Emerging Tools for the Future HEP Landscape

The Theoretical Perspective on the Future of Particle Physics

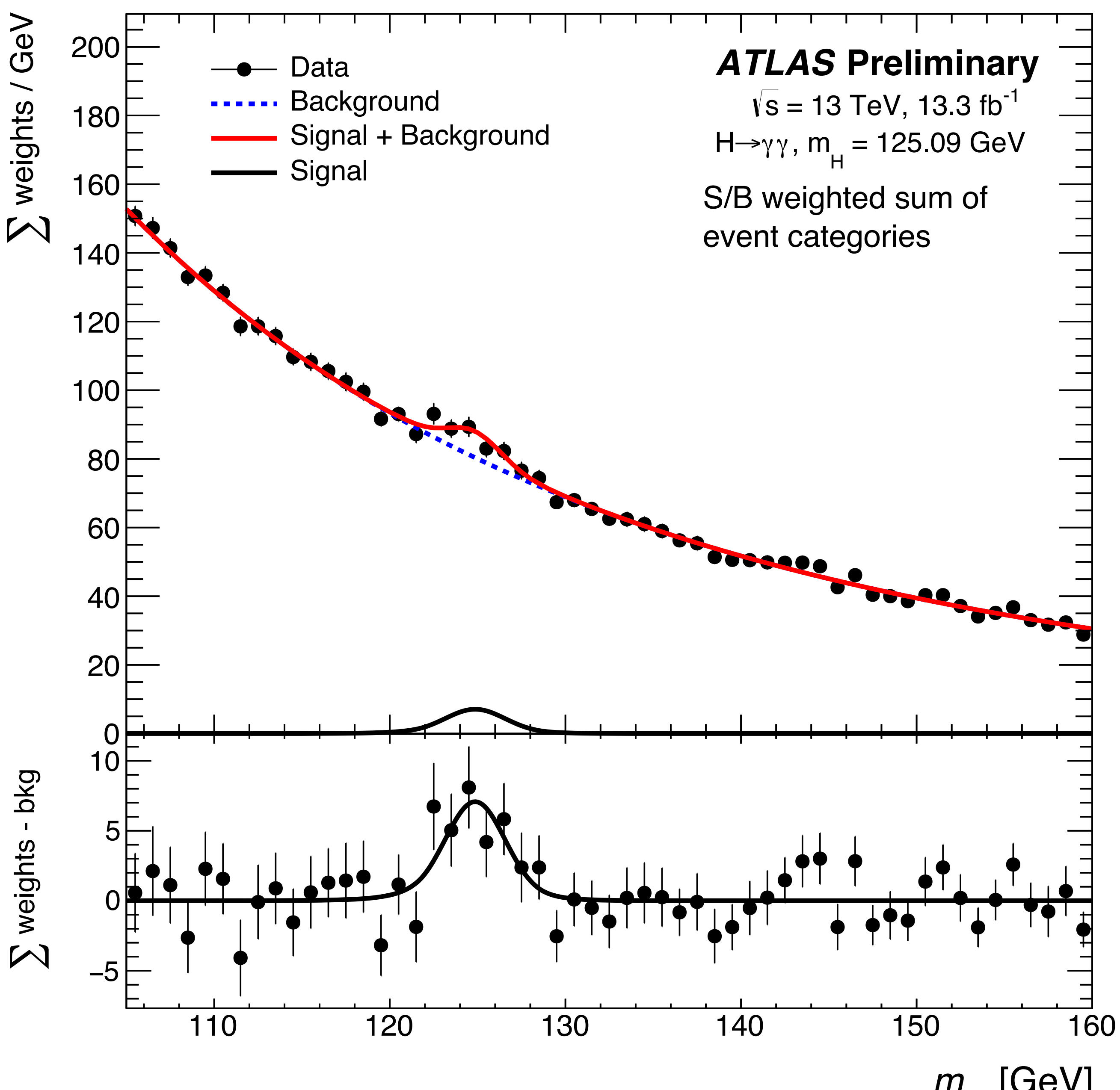
Hitoshi Murayama (Berkeley, Kavli IPMU)

The Last GRC on Particle Physics

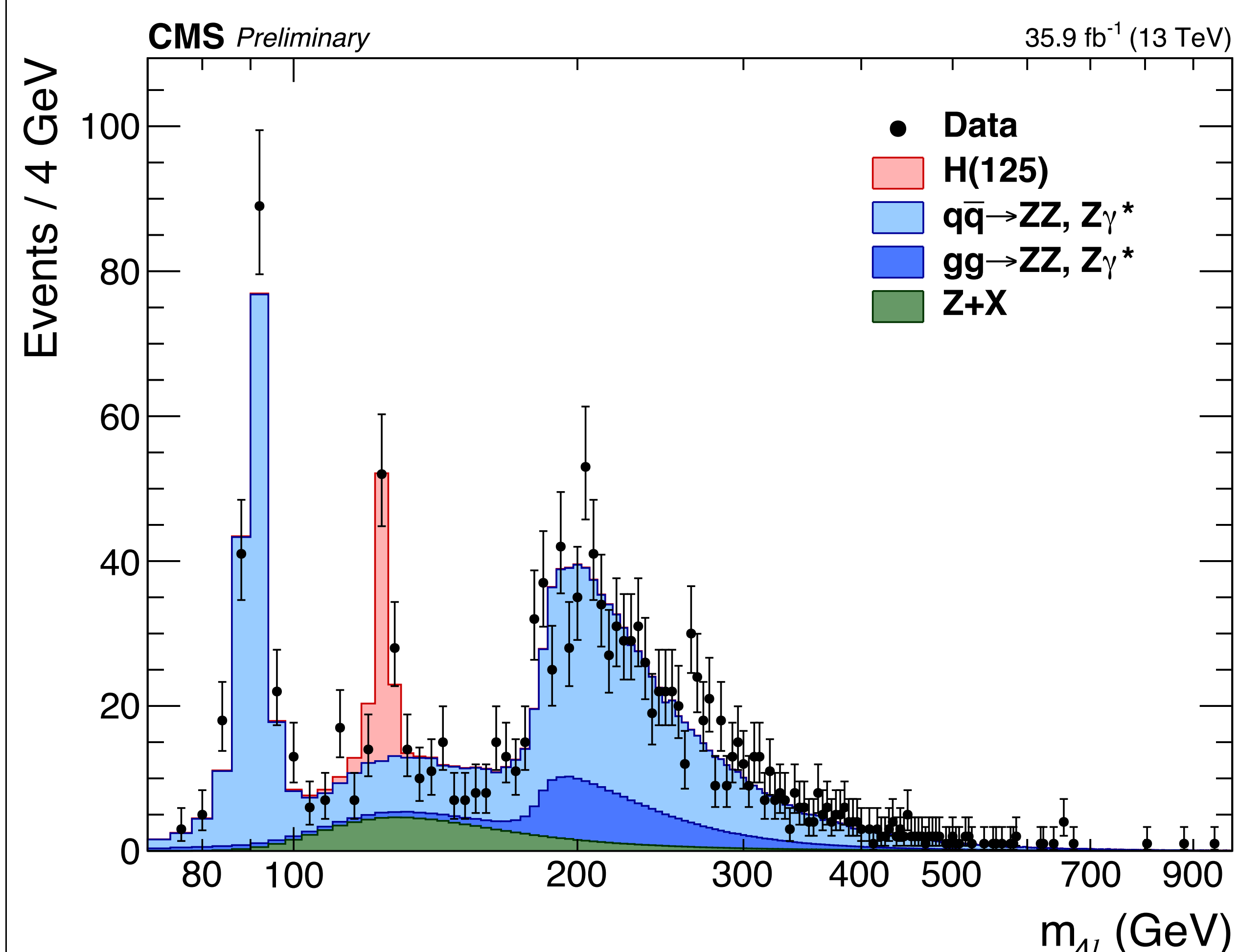
HKUST, July 4, 2019

Beautiful data!

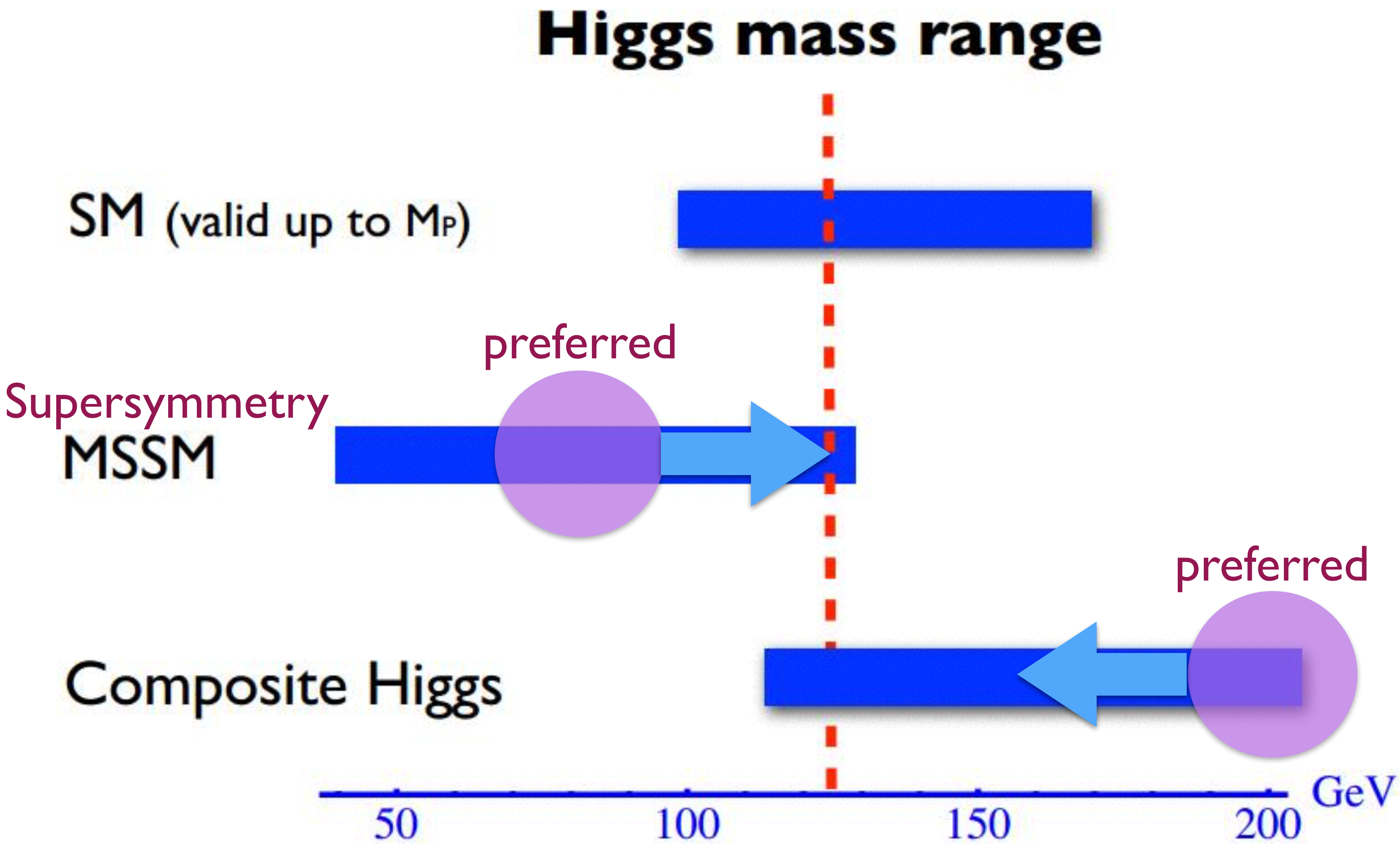
ATLAS-CONF-2016-067



CMS-HIG-16-041



Jónatan Piedra



Higgs mass range
SM (valid up to MP)
preferred
Supersymmetry
MSSM
preferred
Composite Higgs
50
100
150
200
GeV

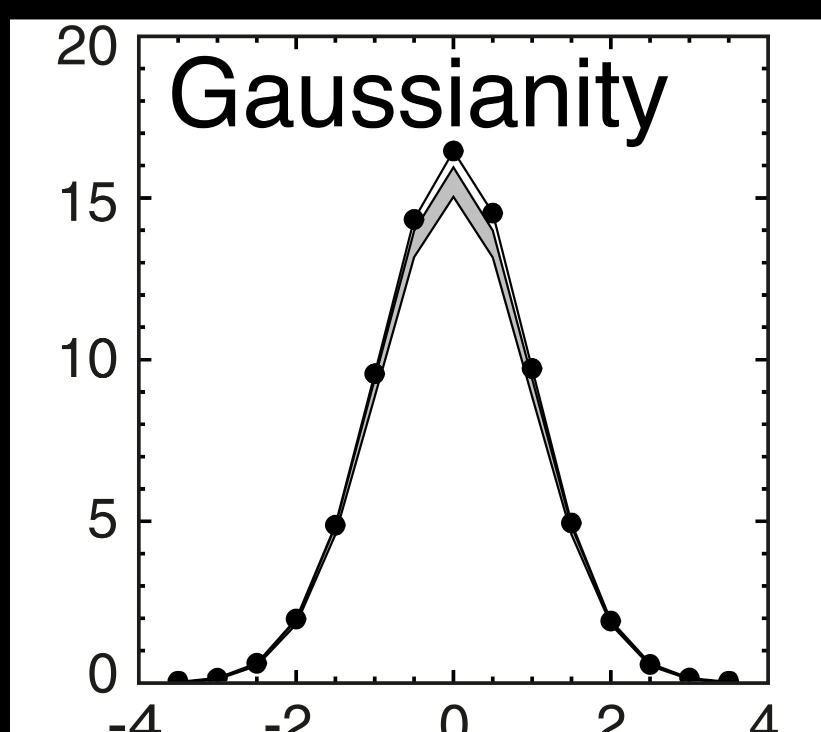
By A Pomarol

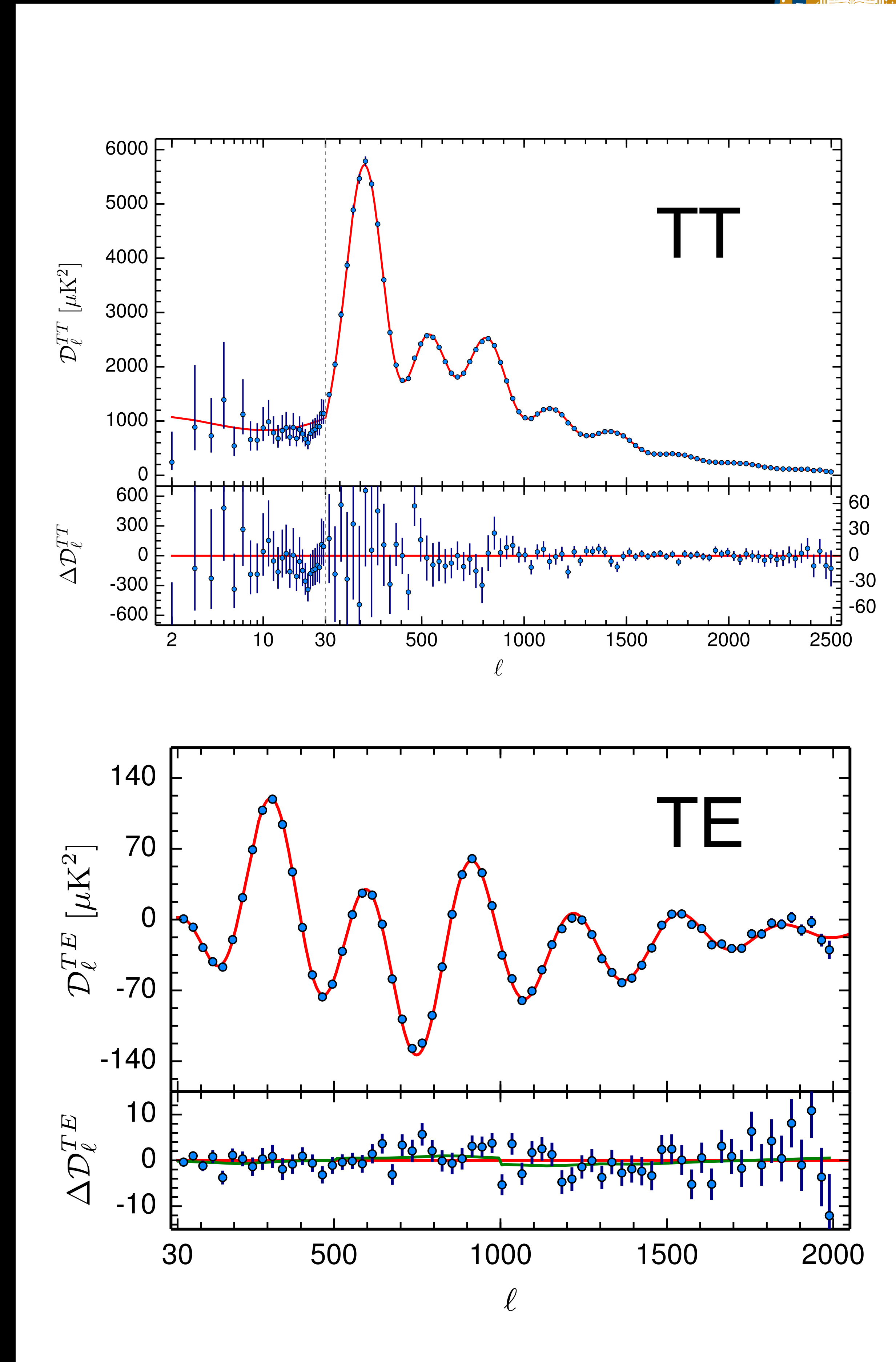
Nima's anguish

m_H=125 GeV seems almost maliciously designed to prolong the agony of BSM theorists….

