Experimental Status of Rare Decays in Charged Leptons and Light Mesons

ICHEP2012
Melbourne

36th International Conference on High Energy Physics

4 – 11 July 2012
Melbourne Convention and Exhibition Centre

Experimental Status of Rare Decays in Charged Leptons and Light Mesons

Yoshitaka Kuno
Department of Physics, Osaka University

July 9th, 2012
Melbourne

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Outline

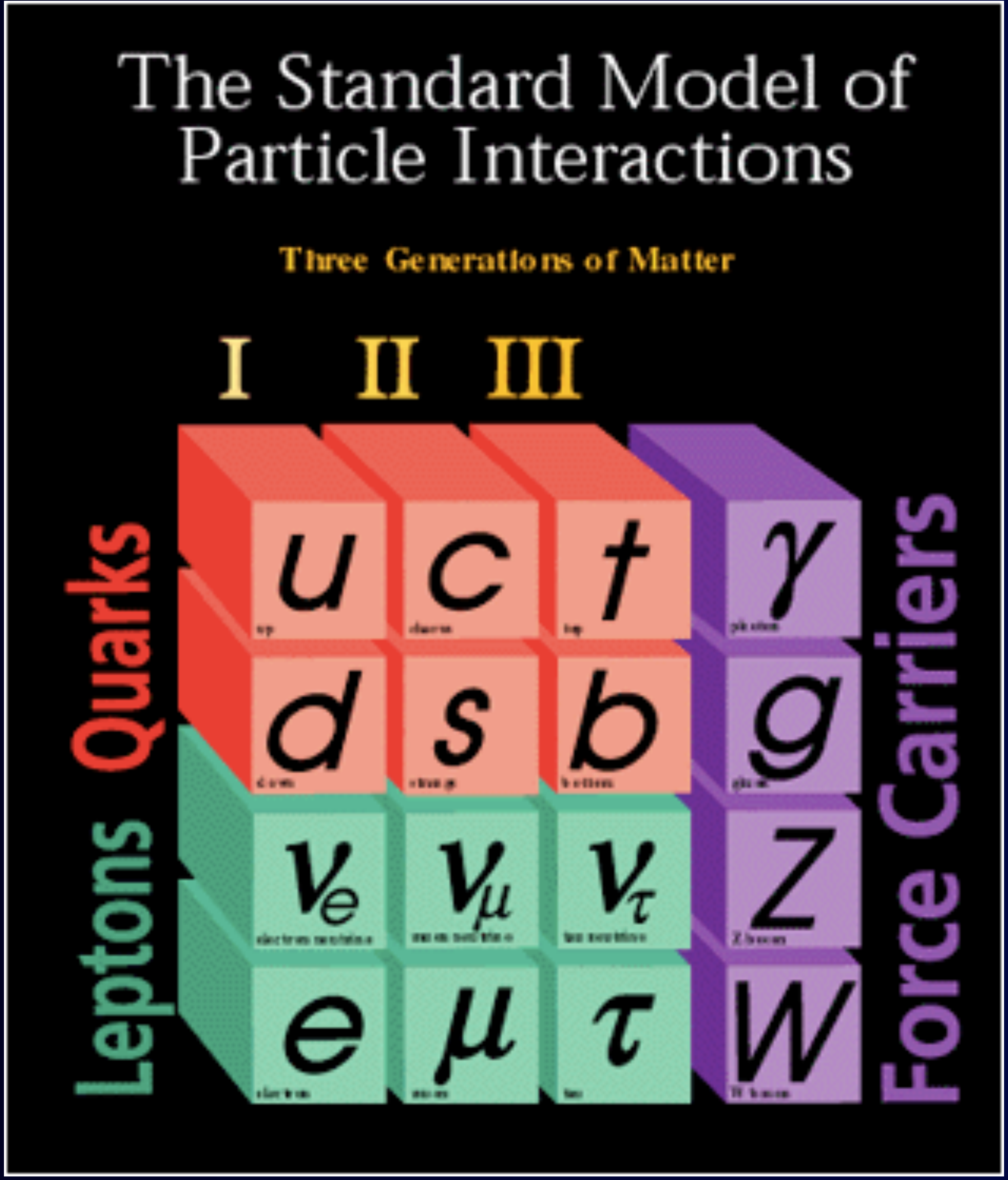
- Why Rare Decays?
- Rare Muon Decays
- Rare Tau Decays
- Rare Kaon Decays
- Rare Charm Decays
- Particle Sources (Facilities)
- Summatry

There are not many new results on these subjects in this conference.
This talk does not have talks on CP violation decays.
Due to time limitation, only selected subjects are shown, sorry.

