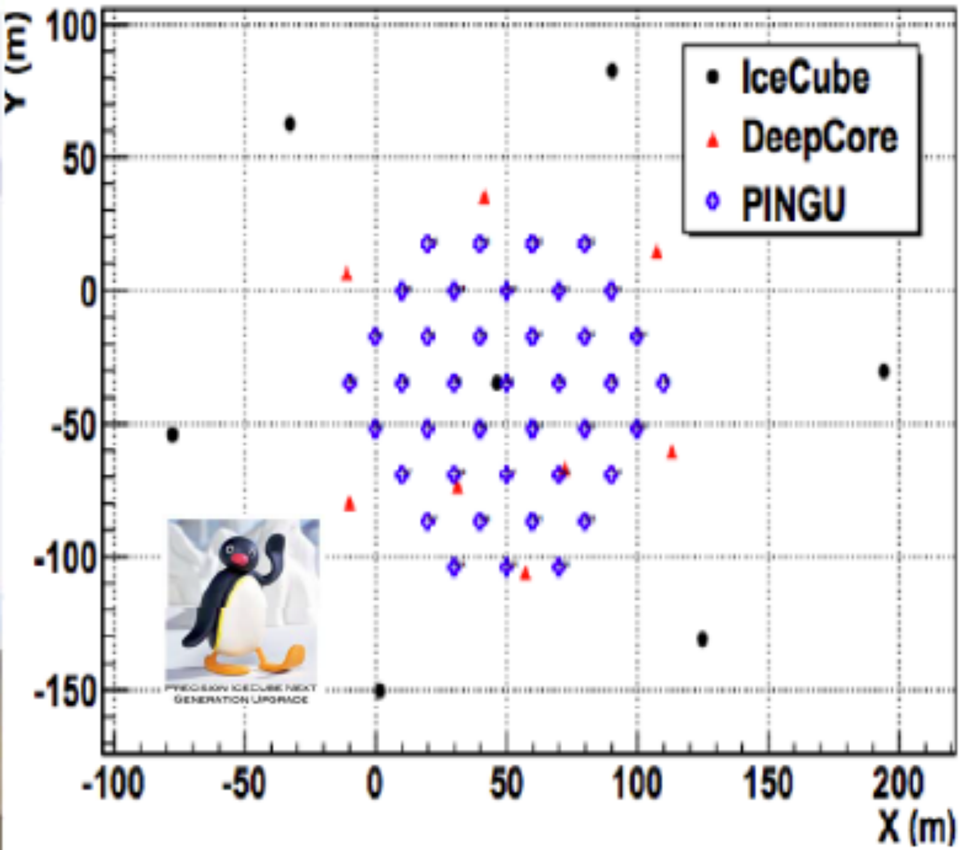
- Fermi-LAT has excluded a light WIMP with the target annihilation cross section for certain annihilation channels
- CTA extends the reach to WIMP masses ~ 10 TeV

