# New Physics

## Summer Camp on ILC

Hitoshi Murayama (Berkeley, Kavli IPMU Tokyo)

September 25, 2020

LINEAR COLLIDER COLLABORATION

BERKELEY CENTER FOR THEORETICAL PHYSICS

BERKELEY LAB

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

# Apology

- I volunteered to give a talk but for some reason totally forgot about it.
    - I don’t have a dedicated assistant any more…
    - and yesterday was 32th anniversary
- Thank you for rescheduling the talk for today!

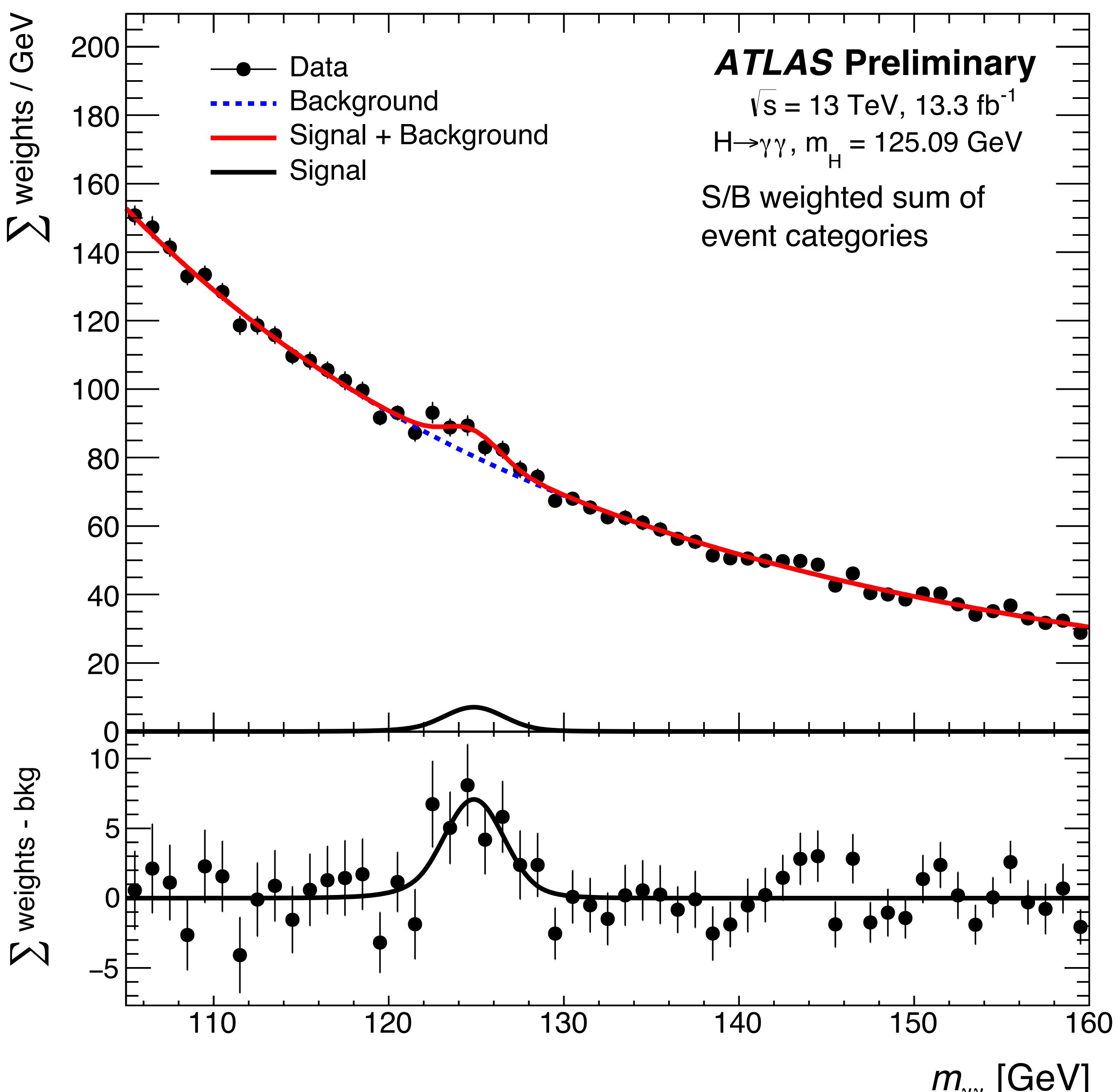
# Disclaimer

- I am trying to find new ways to exploit ILC for new physics searches.  The content of the talk is somewhat sketchy and qualitative.  You are warned that what I will discuss should not be taken literally.  Your mileage may vary.

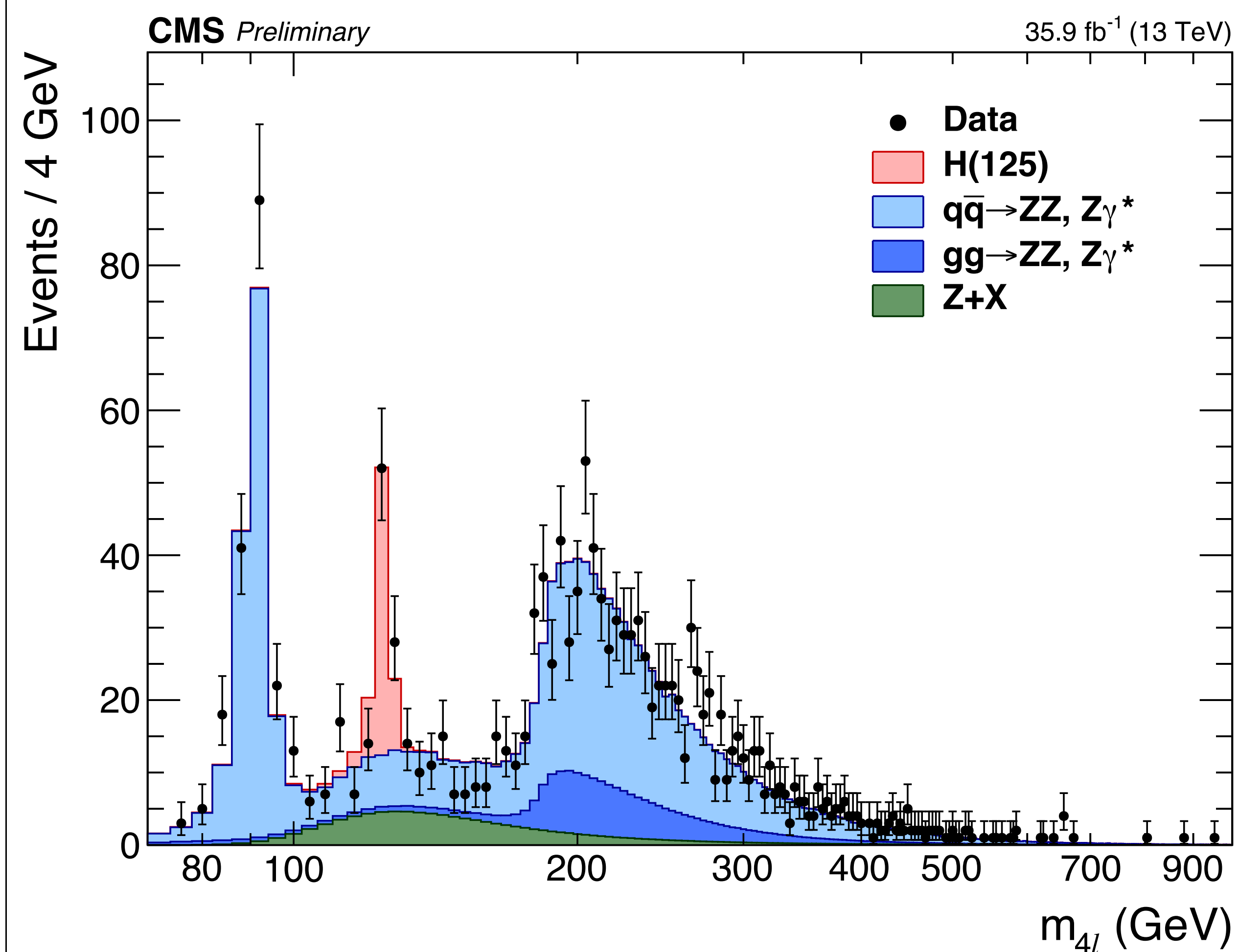
Yes

# Higgs exists!

ATLAS-CONF-2016-067

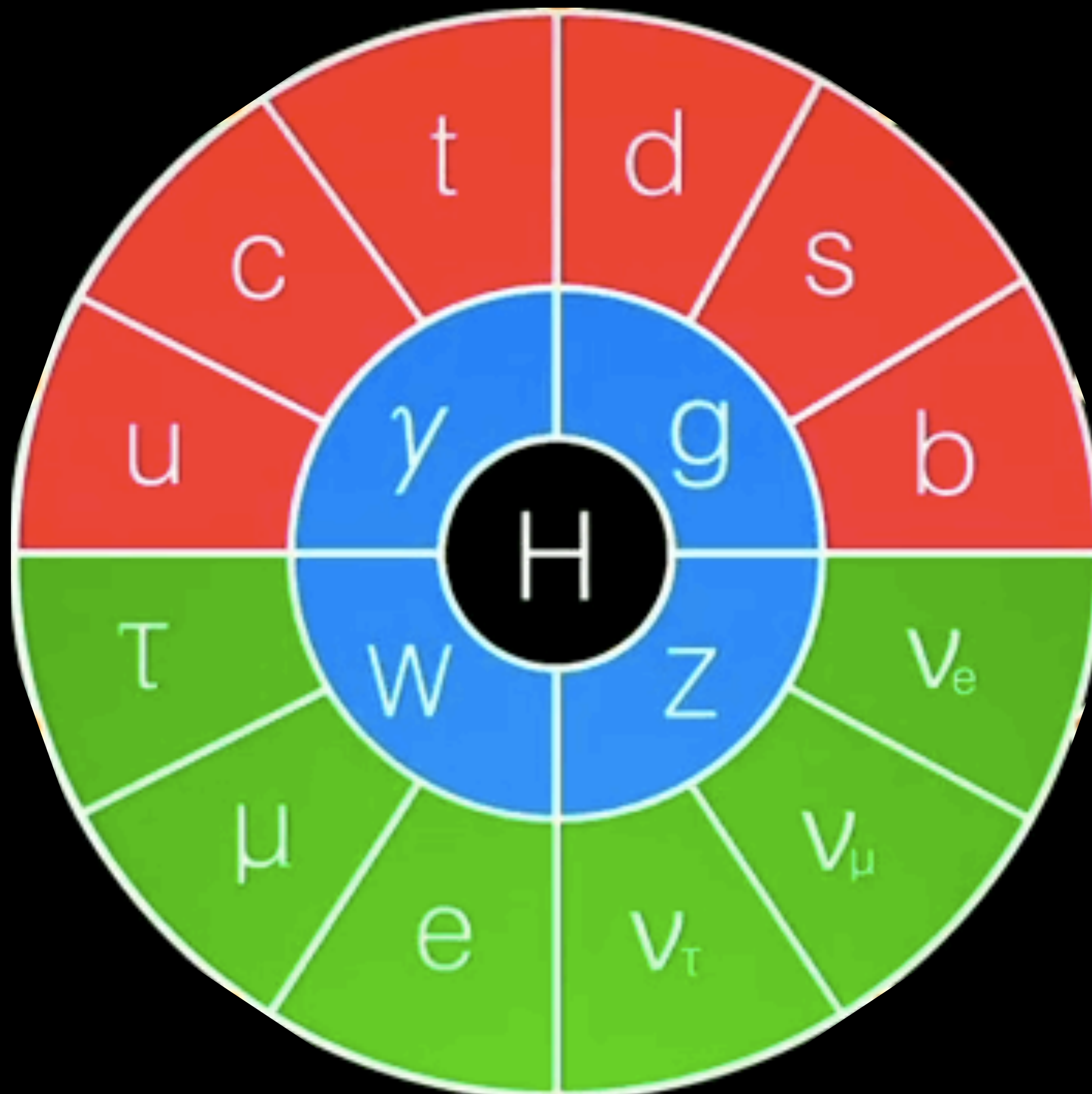



CMS-HIG-16-041

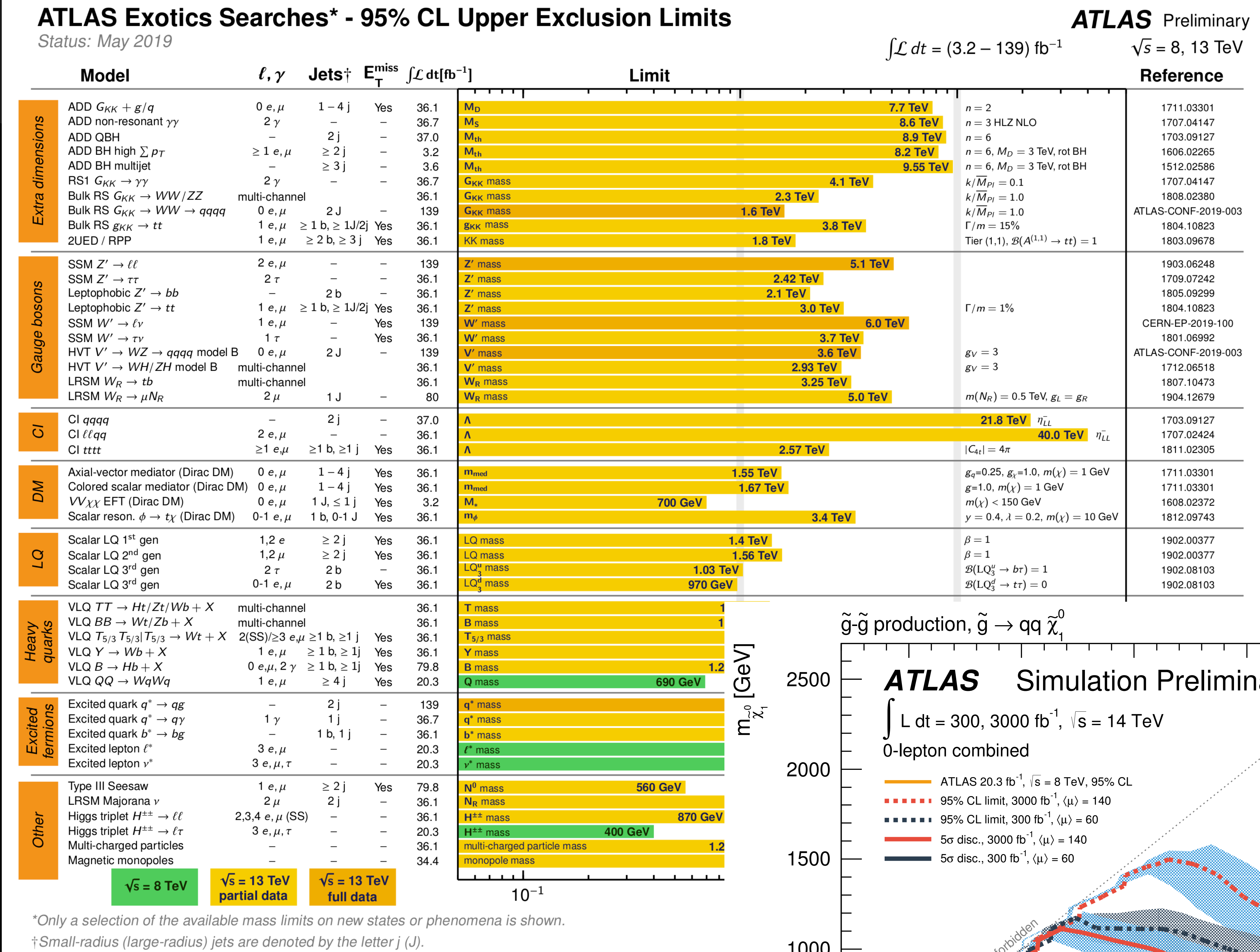


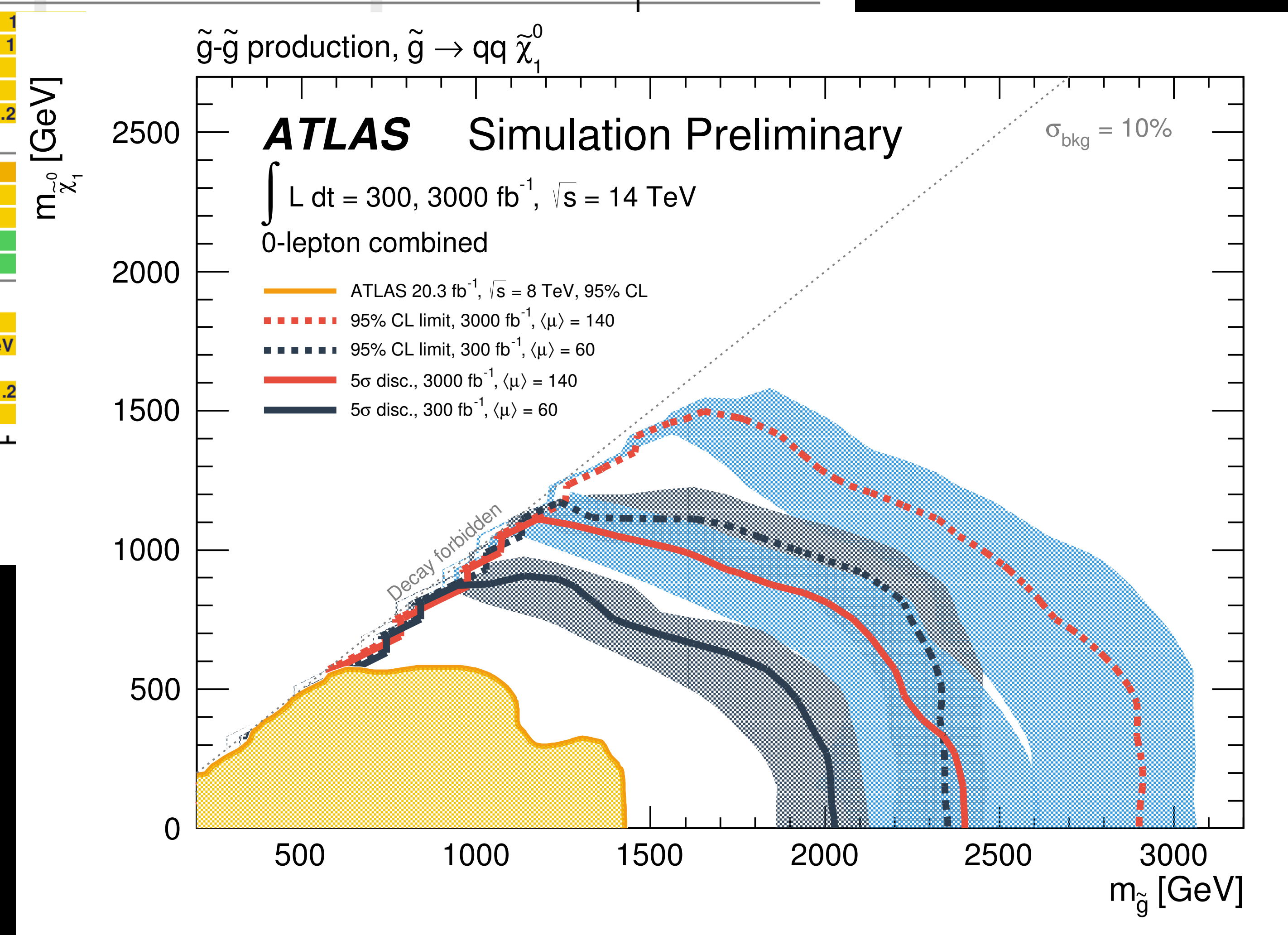

Jónatan Piedra

# Standard Model




***Are we done?***


ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits
Status: May 2019
ATLAS Preliminary
∫ℒ dt = (3.2 – 139) fb⁻¹
√s = 8, 13 TeV
Model
ℓ, γ
Jets†
E_T^miss
∫ℒ dt[fb⁻¹]
Limit
Reference
Extra dimensions
ADD G_KK + g/q 0 e, μ 1 – 4 j Yes 36.1 M_D 7.7 TeV n = 2 1711.03301
ADD non-resonant γγ 2 γ – – 36.7 M_S 8.6 TeV n = 3 HLZ NLO 1707.04147
ADD QBH – 2 j – 37.0 M_th 8.9 TeV n = 6 1703.09127
ADD BH high Σ p_T ≥ 1 e, μ ≥ 2 j – 3.2 M_th 8.2 TeV n = 6, M_D = 3 TeV, rot BH 1606.02265
ADD BH multijet – ≥ 3 j – 3.6 M_th 9.55 TeV n = 6, M_D = 3 TeV, rot BH 1512.02586
RS1 G_KK → γγ 2 γ – – 36.7 G_KK mass 4.1 TeV k/M_Pl = 0.1 1707.04147
Bulk RS G_KK → WW/ZZ multi-channel 36.1 G_KK mass 2.3 TeV k/M_Pl = 1.0 1808.02380
Bulk RS G_KK → WW → qqqq 0 e, μ 2 J – 139 G_KK mass 1.6 TeV k/M_Pl = 1.0 ATLAS-CONF-2019-003
Bulk RS g_KK → tt 1 e, μ ≥ 1 b, ≥ 1J/2j Yes 36.1 g_KK mass 3.8 TeV Γ/m = 15% 1804.10823
2UED / RPP 1 e, μ ≥ 2 b, ≥ 3 j Yes 36.1 KK mass 1.8 TeV Tier (1,1), B(A^(1,1) → tt) = 1 1803.09678
Gauge bosons
SSM Z′ → ℓℓ 2 e, μ – – 139 Z′ mass 5.1 TeV 1903.06248
SSM Z′ → ττ 2 τ – – 36.1 Z′ mass 2.42 TeV 1709.07242
Leptophobic Z′ → bb – 2 b – 36.1 Z′ mass 2.1 TeV 1805.09299
Leptophobic Z′ → tt 1 e, μ ≥ 1 b, ≥ 1J/2j Yes 36.1 Z′ mass 3.0 TeV Γ/m = 1% 1804.10823
SSM W′ → ℓν 1 e, μ – Yes 139 W′ mass 6.0 TeV CERN-EP-2019-100
SSM W′ → τν 1 τ – Yes 36.1 W′ mass 3.7 TeV 1801.06992
HVT V′ → WZ → qqqq model B 0 e, μ 2 J – 139 V′ mass 3.6 TeV g_V = 3 ATLAS-CONF-2019-003
HVT V′ → WH/ZH model B multi-channel 36.1 V′ mass 2.93 TeV g_V = 3 1712.06518
LRSM W_R → tb multi-channel 36.1 W_R mass 3.25 TeV 1807.10473
LRSM W_R → μN_R 2 μ 1 J – 80 W_R mass 5.0 TeV m(N_R) = 0.5 TeV, g_L = g_R 1904.12679
CI
CI qqqq – 2 j – 37.0 Λ 21.8 TeV η⁻_LL 1703.09127
CI ℓℓqq 2 e, μ – – 36.1 Λ 40.0 TeV η⁻_LL 1707.02424
CI tttt ≥1 e,μ ≥1 b, ≥1 j Yes 36.1 Λ 2.57 TeV |C_4t| = 4π 1811.02305
DM
Axial-vector mediator (Dirac DM) 0 e, μ 1 – 4 j Yes 36.1 m_med 1.55 TeV g_q=0.25, g_χ=1.0, m(χ) = 1 GeV 1711.03301
Colored scalar mediator (Dirac DM) 0 e, μ 1 – 4 j Yes 36.1 m_med 1.67 TeV g=1.0, m(χ) = 1 GeV 1711.03301
VV_χχ EFT (Dirac DM) 0 e, μ 1 J, ≤ 1 j Yes 3.2 M_* 700 GeV m(χ) < 150 GeV 1608.02372
Scalar reson. φ → tχ (Dirac DM) 0-1 e, μ 1 b, 0-1 J Yes 36.1 m_φ 3.4 TeV y = 0.4, λ = 0.2, m(χ) = 10 GeV 1812.09743
LQ
Scalar LQ 1st gen 1,2 e ≥ 2 j Yes 36.1 LQ mass 1.4 TeV β = 1 1902.00377
Scalar LQ 2nd gen 1,2 μ ≥ 2 j Yes 36.1 LQ mass 1.56 TeV β = 1 1902.00377
Scalar LQ 3rd gen 2 τ 2 b – 36.1 LQ^u_3 mass 1.03 TeV B(LQ^u_3 → bτ) = 1 1902.08103
Scalar LQ 3rd gen 0-1 e, μ 2 b Yes 36.1 LQ^d_3 mass 970 GeV B(LQ^d_3 → tτ) = 0 1902.08103
Heavy quarks
VLQ TT → Ht/Zt/Wb + X multi-channel 36.1 T mass 1
VLQ BB → Wt/Zb + X multi-channel 36.1 B mass 1
VLQ T_5/3 T_5/3|T_5/3 → Wt + X 2(SS)/≥3 e,μ ≥1 b, ≥1 j Yes 36.1 T_5/3 mass
VLQ Y → Wb + X 1 e, μ ≥ 1 b, ≥ 1j Yes 36.1 Y mass
VLQ B → Hb + X 0 e,μ, 2 γ ≥ 1 b, ≥ 1j Yes 79.8 B mass 1.2
VLQ QQ → WqWq 1 e, μ ≥ 4 j Yes 20.3 Q mass 690 GeV
Excited fermions
Excited quark q* → qg – 2 j – 139 q* mass
Excited quark q* → qγ 1 γ 1 j – 36.7 q* mass
Excited quark b* → bg – 1 b, 1 j – 36.1 b* mass
Excited lepton ℓ* 3 e, μ – – 20.3 ℓ* mass
Excited lepton ν* 3 e, μ, τ – – 20.3 ν* mass
Other
Type III Seesaw 1 e, μ ≥ 2 j Yes 79.8 N⁰ mass 560 GeV
LRSM Majorana ν 2 μ 2 j – 36.1 N_R mass
Higgs triplet H^±± → ℓℓ 2,3,4 e, μ (SS) – – 36.1 H^±± mass 870 GeV
Higgs triplet H^±± → ℓτ 3 e, μ, τ – – 20.3 H^±± mass 400 GeV
Multi-charged particles – – – 36.1 multi-charged particle mass 1.2
Magnetic monopoles – – – 34.4 monopole mass
√s = 8 TeV
√s = 13 TeV partial data
√s = 13 TeV full data
10⁻¹
*Only a selection of the available mass limits on new states or phenomena is shown.
†Small-radius (large-radius) jets are denoted by the letter j (J).