Naturalness works!

- Why is the Universe big?
- Inflation
  - horizon problem
  - flatness problem
  - large entropy

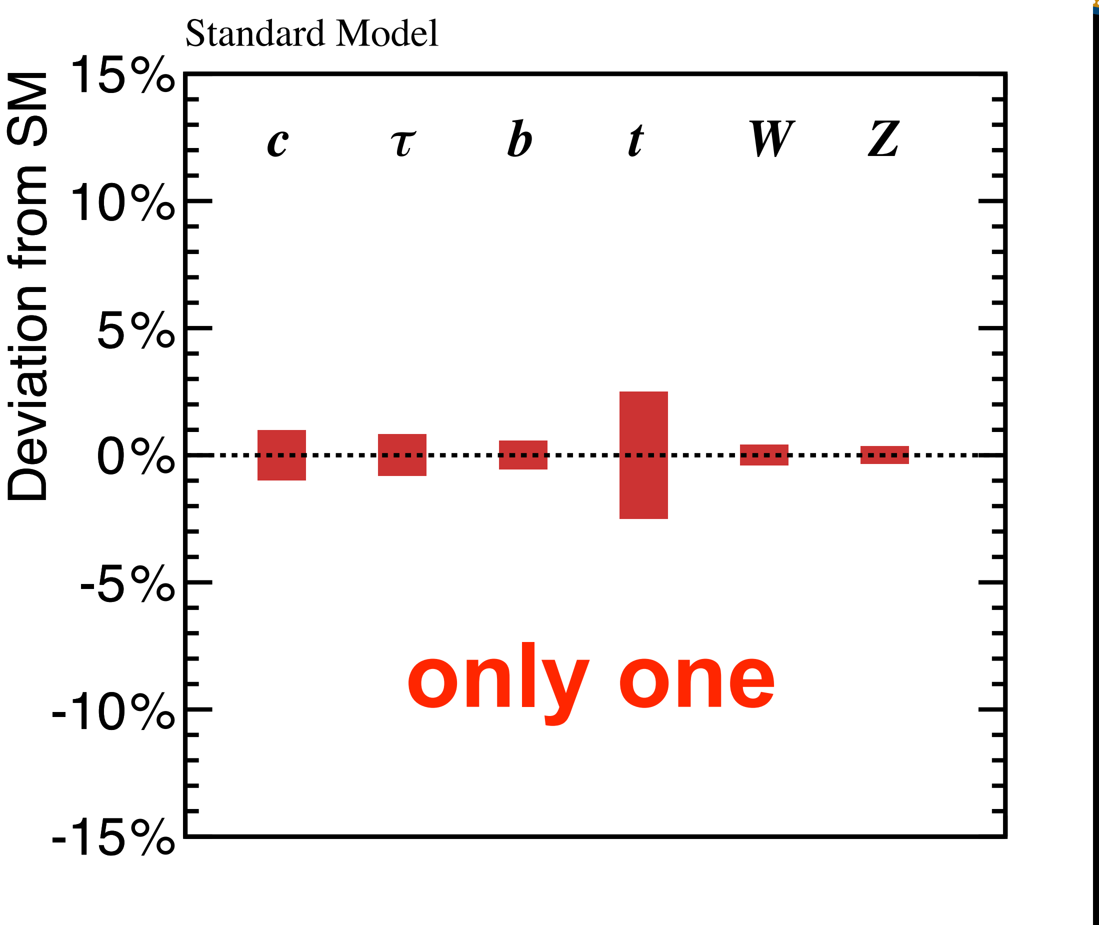


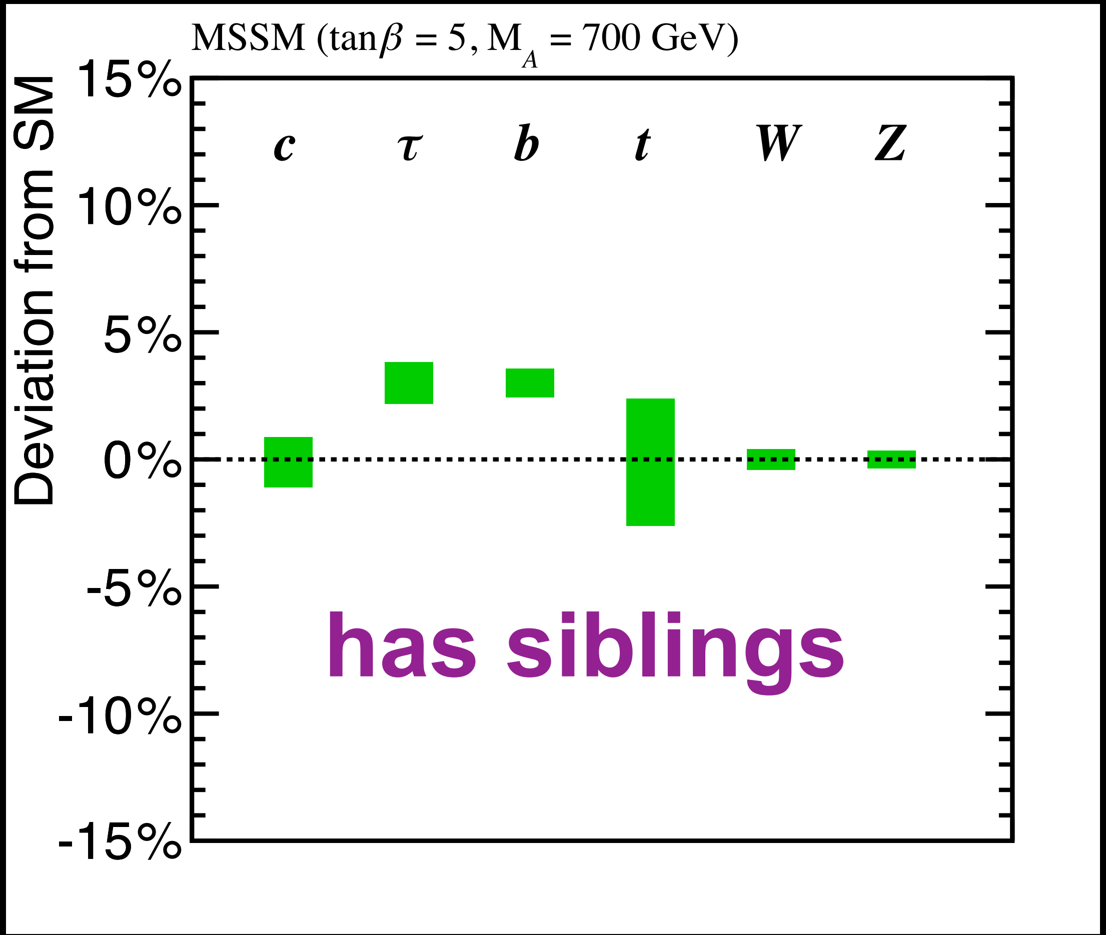


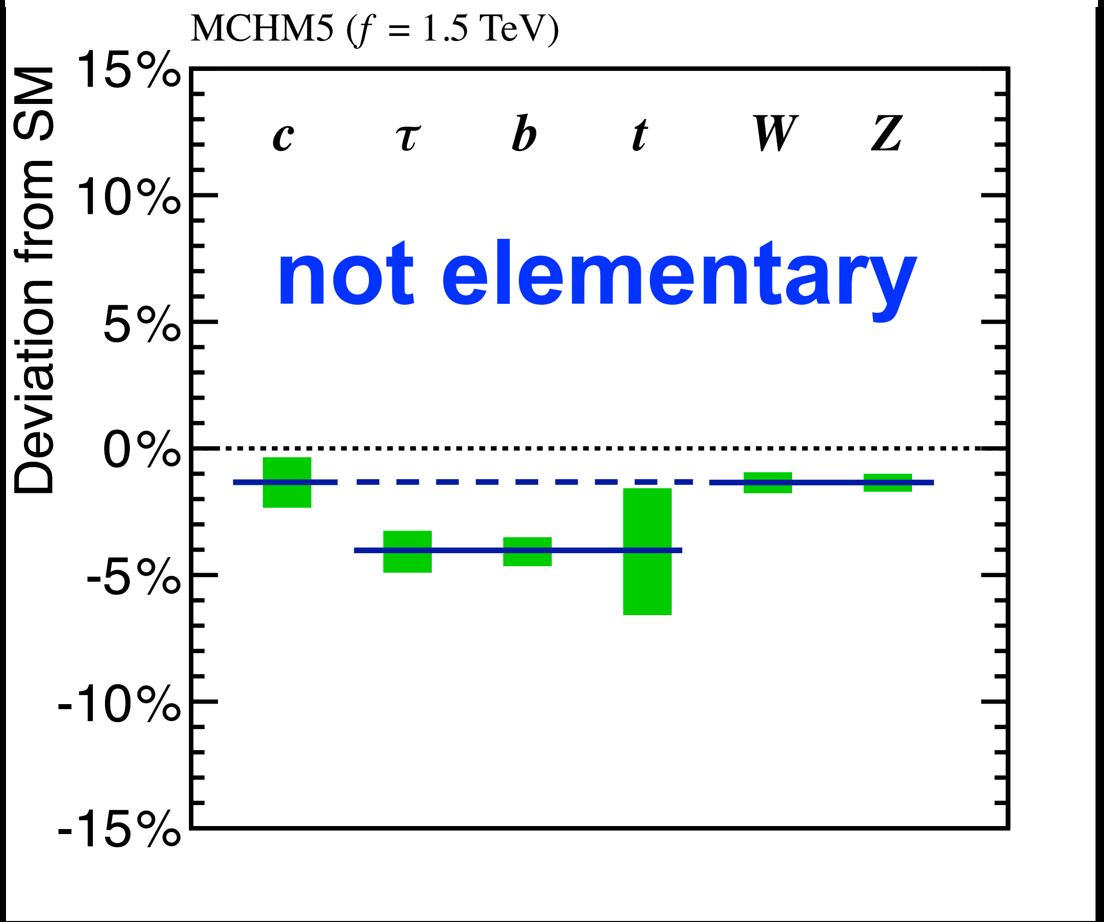
What is Higgs really?

Only one? (SM)
has siblings? (2DHM)
not elementary?

Lumi 1920 fb-1, sqrt(s) = 250 GeV
Lumi 2670 fb-1, sqrt(s) = 500 GeV

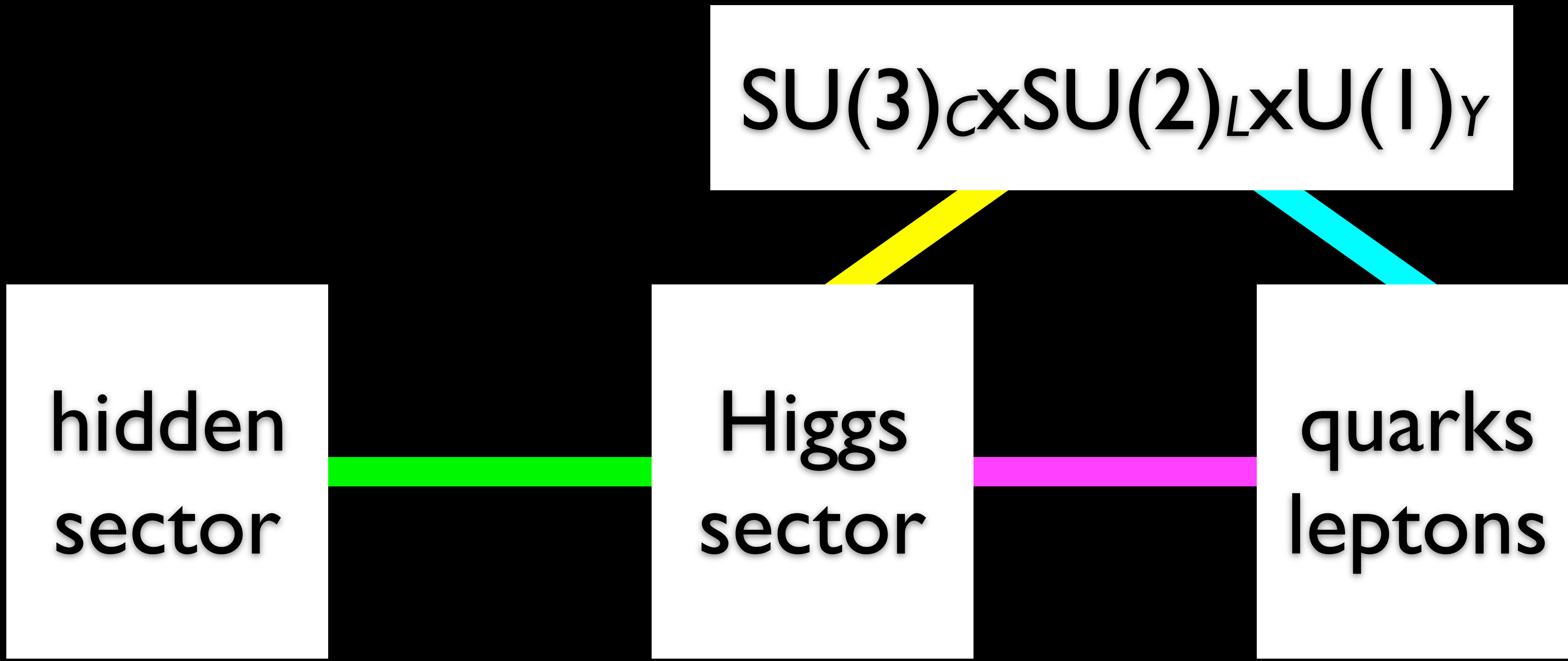






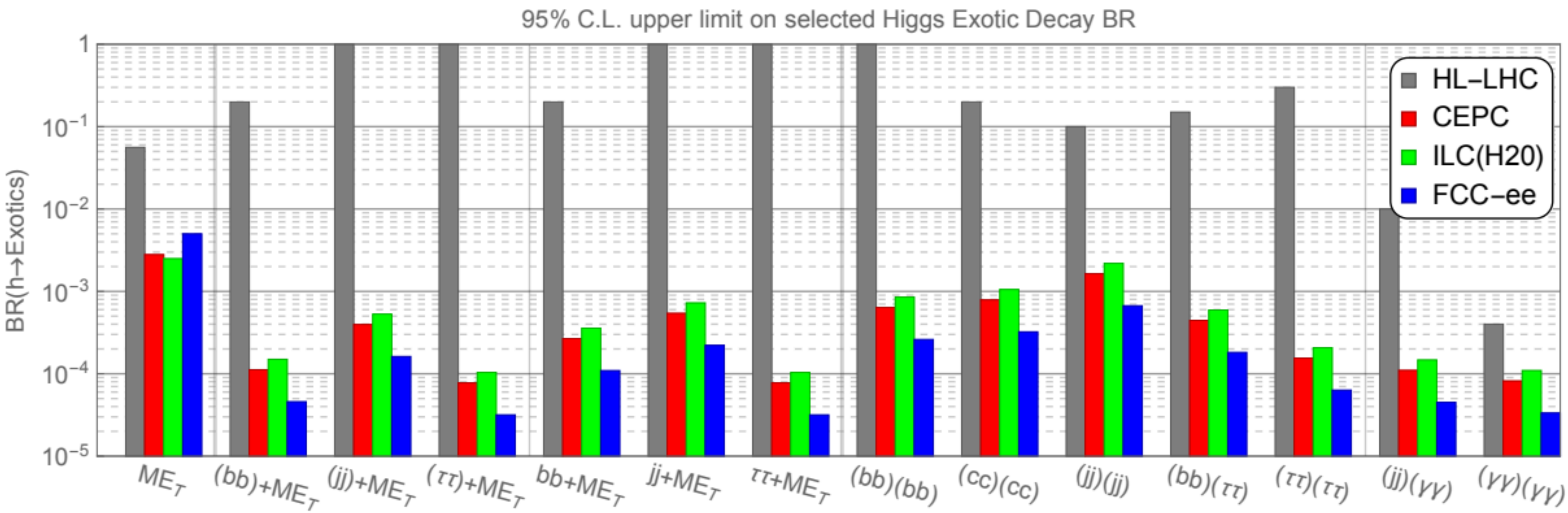
Higgs as a portal

- having discovered the Higgs?
- Higgs boson may connect the Standard Model to other "sectors"