Indirect searches: neutrinos

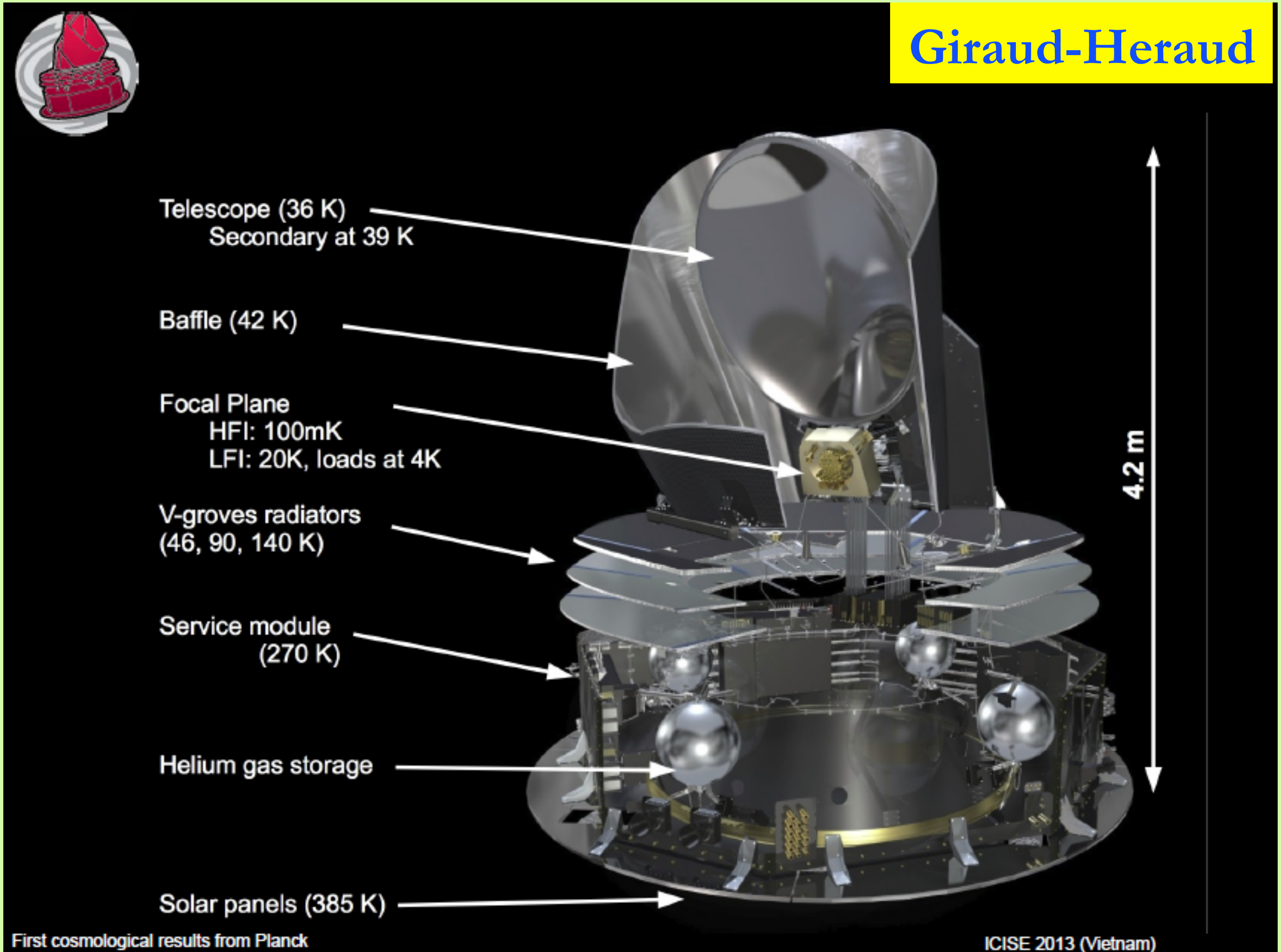
Current: IceCube/DeepCore, ANTARES

Future: PINGU