g̃-g̃ production, g̃ → qq χ̃⁰_1
ATLAS Simulation Preliminary
σ_bkg = 10%
∫ L dt = 300, 3000 fb⁻¹, √s = 14 TeV
0-lepton combined
ATLAS 20.3 fb⁻¹, √s = 8 TeV, 95% CL
95% CL limit, 3000 fb⁻¹, ⟨μ⟩ = 140
95% CL limit, 300 fb⁻¹, ⟨μ⟩ = 60
5σ disc., 3000 fb⁻¹, ⟨μ⟩ = 140
5σ disc., 300 fb⁻¹, ⟨μ⟩ = 60
Decay forbidden
m_χ̃⁰_1 [GeV]
m_g̃ [GeV]
0
500
1000
1500
2000
2500
3000

ENGINEERING
**Machines That Change Shape**

MEDICINE
**An Off Switch for Cancer**

NEUROSCIENCE
**How to Reach "Vegetative" Patients**

# SCIENTIFIC AMERICAN

ScientificAmerican.com

# A CRISIS IN PHYSICS?

IF SUPERSYMMETRY DOESN'T PAN OUT, SCIENTISTS NEED A NEW WAY TO EXPLAIN THE UNIVERSE

0 74470 38527 5
$5.99 U.S.
MAY 2014

# been there before

The New York Times

Science

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH

ENVIRONMENT

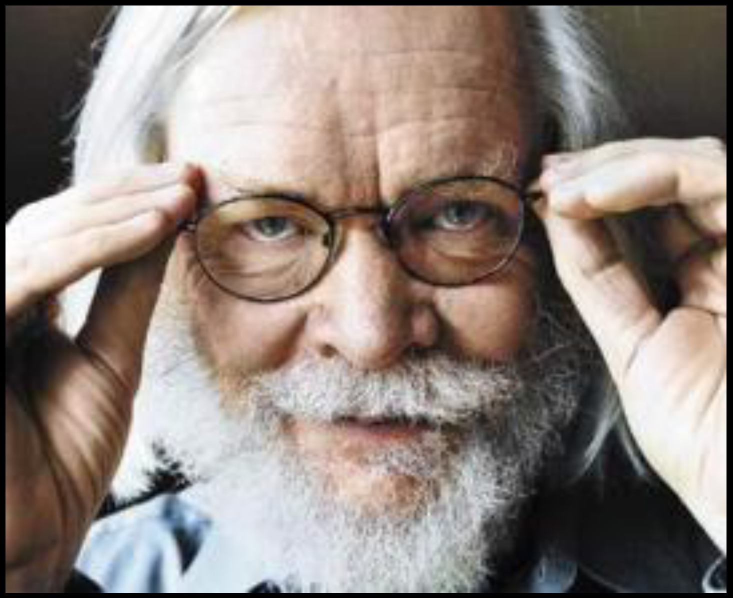
## 315 Physicists Report Failure In Search for Supersymmetry

By MALCOLM W. BROWNE

Published: January 5, 1993

Three hundred and fifteen physicists worked on the experiment.

Their apparatus included the Tevatron, the world's most powerful particle accelerator, as well as a $65 million detector weighing as



# Better Late Than Never

Even $m_{SUSY}$~10 TeV ameliorates fine-tuning from $10^{-36}$ to $10^{-4}$

# lore

- LHC has not discovered any new physics
- ILC energy is much lower than LHC
- ILC will never discover new particles
- focus on deviation from SM in precision measurements = indirect probe
- maybe unusually difficult case at LHC?

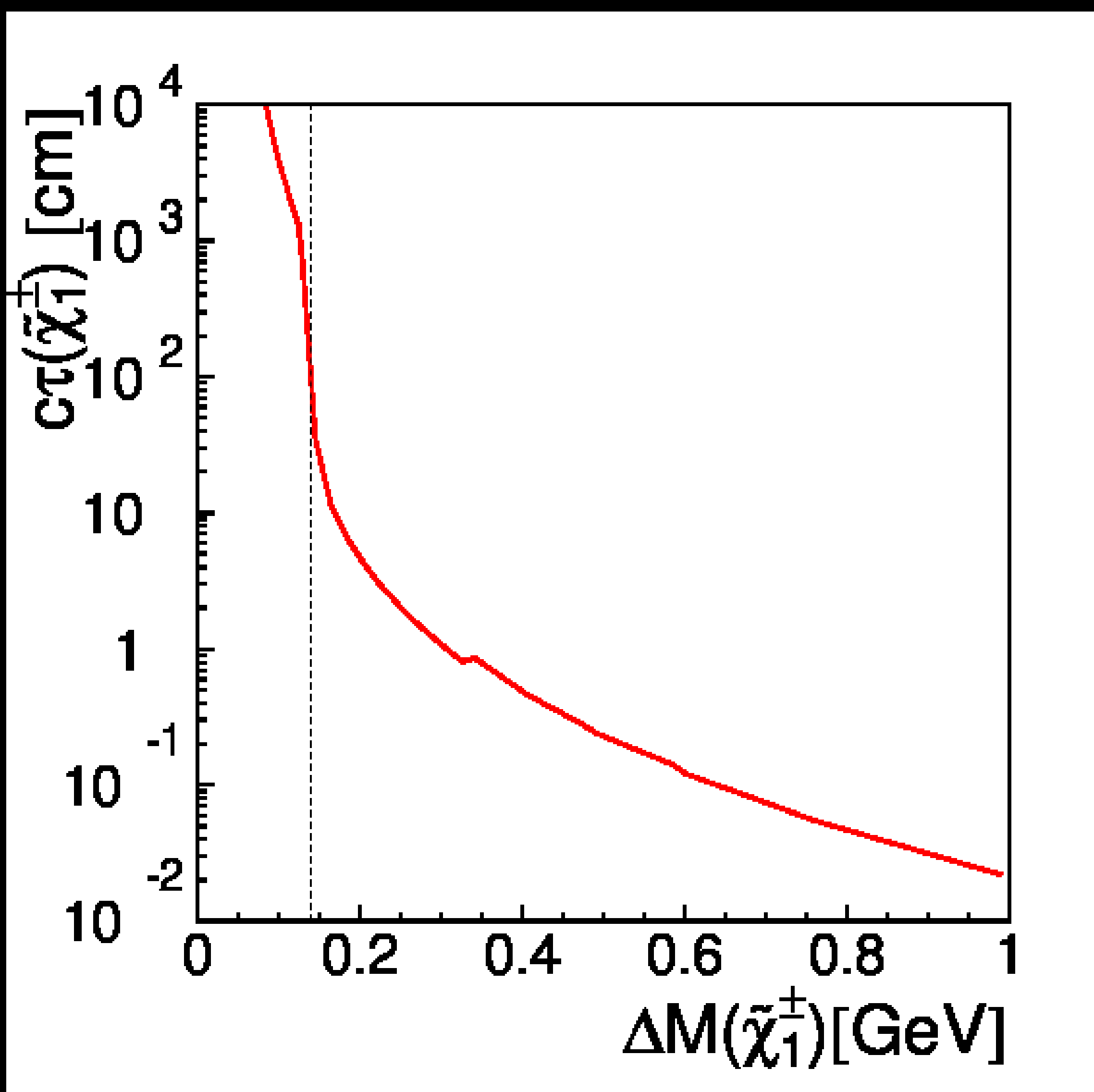
R-parity violation
compressed spectrum
disappearing tracks
clever analysis

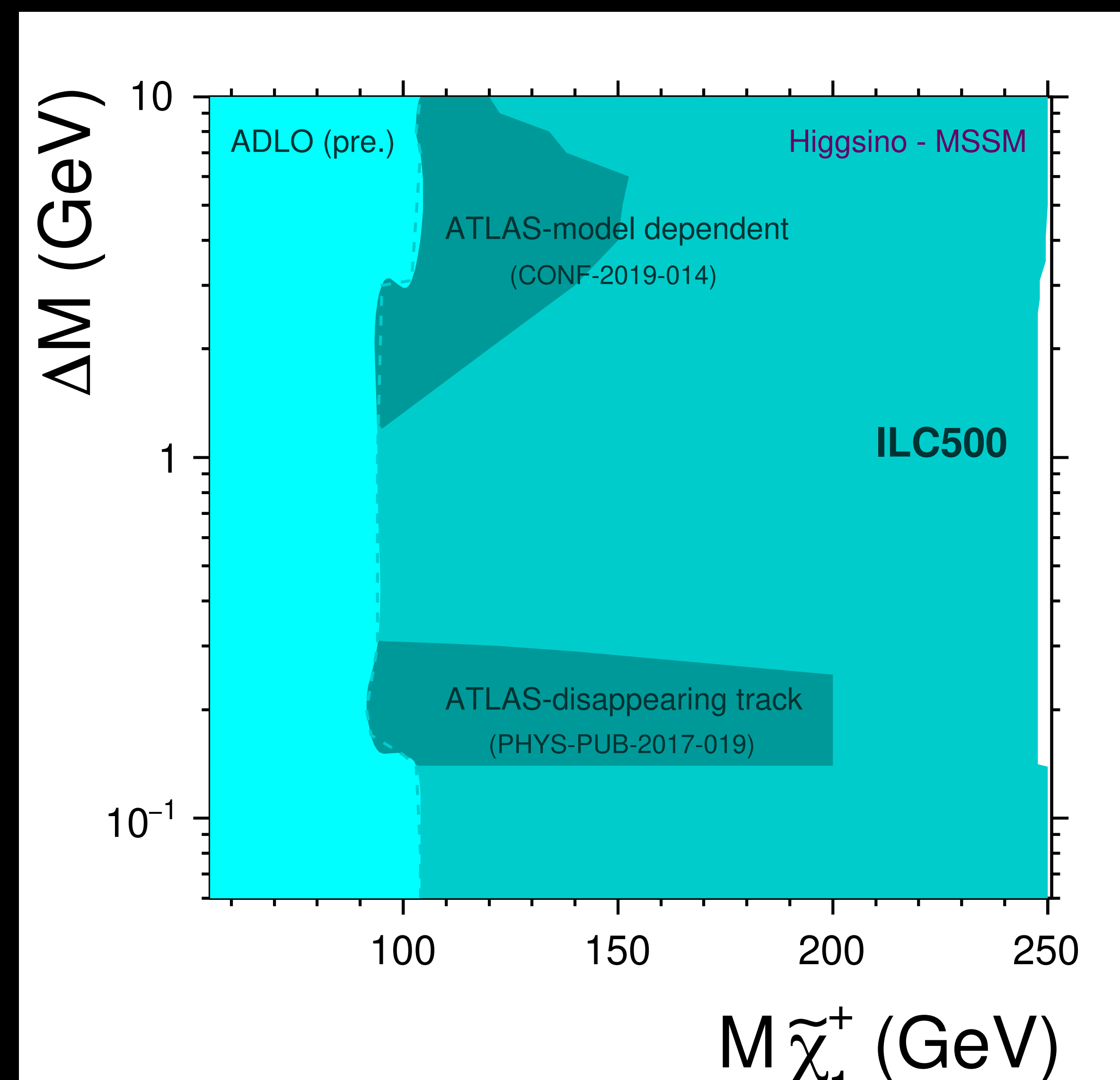
clever analysis
precision Higgs, flavor
HL-LHC
ILC!

# higgsino, wino

$$\tilde{\chi}^{\pm} \to \tilde{\chi}^{0} + X \qquad X = \pi^{\pm}, \ell^{\pm}\nu_{\ell}, \mathrm{etc}$$

$$\tilde{\chi}^{\pm} + \mathrm{detector} \to \tilde{\chi}^{0}$$

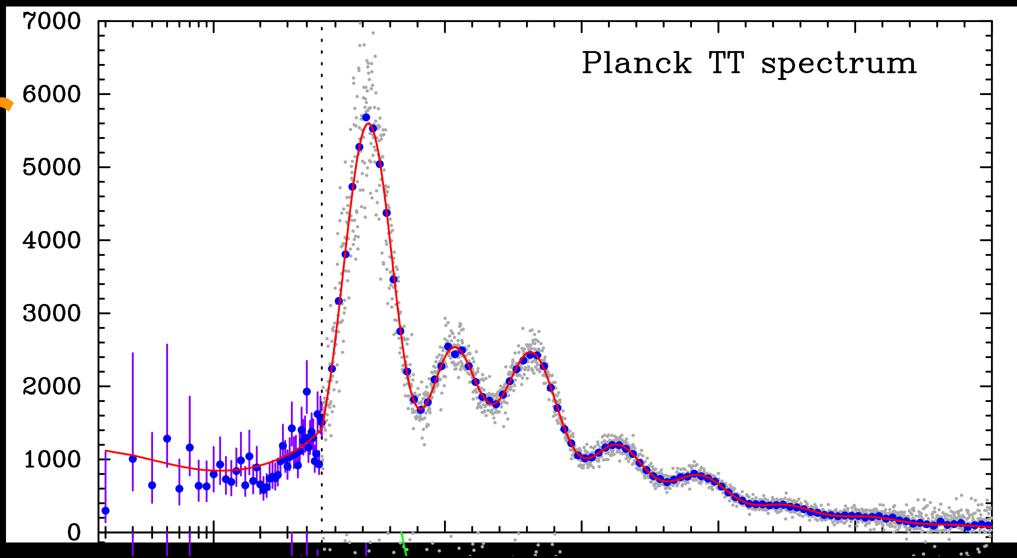



arXiv:2002.01239

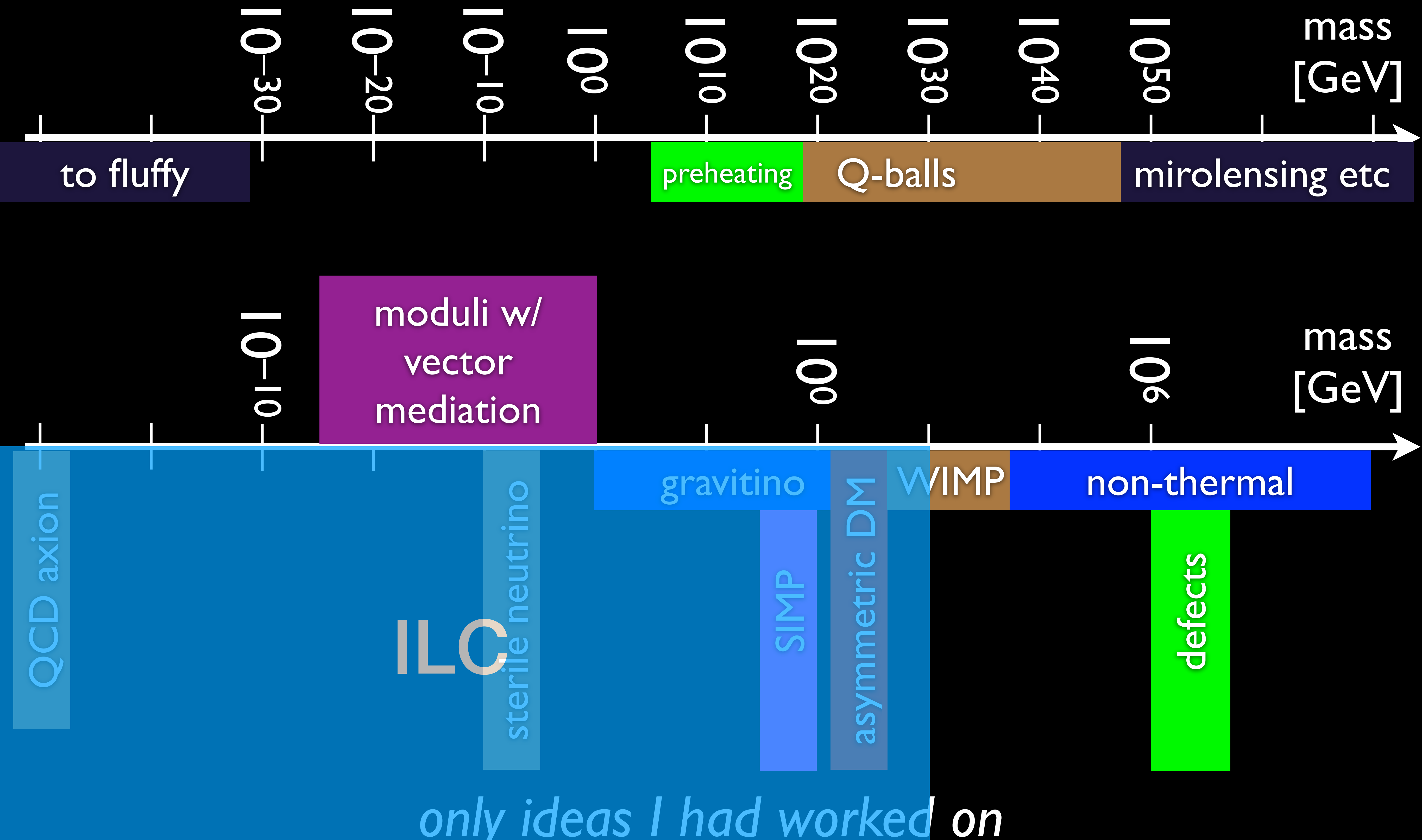
# Five evidences for physics beyond SM

- 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

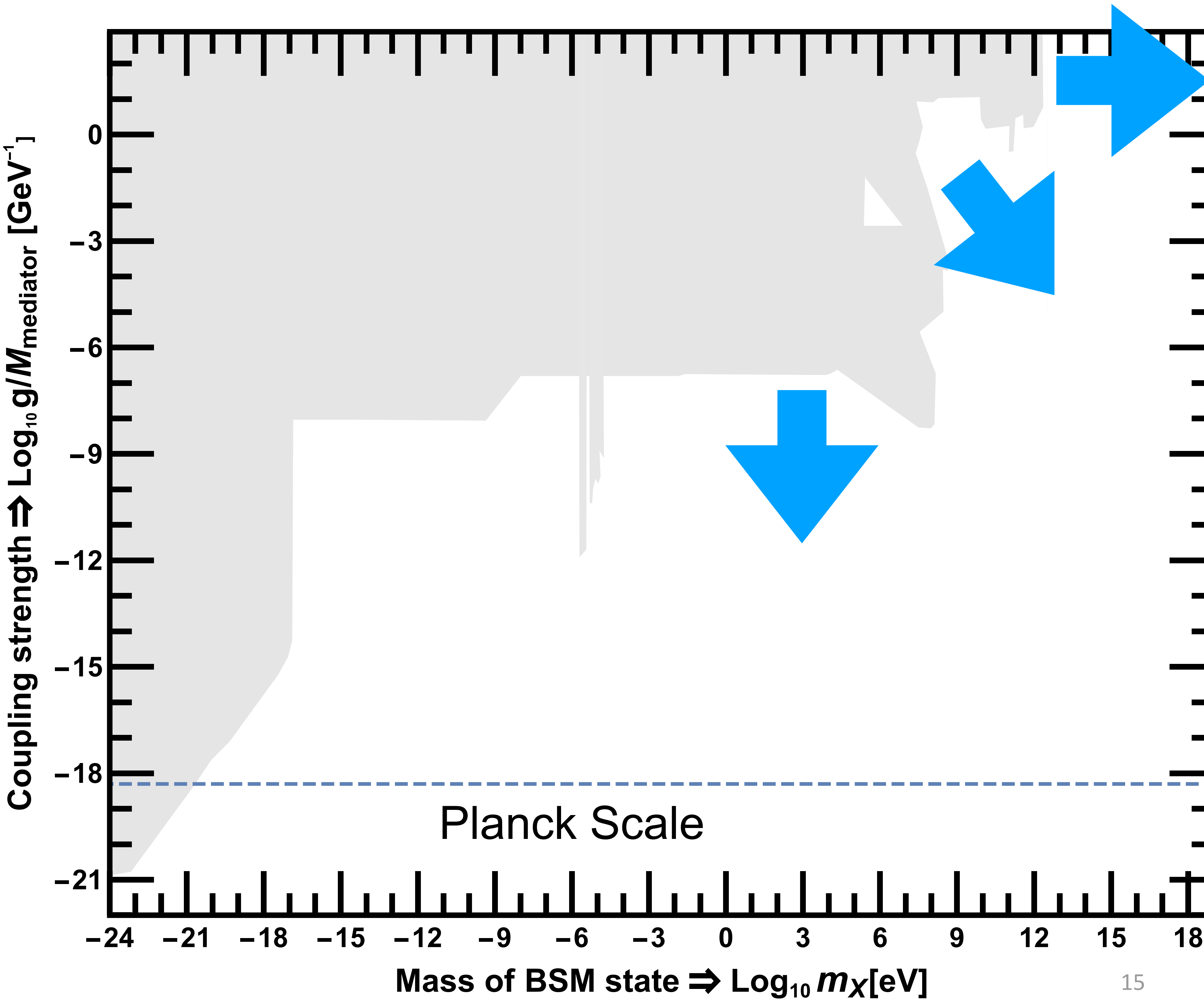



We don't really know their energy scales...