$\mathcal{L} = \mathcal{O}_{hidden} H^\dagger H$

Higgs exotic decay

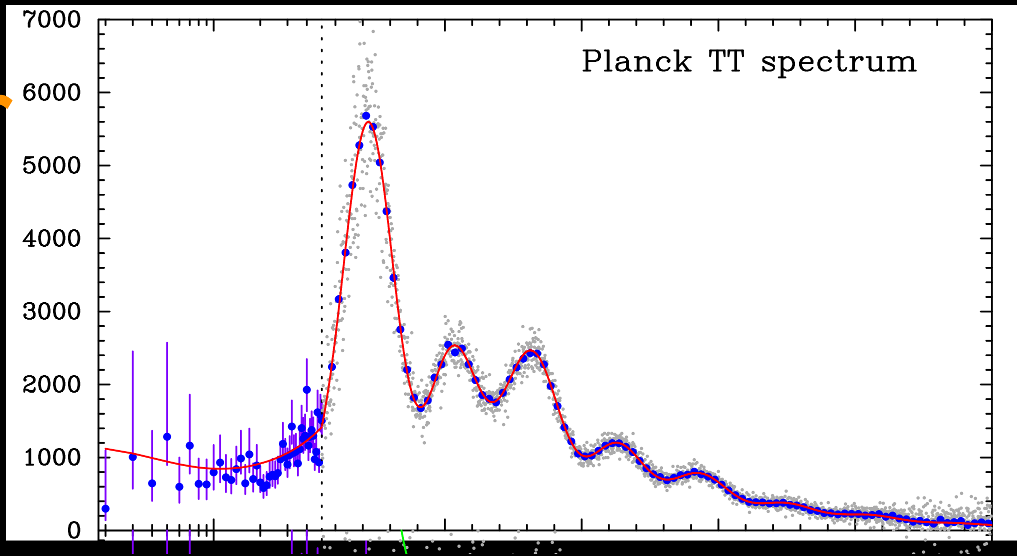


Complementary to hadron collider searches

Liantao Wang, GRC 2019

Five evidences for physics beyond SM

- Since 1998, it became clear that there are at least five missing pieces in the SM
  - non-baryonic dark matter
  - neutrino mass
  - dark energy
  - apparently acausal density fluctuations
  - baryon asymmetry

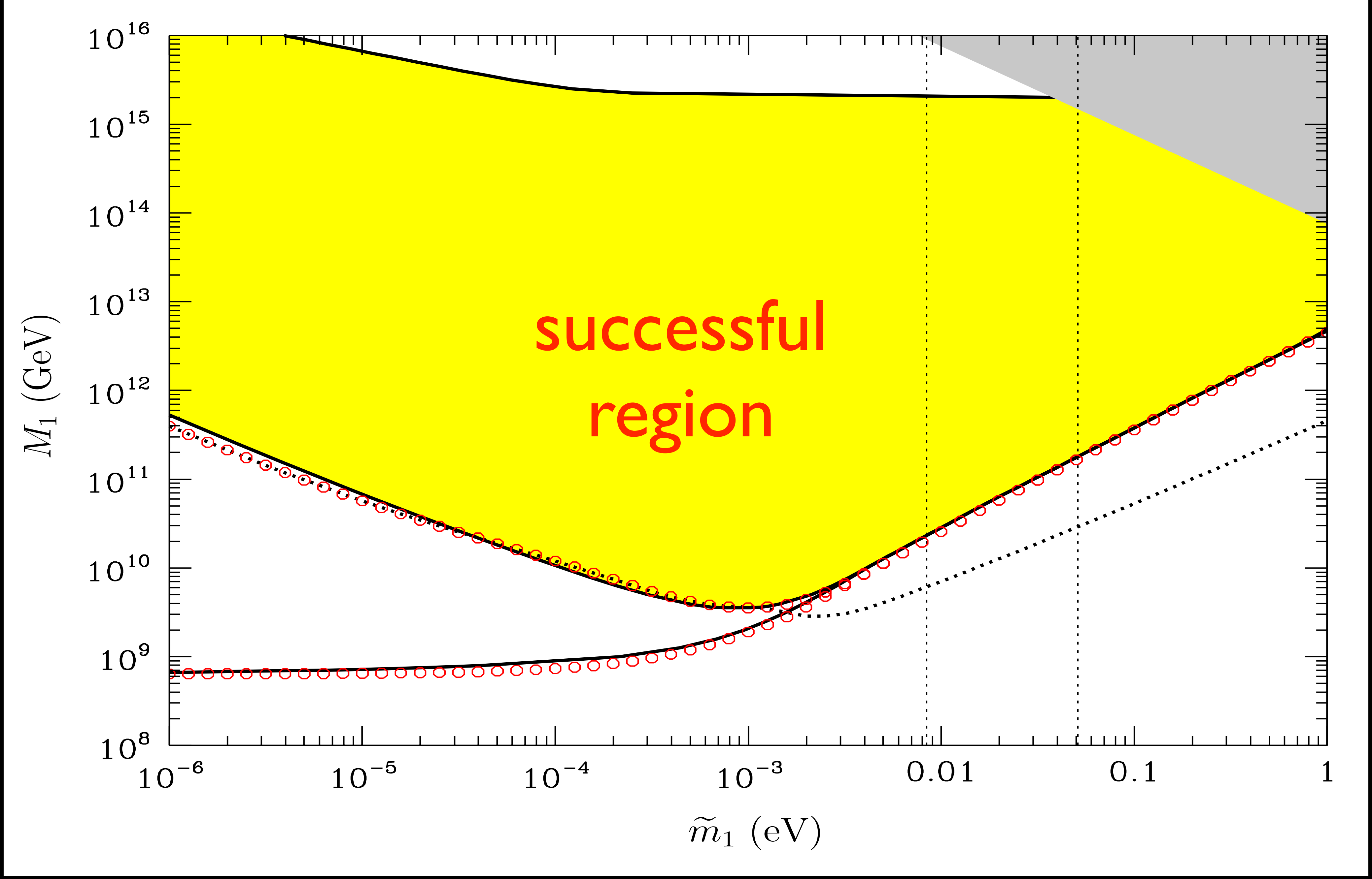


We don't really know their energy scales...

Inconvenient Truth

- colliders are expensive
  - constant CERN budget ~1BCHF
  - construction 300-400MCHF/year
  - CLIC380 ~6BCHF, FCC-ee ~12BCHF
  - HE-LHC ~ 7BCHF, FCC-hh ~24BCHF???
  - 38.5 TeV (100km+6T) ~15BCHF
- Hope for e^+e^- & higher energy pp
- R&D on high-B magnets, plasma, μμ, …
- we need more resources
- need interconnected approach
  - non-accelerator projects important
  - many *new tools* emerging

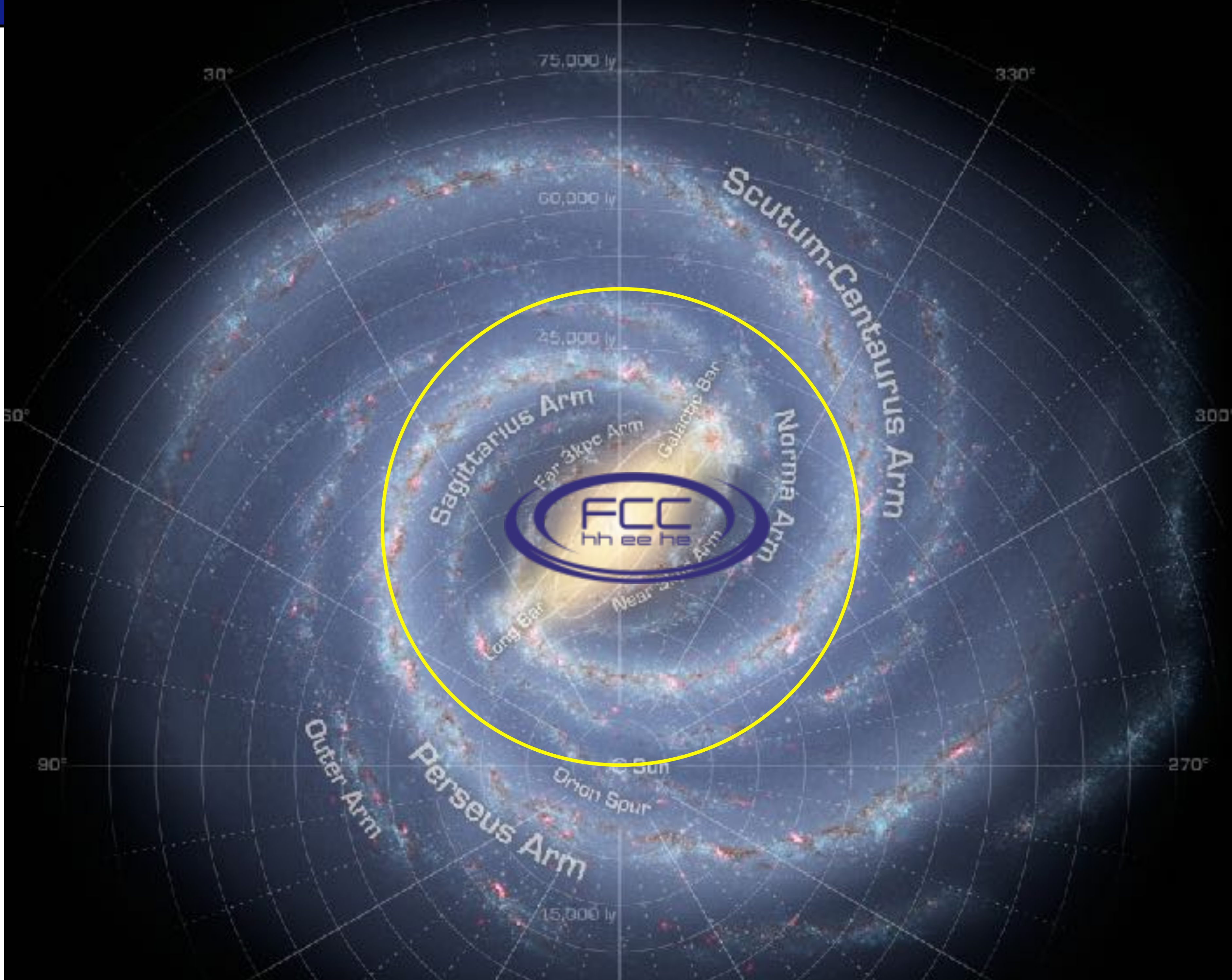
Seesaw&Leptogenesis



$$\tilde{m}_1 = \frac{(m_D^\dagger m_D)_{11}}{M_1}$$

di Bari, Plümacher, Buchmüller

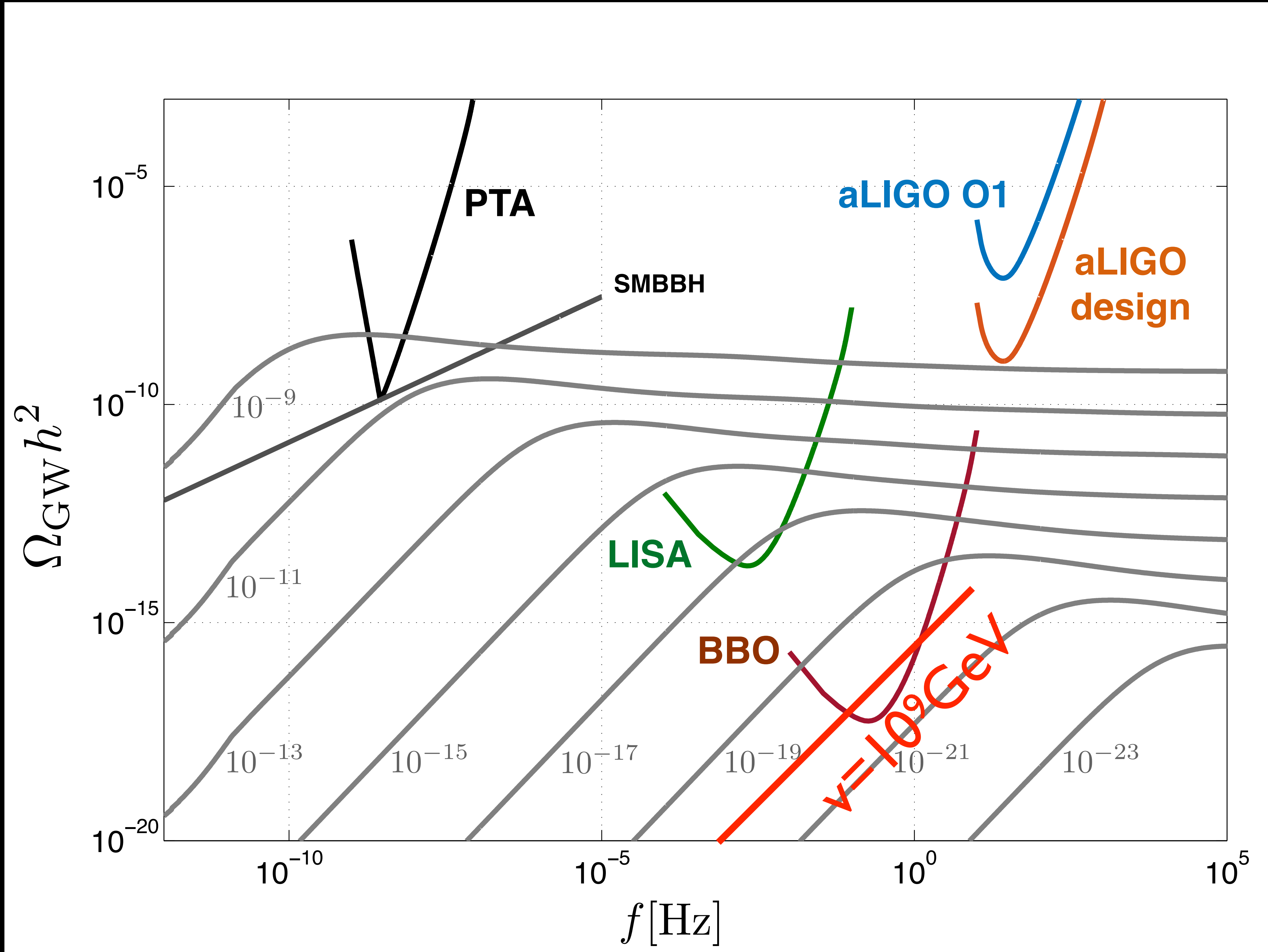
How do we test it?



build a 10^{14} GeV collider

new symmetry breaking

- $10^9 < M_R < 10^{14}$ GeV $\ll M_{GUT}, M_{Pl}$
- need symmetry to forbid MR
- $<\varphi>\nu_R\nu_R$
- gravitational wave from
  - 1st order phase transition
  - topological defects