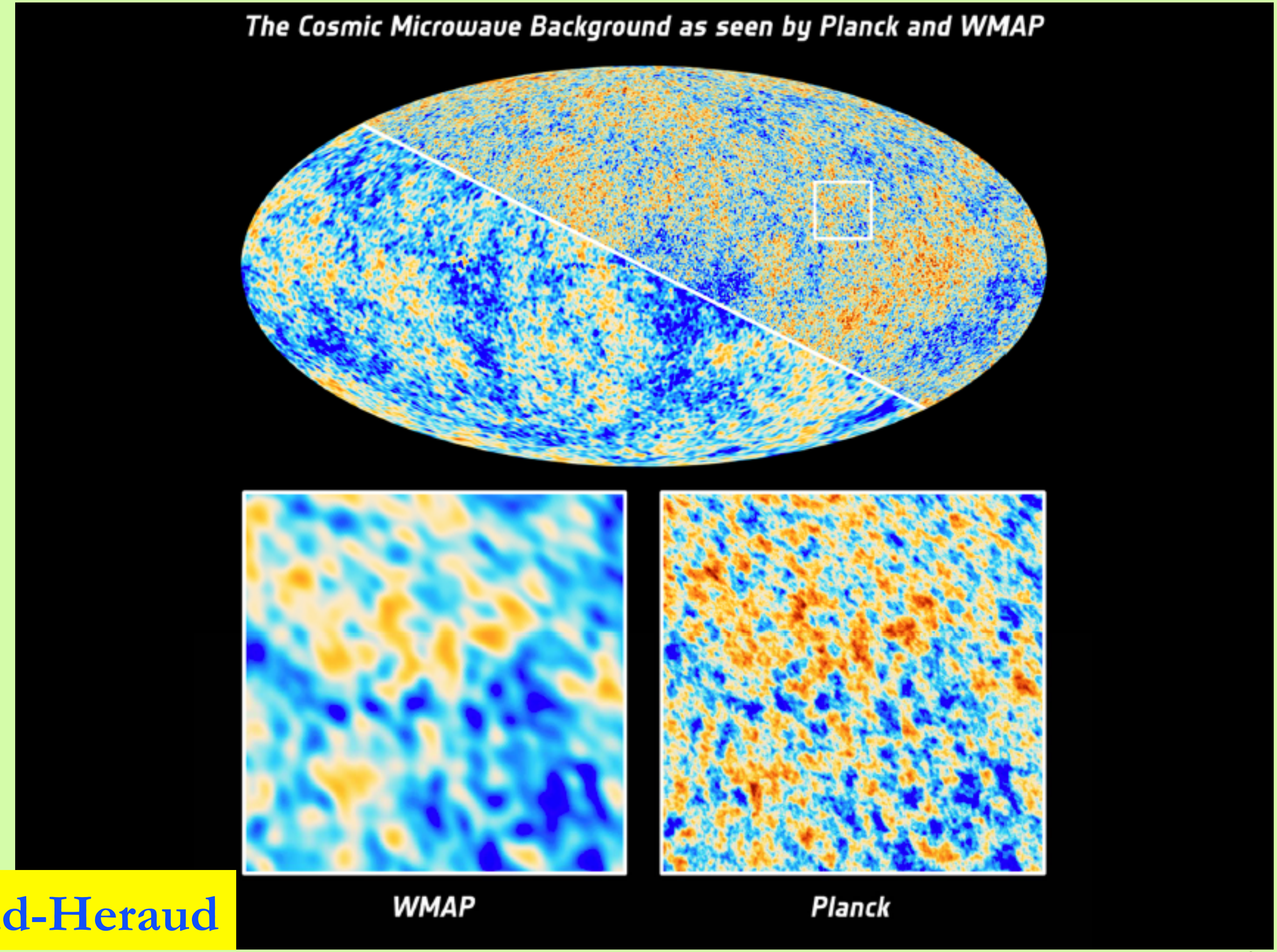




Planck – Cosmic Microwave Background

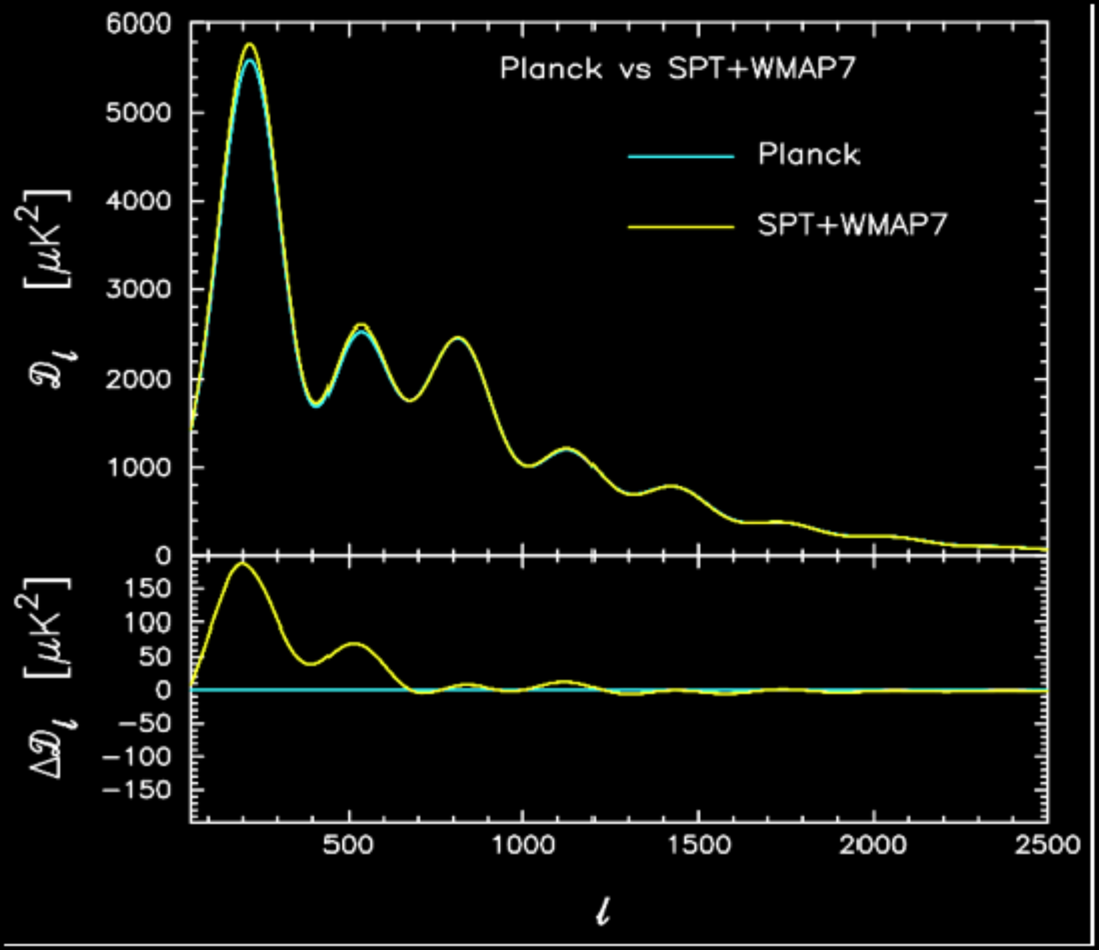


Planck – Resolution



Giraud-Heraud