# where is dark matter?

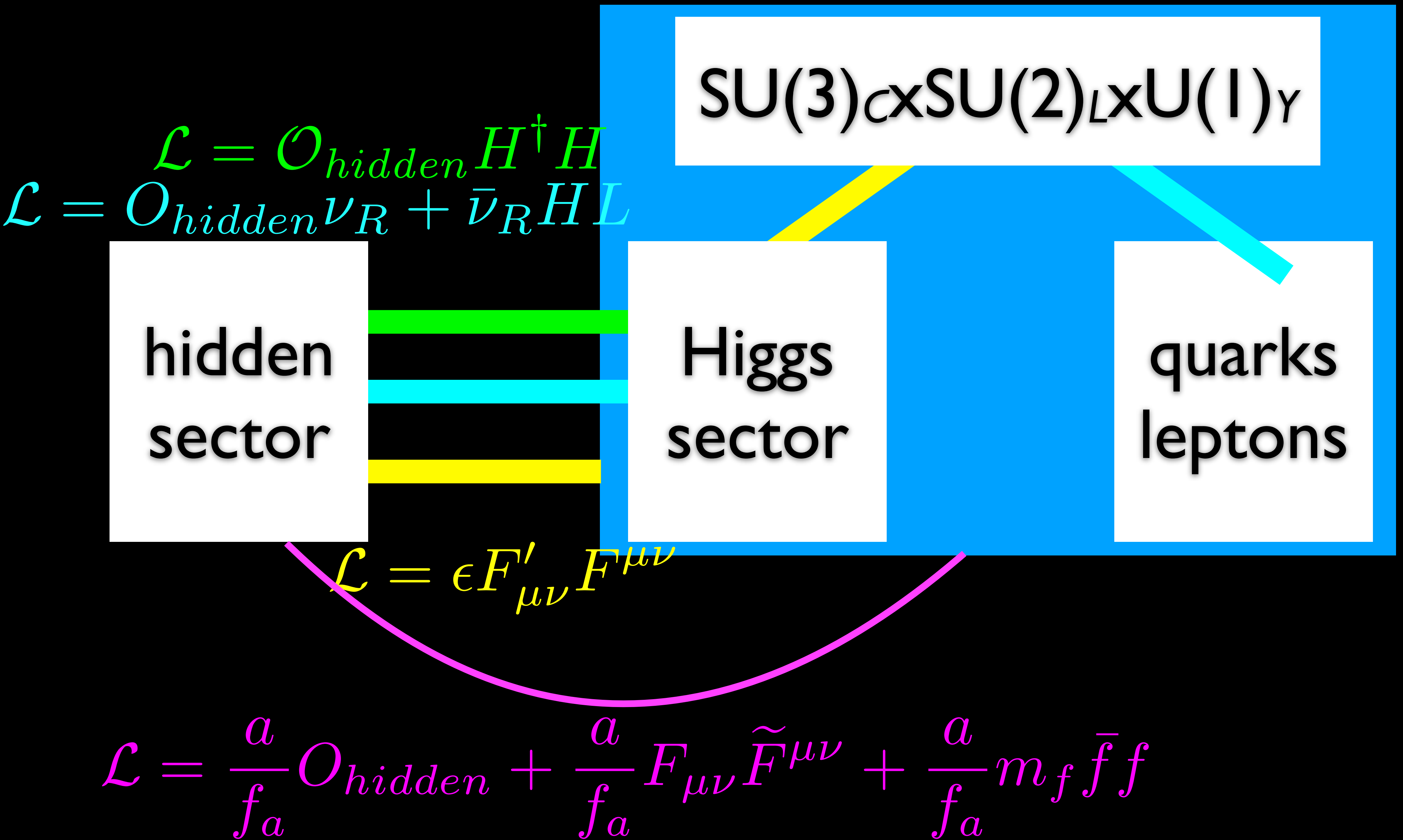


# Where is new physics?



# portals

- light new physics must be neutral under SM



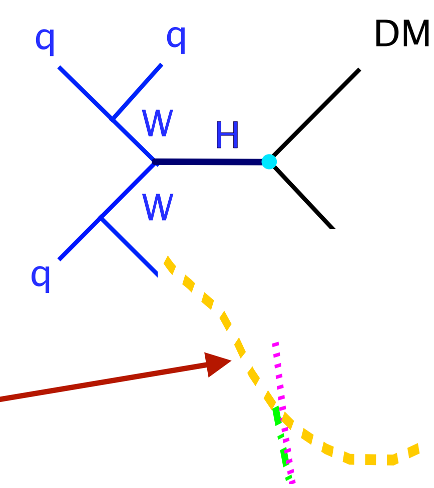
# Higgs portal, plot for direct searches

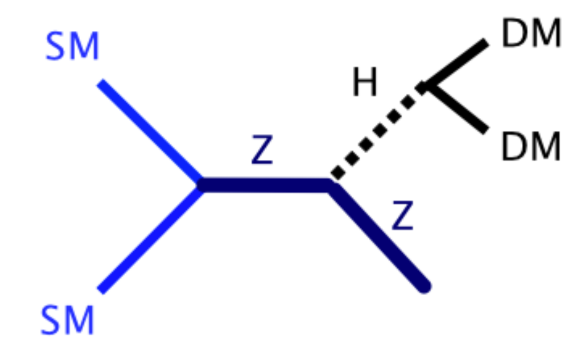
- Limits on BR can be translated to limits in the DM-nucleon plane

$$\sigma_{\chi N} = \Gamma_{\rm inv} \frac{8 m_N^4 f_N^2}{v^2 \beta m_h^3 (m_\chi + m_N)^2} g_\chi \left(\frac{m_h}{m_\chi}\right), \qquad (15)$$

arXiv:1708.02245

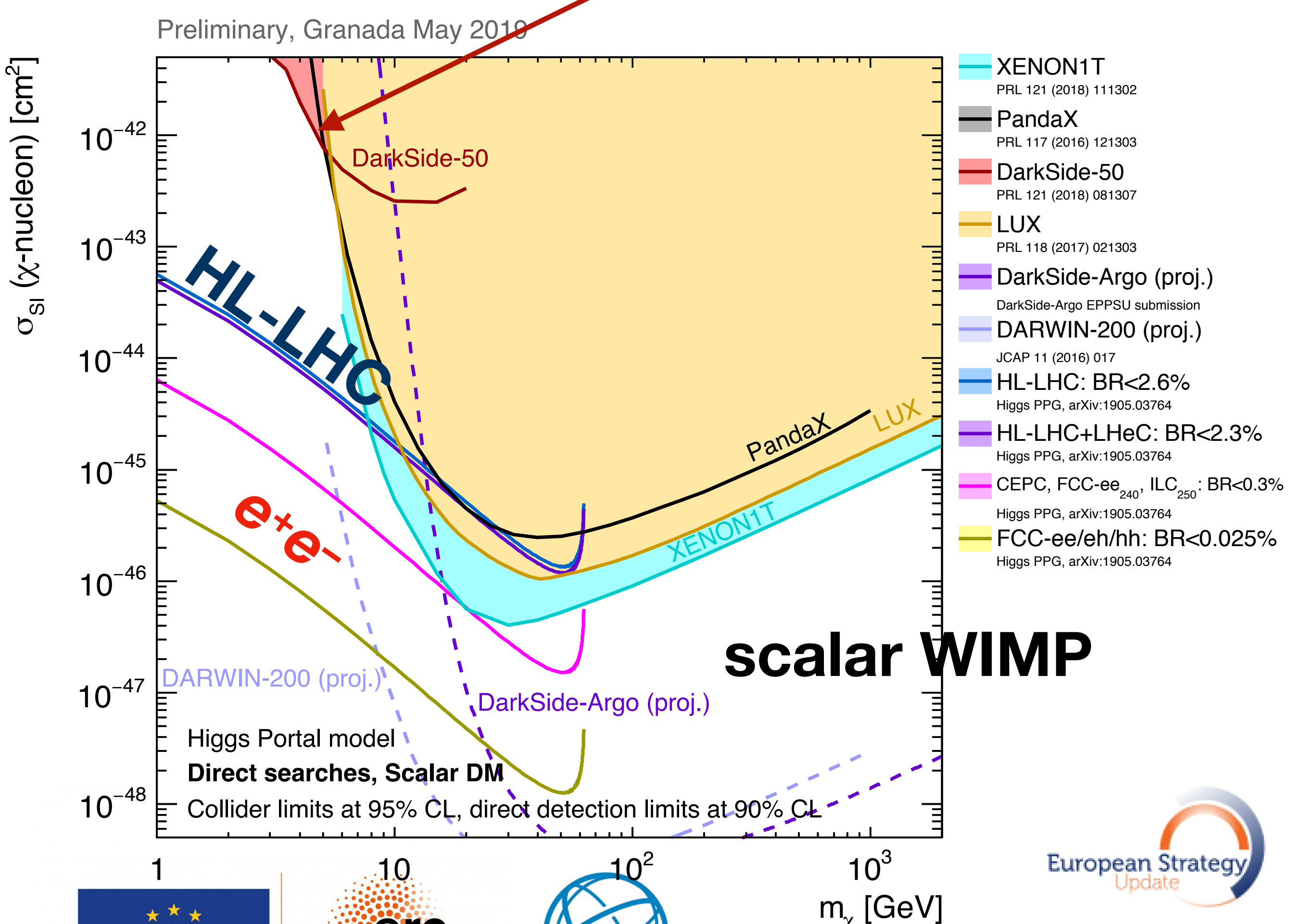
where $g_S(x) = 1$, $g_f(x) = 2/(x^2-4)$, $\beta = \sqrt{1 - 4m_\chi^2/m_h^2}$, $v = 246$ GeV

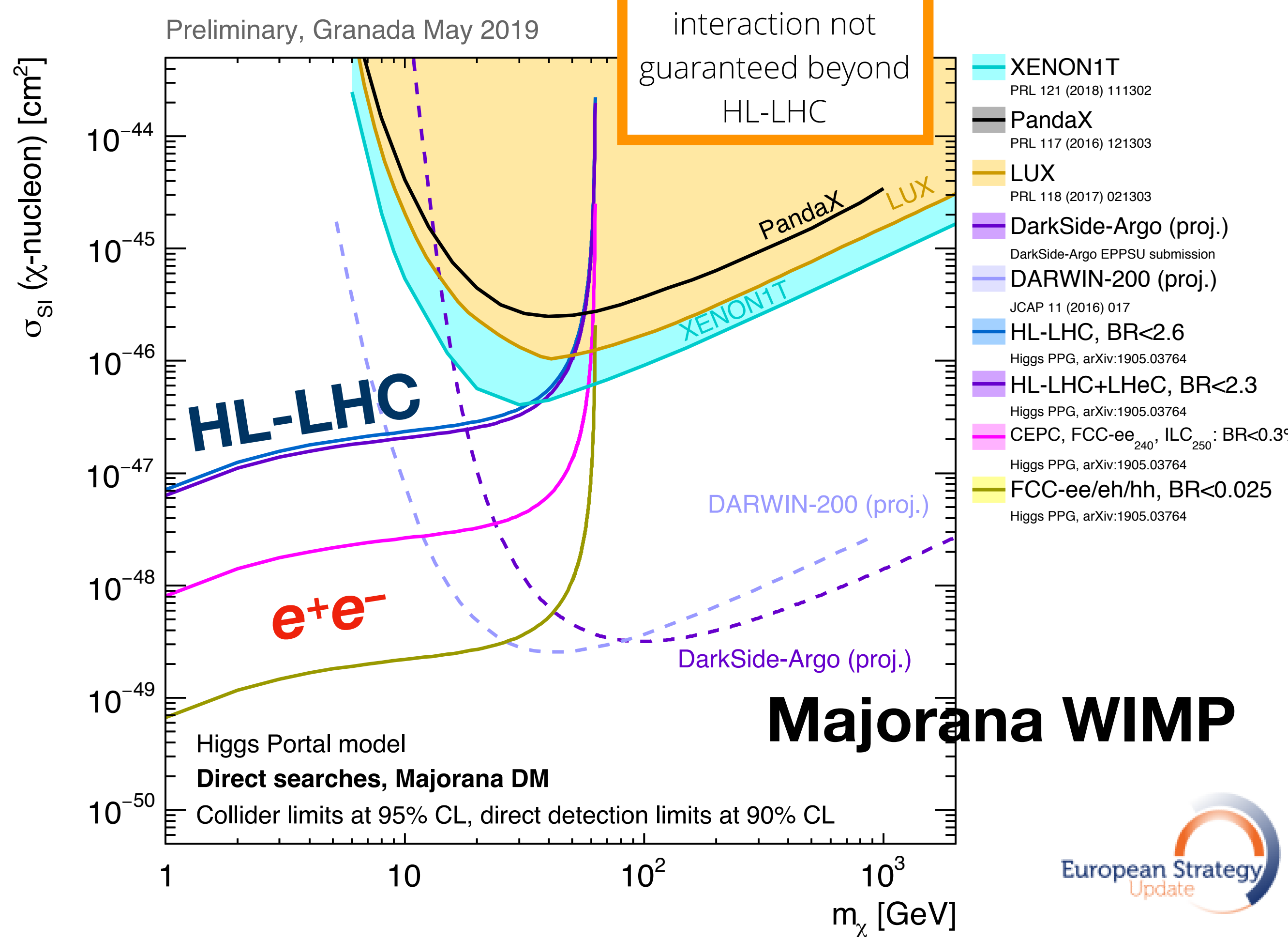


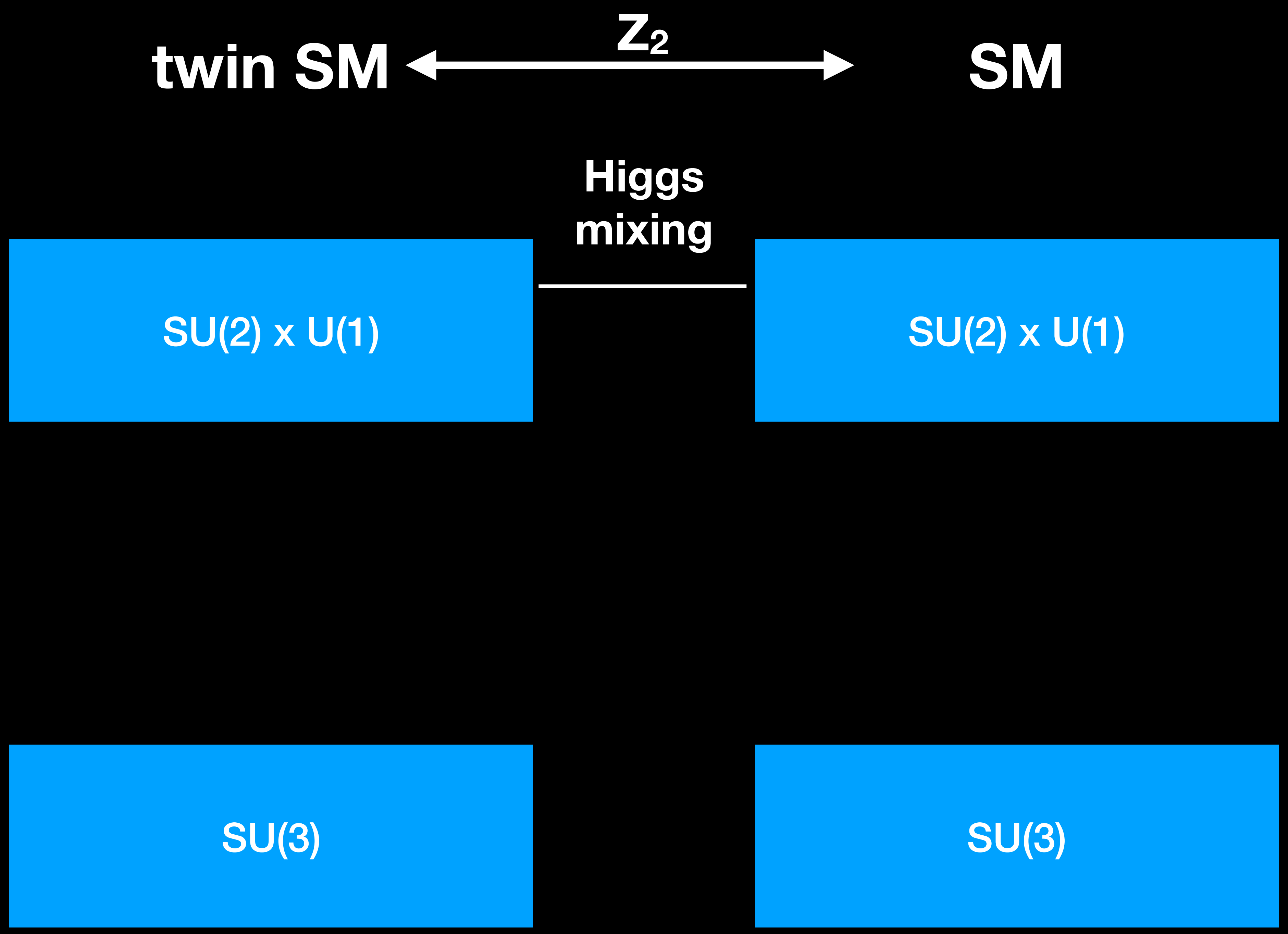




**direct detection limits**

Caveat: EFT validity in Higgs-DM interaction not guaranteed beyond HL-LHC

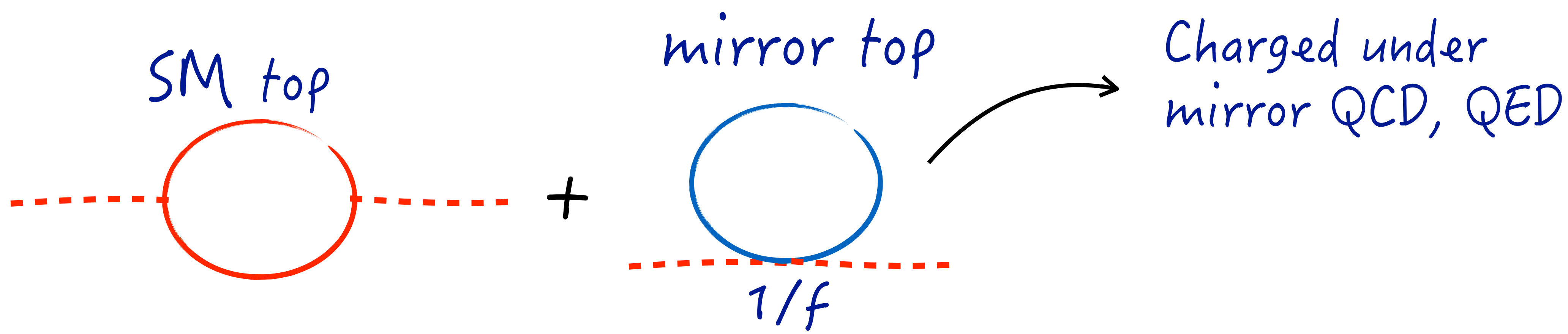



twin SM
$Z_2$
SM
Higgs mixing
SU(2) x U(1)
SU(2) x U(1)
SU(3)
SU(3)

# Twin Higgs

- All NP within LHC reach is SM neutral.
- PNGB Higgs, cancelation ...





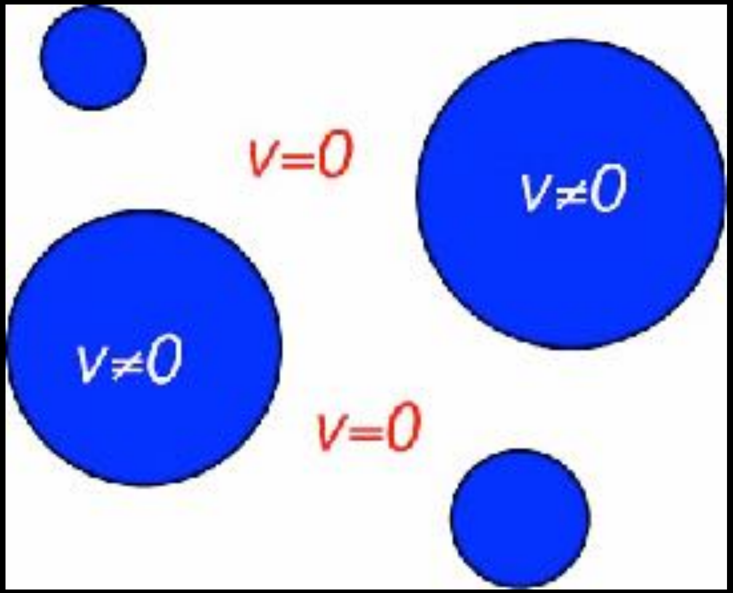
Roni Harnik and Zackaria Chacko, JHU workshop 2017 in Budapest

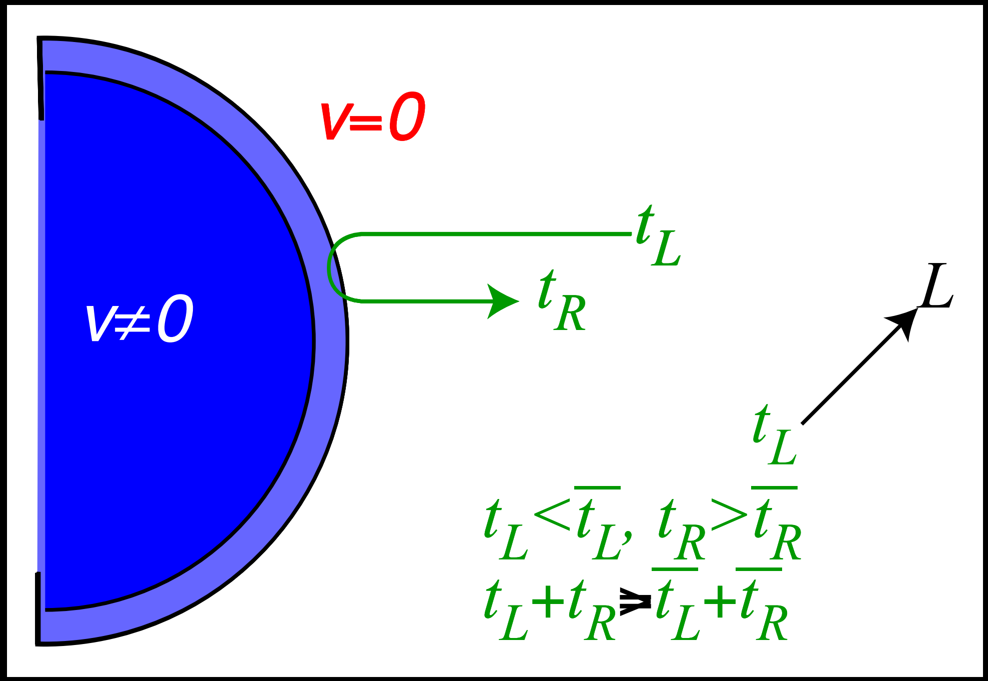
# Antisymmetric Matters genesis

Nell Hall, Thomas Konstandin,
HM, Robert McGehee
arXiv:1911.12342

# Electroweak Baryogenesis

- First-order phase transition
- Different reflection probabilities for $t_L$, $t_R$
- asymmetry in top quark
- Left-handed top quark asymmetry partially converted to lepton asymmetry via anomaly
- Remaining top quark asymmetry becomes baryon asymmetry
- need *varying CP phase* inside the bubble wall (G. Servant)
- fixed KM phase doesn't help
- need CPV in Higgs sector