Future experiments DECIGO/BBO can probe $G\mu \sim 10^{-20}$

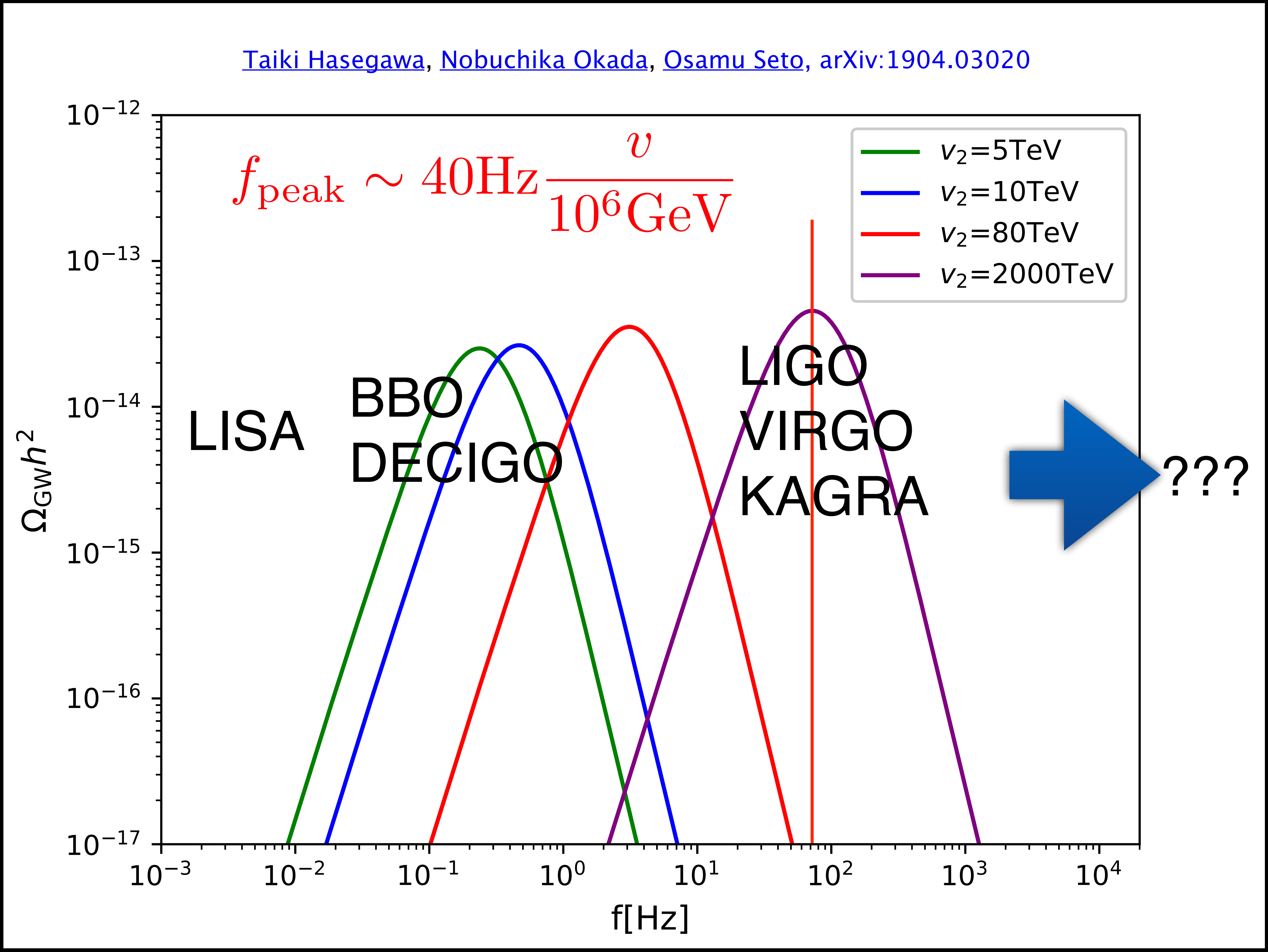
$v \sim \mu^{1/2} \sim (10^{-20})^{1/2} M_{Pl} \sim 10^9$ GeV

can probe the whole seesaw/leptogenesis range!

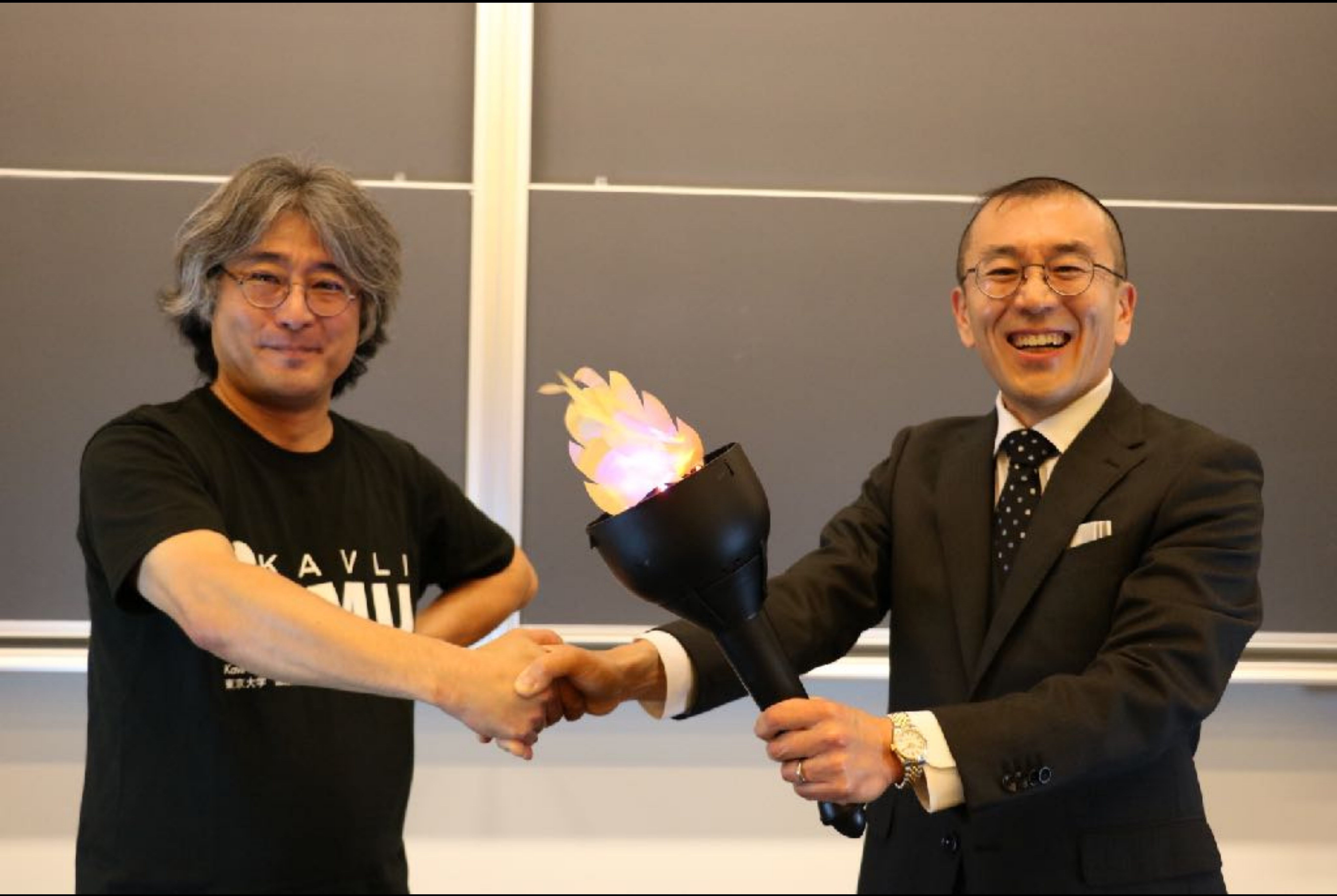
But particle production?

Jose J. Blanco-Pillado, Ken D. Olum, Xavier Siemens arXiv:1709.02434

1st order Phase Transition

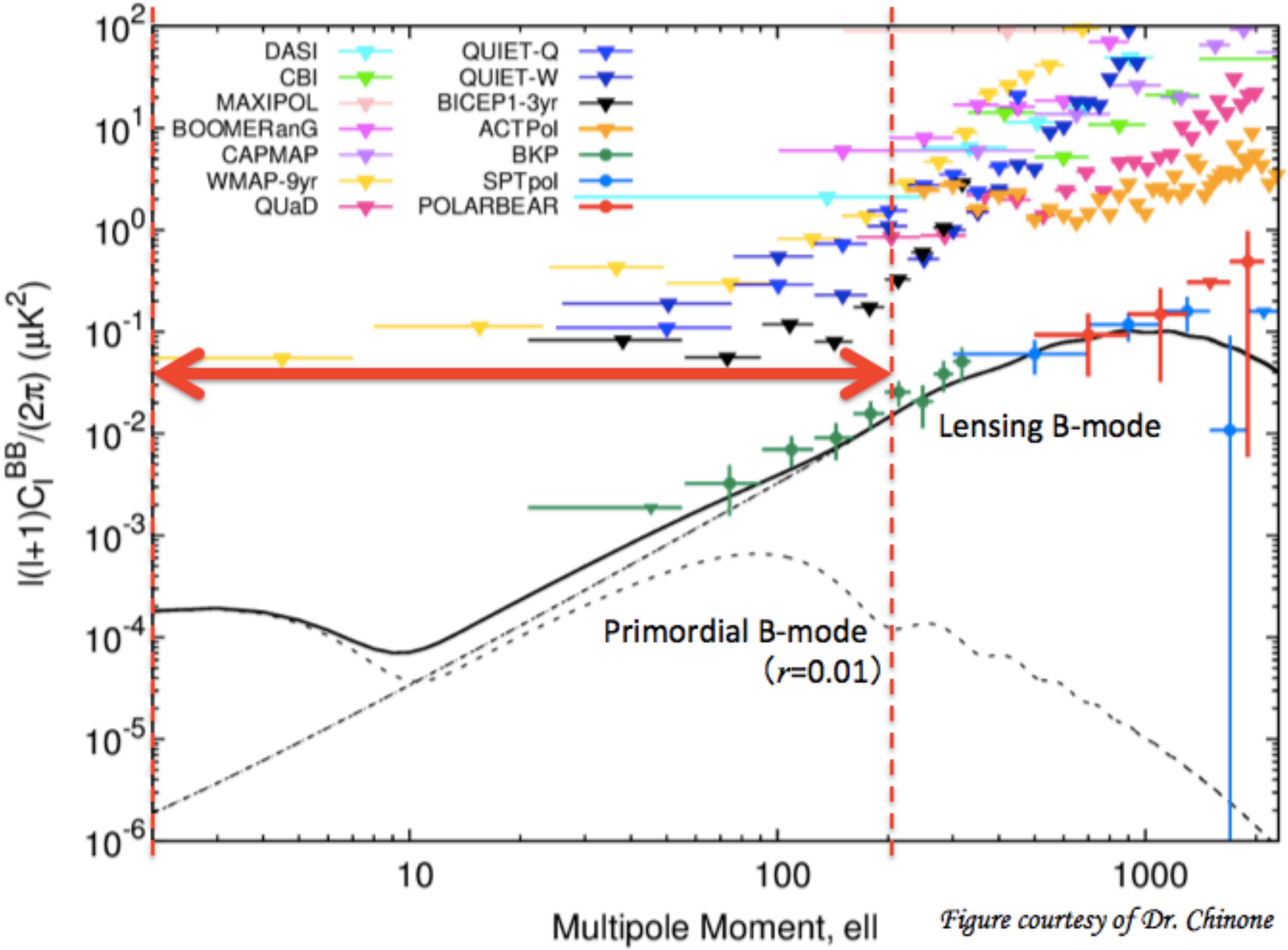


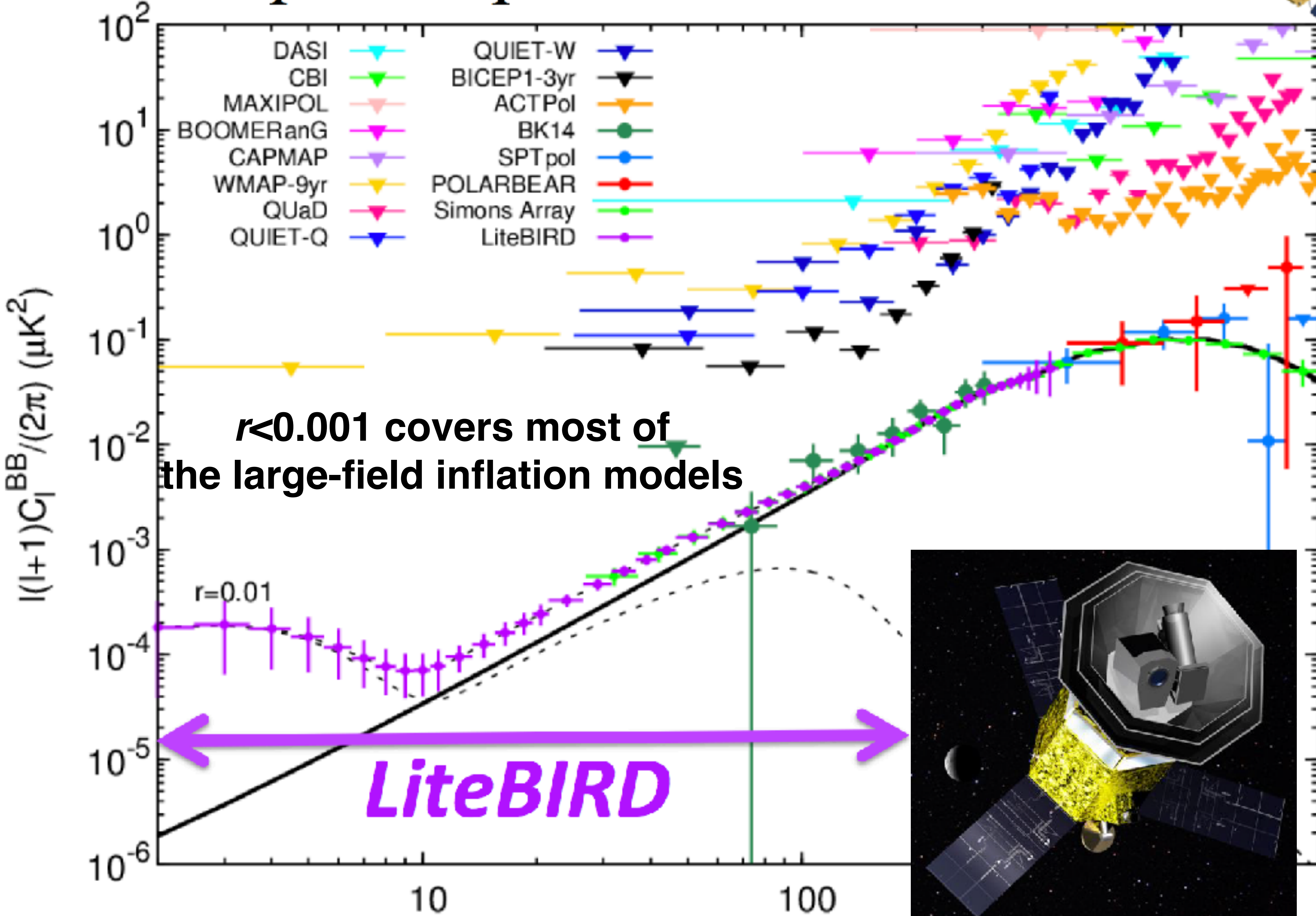
Passed the Torch Oct 15, 2018



June 20, 2019


Planck
Jean-Loup Puget
Masashi Hazumi
LiteBIRD
July 1, 2019


DASI
CBI
MAXIPOL
BOOMERanG
CAPMAP
WMAP-9yr
QUaD
QUIET-Q
QUIET-W
BICEP1-3yr
ACTPol
BKP
SPTpol
POLARBEAR
Lensing B-mode
Primordial B-mode
(r=0.01)
l(l+1)C_l^BB/(2π) (μK^2)
Multipole Moment, ell
10
100
1000
Figure courtesy of Dr. Chinone