Comparison between Planck and WMAP temperature spectra

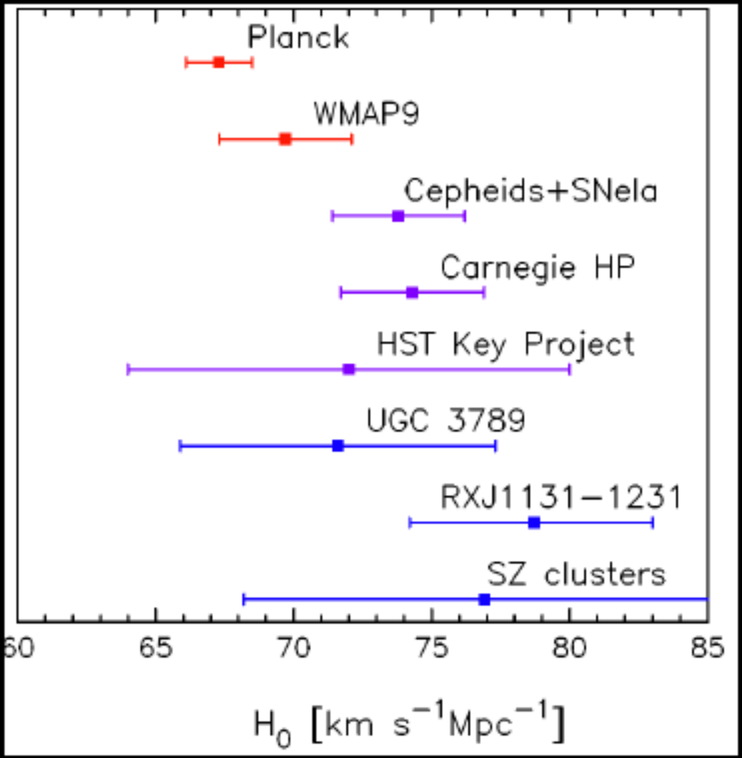


Giraud-Heraud

ICISE 2013 (Vietnam)