Why Rare Decays ?

woodblock prints on “Kabuki” actors
by Tsuruya Kokei (1978-2000)

Now, the Standard Model has the Higgs boson



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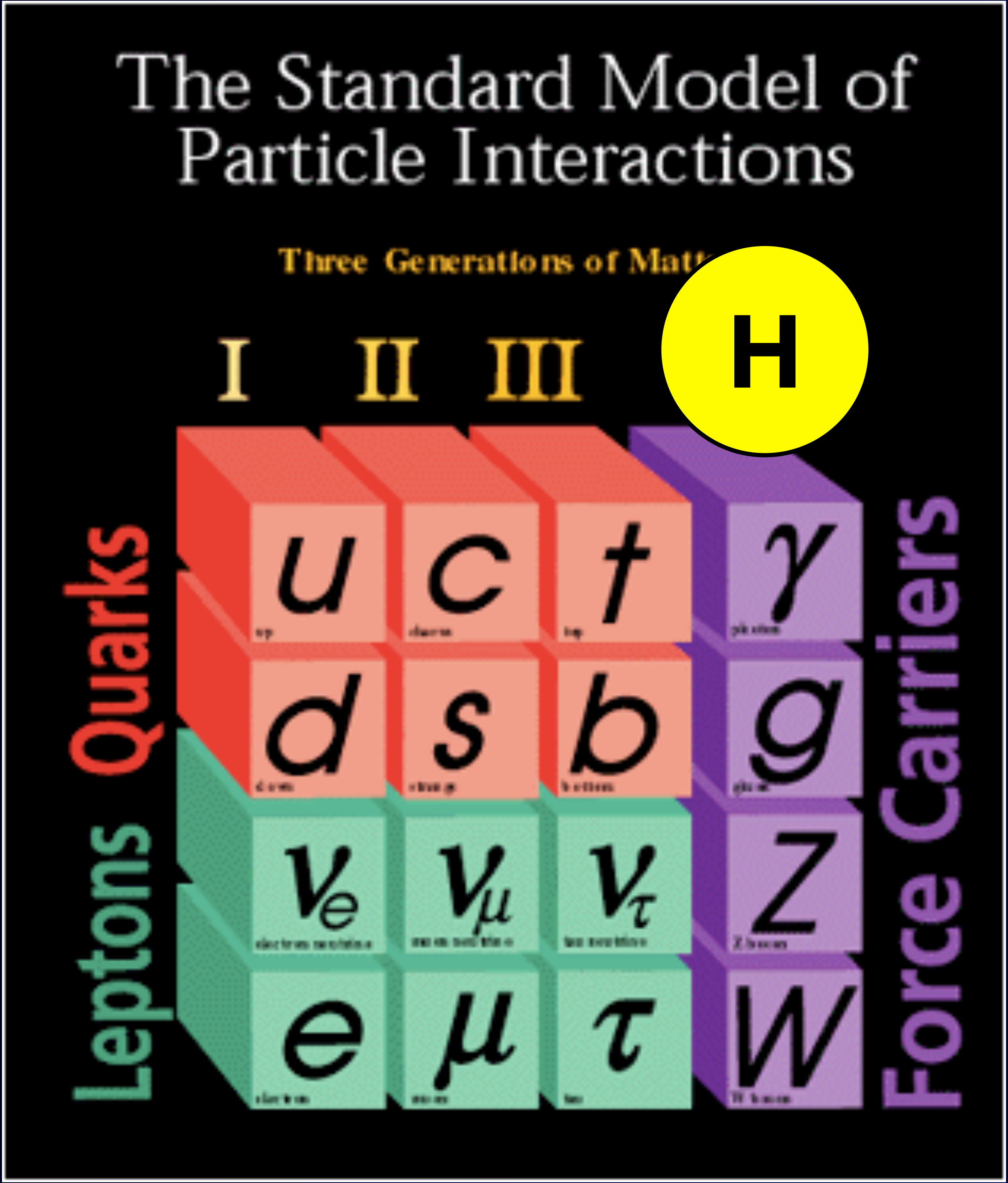