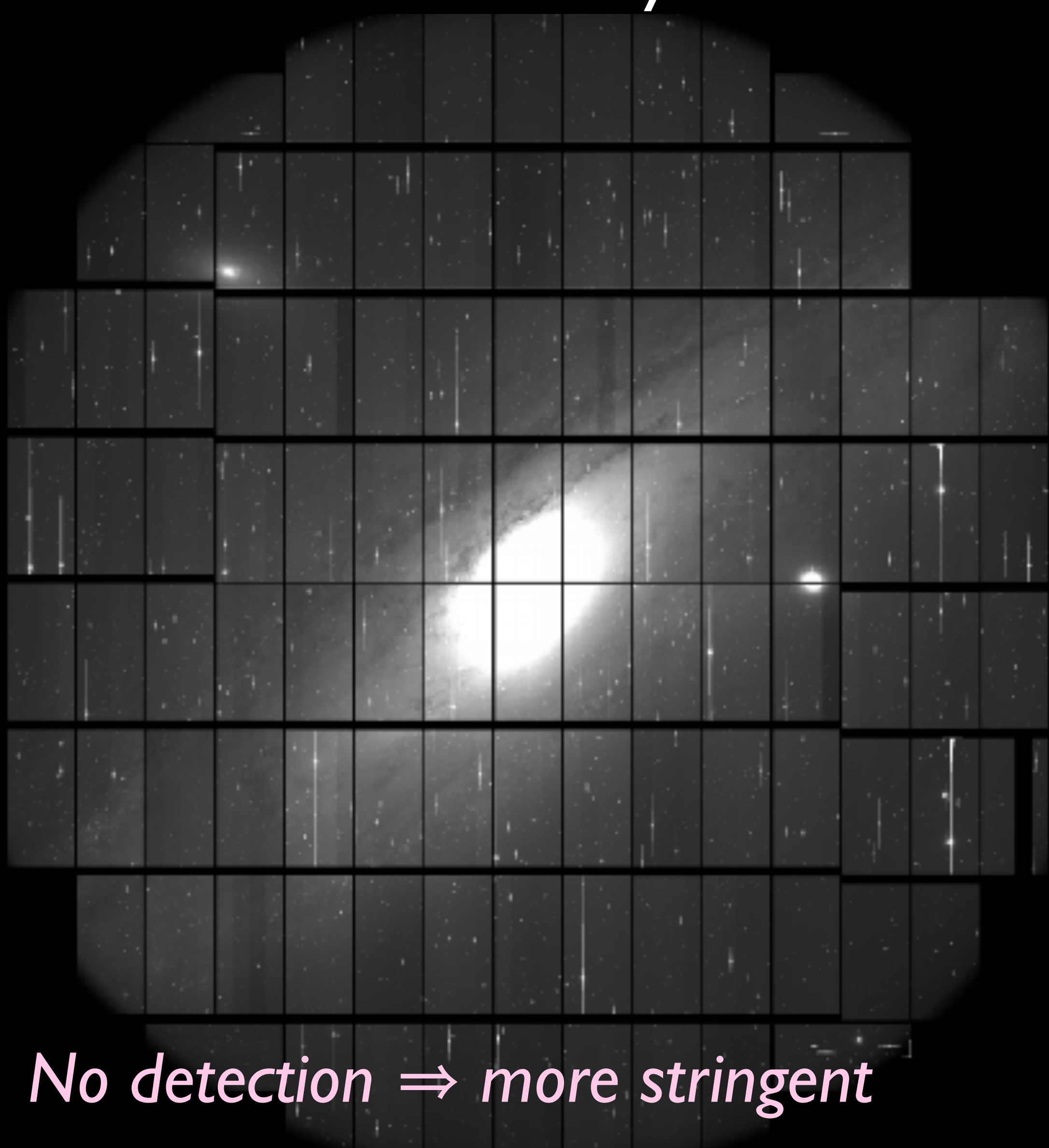


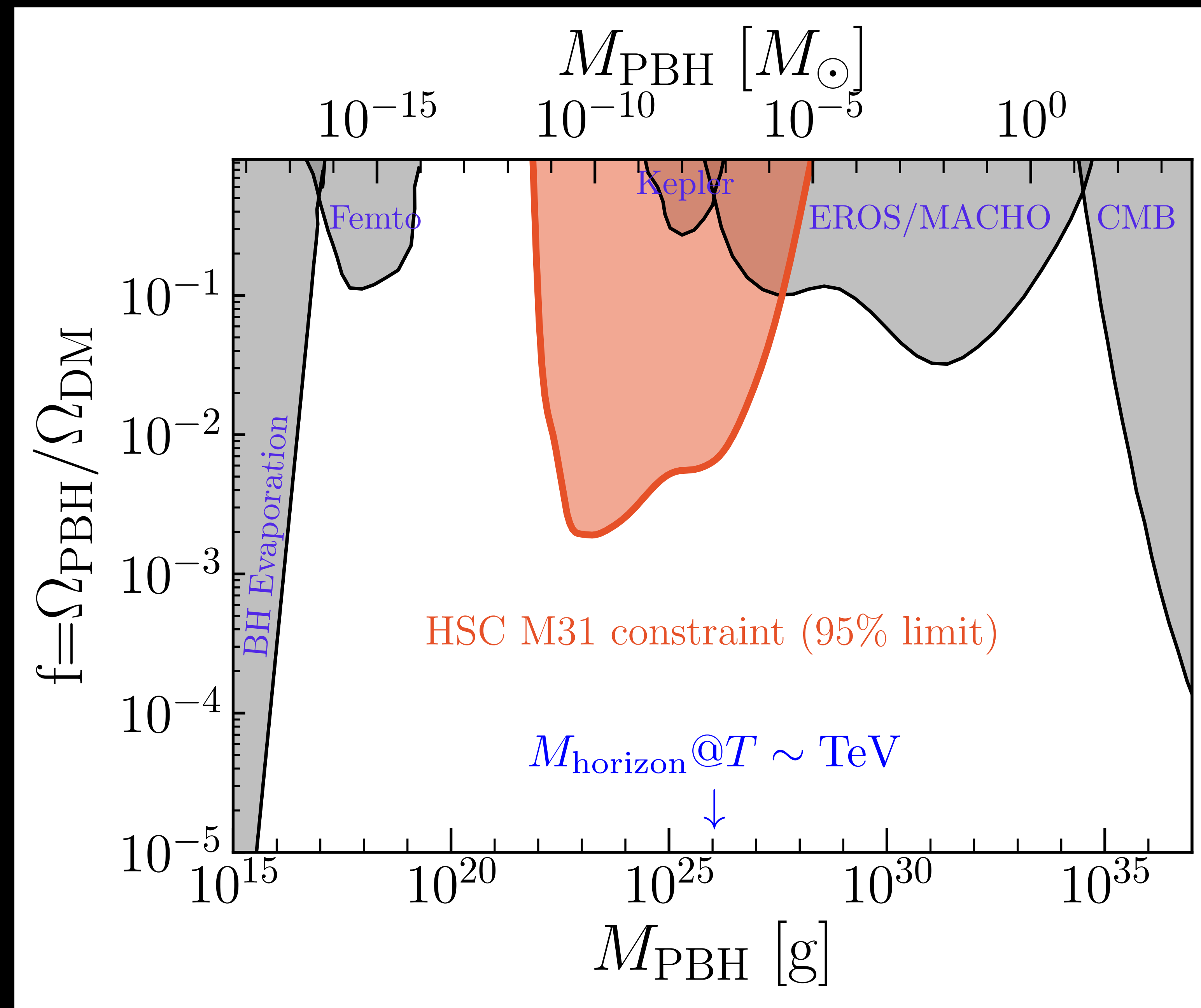
now downselect by JAXA 2019, expected launch 2027

Best limit on Black Hole dark matter

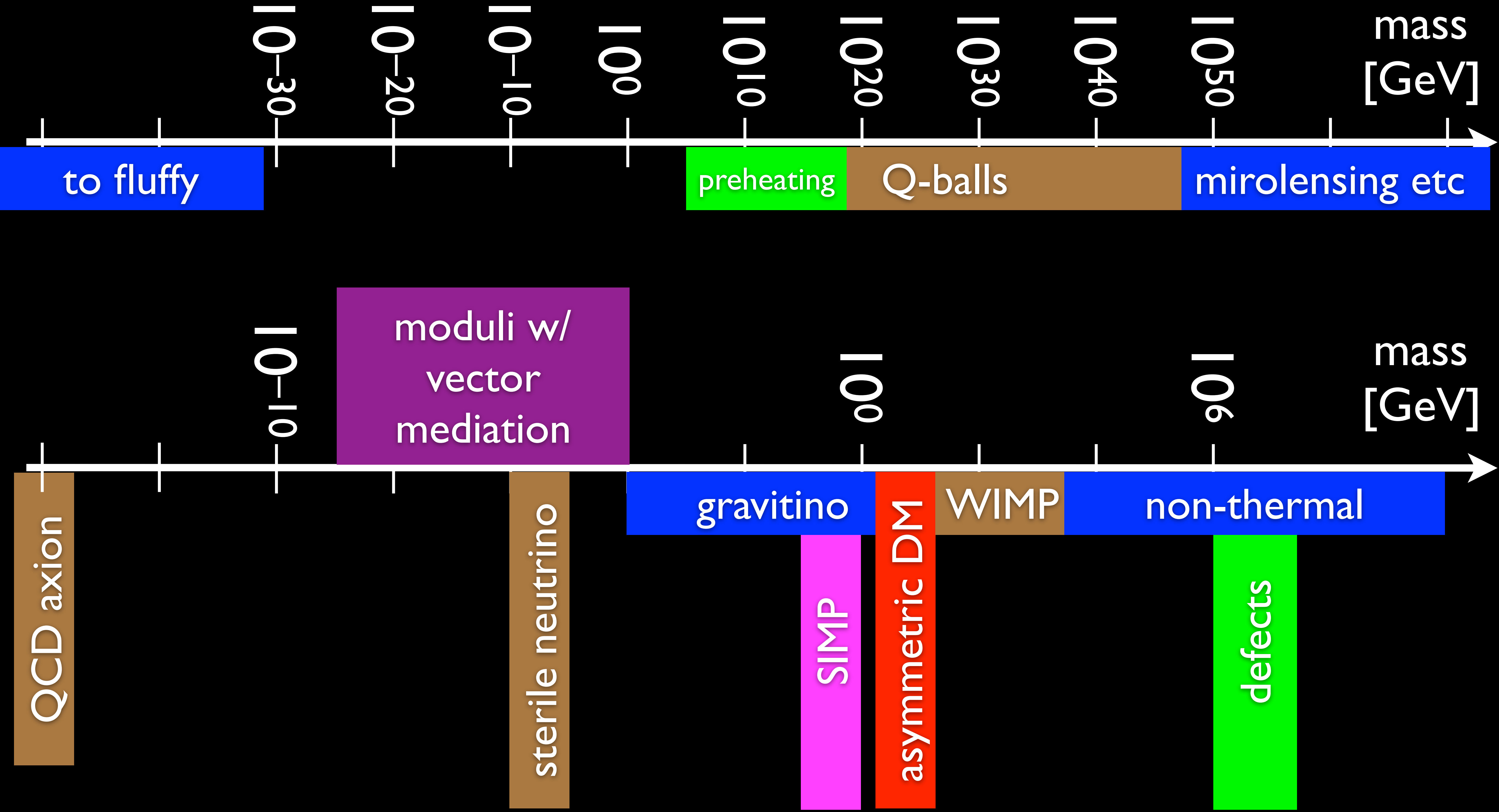
Niikura, Takada et al., Nature Astronomy

observe Andromeda for one night
read out CCDs every 2 min





No detection ⇒ more stringent upper bound, than 2yr Kepler data (Griest et al.)