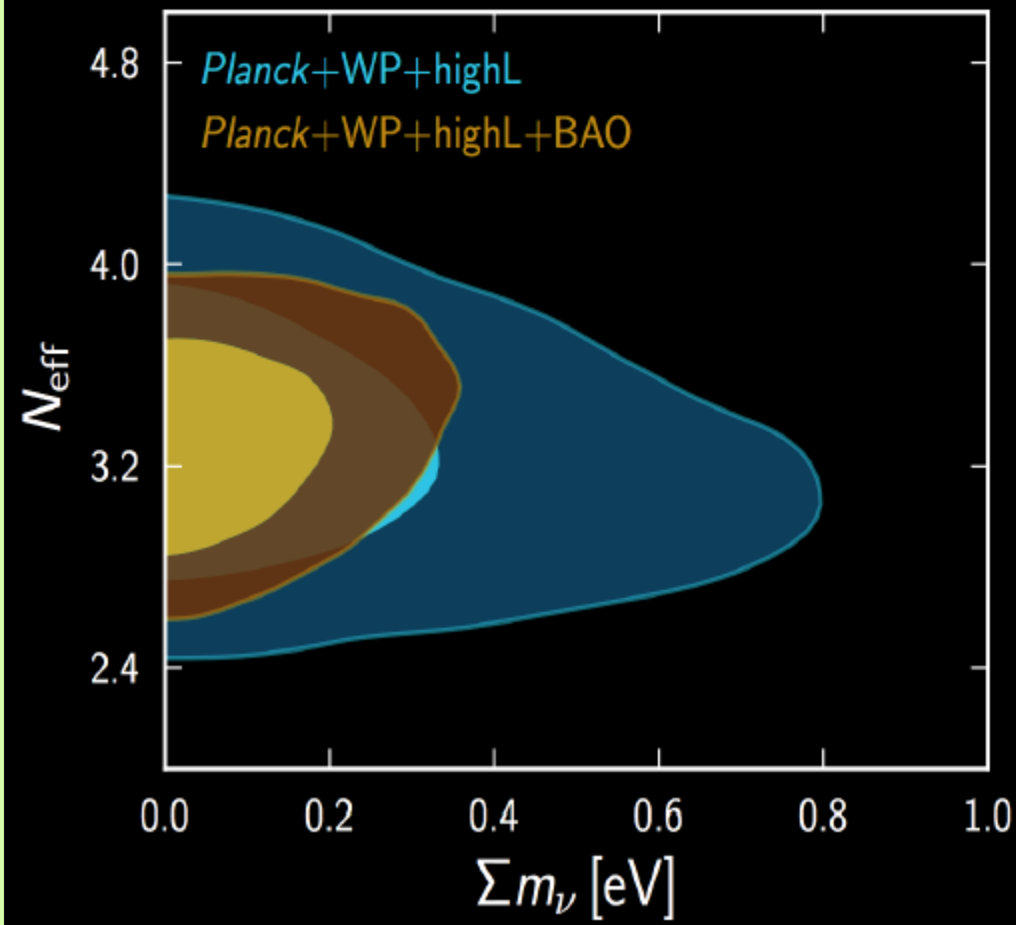
Expansion rate (Hubble constant)

- $H0 = 67.3 \pm 1.2$ km/s/Mpc
- Difference with WMAP comes from large matter content preferred by Planck
- Tension at 2.5σ between Planck and Cepheids or SNIa measurements



Giraud-Heraud

Mass and number of neutrinos



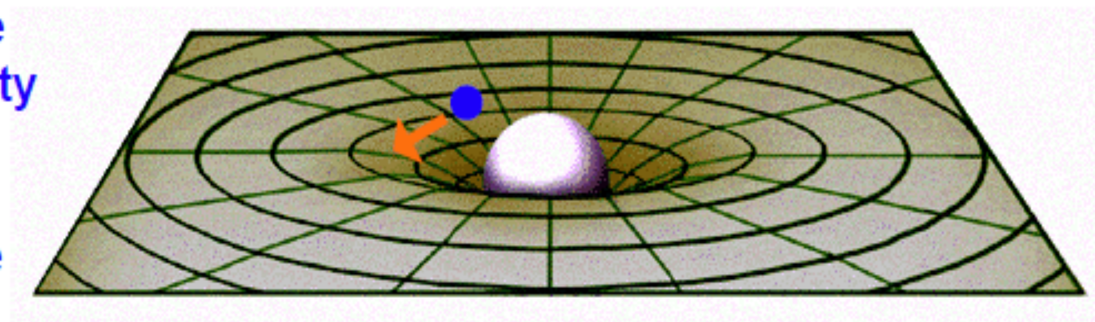
- much of this is from lensing and in conjunction with BAO
- $\Sigma m_\nu < 0.23$ eV
- $N_{eff} = 3.3 \pm 0.27$

Giraud-Heraud

ICISE 2013 (Vietnam)