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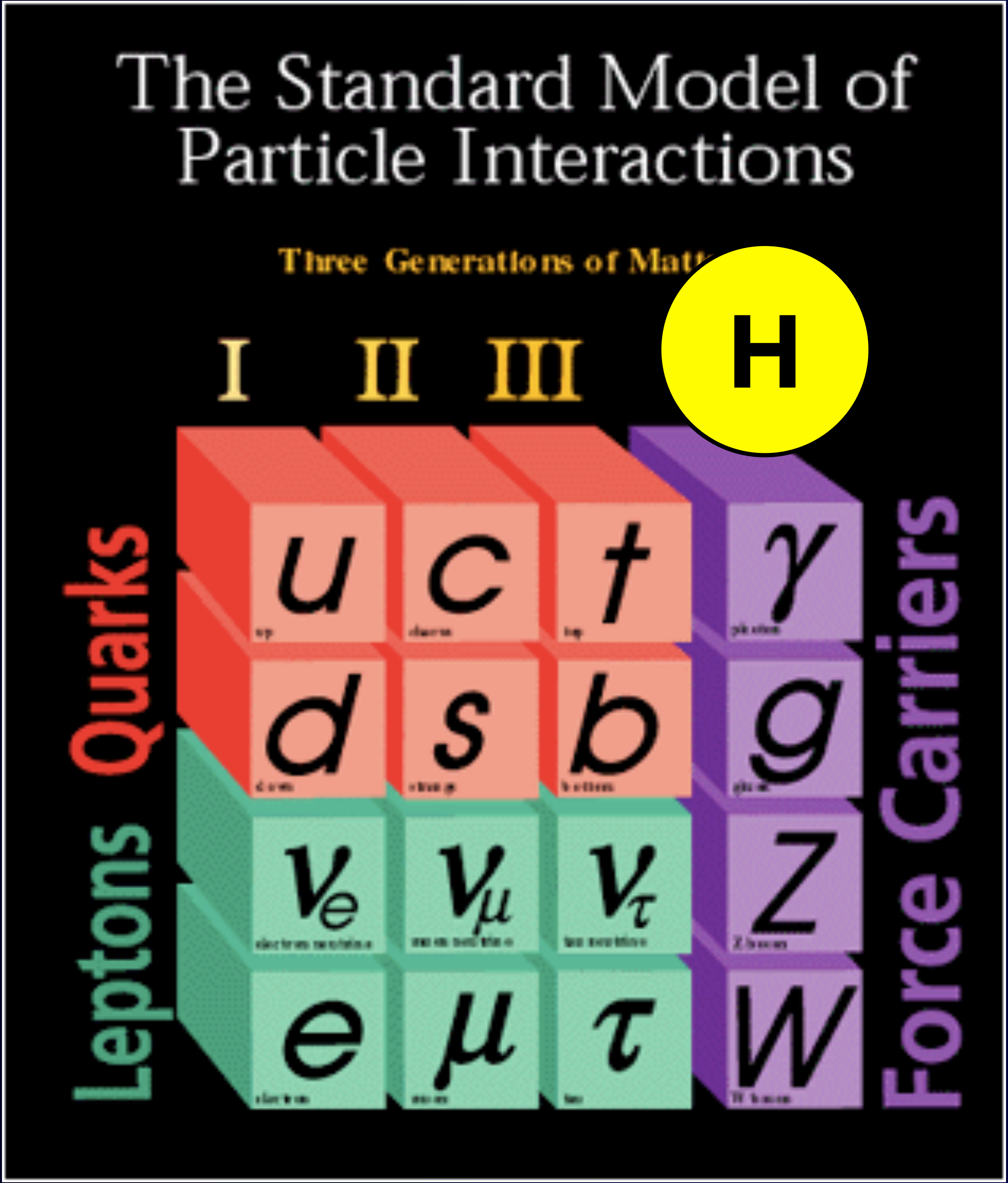
The Standard Model can explain most of the experimental results. However, there are many undetermined parameters and issues.