# Electric Dipole Moment


Oct 2018

ARTICLE

https://doi.org/10.1038/s41586-018-0599-8

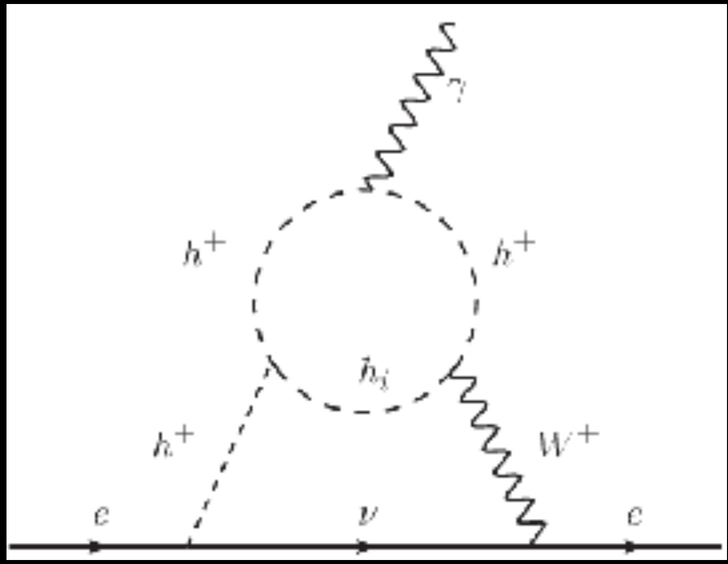
**Improved limit on the electric dipole moment of the electron**

ACME Collaboration*

- baryon asymmetry limited by the sphaleron rate $\Gamma \sim 20\, \alpha_W^5\, T \sim 10^{-6}\, T$

**$d_e \leq 1.1\times10^{-29}$ *e* cm**

- Can't lose much more to obtain $10^{-9}$
- need
  - new physics for 1st order PT at the Higgs scale v=250 GeV
  - CP violation×efficiency $\geq 10^{-3}$




**Barr-Zee diagrams**

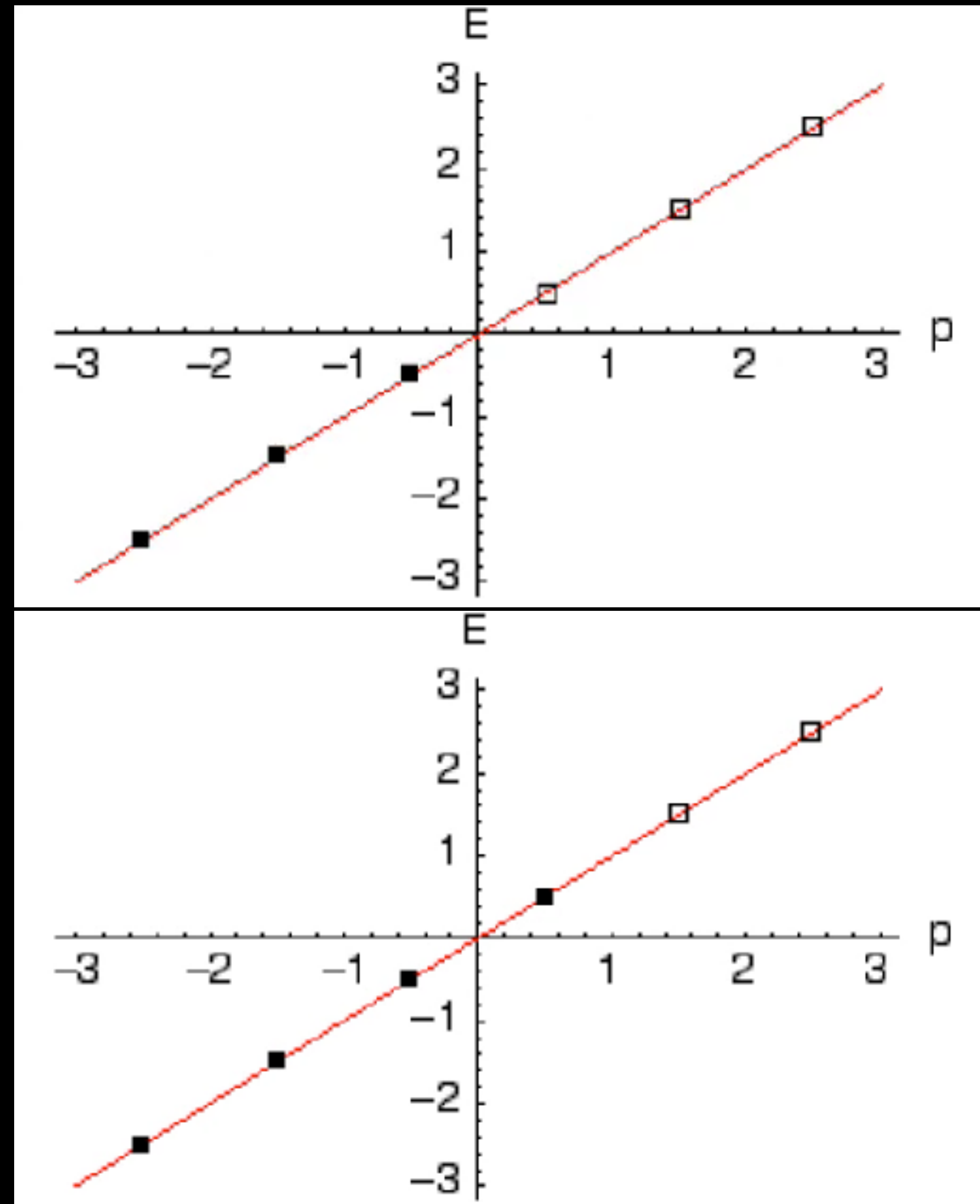
$$d_e \approx \frac{e m_e}{(16\pi^2)^2}\frac{1}{v^2}\sin\delta = 1.6\times10^{-22} e\mathrm{cm}\sin\delta$$

# Anomaly!

- *W* and *Z* bosons massless at high temperature
- *W* field fluctuates just like in thermal plasma
- solve Dirac equation in the presence of the fluctuating *W* field

$$\Delta q = \Delta q = \Delta q = \Delta L$$

$\tau(^3He \rightarrow e^+ \mu^+ \bar{\nu}_\tau) \sim 10^{150}$yrs



# Sakharov Conditions

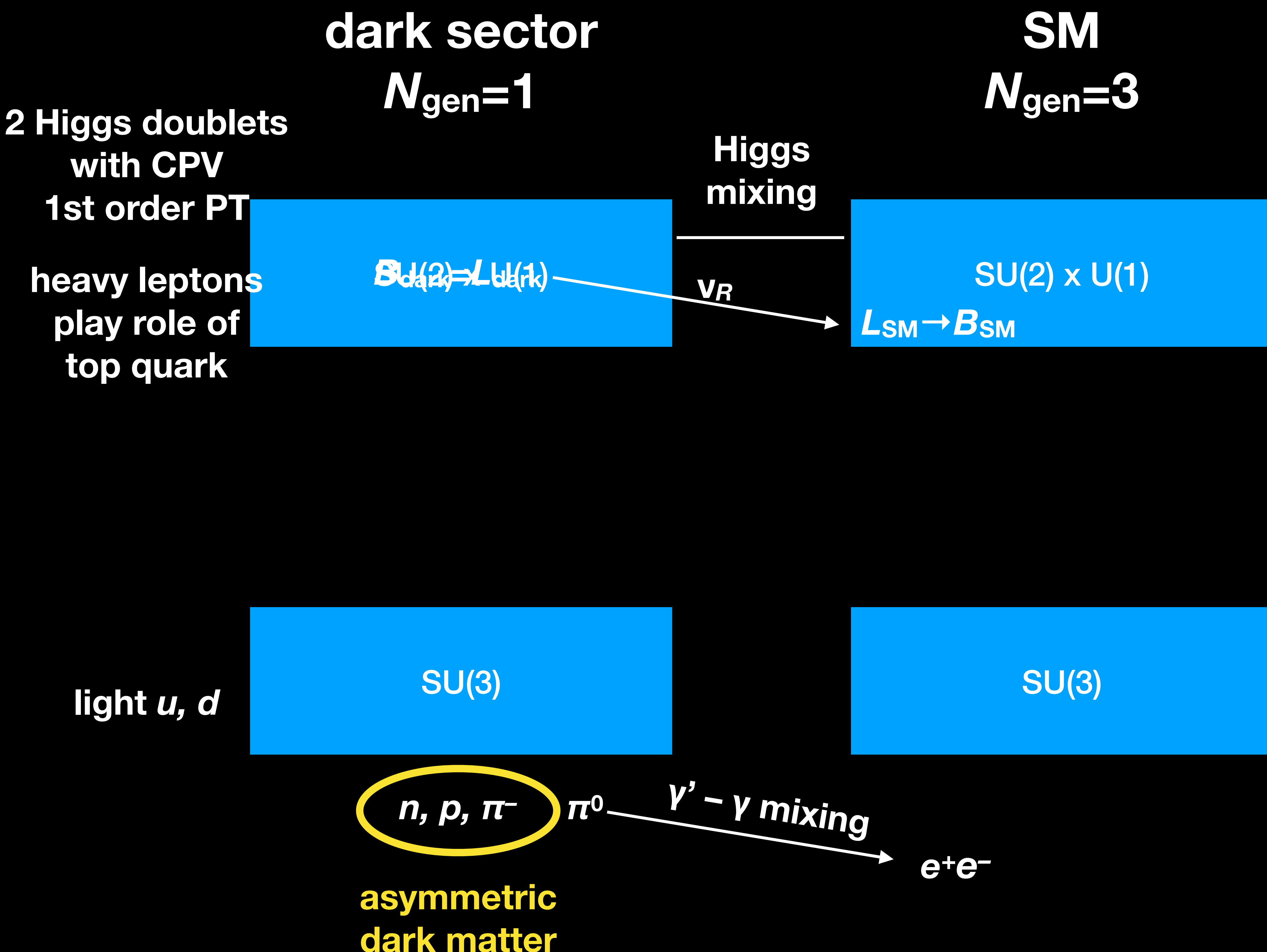
- Standard Model may have all three ingredients
- Baryon number violation
  - Electroweak anomaly (sphaleron effect)
- CP violation
  - Kobayashi–Maskawa phase

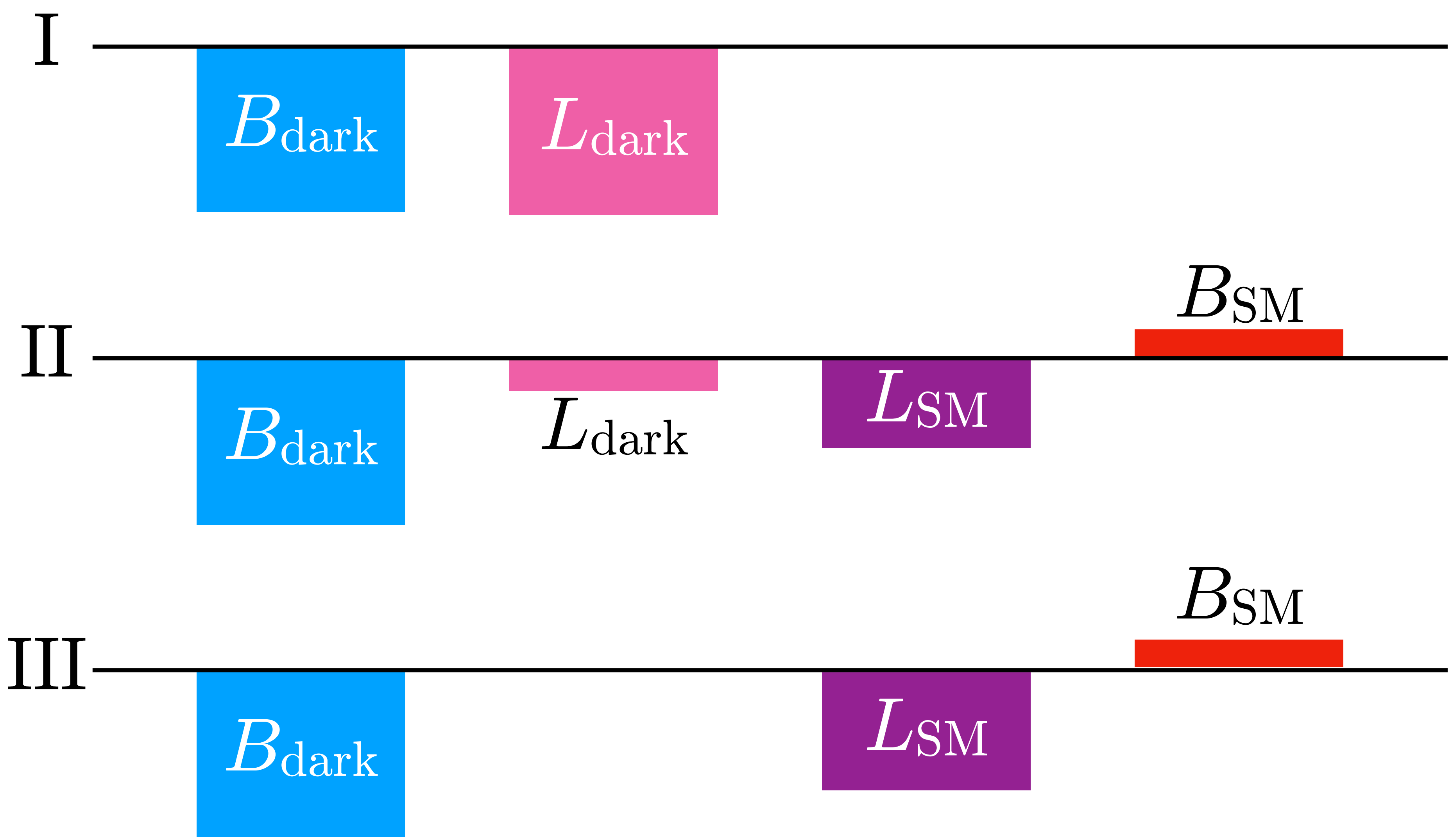
$$J \propto \det[M_u^\dagger M_u, M_d^\dagger M_d]/T_{EW}^{12} \sim 10^{-20} \ll 10^{-10}$$

- Non-equilibrium
  - First-order phase transition of Higgs

**requires $m_h < 75$ GeV**

- Experimentally testable?

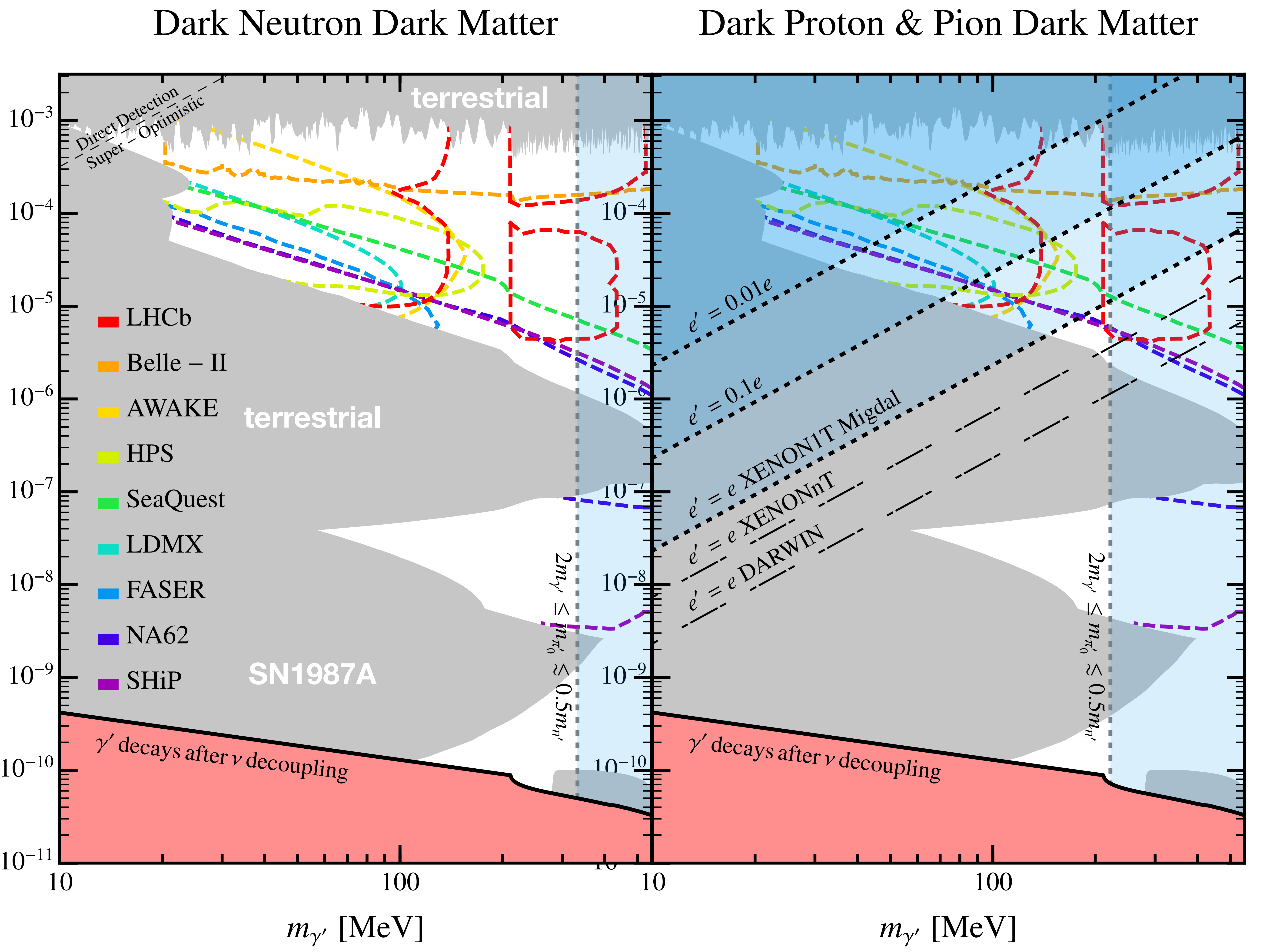

dark sector
Ngen=1
SM
Ngen=3
2 Higgs doublets
with CPV
1st order PT
heavy leptons
play role of
top quark
Higgs
mixing
SU(2) x U(1)
Bdark→Ldark
νR
SU(2) x U(1)
LSM→BSM
light u, d
SU(3)
SU(3)
n, p, π−
π0
γ' – γ mixing
e+e−
asymmetric
dark matter



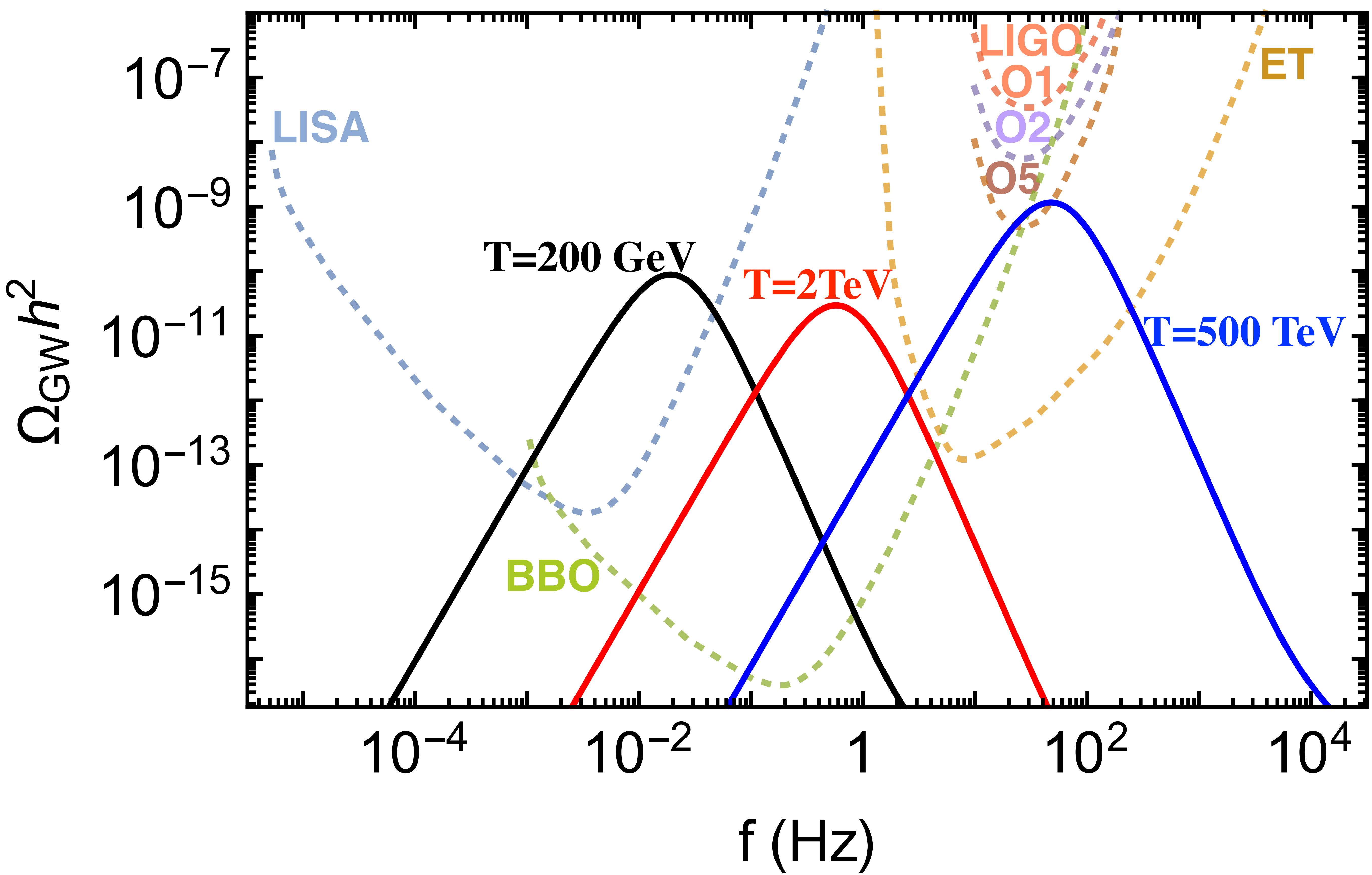

**If $M_N > T_{\rm sphaleron}$** $B_{\rm SM} = \frac{36}{133} B_{\rm dark}, \quad L_{\rm SM} = -\frac{97}{133} B_{\rm dark}$ **$m_{n'}$=1.58 GeV**

**If $M_N < T_{\rm sphaleron}$** $B_{\rm SM} = \frac{12}{37} B_{\rm dark}, \quad L_{\rm SM} = -\frac{25}{37} B_{\rm dark}$ **$m_{n'}$=1.33 GeV**