Gravitational Waves

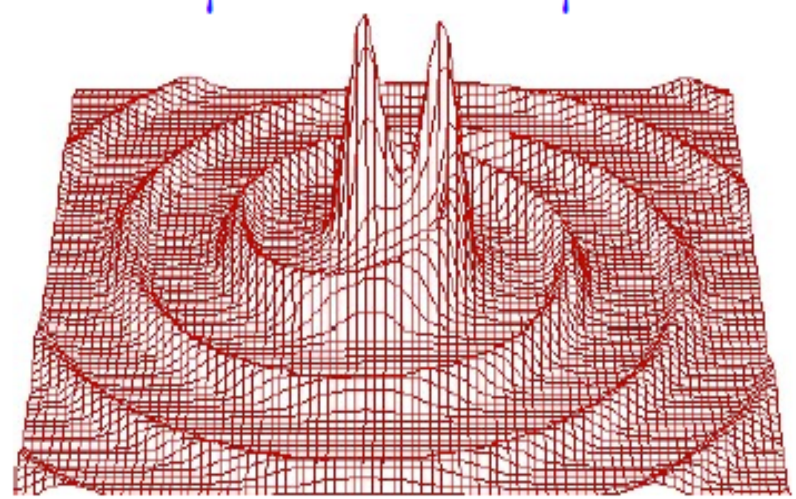
Static gravitational fields are described in General Relativity as a curvature or warpage of space-time, changing the distance between space-time events.



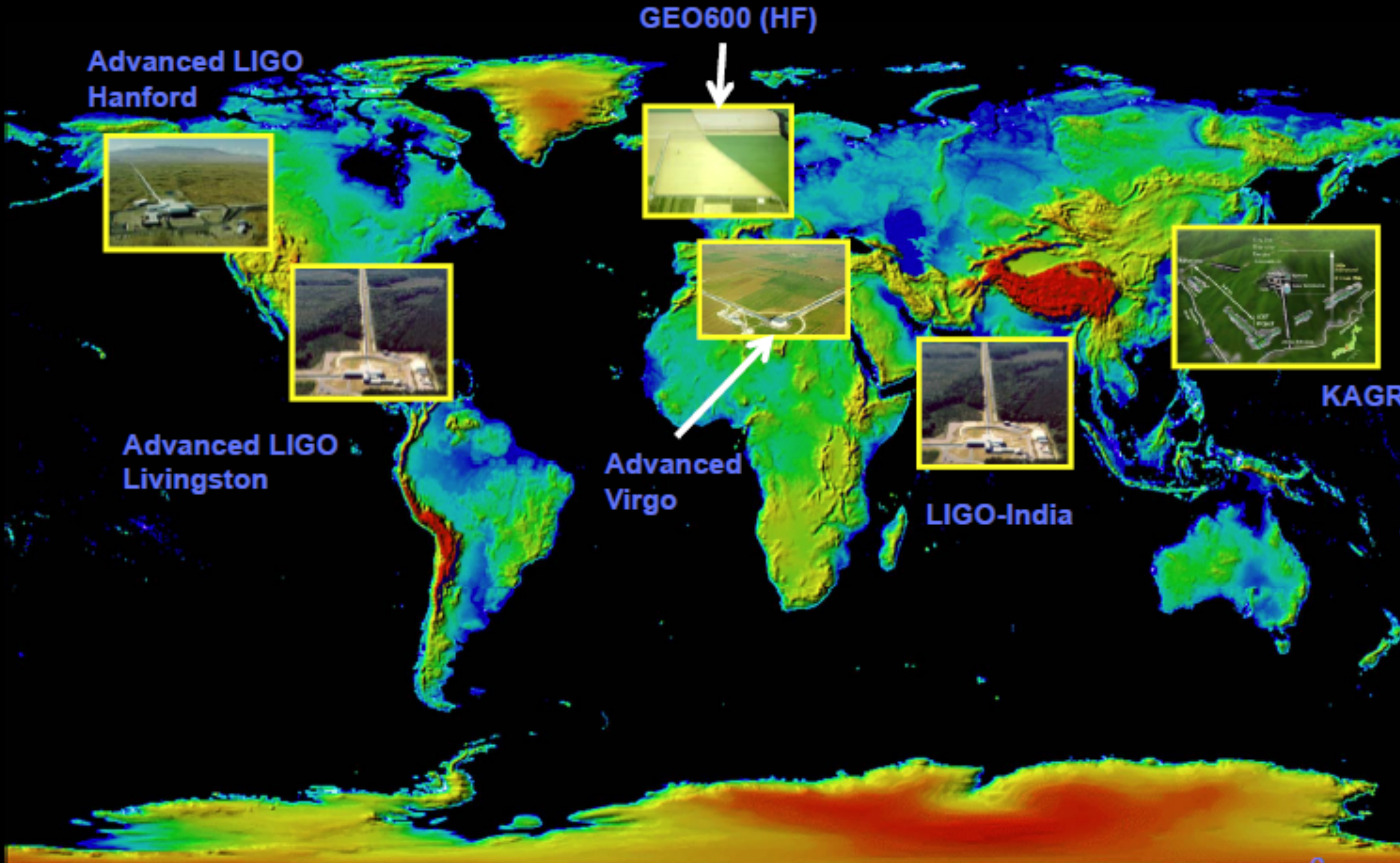
Shortest straight-line path of a nearby test-mass is a ~Keplerian orbit.