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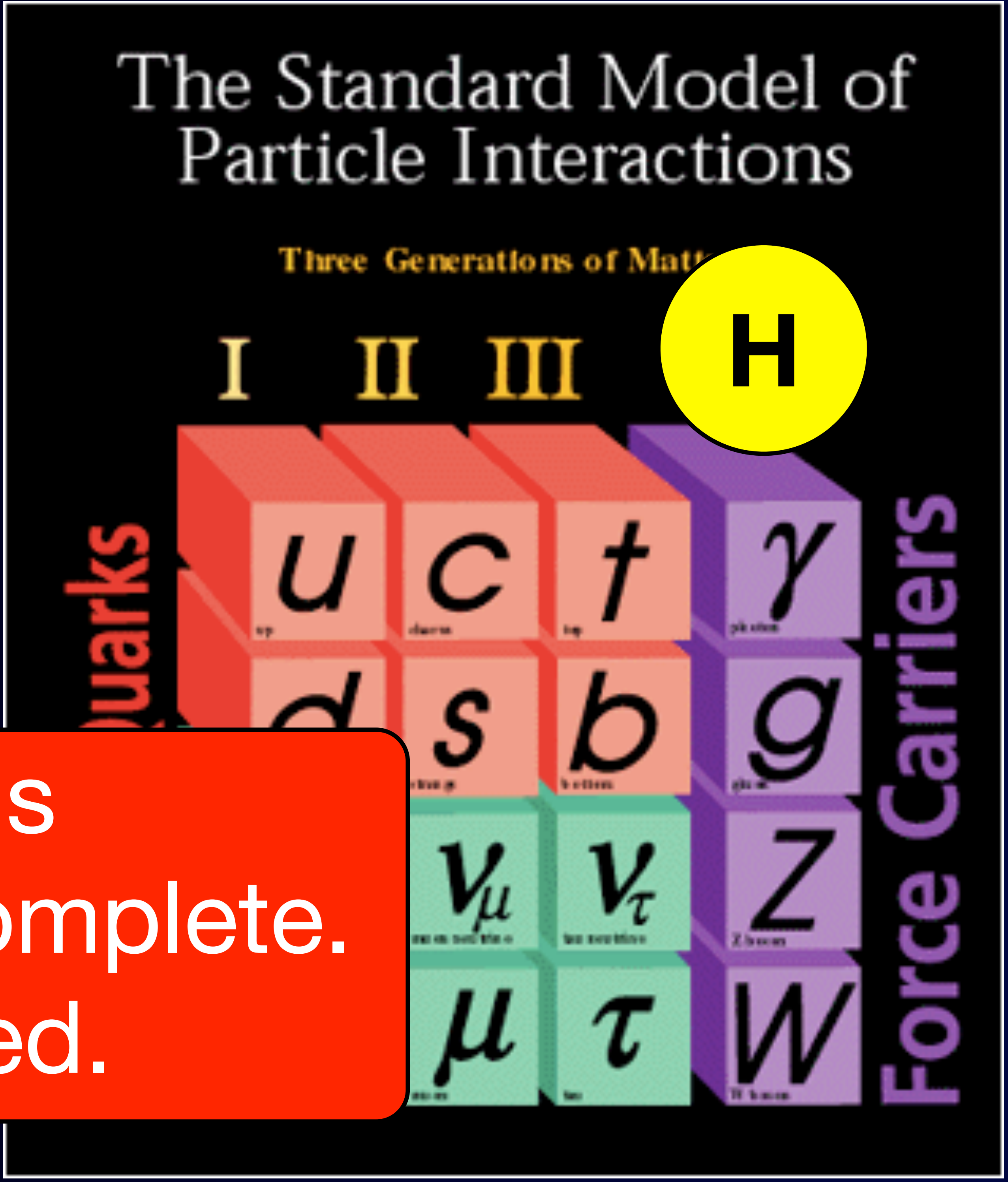
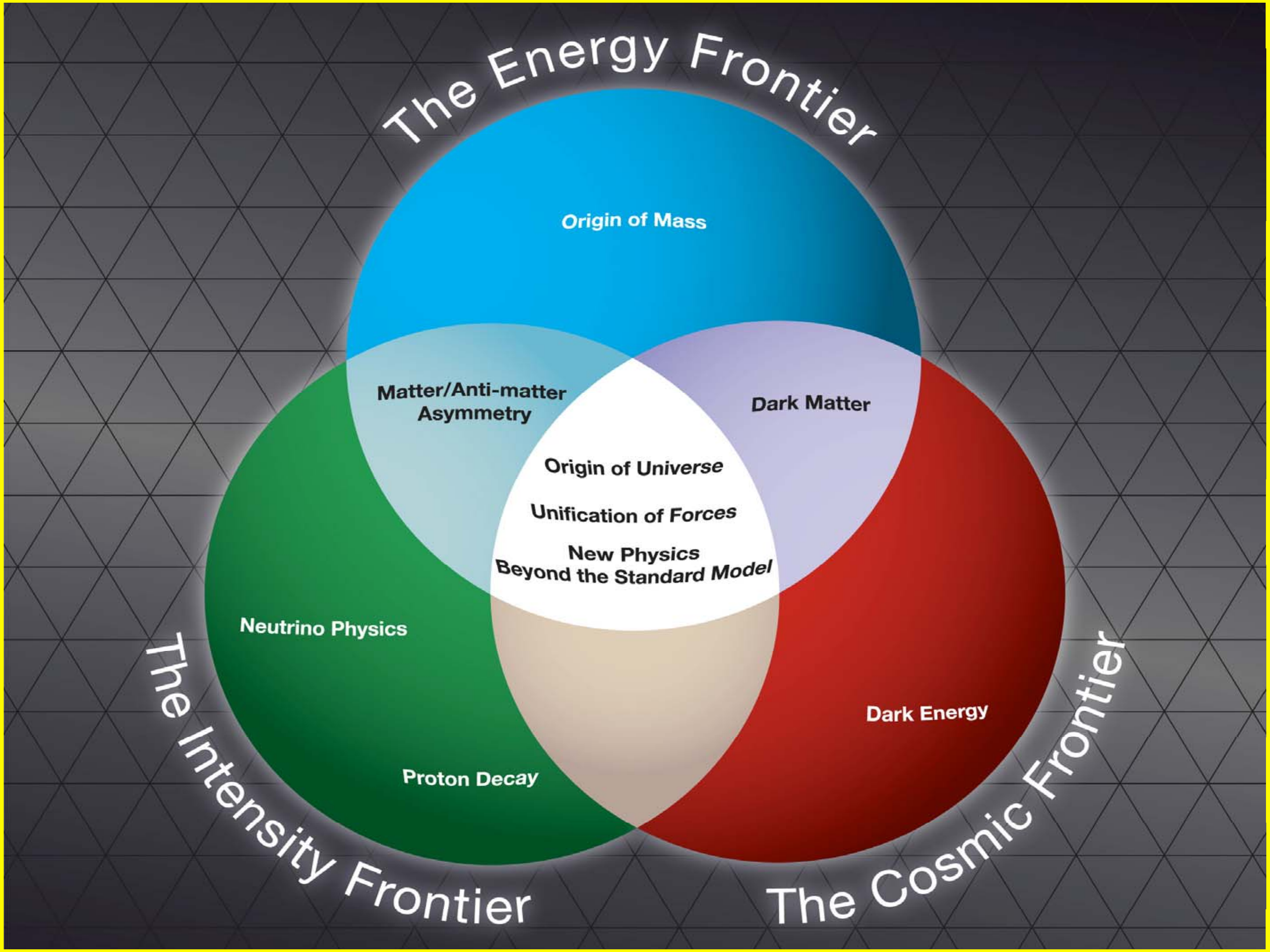