**If the asymmetry goes from SM (leptogenesis?) to dark sector, dark baryons are ~20 GeV**



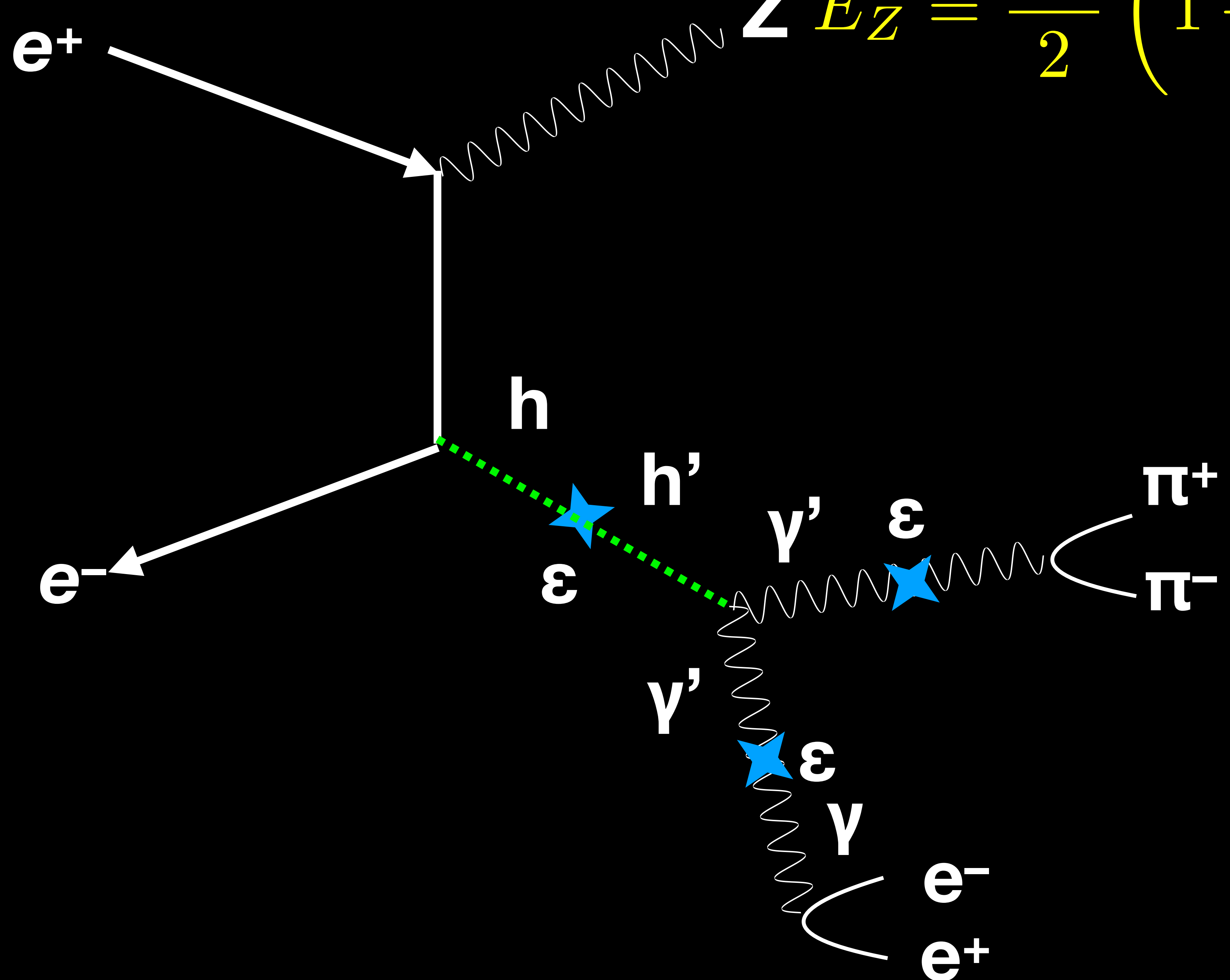
Dark Neutron Dark Matter
Dark Proton & Pion Dark Matter
terrestrial
Direct Detection
Super − Optimistic
LHCb
Belle − II
AWAKE
HPS
SeaQuest
LDMX
FASER
NA62
SHiP
terrestrial
SN1987A
$\gamma'$ decays after $\nu$ decoupling
$2m_{\gamma'} \leq m_{\pi'_0} \lesssim 0.5 m_{n'}$
$e' = 0.01e$
$e' = 0.1e$
$e' = e$ XENON1T Migdal
$e' = e$ XENONnT
$e' = e$ DARWIN
$m_{\gamma'}$ [MeV]



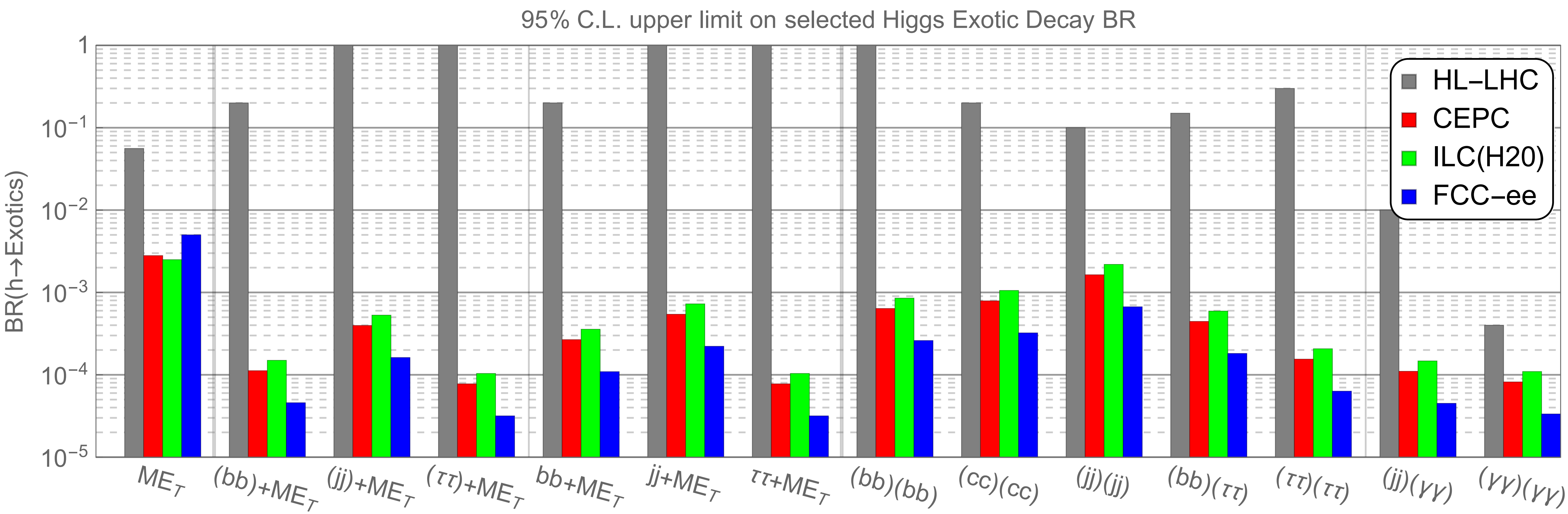
LISA
BBO
LIGO
O1
O2
O5
ET
T=200 GeV
T=2TeV
T=500 TeV
$\Omega_{GW}h^2$
$10^{-7}$
$10^{-9}$
$10^{-11}$
$10^{-13}$
$10^{-15}$
$10^{-4}$
$10^{-2}$
1
$10^{2}$
$10^{4}$
f (Hz)

# Higgs portal

$$E_Z = \frac{\sqrt{s}}{2}\left(1 + \frac{m_Z^2}{s} - \frac{M_h^2}{s}\right)$$

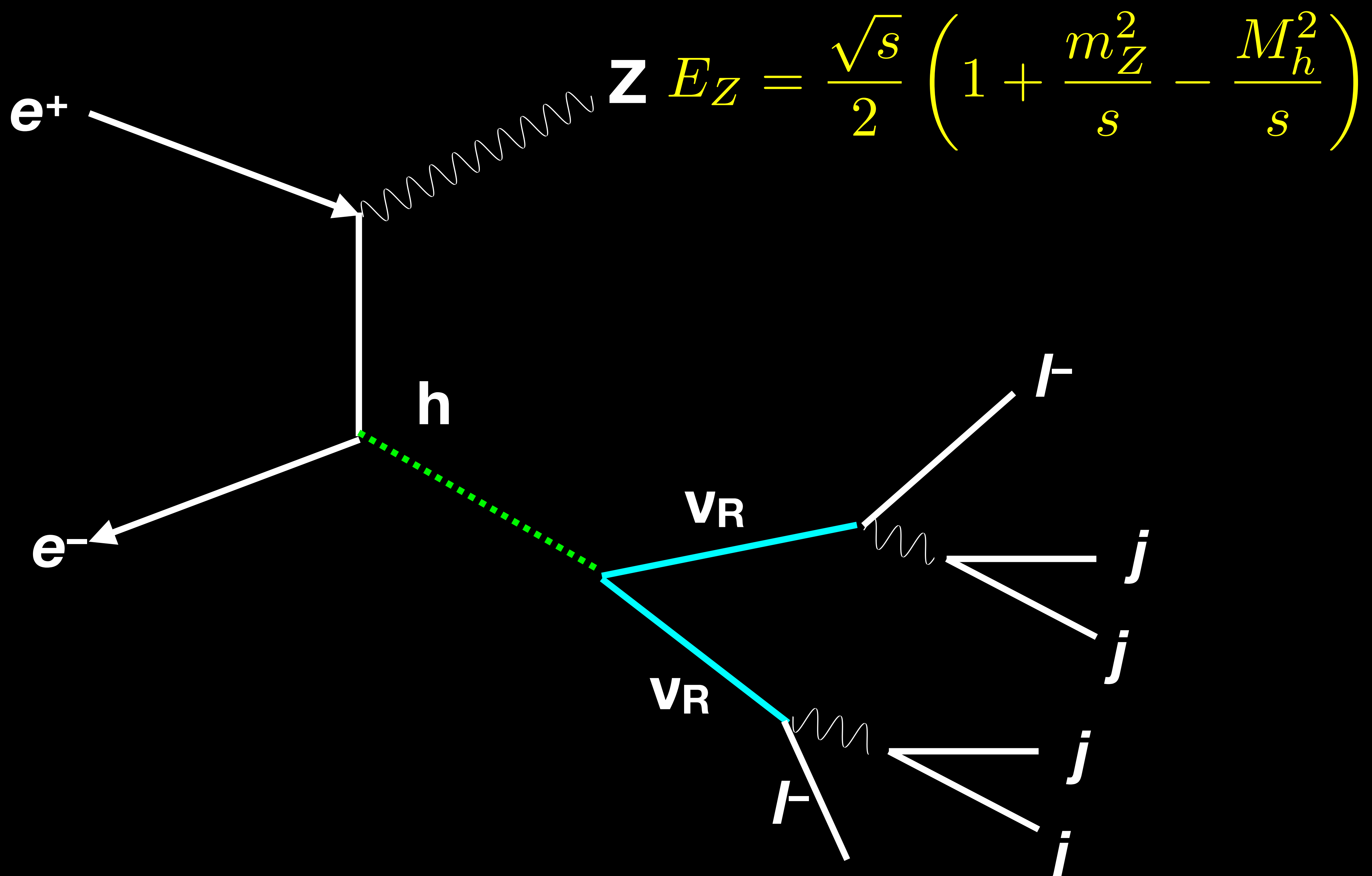


# Higgs →dark sector →SM

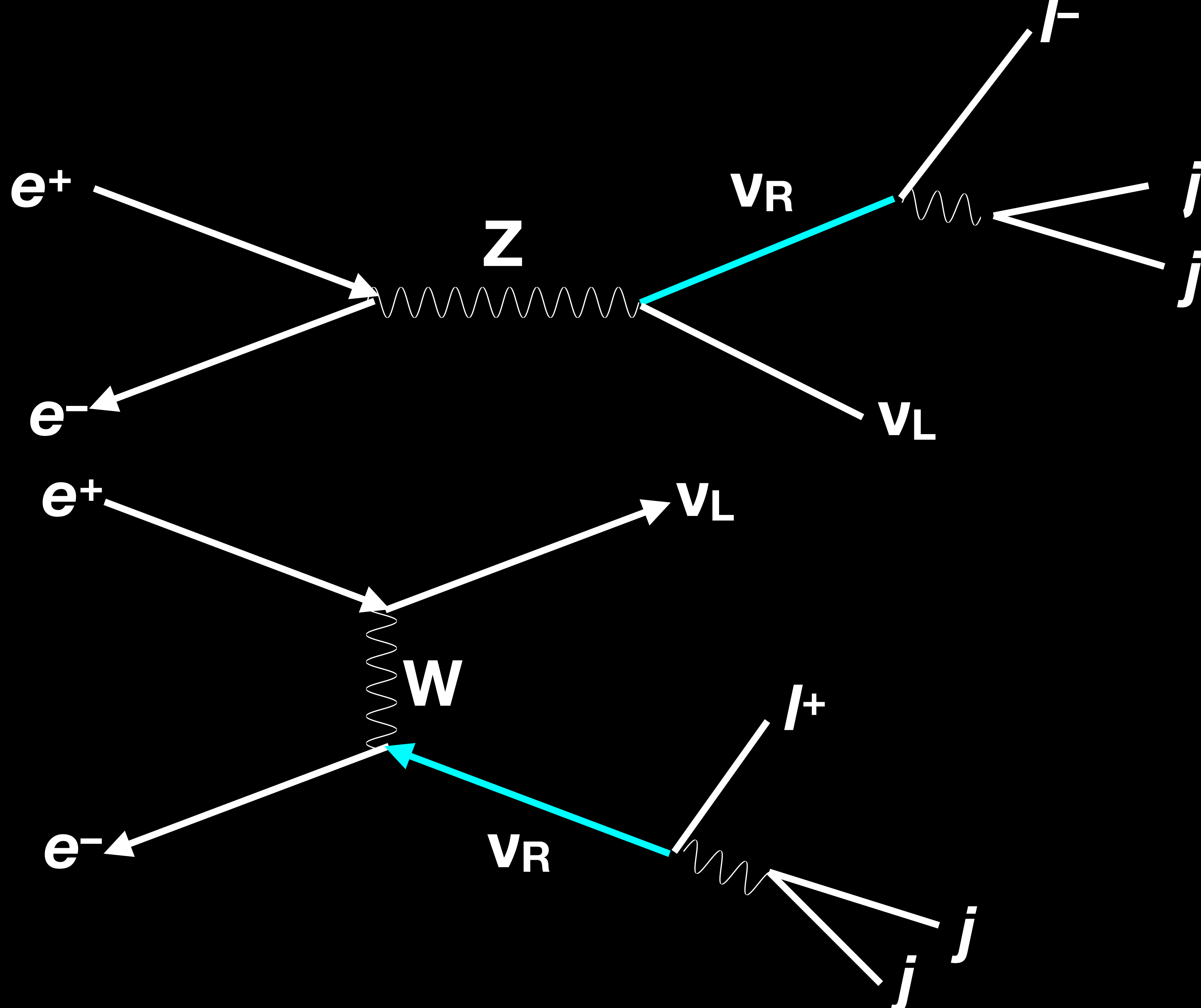


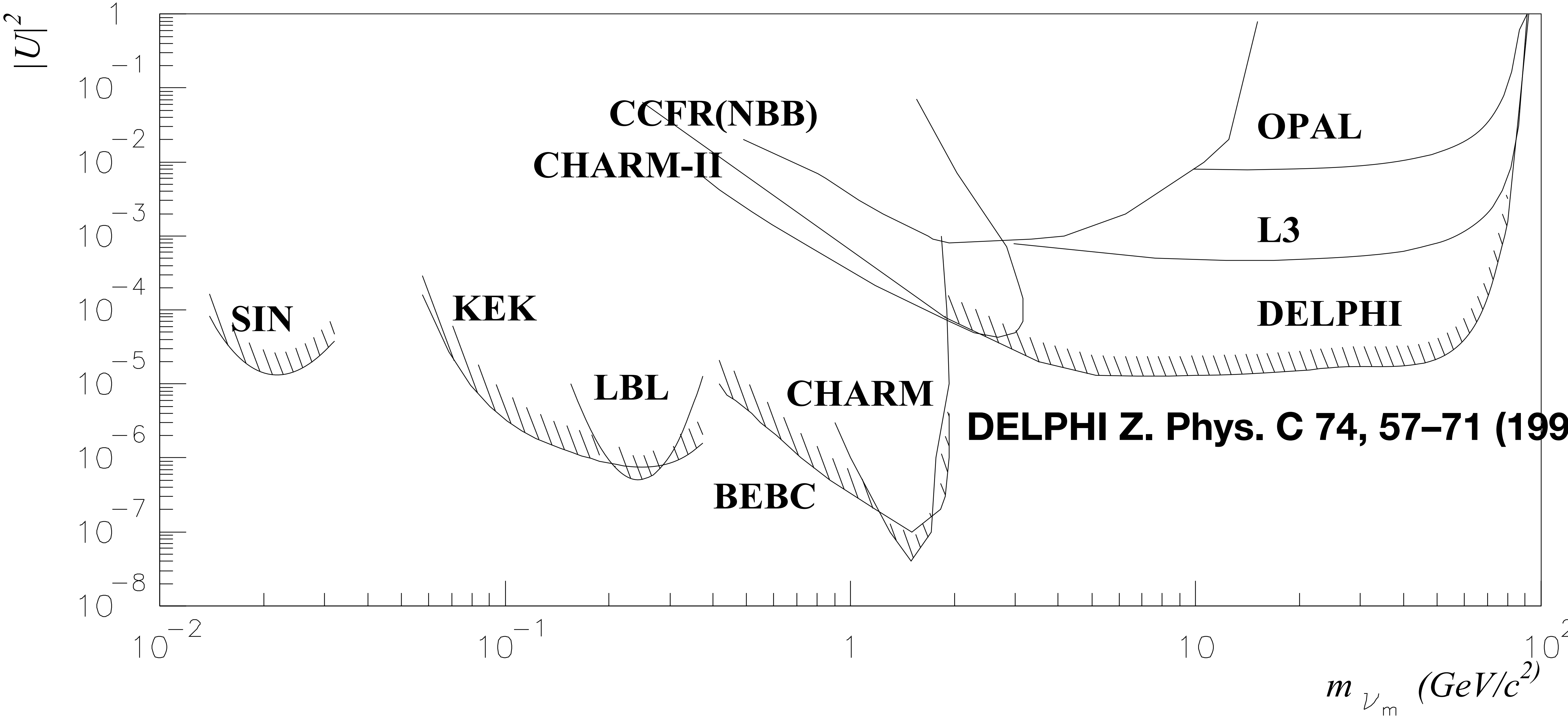

**Zhen Liu, Lian-Tao Wang, Hao Zhang, arXiv:1612.09284**

# neutrino portal

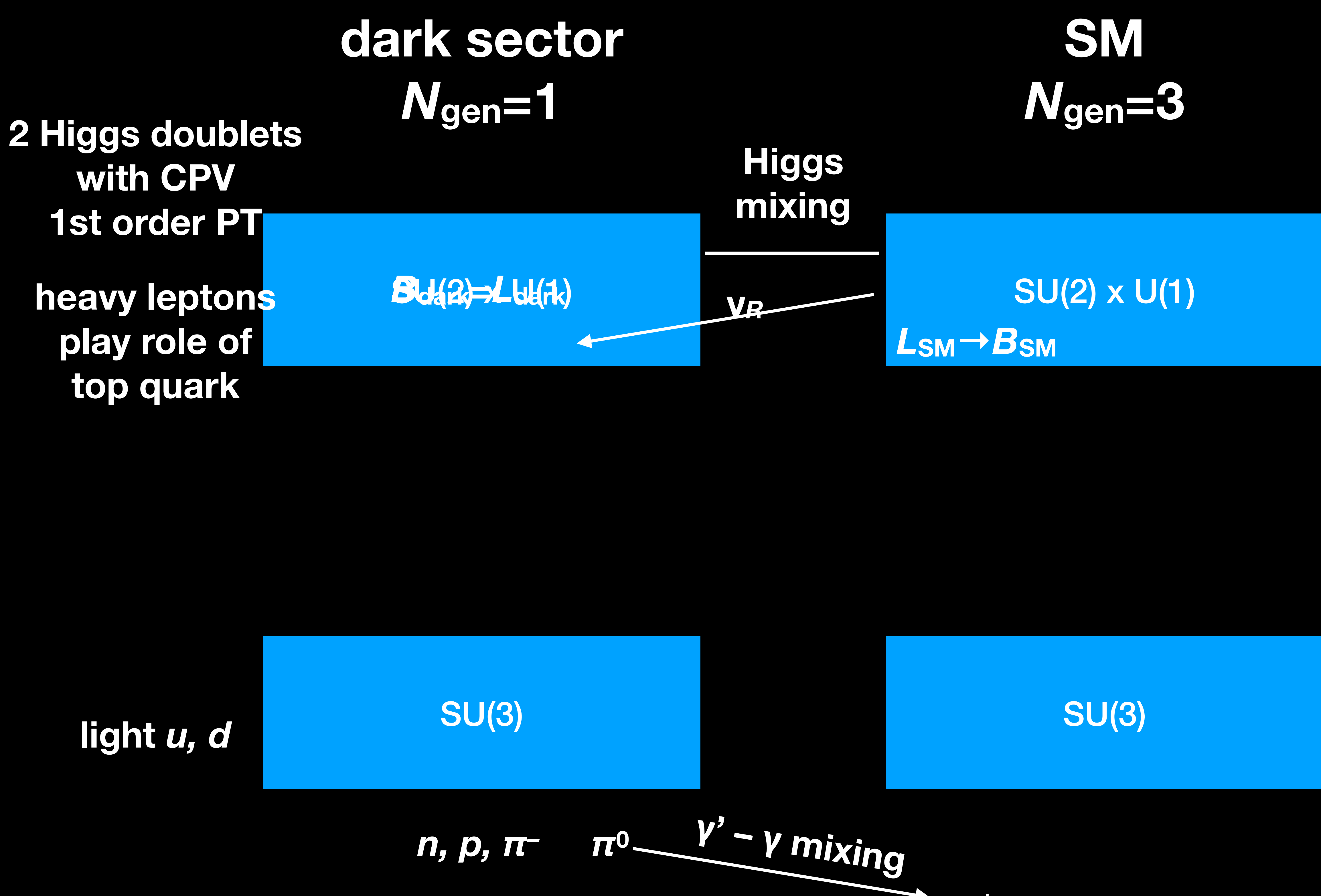


# neutrino portal





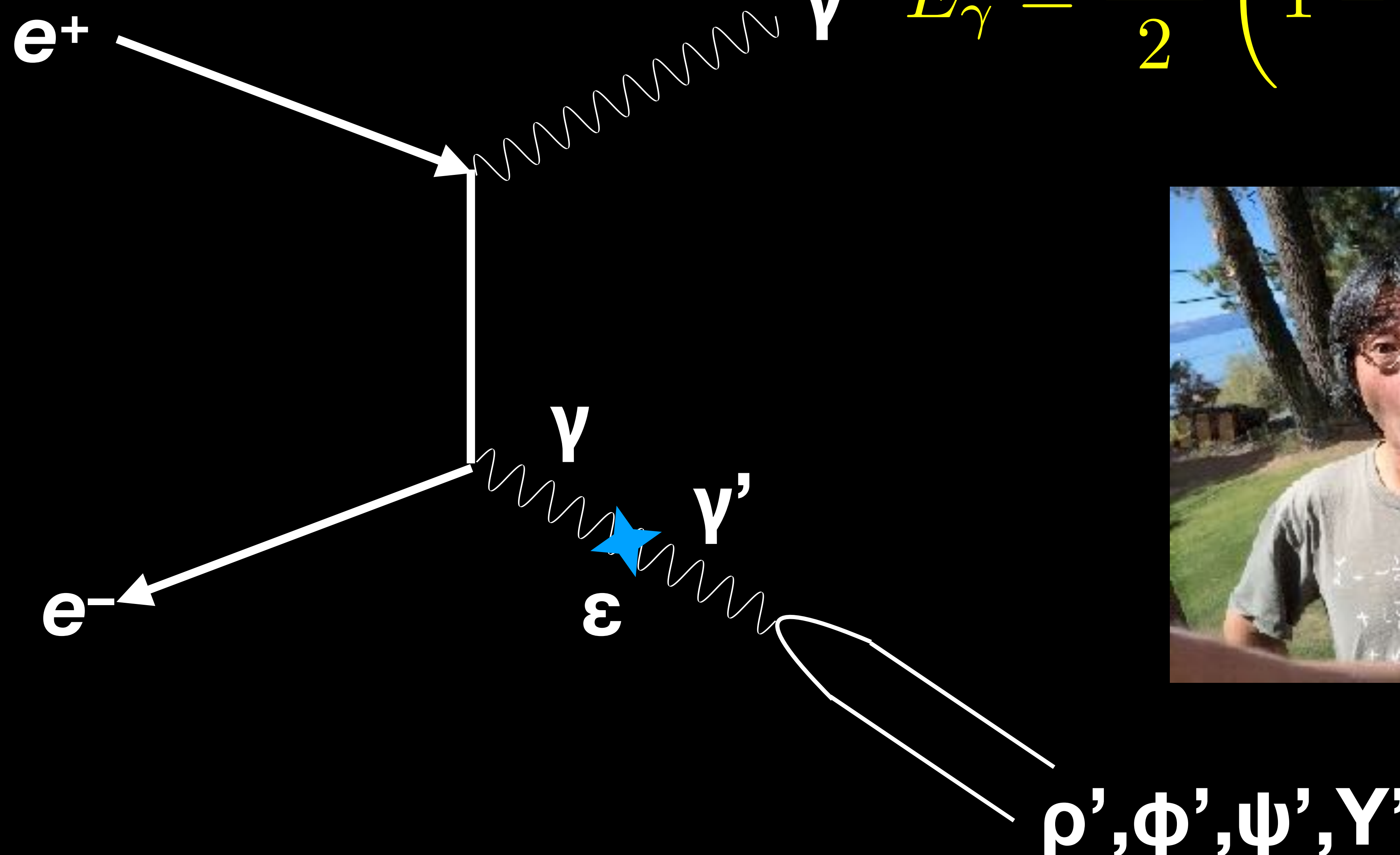

DELPHI Z. Phys. C 74, 57–71 (1997)