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

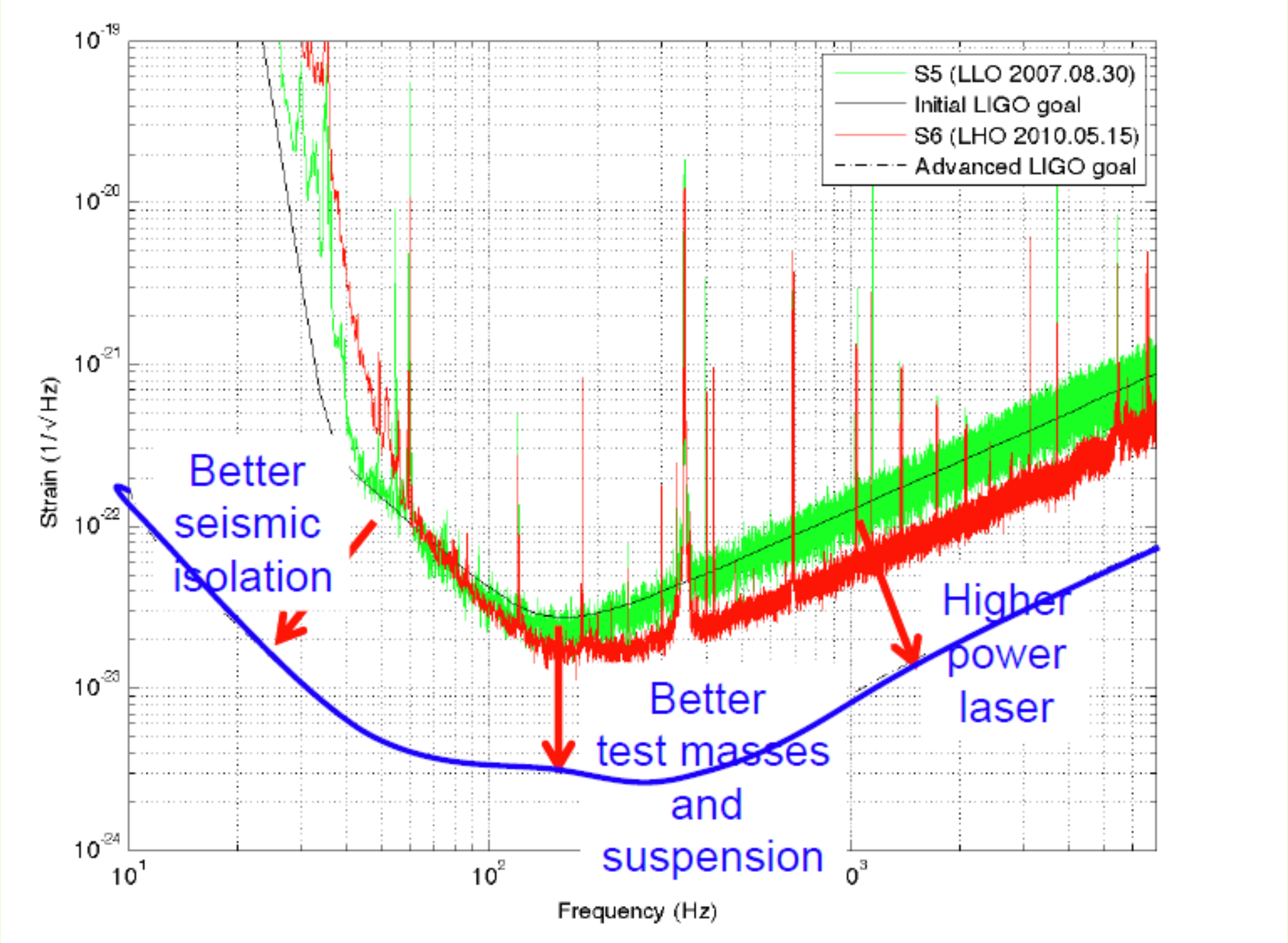
If the source is moving (at speeds close to c), *eg*, because it's orbiting a companion, the "news" of the changing gravitational field propagates outward as gravitational radiation – a wave of spacetime curvature