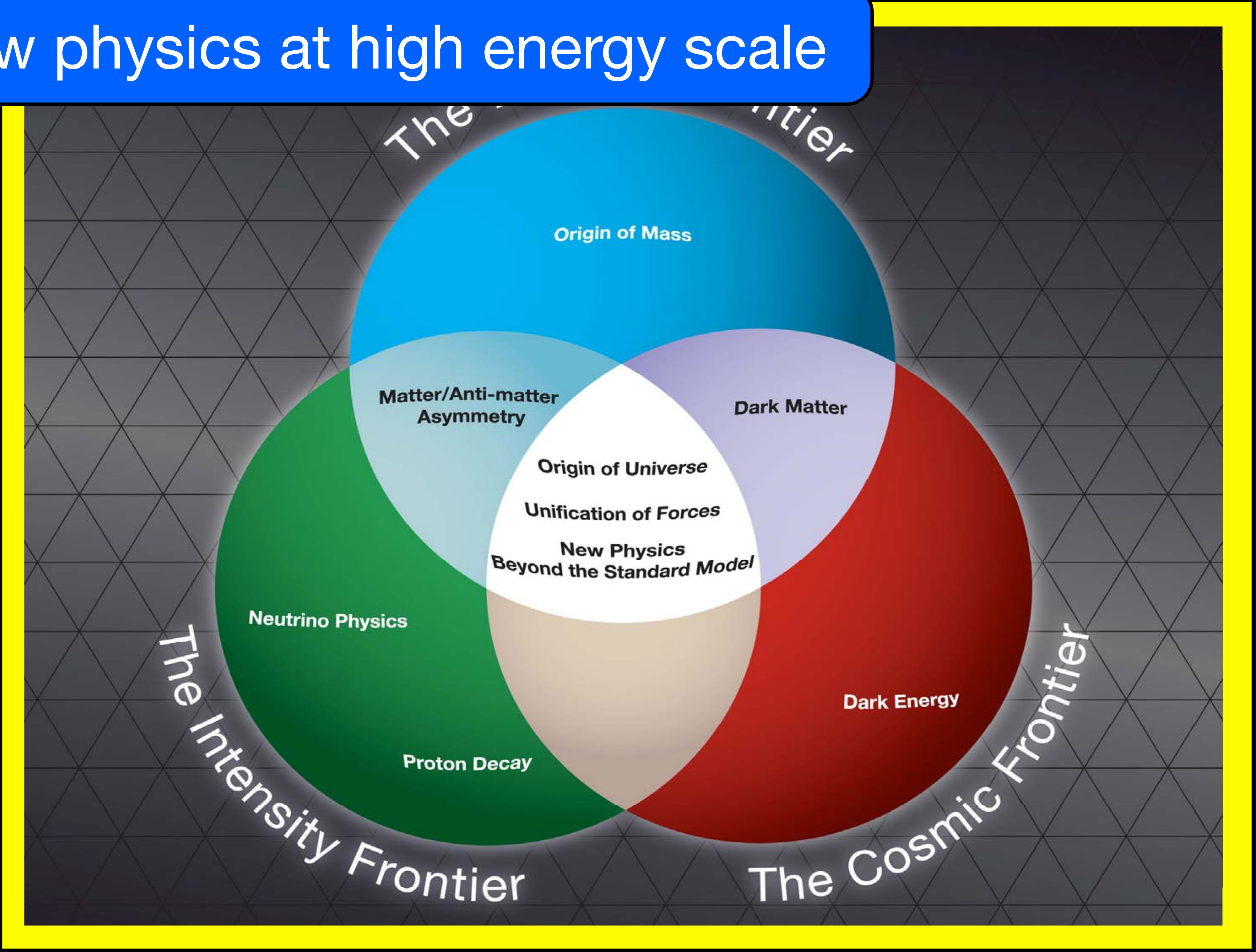
The Standard Model is considered to be incomplete. New Physics is needed.