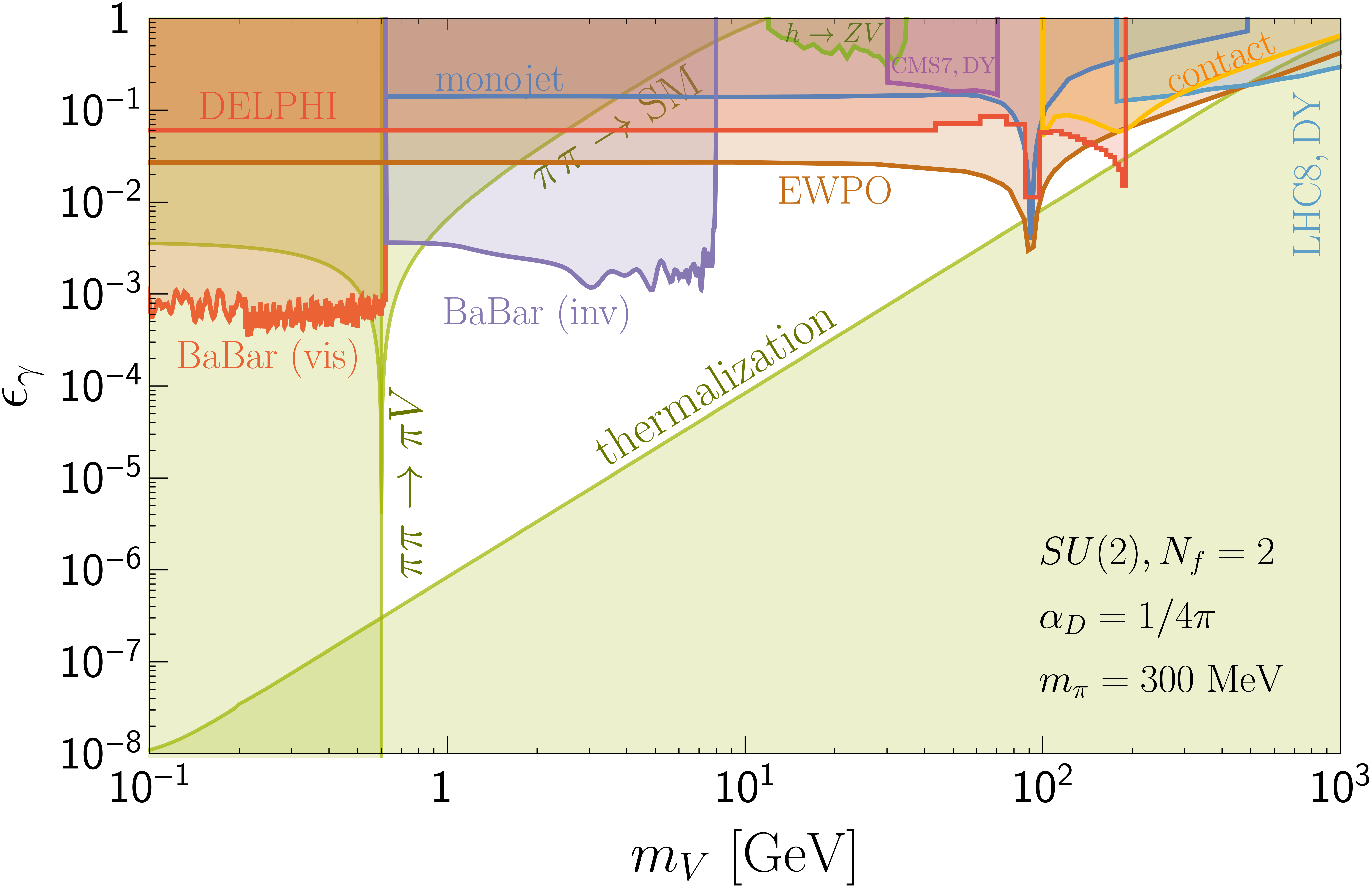

If the asymmetry goes from SM to dark sector,
dark baryons are ~50 GeV

# Dark Spectroscopy

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

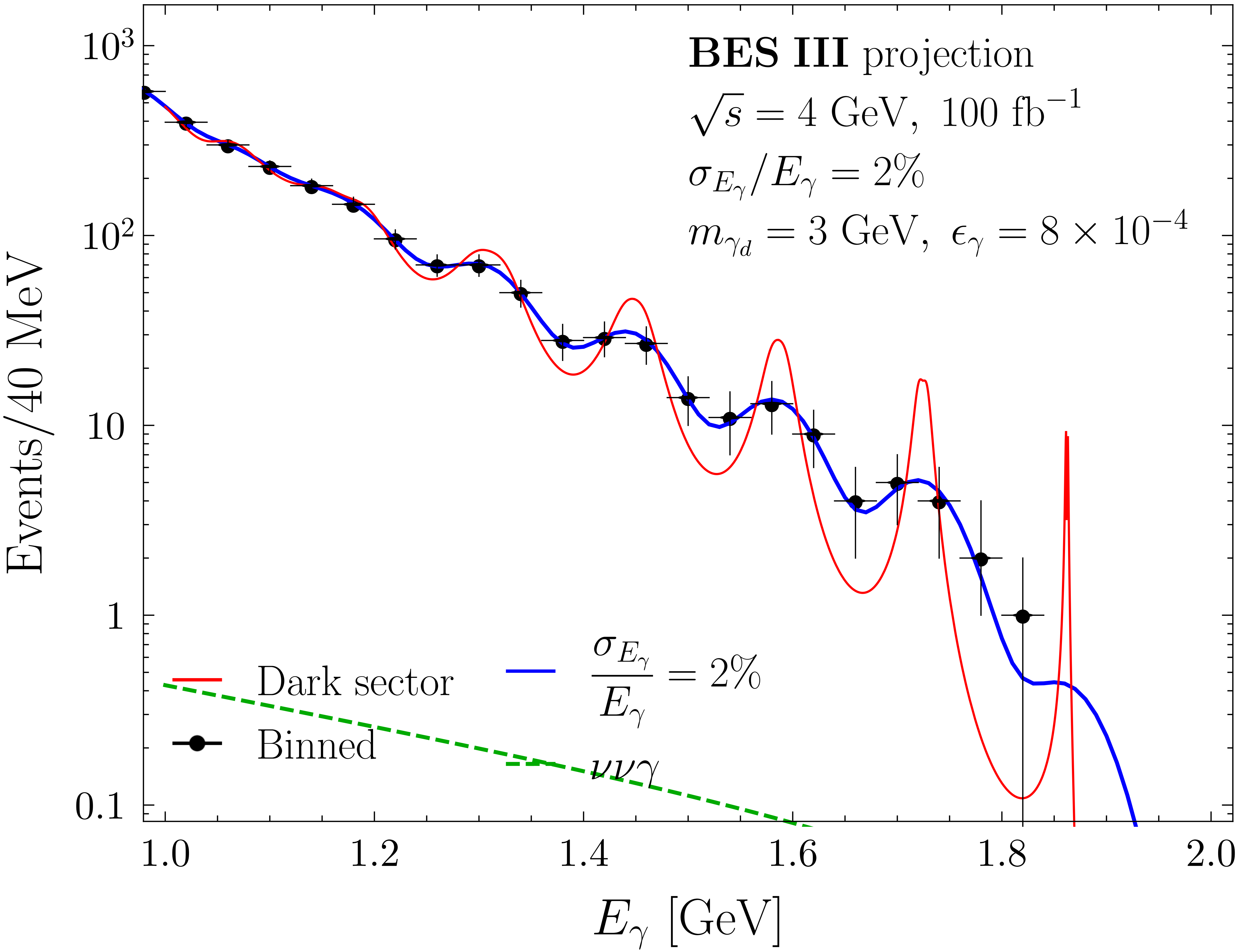



Yonit Hochberg, Eric Kuflik, HM, arXiv:1512.07917, 1706.05008

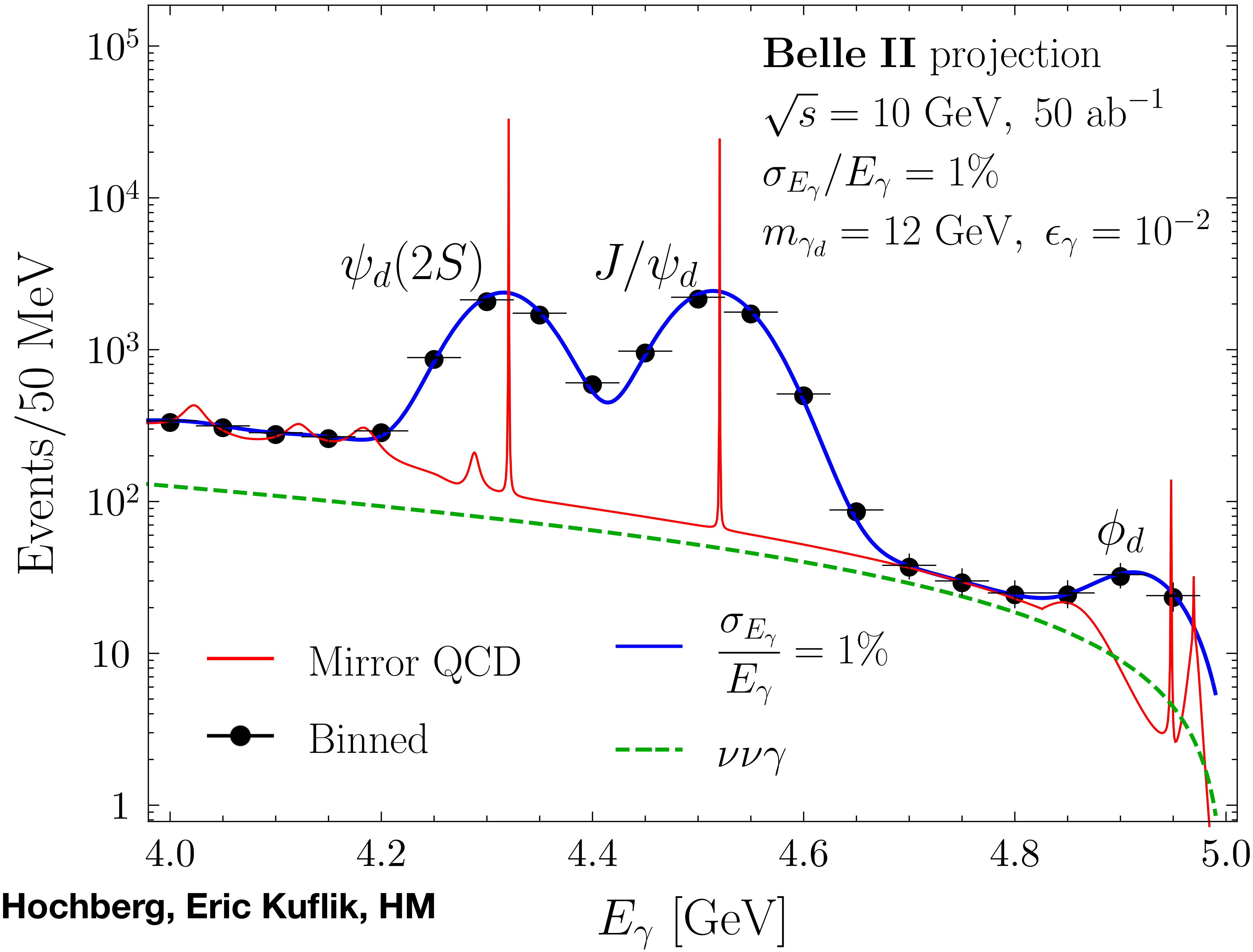


DELPHI
monojet
$\pi\pi \to SM$
$h \to ZV$
CMS7, DY
contact
LHC8, DY
EWPO
BaBar (inv)
BaBar (vis)
$\pi\pi \to \pi V$
thermalization
$SU(2), N_f = 2$
$\alpha_D = 1/4\pi$
$m_\pi = 300$ MeV
$\epsilon_\gamma$
$m_V$ [GeV]
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$10^{-8}$
$10^{-1}$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

# Dark Spectroscopy

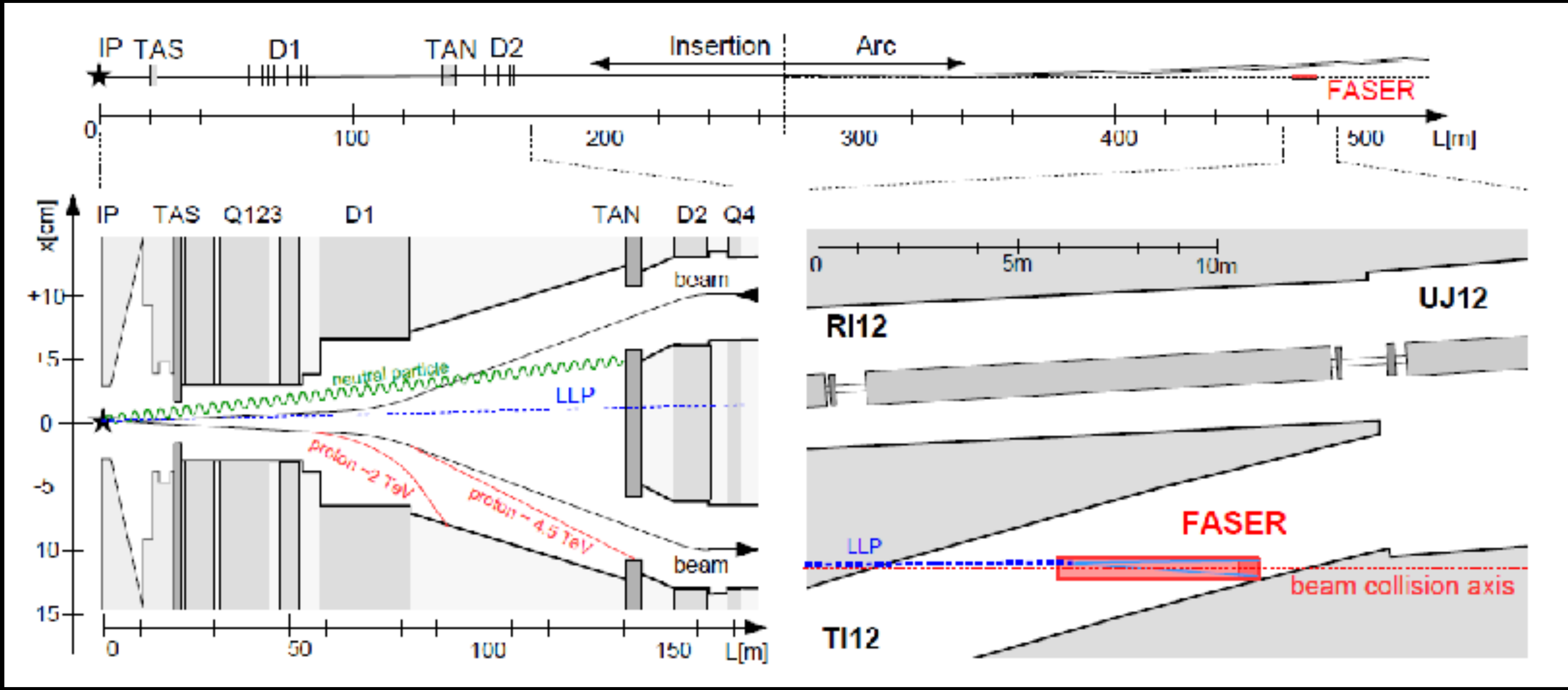


# Dark Spectroscopy

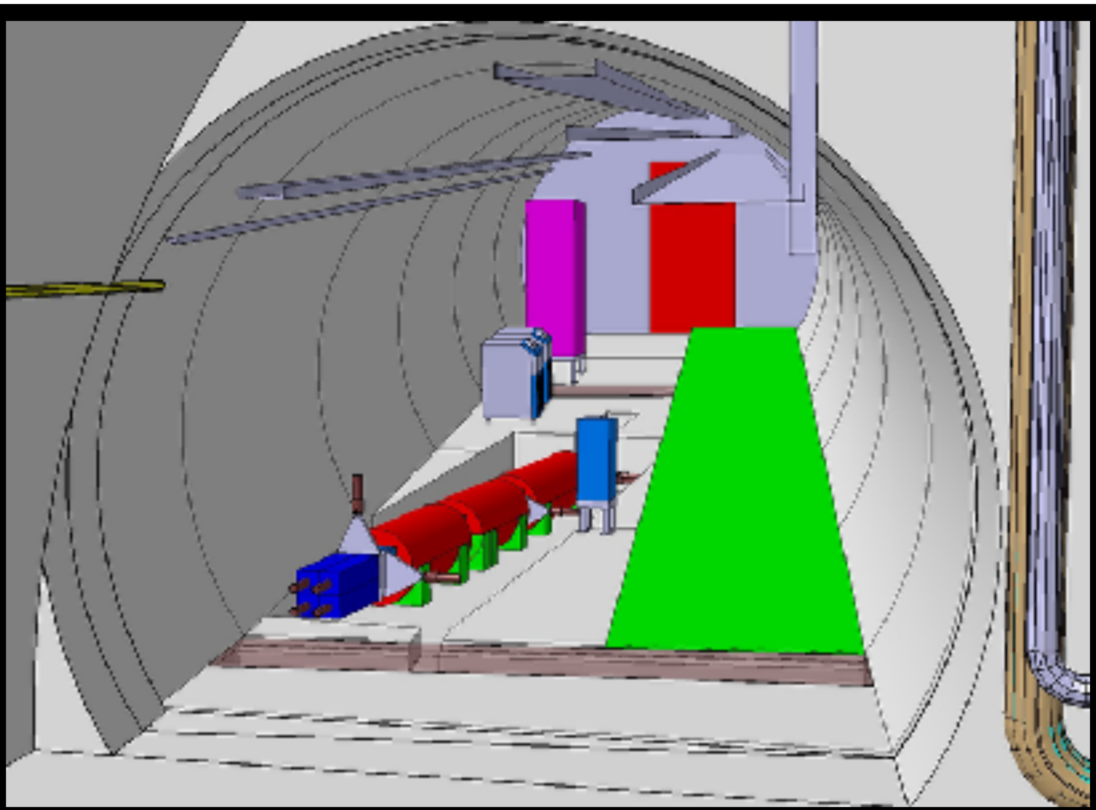



**Yonit Hochberg, Eric Kuflik, HM**

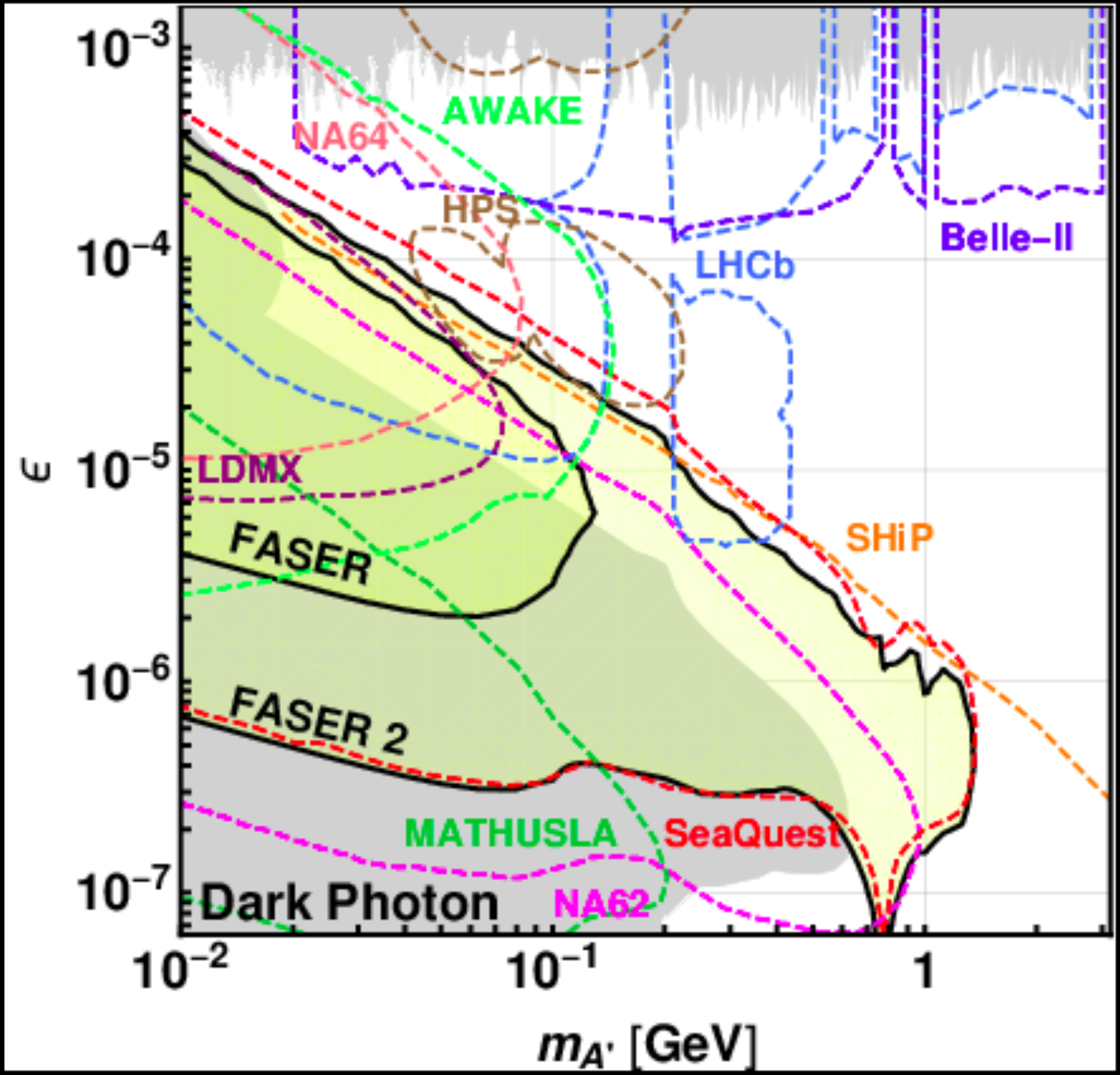
# FASER@LHC



IP TAS D1 TAN D2
Insertion
Arc
FASER
0
100
200
300
400
500
L[m]
x[cm]
IP TAS Q123 D1 TAN D2 Q4
+10
+5
0
-5
-10
-15
beam
neutral particle
LLP
proton ~2 TeV
proton ~ 4.5 TeV
beam
0
50
100
150
L[m]
0
5m
10m
UJ12
RI12
FASER
LLP
beam collision axis
TI12