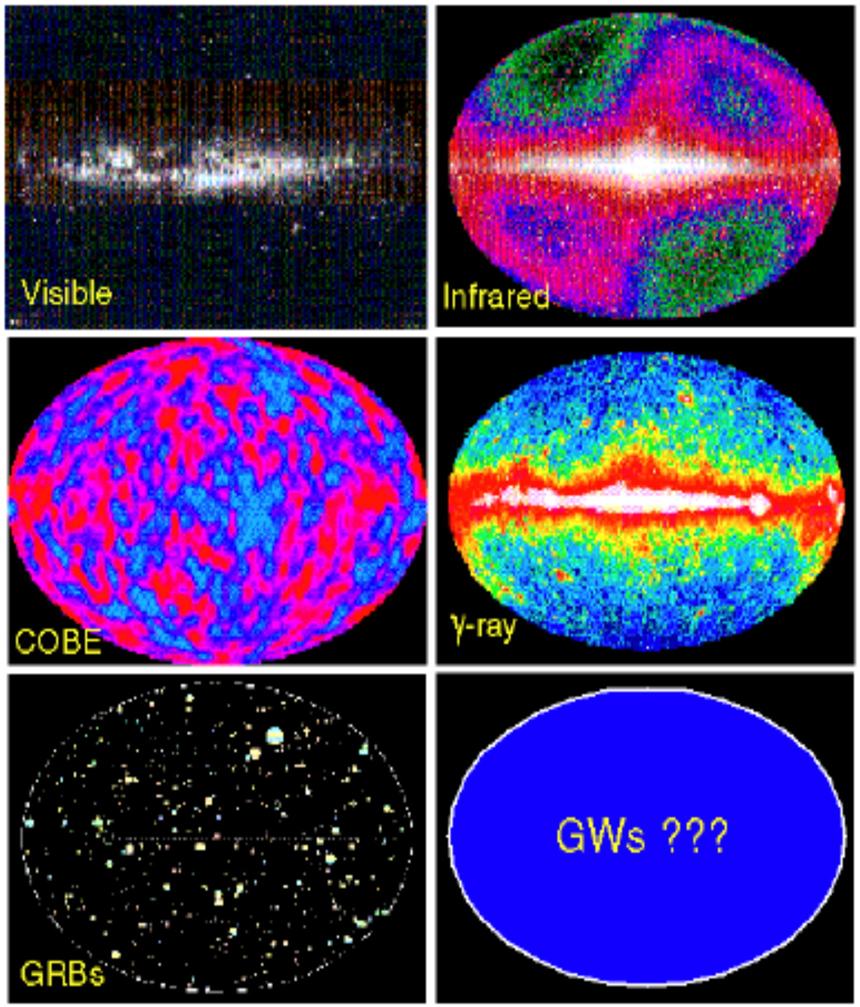
The Advanced GW Detector Network



Interferometric Detectors



A new 'window' on the Universe



The history of Astronomy:
new bands of the EM spectrum opened → major discoveries!

GWs aren't just a new band, they're a new spectrum, with very different and complementary properties to EM waves.

- Vibrations *of* space-time, not *in* space-time
- Emitted by coherent motion of huge masses moving at near light-speed; not vibrations of electrons in atoms
- Can't be absorbed, scattered, or shielded.

GW astronomy is a totally new, unique window on the universe

Gross

~~The Extreme~~ CREDIBLE Scenario

- ★ The Higgs(-like) boson ≠ SM Higgs
- ★ Direct production of SUSY particles
- ★ Detection of Dark Matter, in the sky, underground and at the LHC
- ★ Strong guidance for the next steps!

ILC, CLIC, HL-LHC, VLHC, HHC, ...

Rencontres du Vietnam

I have discussed a non-inclusive set of exciting opportunities, and am confident we can look forward to a new era of discovery and a rich future for our field!

Congratulations ICISE, where we look forward to visiting, presenting and discussing these exciting new discoveries