Three Frontiers of Particle Physics



Three Frontiers of Particle Physics

To explore new physics at high energy scale



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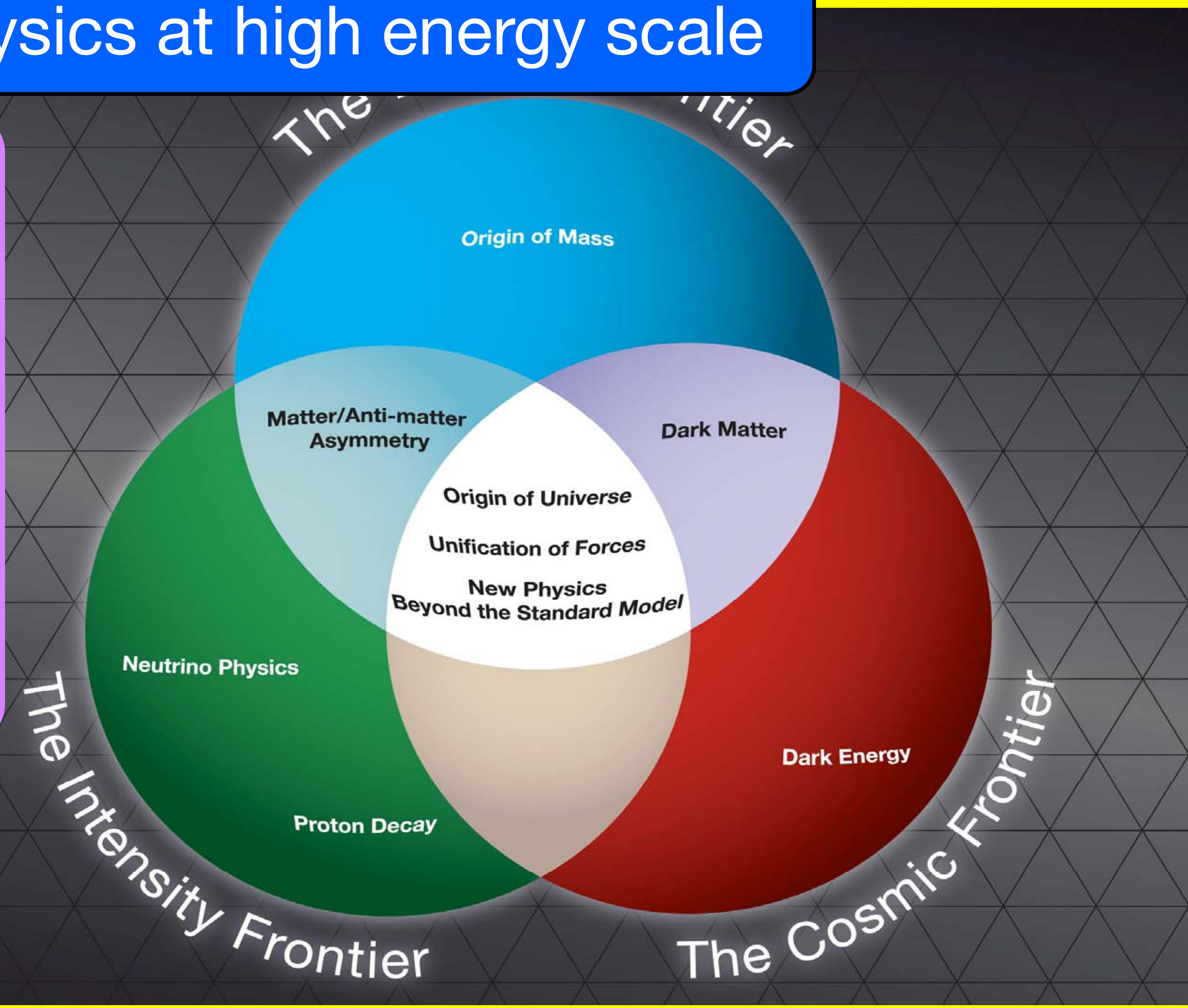
The Intensity Frontier

use intense beams to observe rare processes and study the particle properties to probe physics beyond the SM.