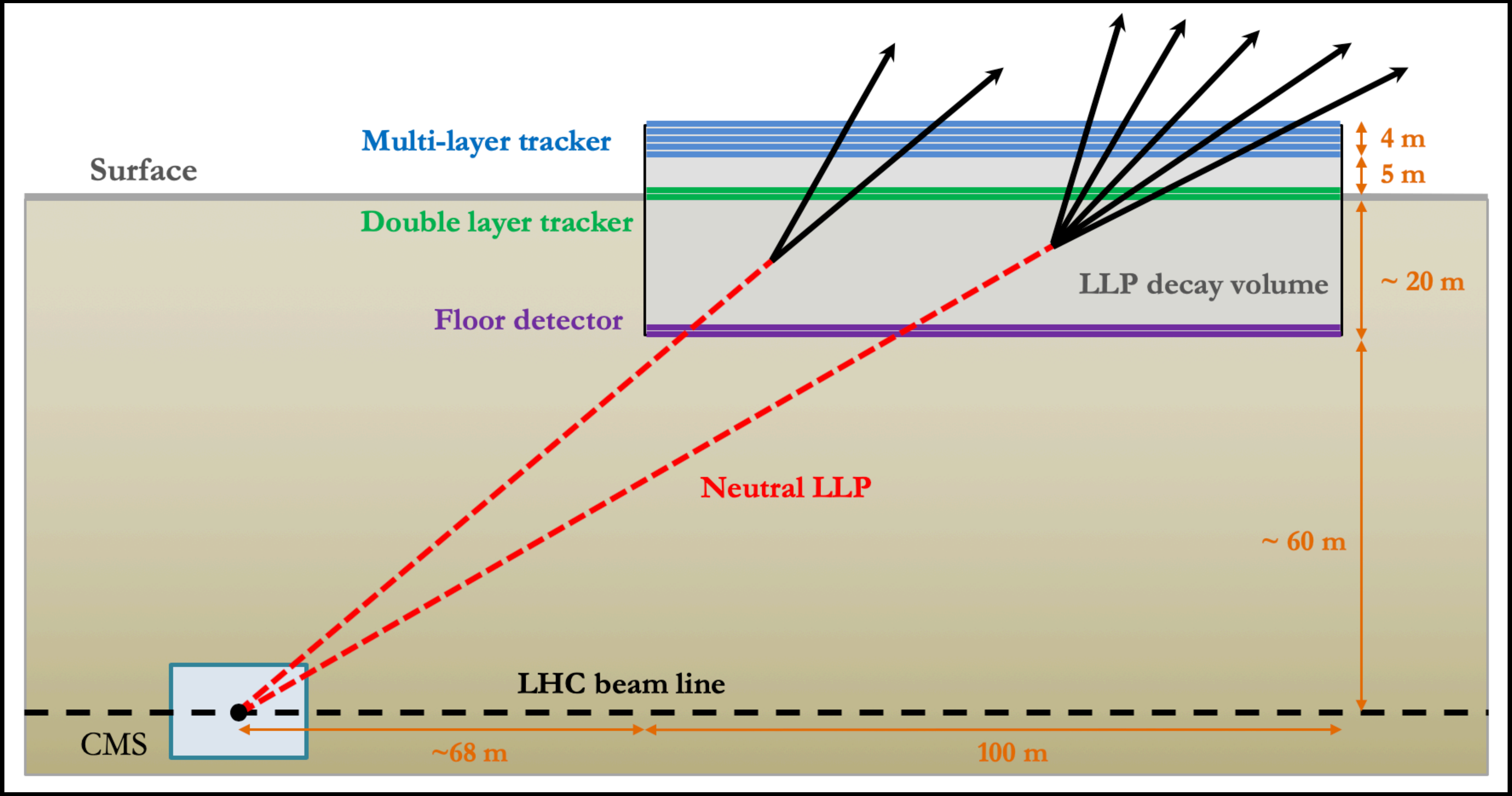



# FASER@LHC

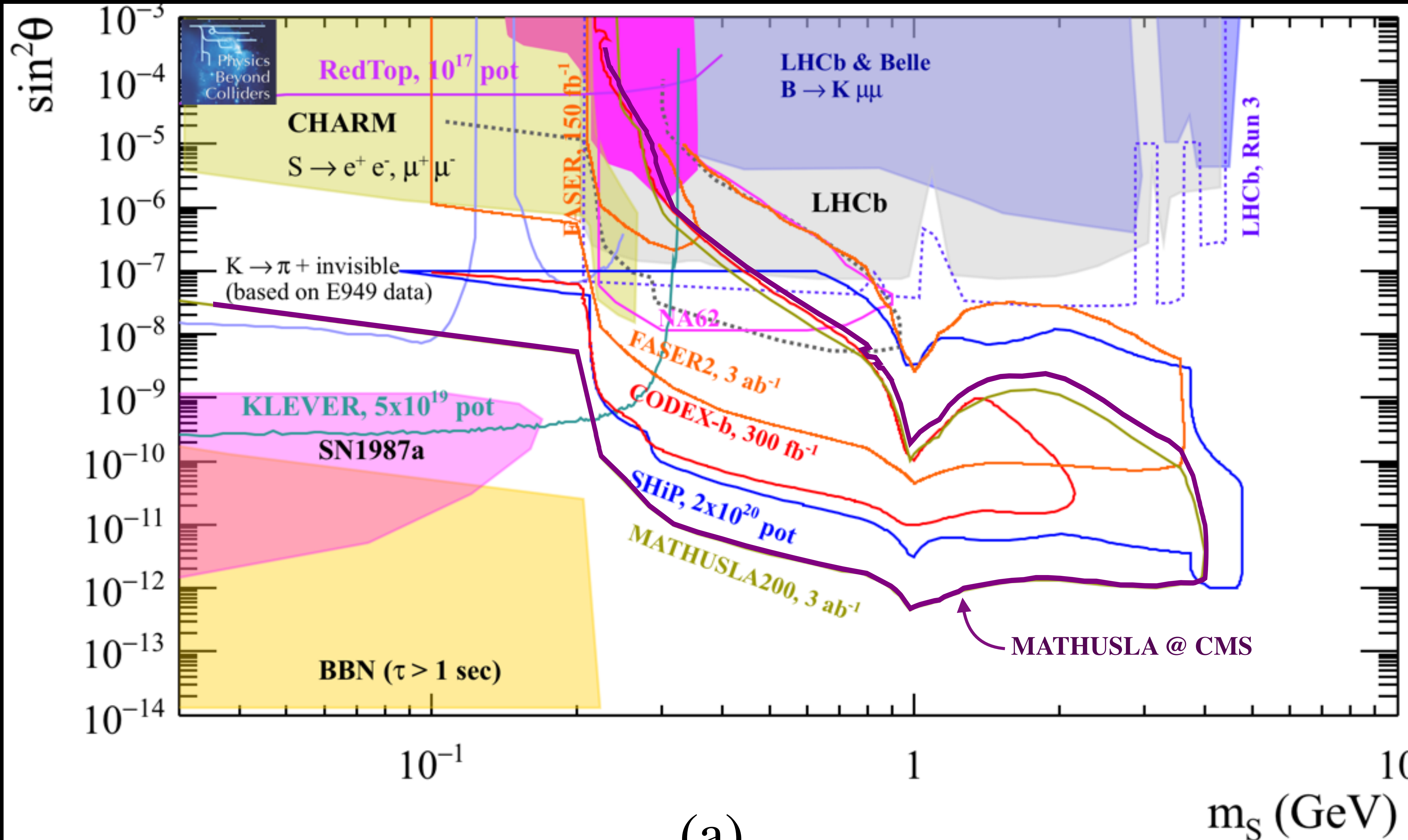


$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$\epsilon$
AWAKE
NA64
HPS
LHCb
Belle-II
LDMX
FASER
SHiP
FASER 2
MATHUSLA
SeaQuest
Dark Photon
NA62
$10^{-2}$
$10^{-1}$
1
$m_{A'}$ [GeV]

# Mathulsa@LHC



# Mathulsa@LHC




a long-lived scalar mixed with Higgs

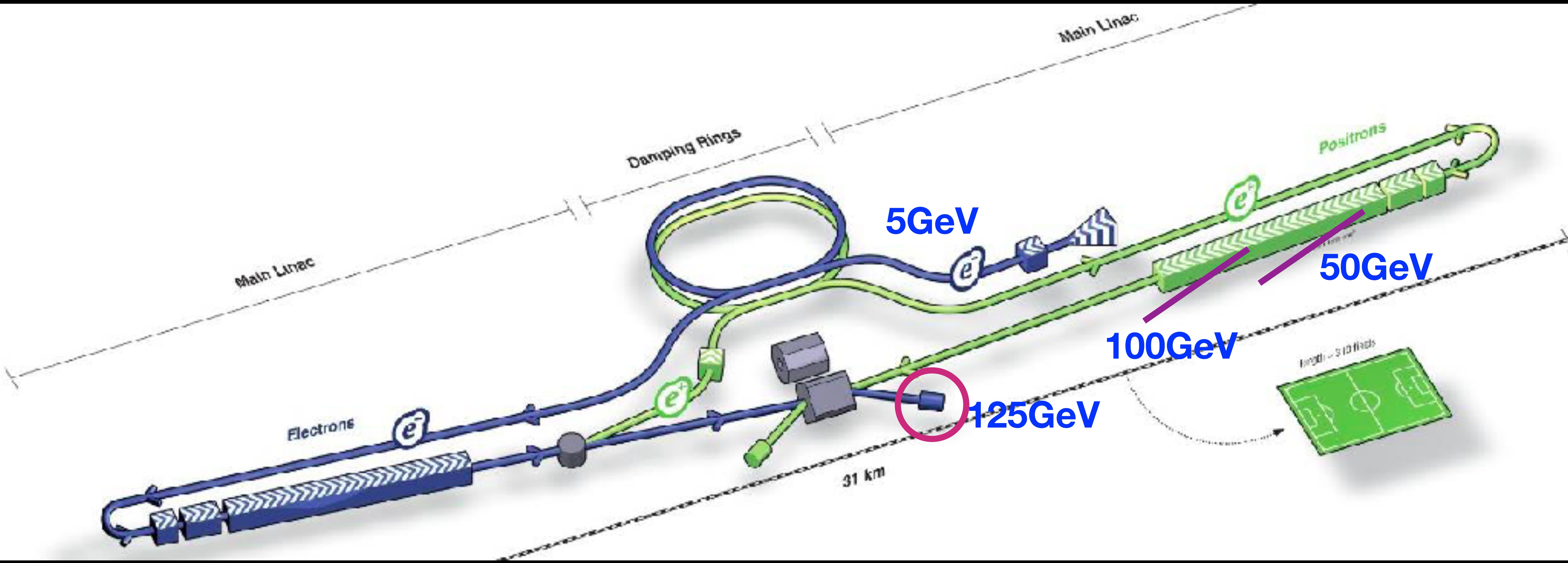
**Table 1.** Projects considered in the PBC–BSM working group categorized in terms of their sensitivity to a set of benchmark models in a given mass range. The characteristics of the required beam lines, whenever applicable, are also displayed.

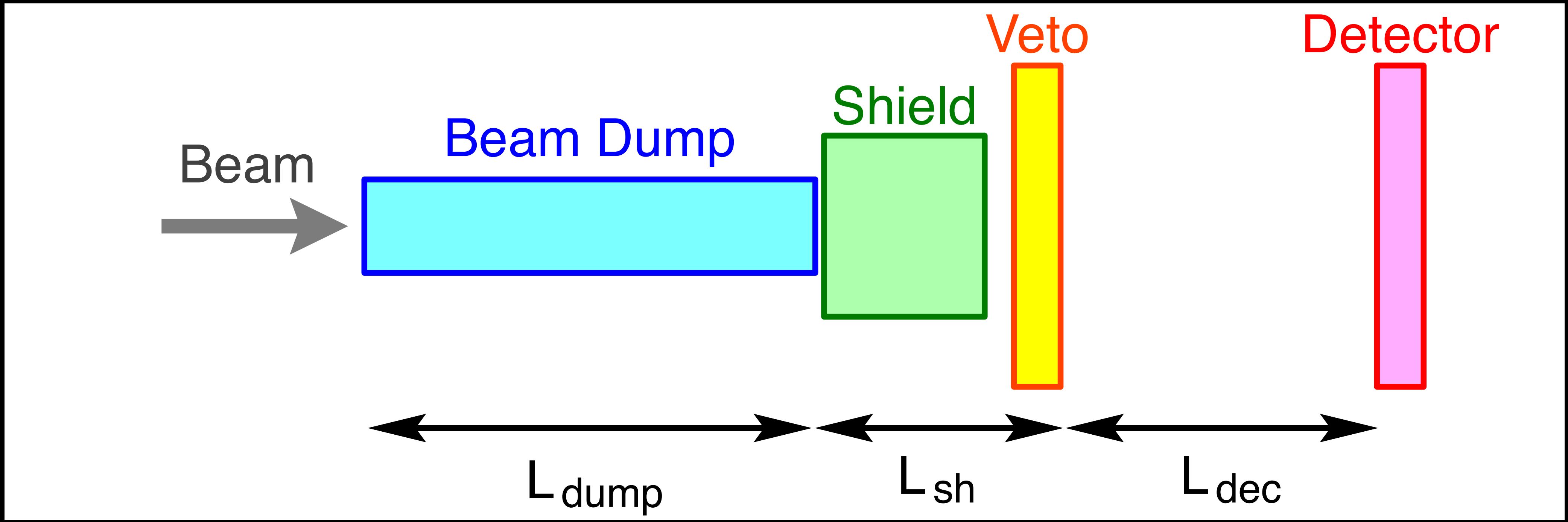
| Proposal | Main physics cases | Beam line | Beam type | Beam yield |
|---|---|---|---|---|
| **Sub-eV mass range:** | | | | |
| IAXO | Axions/ALPs (photon coupling) | — | Axions from sun | — |
| JURA | Axions/ALPs (photon coupling) | Laboratory | eV photons | — |
| CPEDM | $p$, $d$ oEDMs | EDM ring | $p$, $d$ | — |
| | axions/ALPs (gluon coupling) | | $p$, $d$ | — |
| LHC-FT | Charmed hadrons oEDMs | LHCb IP | 7 TeV $p$ | — |
| **MeV–GeV mass range:** | | | | |
| SHiP | ALPs, dark photons, dark scalars LDM, HNLs, lepto-phobic DM, | BDF, SPS | 400 GeV $p$ | $2 \times 10^{20}$/5 years |
| $NA62^{++}$ | ALPs, dark photons, dark scalars, HNLs | K12, SPS | 400 GeV $p$ | up to $3 \times 10^{18}$/year |
| $NA64^{++}$ | ALPs, dark photons, dark scalars, LDM | H4, SPS | 100 GeV $e^-$ | $5 \times 10^{12}$ eot/year |
| | $+ L_\mu - L_\tau$ | M2, SPS | 160 GeV $\mu$ | $10^{12} - 10^{13}$ mot/year |
| | + CP, CPT, leptophobic DM | H2-H8, T9 | $\sim$40 GeV $\pi$, $K$, $p$ | $5 \times 10^{12}$/year |
| LDMX | Dark photon, LDM, ALPs | eSPS | 8 (SLAC) -16 (eSPS) GeV $e^-$ | $10^{16} - 10^{18}$ eot/year |
| AWAKE/NA64 | Dark photon | AWAKE beam | 30-50 GeV $e^-$ | $10^{16}$ eot/year |
| REDTOP | Dark photon, dark scalar, ALPs | CERN PS | 1.8 or 3.5 GeV | $10^{17}$ pot |
| MATHUSLA200 | Weak-scale LLPs, dark scalar, Dark photon, ALPs, HNLs | ATLAS or CMS IP | 14 TeV $p$ | 3000 $fb^{-1}$ |
| FASER | Dark photon, dark scalar, ALPs, HNLs, $B - L$ gauge bosons | ATLAS IP | 14 TeV $p$ | 3000 $fb^{-1}$ |
| MilliQan | Milli charge | CMS IP | 14 TeV $p$ | 300–3000 $fb^{-1}$ |
| CODEX-b | Dark scalar, HNLs, ALPs, LDM, Higgs decays | LHCb IP | 14 TeV $p$ | 300 $fb^{-1}$ |
| >> **TeV mass range:** | | | | |
| KLEVER | $K_L \to \pi^0 \nu \bar{\nu}$ | P42/K12 | 400 GeV $p$ | $5 \times 10^{19}$ pot /5 years |