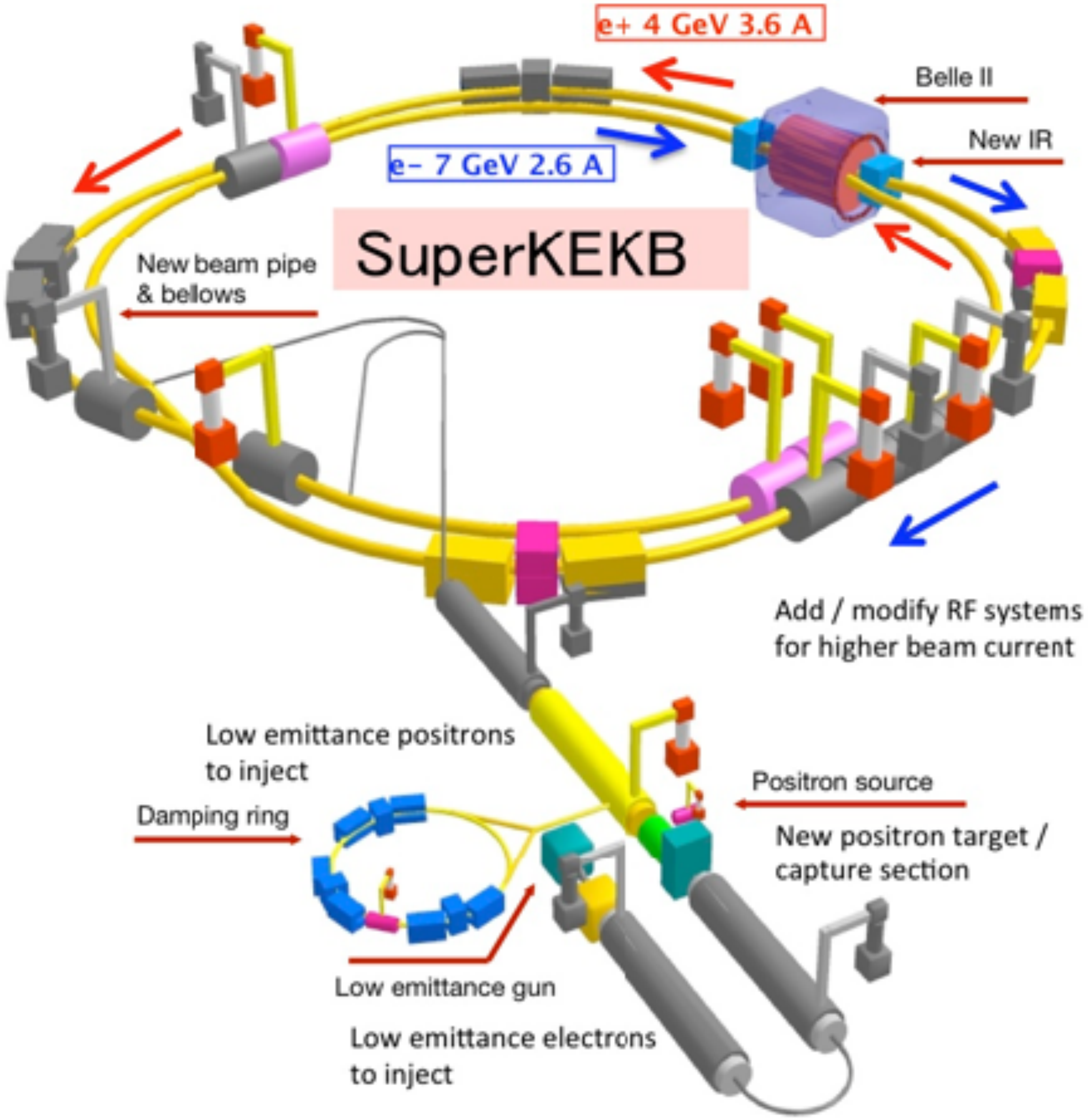
SIMP: dark hadrons

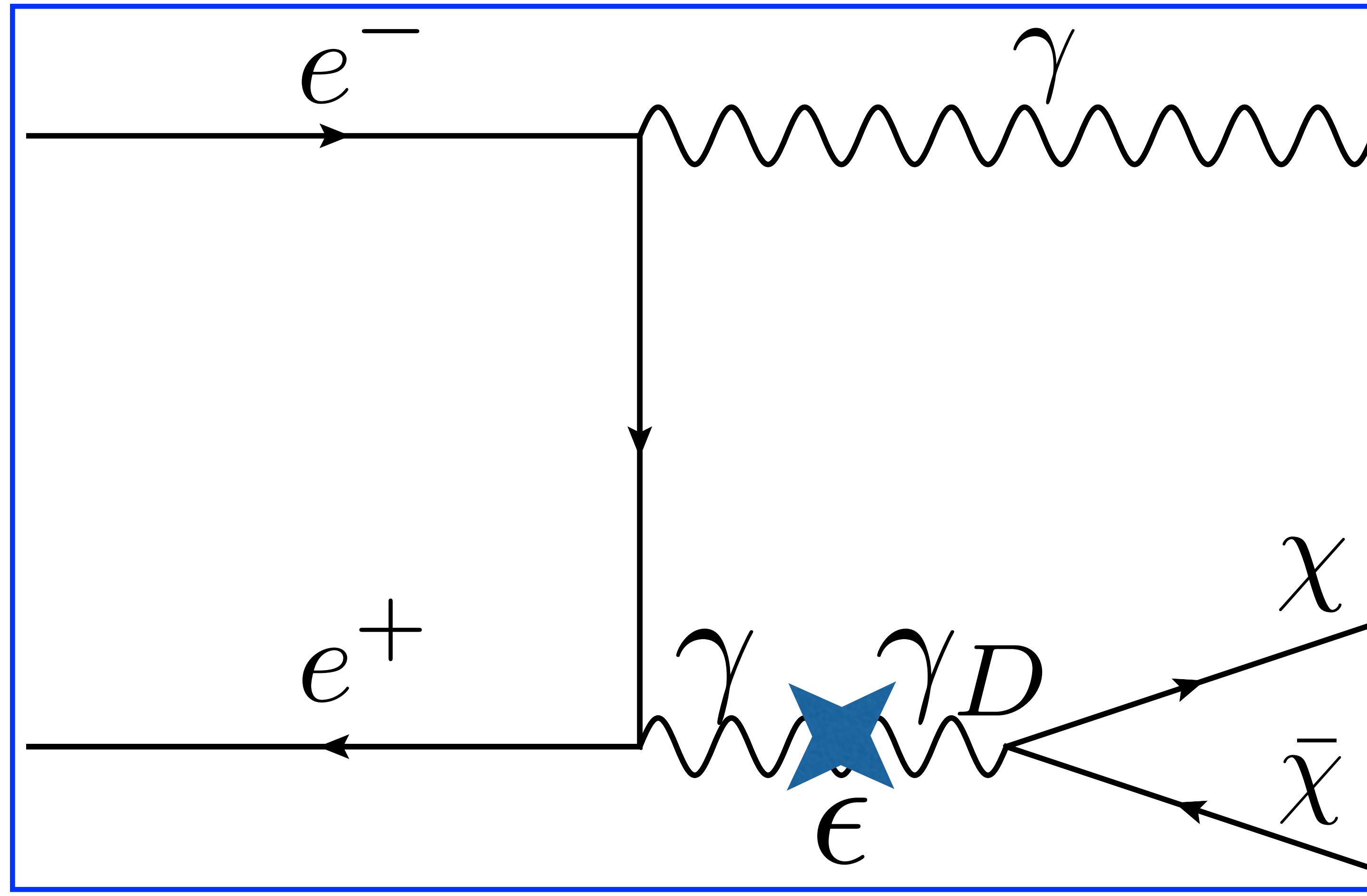
m~0.3GeV, σ~10^{-24}cm^2

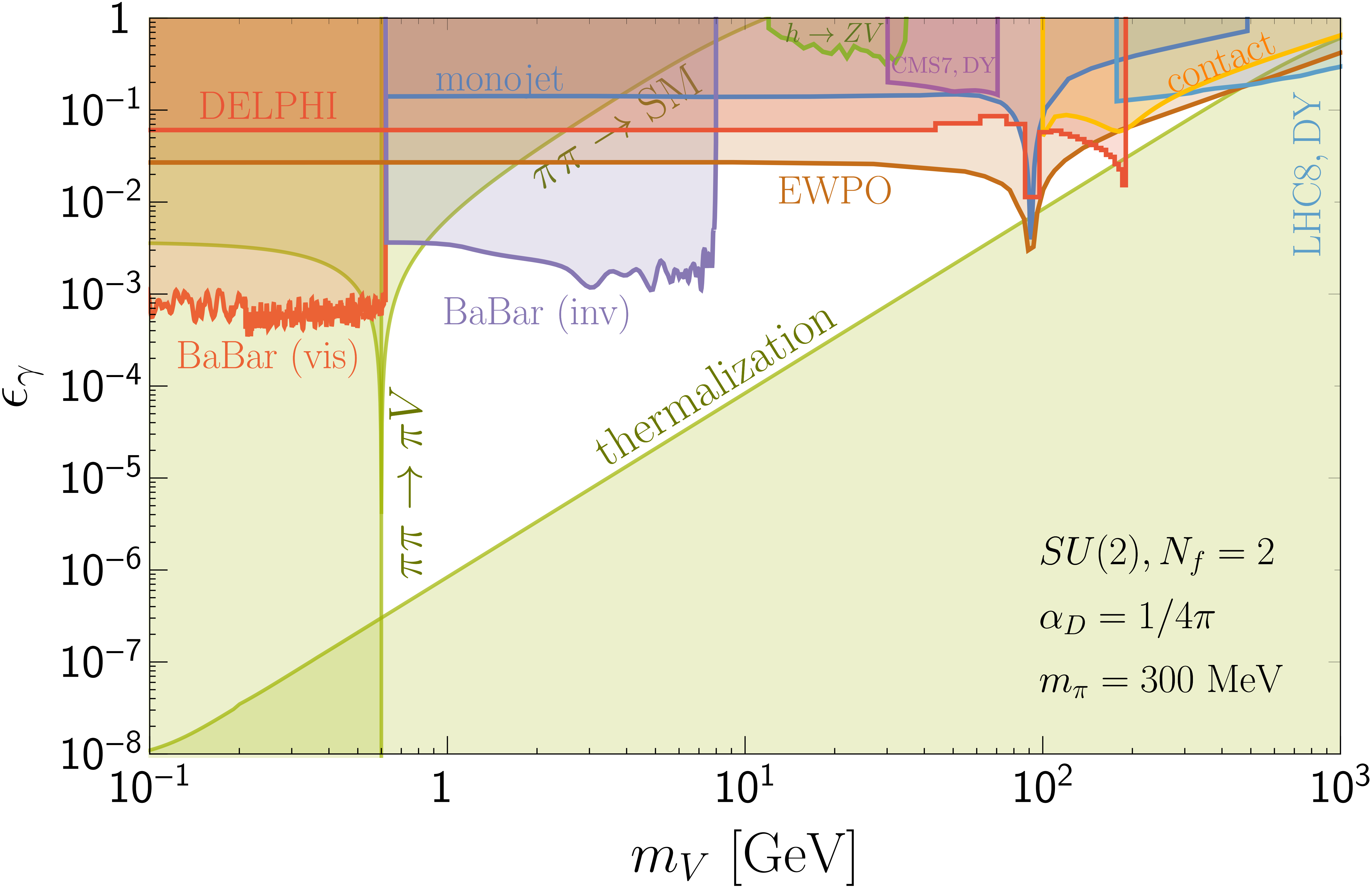
SuperKEKB & Belle II

50 ab^{-1}!

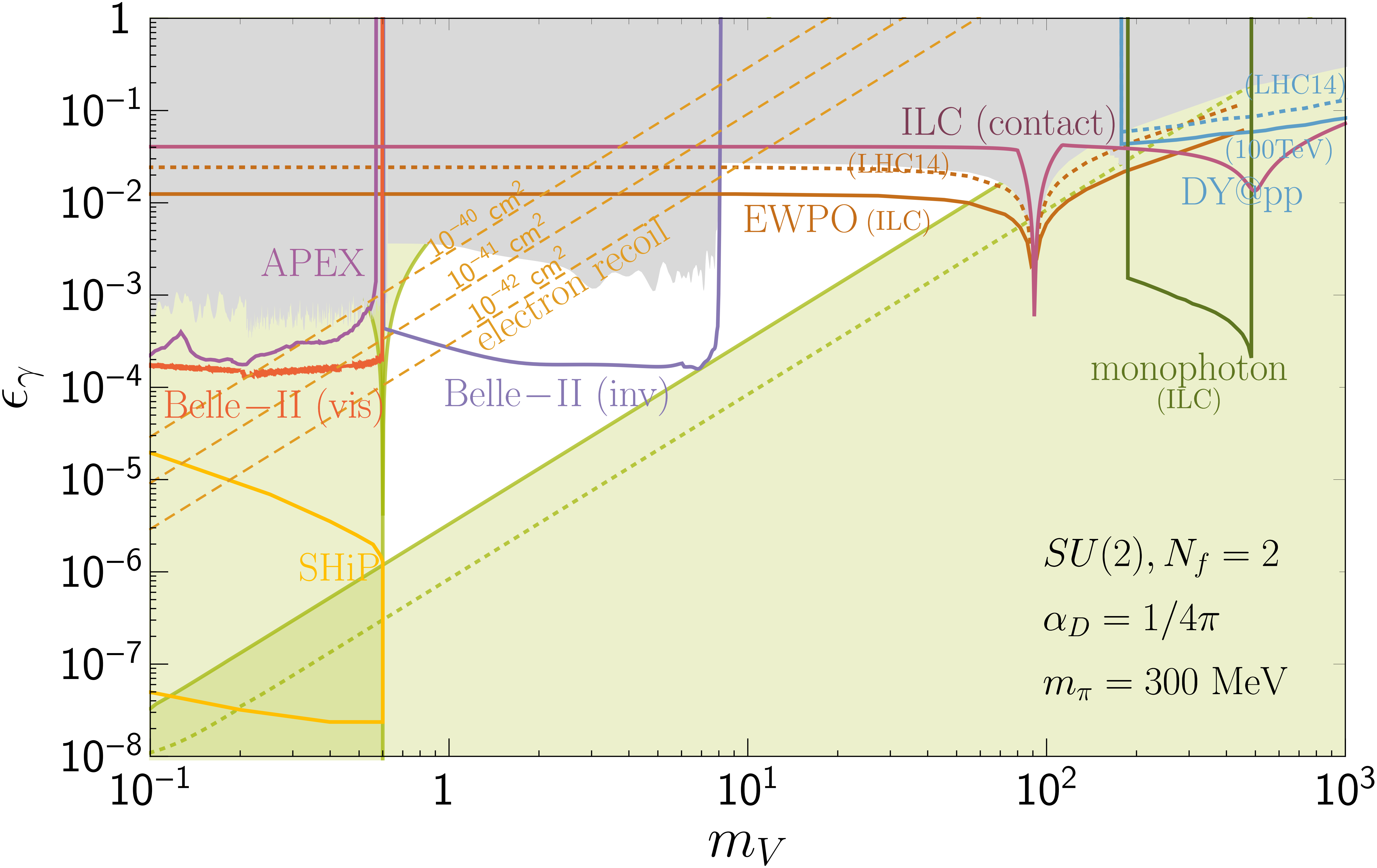
$$E_\gamma = \frac{\sqrt{s}}{2}\left(1 - \frac{M_{\rm inv}^2}{s}\right)$$



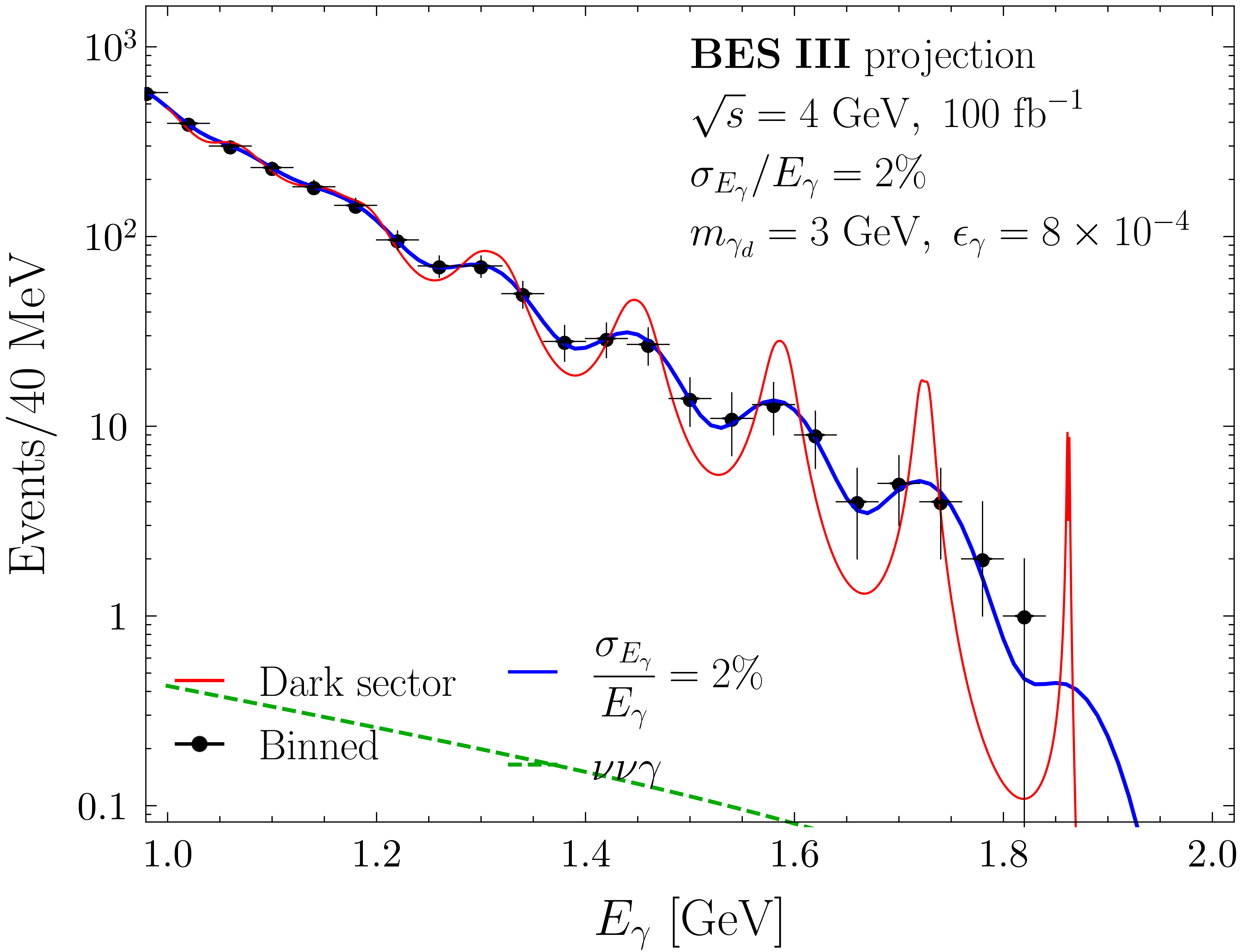




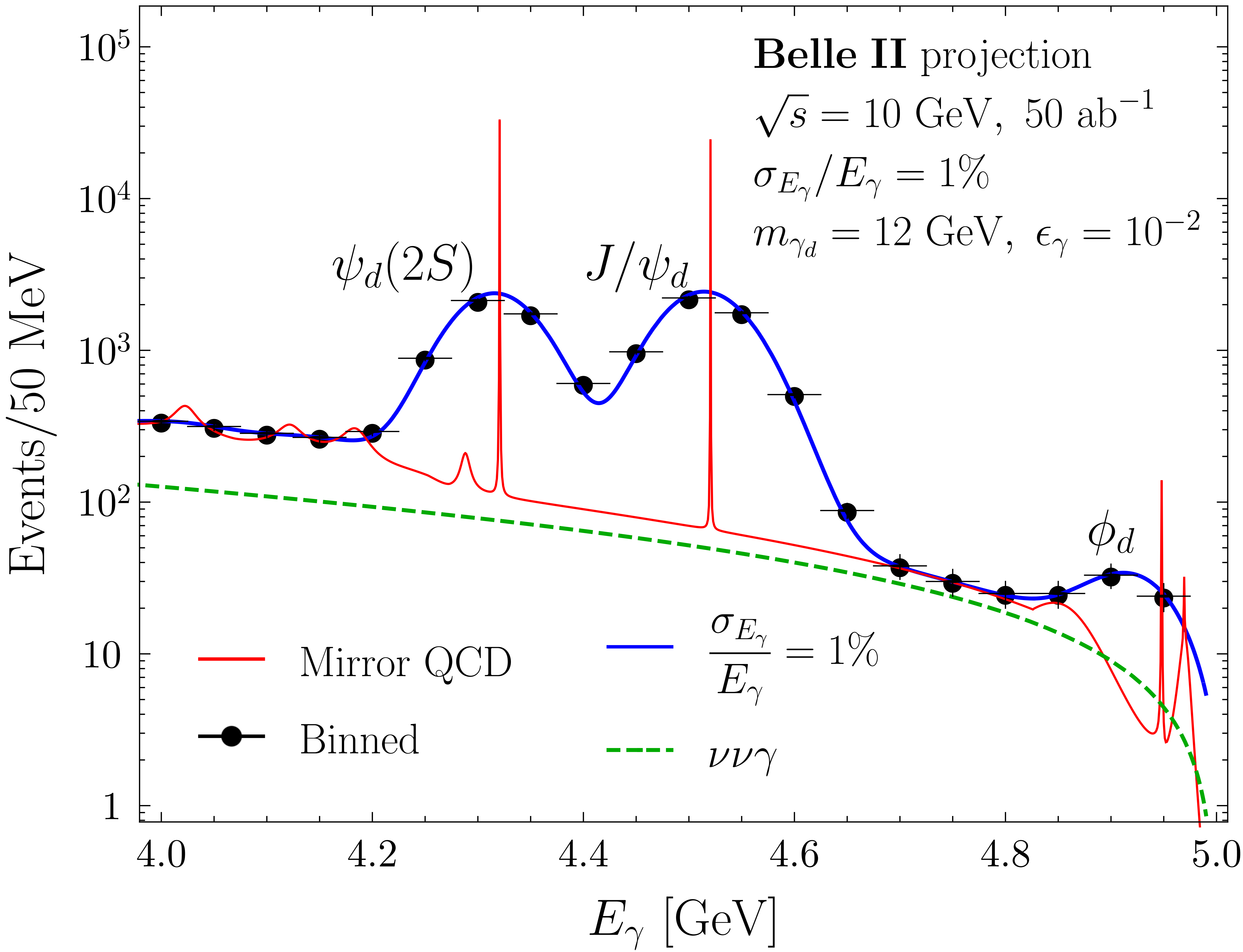
DELPHI
monojet
$\pi\pi \to SM$
$h \to ZV$
CMS7, DY
contact
LHC8, DY
EWPO
BaBar (inv)
BaBar (vis)
$\pi\pi \to \pi V$
thermalization
$SU(2), N_f = 2$
$\alpha_D = 1/4\pi$
$m_\pi = 300$ MeV
ϵ_γ
m_V [GeV]
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{1}
10^{2}
10^{3}