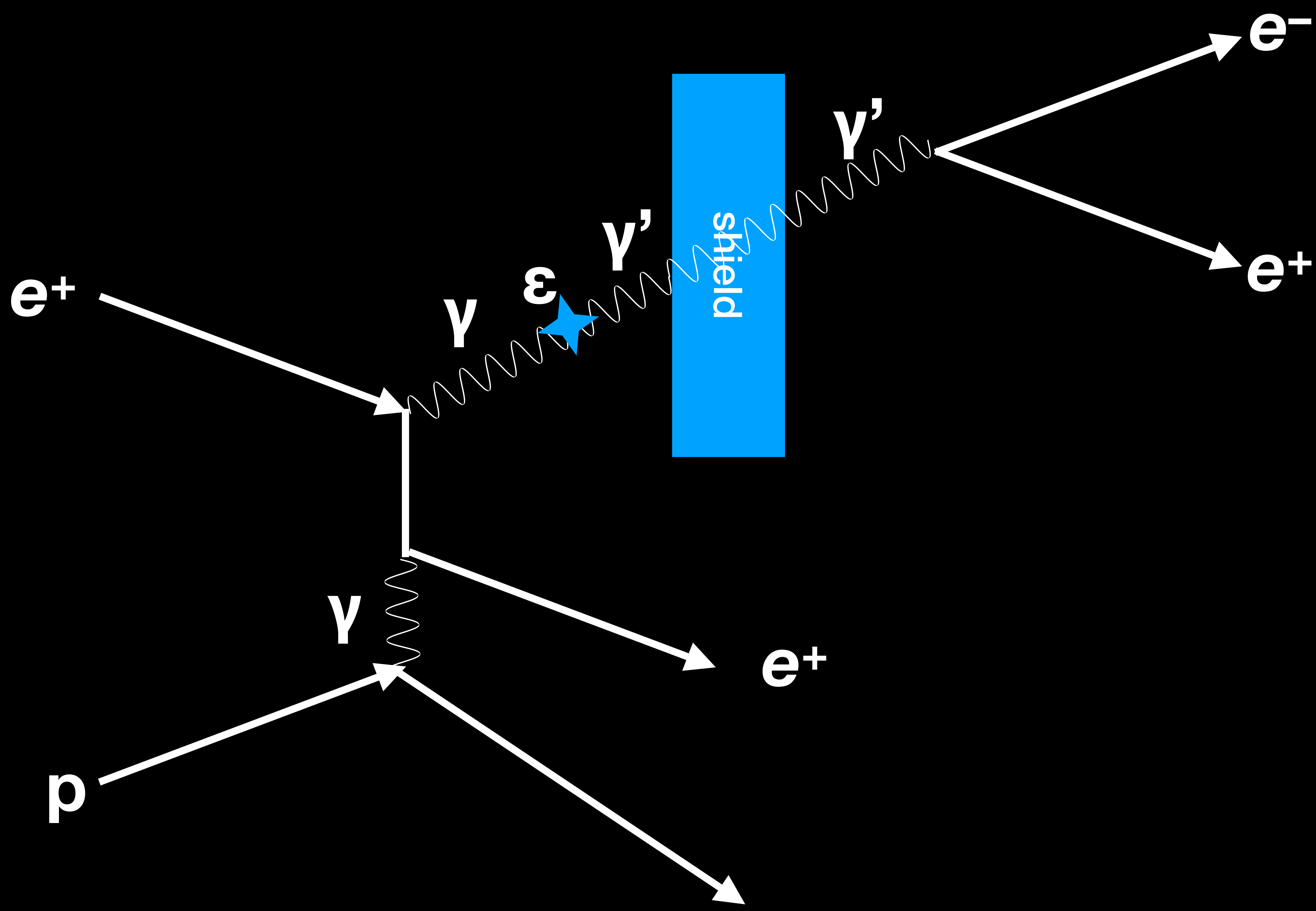
**ILC250: $10^{21}$ $e^\pm$ / year**

# fixed target, beam dump

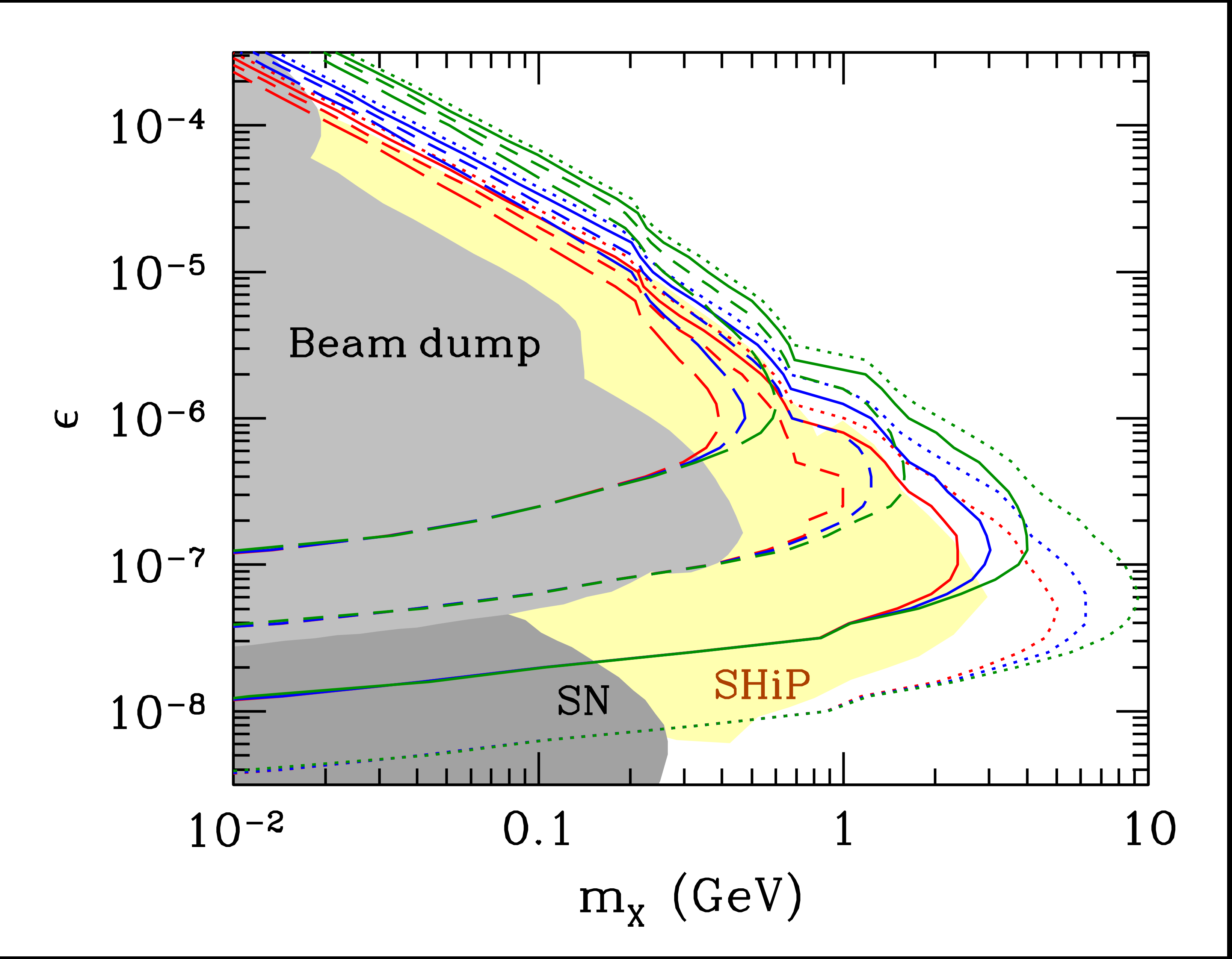


# dark photon, axion, sterile neutrino, etc



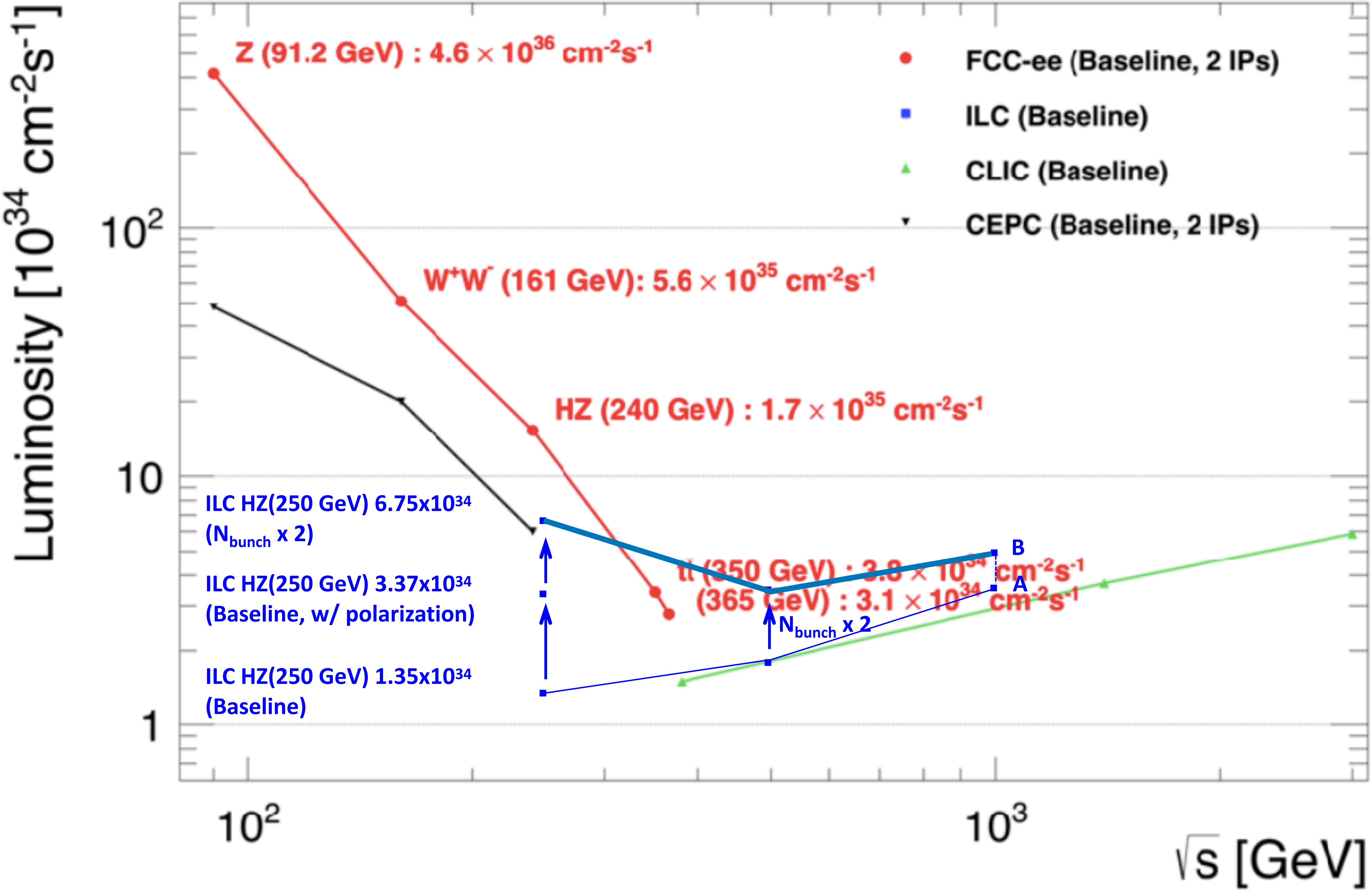
# beam dump




Shinya Kanemura, Takeo Moroi, Tomohiko Tanabe, arXiv:1507.02809

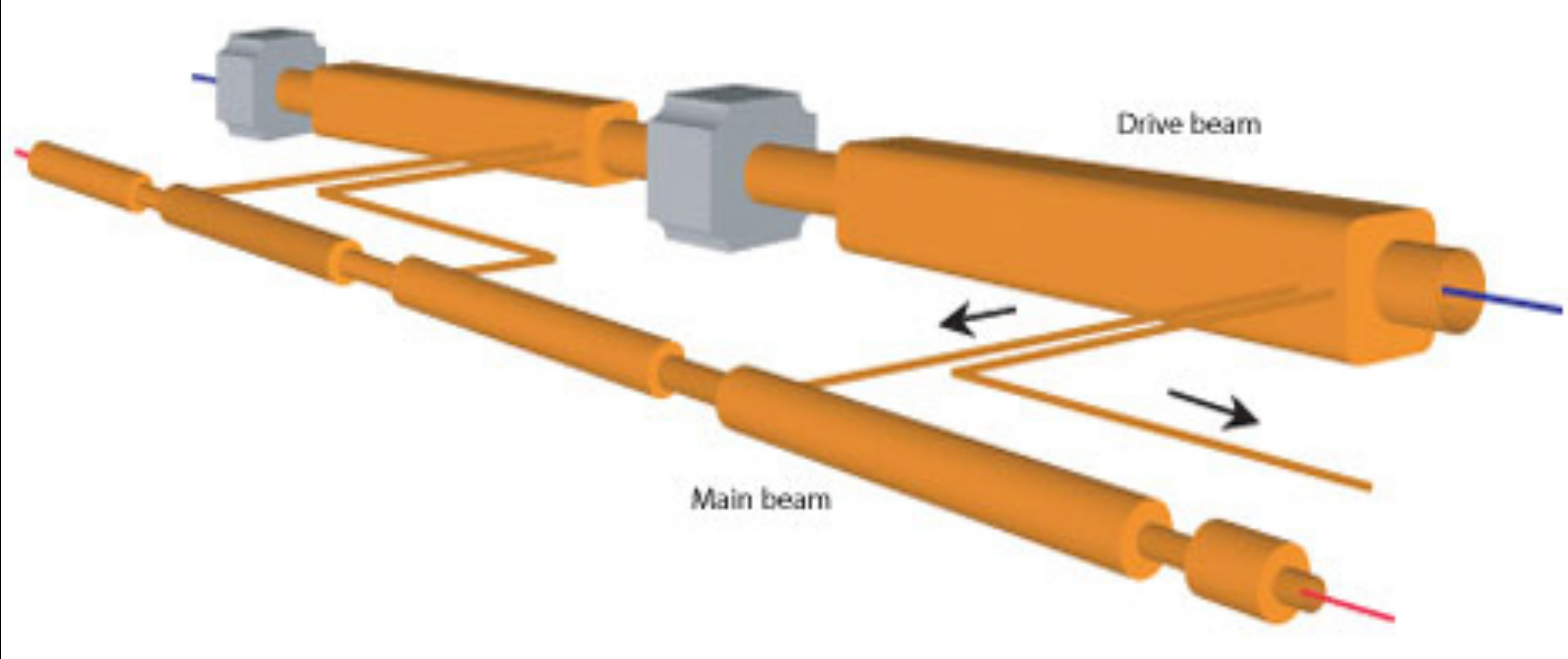
# future upgrades

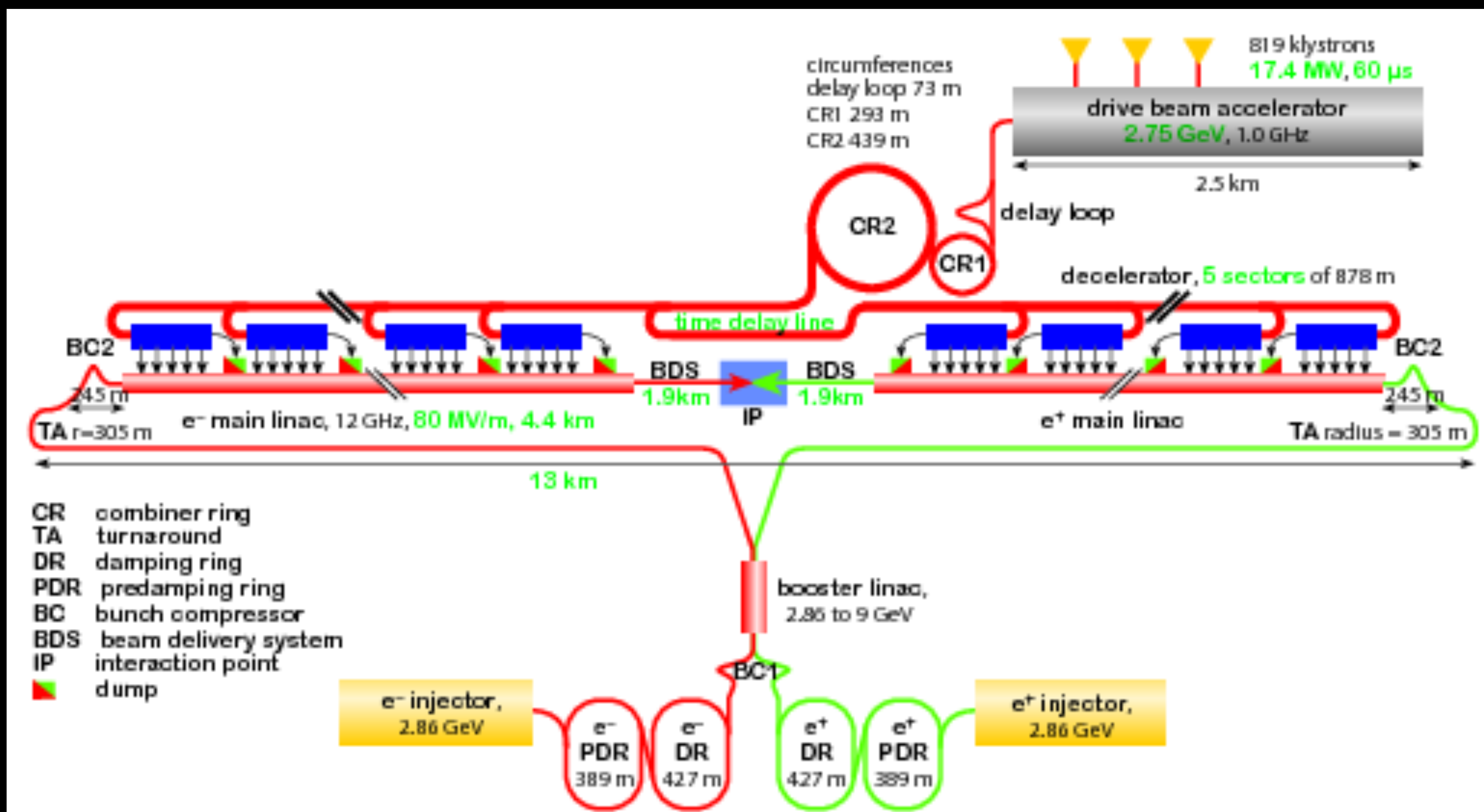
| | | |
|---|---|---|
| ILC Nb | 40MV/m | 1TeV |
| ILC $Nb_3Sn$ | 100MV/m | 3TeV |
| CLIC | 100MV/m | 3TeV |
| PWFA | 1GV/m | 30TeV |



Z (91.2 GeV) : 4.6 × 10^36 cm^-2s^-1
W+W- (161 GeV): 5.6 × 10^35 cm^-2s^-1
HZ (240 GeV) : 1.7 × 10^35 cm^-2s^-1
tt (350 GeV) : 3.8 × 10^34 cm^-2s^-1
(365 GeV) : 3.1 × 10^34 cm^-2s^-1
FCC-ee (Baseline, 2 IPs)
ILC (Baseline)
CLIC (Baseline)
CEPC (Baseline, 2 IPs)
ILC HZ(250 GeV) 6.75x10^34
(N_bunch x 2)
ILC HZ(250 GeV) 3.37x10^34
(Baseline, w/ polarization)
ILC HZ(250 GeV) 1.35x10^34
(Baseline)
N_bunch x 2
B
A
Luminosity [10^34 cm^-2s^-1]
√s [GeV]
10^2
10
1
10^2
10^3

# CLIC


Drive beam
Main beam


819 klystrons
17.4 MW, 60 μs
drive beam accelerator
2.75 GeV, 1.0 GHz
2.5 km
circumferences
delay loop 73 m
CR1 293 m
CR2 439 m
delay loop
CR2
CR1
decelerator, 5 sectors of 878 m
time delay line
BC2
BC2
BDS
1.9km
BDS
1.9km
IP
245 m
245 m
TA r=305 m
e⁻ main linac, 12 GHz, 80 MV/m, 4.4 km
e⁺ main linac
TA radius = 305 m
13 km
CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump
booster linac,
2.86 to 9 GeV
BC1
e⁻ injector,
2.86 GeV
e⁺ injector,
2.86 GeV
e⁻
PDR
389 m
e⁻
DR
427 m
e⁺
DR
427 m
e⁺
PDR
389 m

# 30 TeV

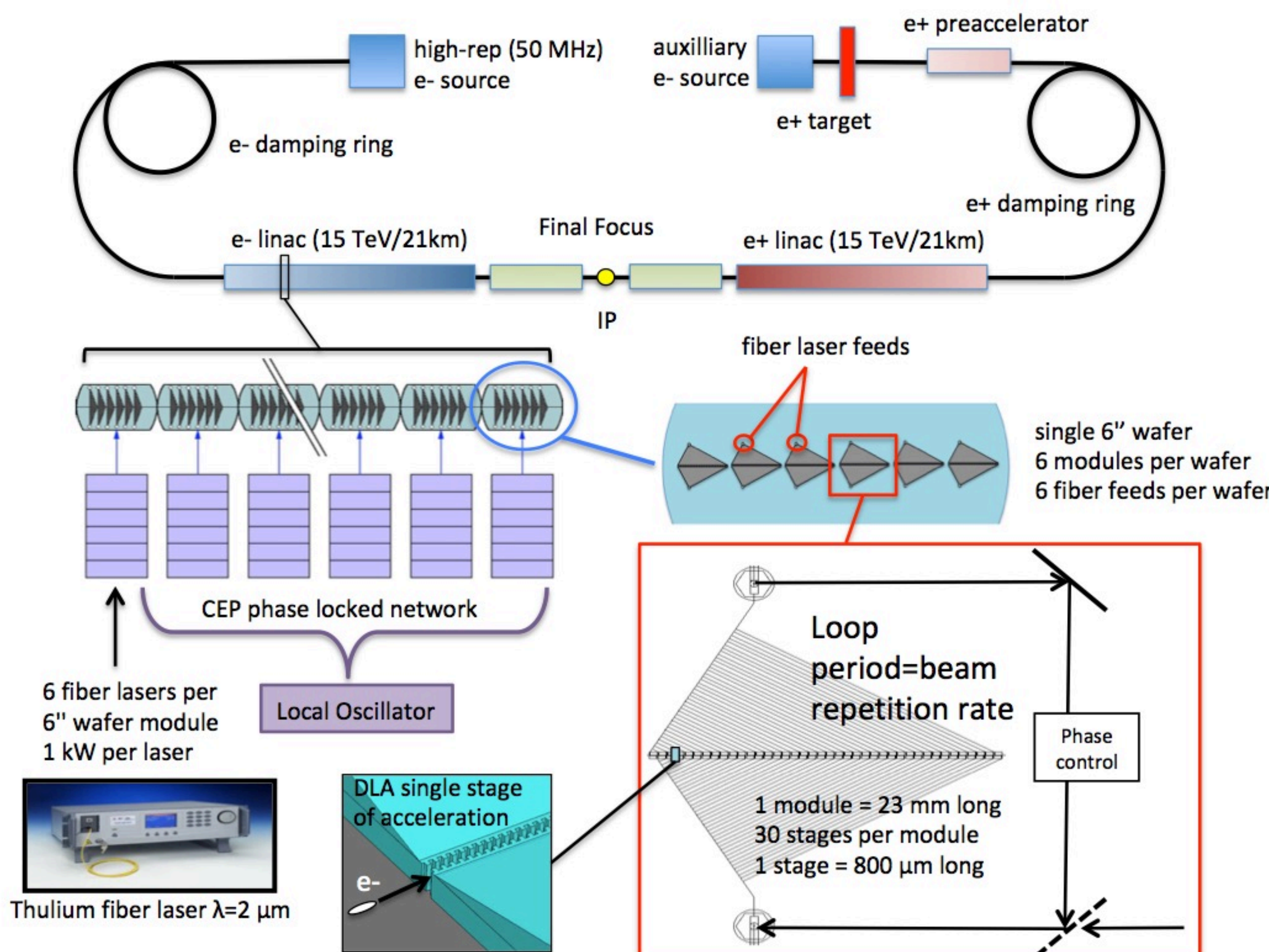
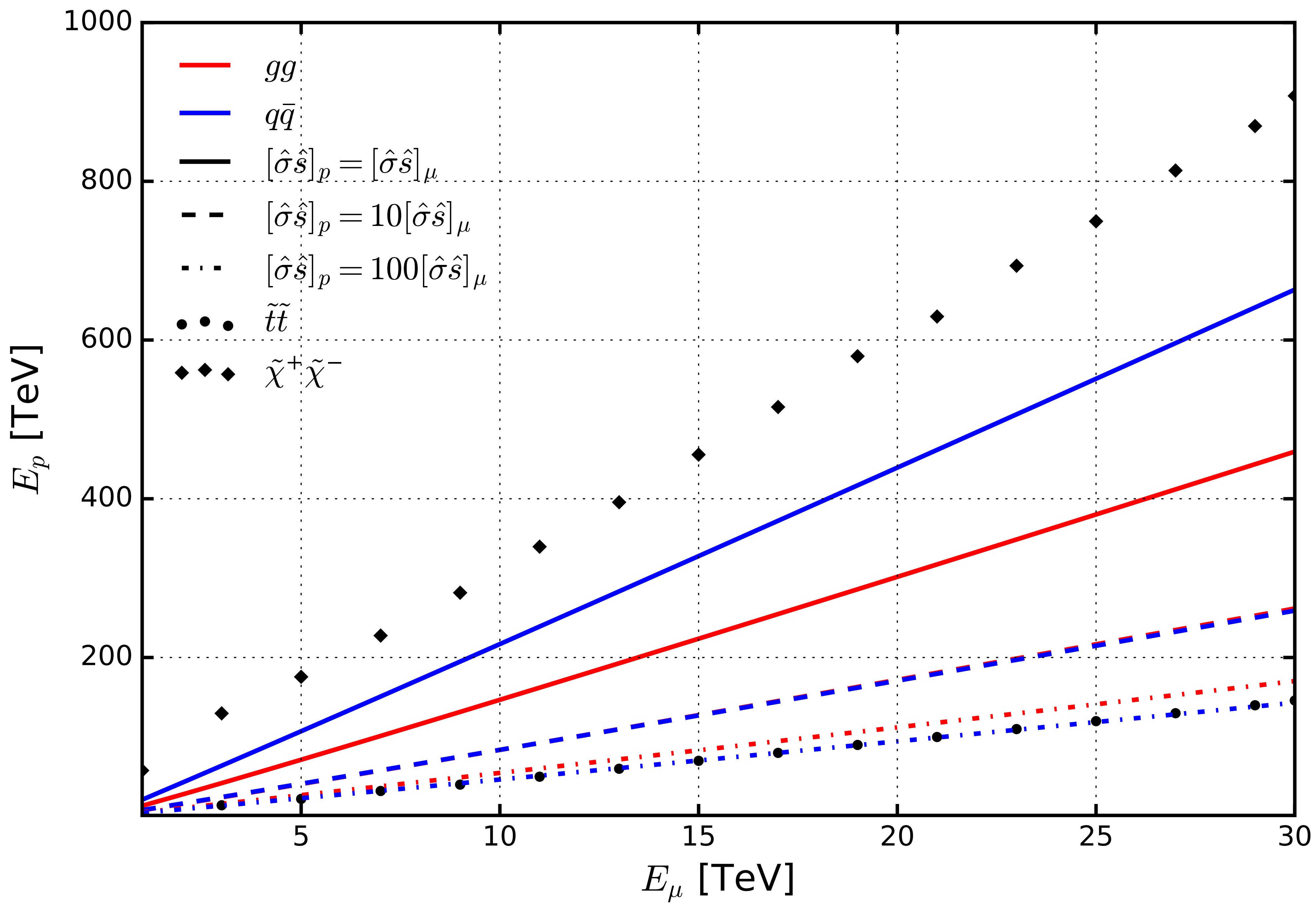



Fig. 5.1: Conceptual schematic of a 30 TeV DLA e+ e- collider driven by a carrier envelope phase locked network of energy-efficient solid-state fiber lasers at 20 MHz repetition rate. Laser power is distributed by photonic waveguides to a sequence of dielectric accelerating, focusing, and steering elements co-fabricated on 6-inch wafers which are aligned and stabilized using mechanical and thermal active feedback systems.

# lepton vs proton




**arXiv:2005.10289**

# What I discussed

- mass vs coupling
- exotic Higgs/Z decay
- dark spectroscopy
- long-lived particle
- beam dump
- higher energies

# ILC

- despite lack of new physics at LHC, ILC has many opportunities to discover new physics
- so far emphasis on precision measurements
- light dark sector: active discussions recently
- standard collider mode, detectors away from IP, beam dump, fixed target
- more ideas?