1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
ϵ_γ
10^{-1}
1
10^{1}
10^{2}
10^{3}
m_V
ILC (contact)
(LHC14)
(LHC14)
(100TeV)
DY@pp
EWPO (ILC)
APEX
10^{-40} cm^2
10^{-41} cm^2
10^{-42} cm^2
electron recoil
Belle−II (vis)
Belle−II (inv)
monophoton
(ILC)
SHiP
$SU(2), N_f = 2$
$\alpha_D = 1/4\pi$
$m_\pi = 300$ MeV



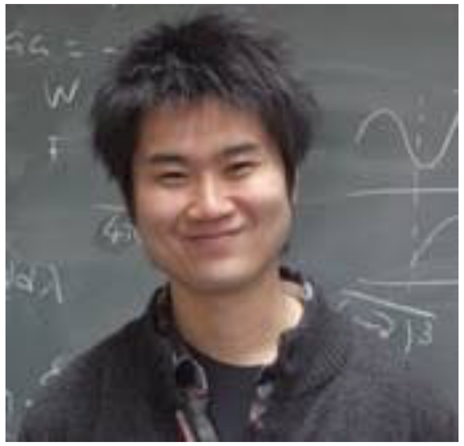
BES III projection
$\sqrt{s} = 4$ GeV, 100 fb^{-1}
$\sigma_{E_\gamma}/E_\gamma = 2\%$
$m_{\gamma_d} = 3$ GeV, $\epsilon_\gamma = 8 \times 10^{-4}$
Dark sector
Binned
$\frac{\sigma_{E_\gamma}}{E_\gamma} = 2\%$
$\nu\nu\gamma$
Events/40 MeV
E_γ [GeV]
10^3
10^2
10
1
0.1
1.0
1.2
1.4
1.6
1.8
2.0



Belle II projection
$\sqrt{s} = 10$ GeV, 50 ab^{-1}
$\sigma_{E_\gamma}/E_\gamma = 1\%$
$m_{\gamma_d} = 12$ GeV, $\epsilon_\gamma = 10^{-2}$
$\psi_d(2S)$
J/ψ_d
ϕ_d
Mirror QCD
Binned
$\frac{\sigma_{E_\gamma}}{E_\gamma} = 1\%$
$\nu\nu\gamma$
Events/50 MeV
E_γ [GeV]

DDO 154 dwarf galaxy

Diversity in stellar distribution

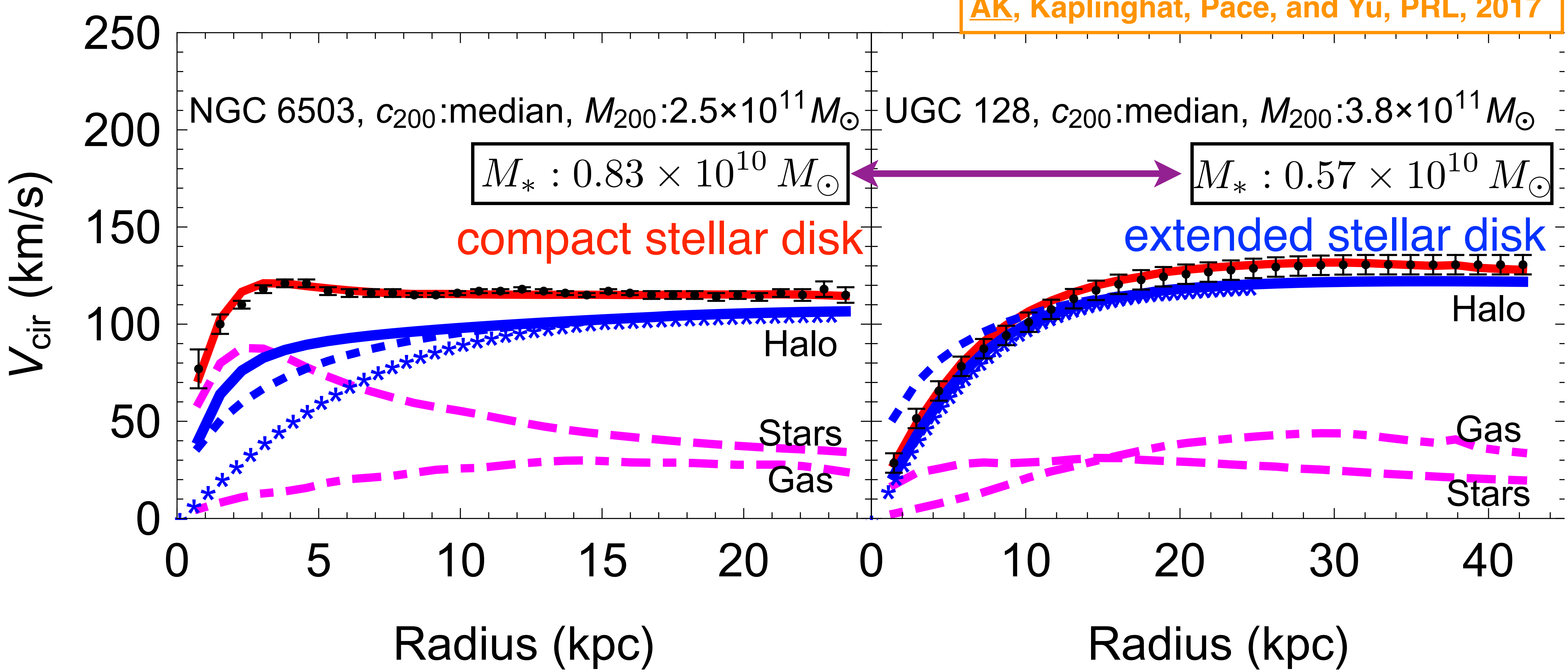


Ayuki Kamada

Similar outer circular velocity and stellar mass, but different stellar distribution

- compact → redistribute SIDM significantly
- extended → unchange SIDM distribution

AK, Kaplinghat, Pace, and Yu, PRL, 2017

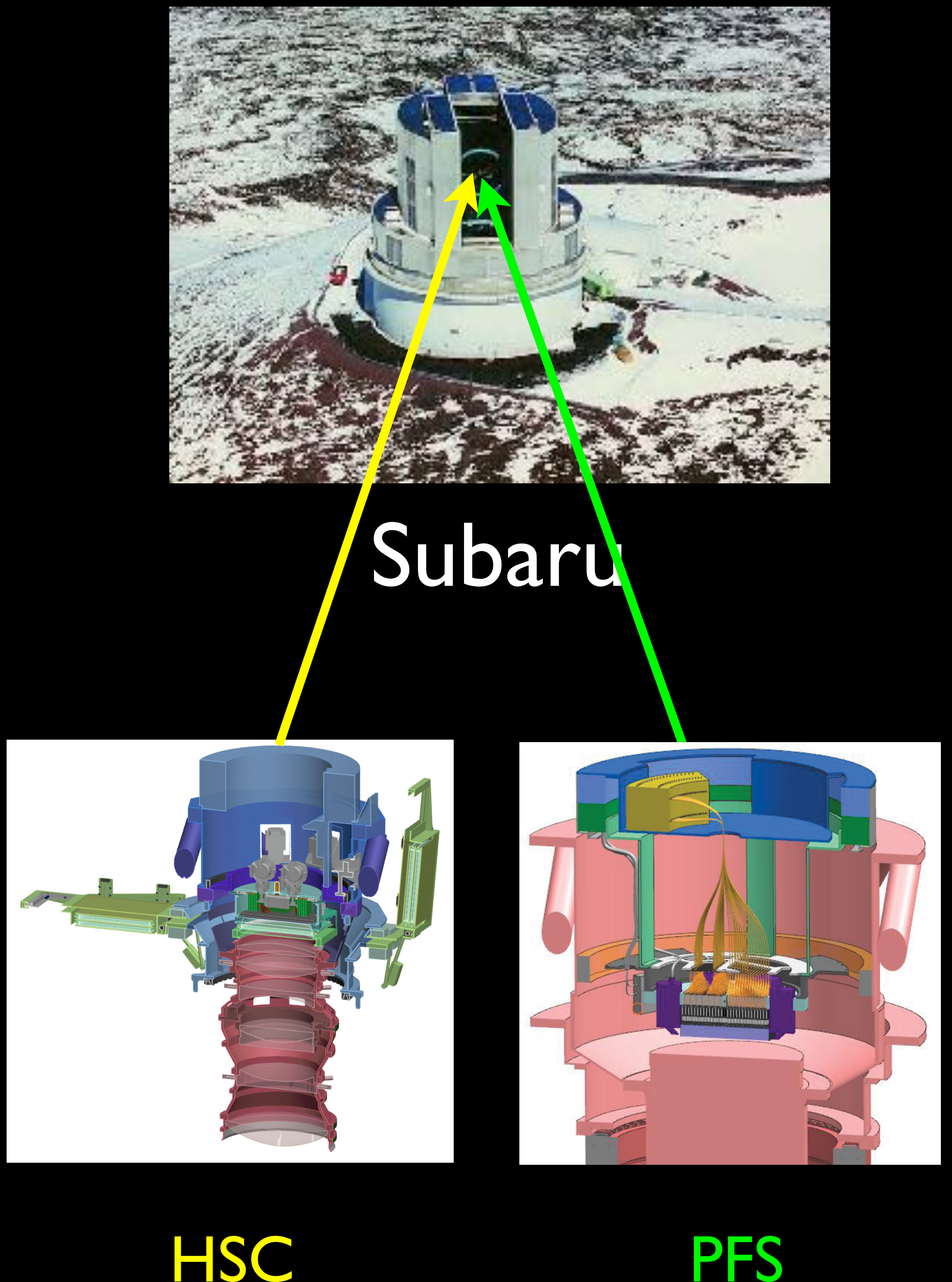


SuMIRe

Prime Focus Spectrograph

Subaru Measurement of Images and Redshifts

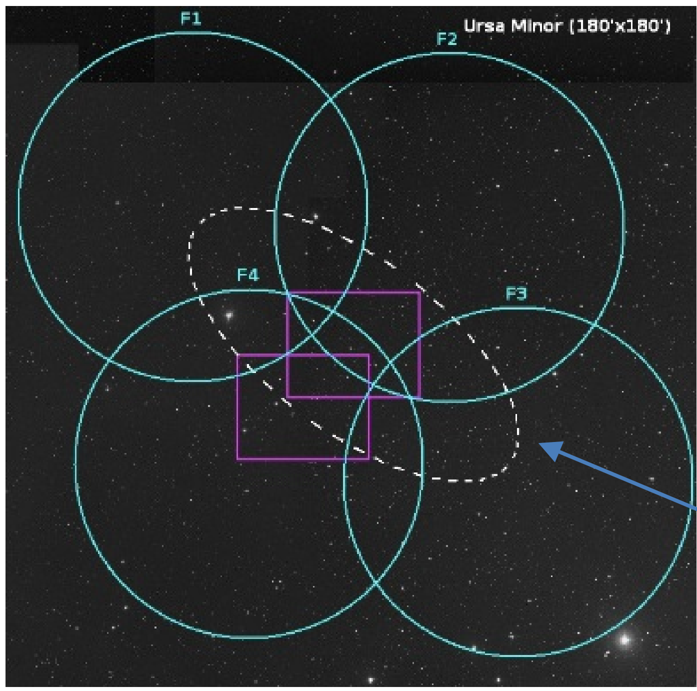
- one of the largest telescopes: 8.2m
- big field of view ~1.5°
- Imaging with Hyper Suprime-Cam (HSC)
  - 870M pixels
  - ~300M galaxy images
  - 2014–2019, 330 nights
- spectroscopy with PrimeFocusSpectrograph (PFS)
  - 2394 optical fibers, 280–1260nm
  - >1M redshifts
  - 2022–2026 360 nights



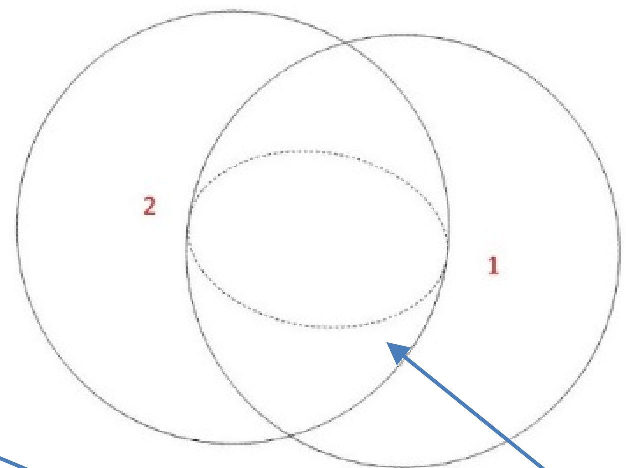
PFS pointings for MW satellites

~ HSC imaging data are available for all samples ~

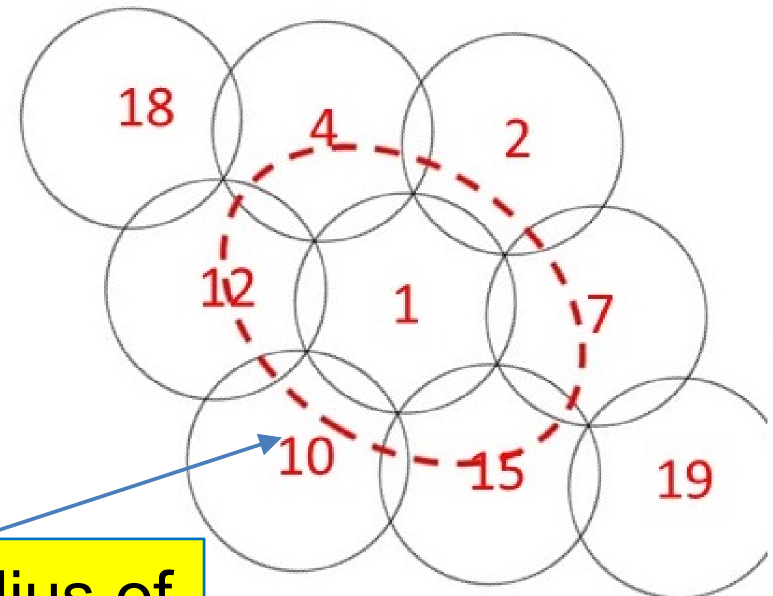
Ursa Minor



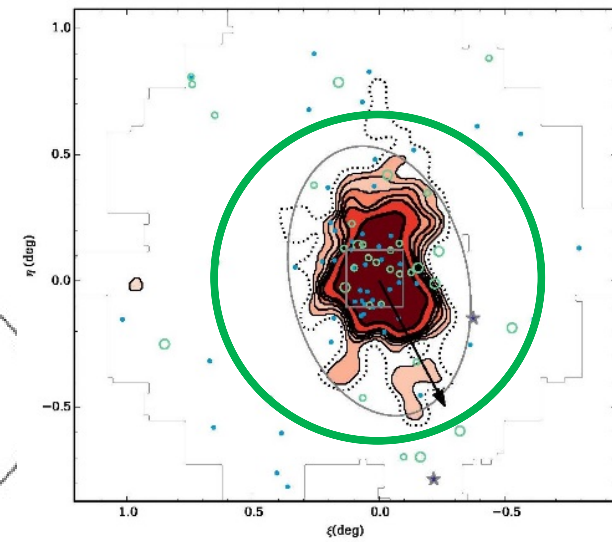
Draco



Sextans

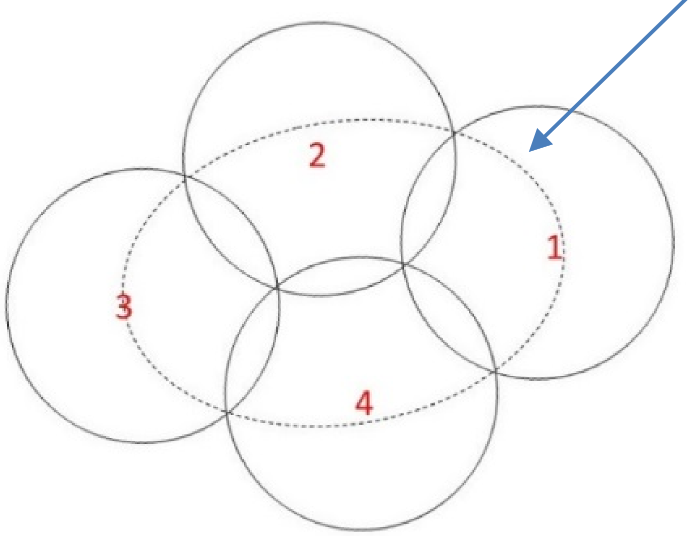


Bootes I

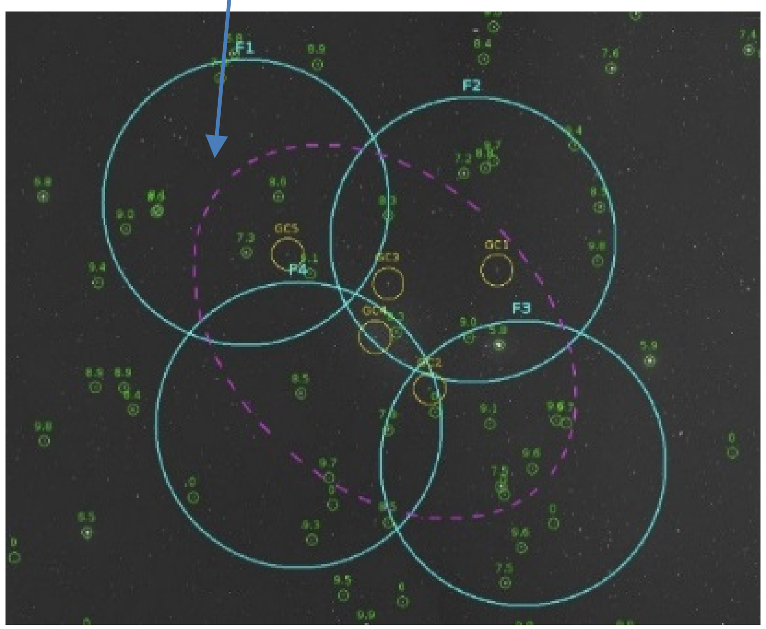


tidal radius of stellar comp.

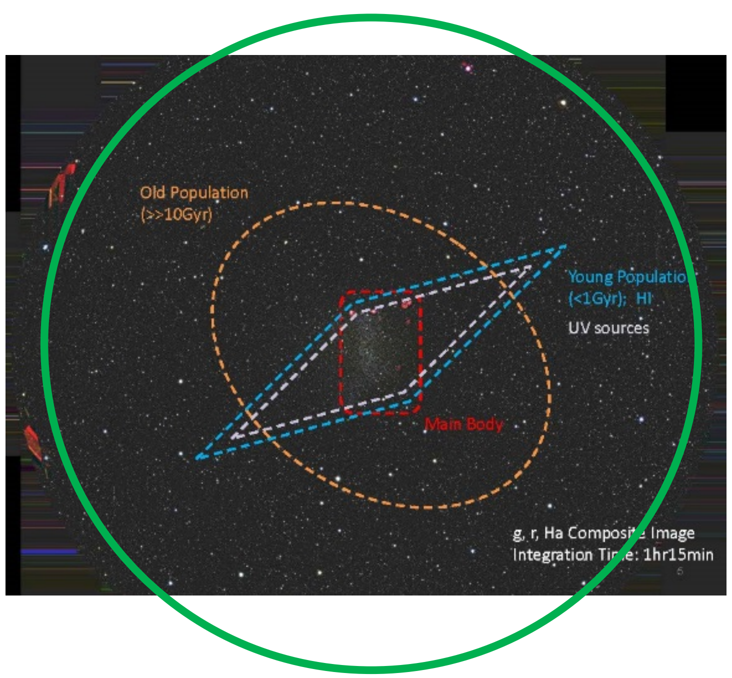
Sculptor



Fornax



NGC6822



Conclusions

- SM is technically UV complete
  - Matt Reece: *No no-lose theorem*
- Problems have sharpened
- Particle physics is as interesting as ever!
- facing resource problems
- interconnected approach with new tools

We’ll do whatever we can!

東京大学 THE UNIVERSITY OF TOKYO

UTIAS 東京大学国際高等研究所 THE UNIVERSITY OF TOKYO INSTITUTES FOR ADVANCED STUDY

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

Emerging Tools for the Future HEP Landscape

The Theoretical Perspective on the Future of Particle Physics

Hitoshi Murayama (Berkeley, Kavli IPMU)

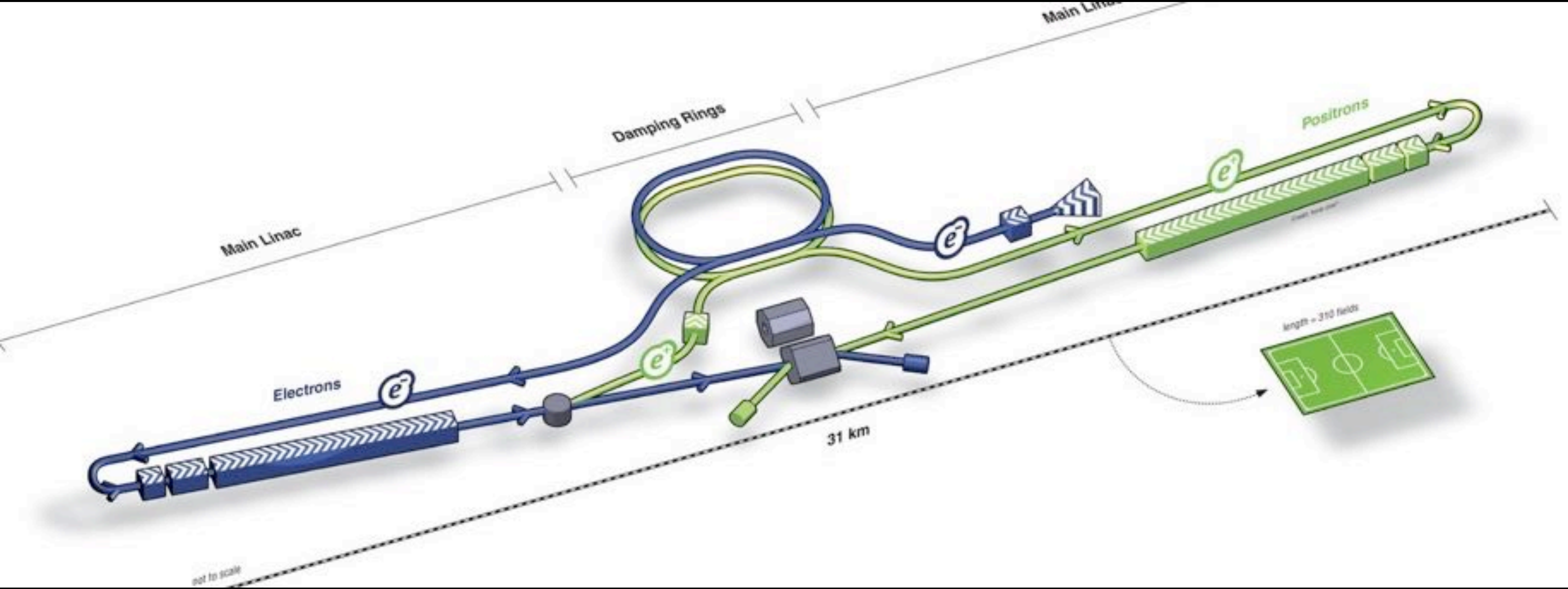
The Last GRC on Particle Physics

HKUST, July 4, 2019

BERKELEY CENTER FOR THEORETICAL PHYSICS

BERKELEY LAB

Status of ILC in Japan



Keisuke Isogai
Director General of
Research Promotion Bureau
MEXT

ICFA meeting March 7

MECSST = MEXT

MEXT's view in regard to the ILC project
Executive Summary

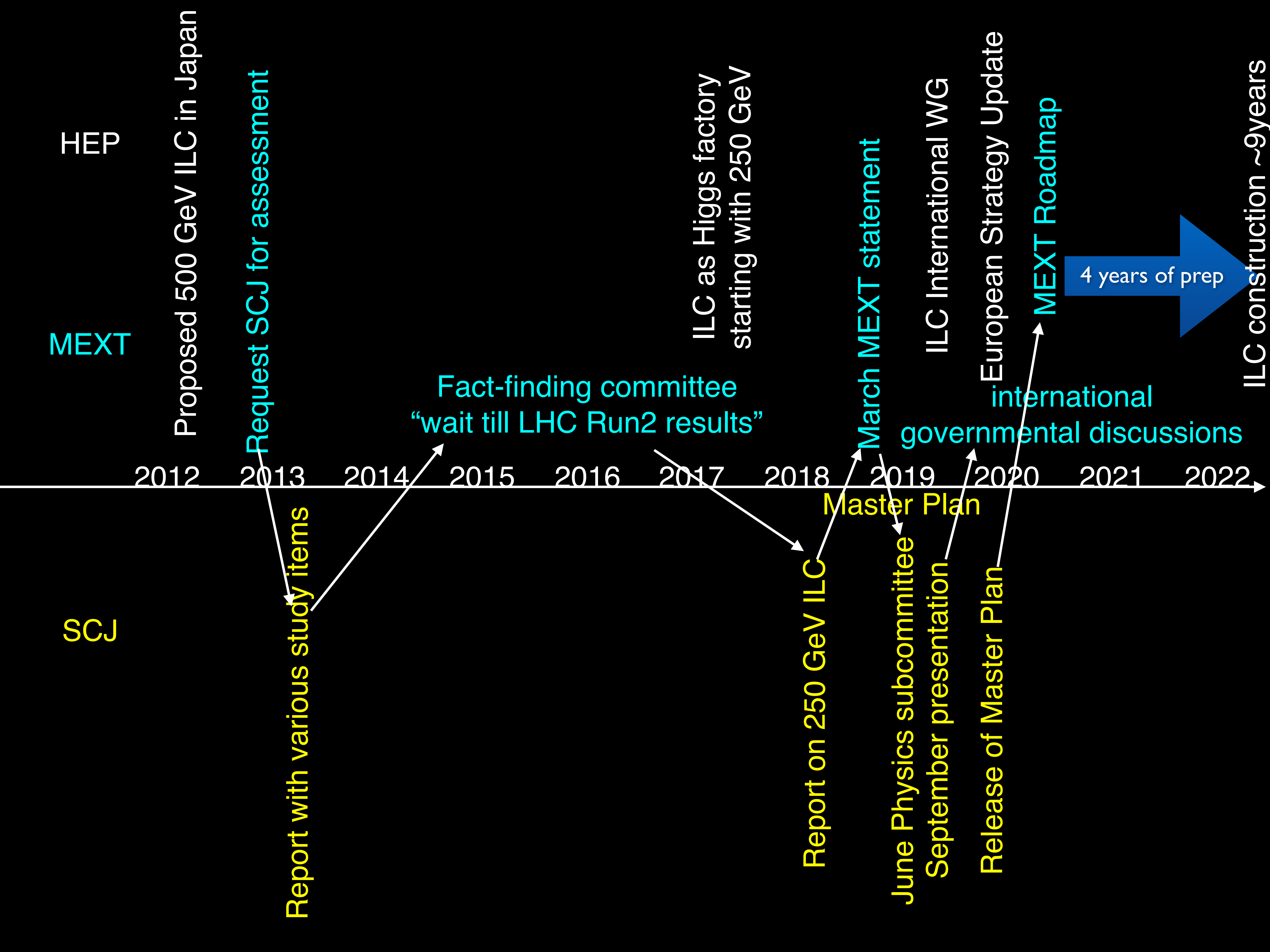
March 7, 2019
Research Promotion Bureau, MEXT

- Following the opinion of the SCJ, MEXT has not yet reached declaration for hosting the ILC in Japan at this moment. The ILC project requires further discussion in formal academic decision-making processes such as the SCJ Master Plan, where it has to be clarified whether the ILC project can gain understanding and support from the domestic academic community.

- MEXT will pay close attention to the progress of the discussions at the European Strategy for Particle Physics Update.

- The ILC project has certain scientific significance in particle physics particularly in the precision measurements of the Higgs boson, and also has possibility in the technological advancement and in its effect on the local community, although the SCJ pointed out some concerns with the ILC project. Therefore, considering the above points, MEXT will continue to discuss the ILC project with other governments while having an interest in the ILC project.

Given the statement this time, I hope discussions in the scientific community both in and outside Japan will continue, and we intend to continue exchange of opinions internationally at the governmental level. As for the timeline, as we outlined in the statement, we will keep our eyes on the Master Plan process of the Science Council of Japan domestically, as well as the European Strategy Update for Particle Physics. We will act based on the discussions in the scientific community in and outside Japan. The completion of the Master Plan will be around February 2020, and the European Strategy in May 2020, and we will follow up on them.


HEP
MEXT
SCJ
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Proposed 500 GeV ILC in Japan
Request SCJ for assessment
Report with various study items
Fact-finding committee
“wait till LHC Run2 results”
ILC as Higgs factory
starting with 250 GeV
Report on 250 GeV ILC
March MEXT statement
Master Plan
June Physics subcommittee
ILC International WG
September presentation
international
governmental discussions
European Strategy Update
Release of Master Plan
MEXT Roadmap
4 years of prep
ILC construction ~9years

KEK
High Energy Accelerator Research Organization

Actions to be done by MEXT

Answers given by MEXT at the Diet session on March 13, 2019.

- In the future, while paying close attention to the progress of discussions on the European Elementary Particle Physics Strategy, we would like to **deepen discussions with France and Germany at the governmental level**, by proposing, for instance, to establish a standing discussion group similar to the one with the US. (Mr.Isogai)

- So, also for the ILC project, we expect there will be **a working group set up in the High Energy Accelerator Research Organization, so-called KEK, and at its initiative,** discussions within the community of domestic and foreign researchers will proceed regarding international cost sharing, etc. (Mr.Isogai)

- As I mentioned earlier, I am also aware that this is a project of great significance both from the academic research point of view and from the perspective of regional revitalization. Therefore, I would like to **continue our investigations, closely collaborating with related communities while keeping an eye on the international situation.** (Minister Shibayama)

Stefan Kaufmann
Ryu Shionoya
July 2

Official launch of the Japan-Germany and Japan-France discussion groups on ILC after consultation among congress people and relevant ministries in both countries. We also agreed to pursue trilateral cooperation.

Olivier Becht
Takeo Kawamura
Ryu Shionoya
Shintaro Ito
July 1

ILC International Working Group Established -- First Meeting Held in Granada

2019/05/21 Topics

2019年
2018年
2017年
2013年
2011年

- Model of international cost-sharing for construction and operation
- Organization and governance of the ILC Laboratory
- International sharing of the remaining technical preparation

Patricia McBride

Report to MEXT this September