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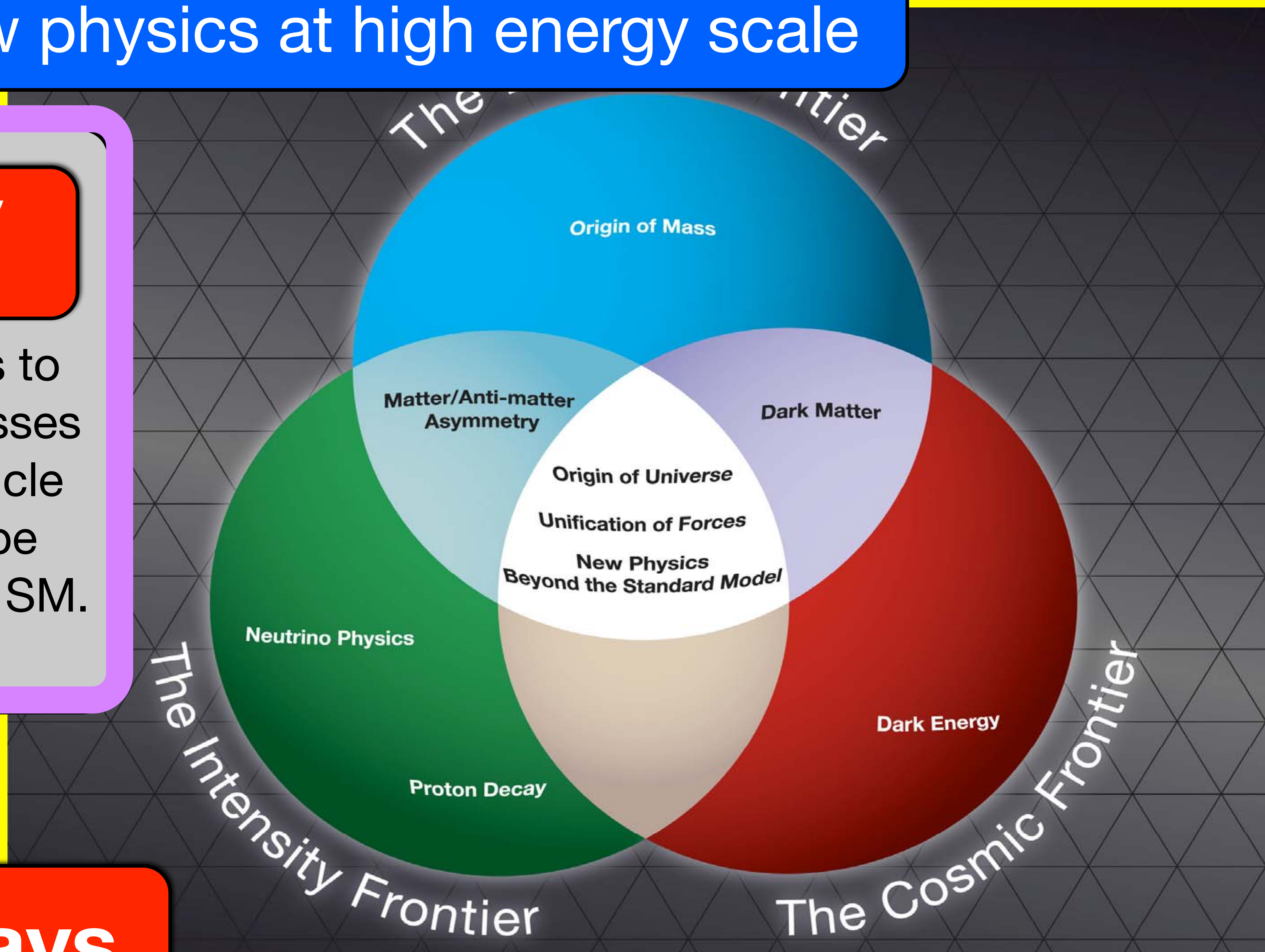

Rare Decays

Guideline for Rare Decay Searches

New physics effects may be very small.

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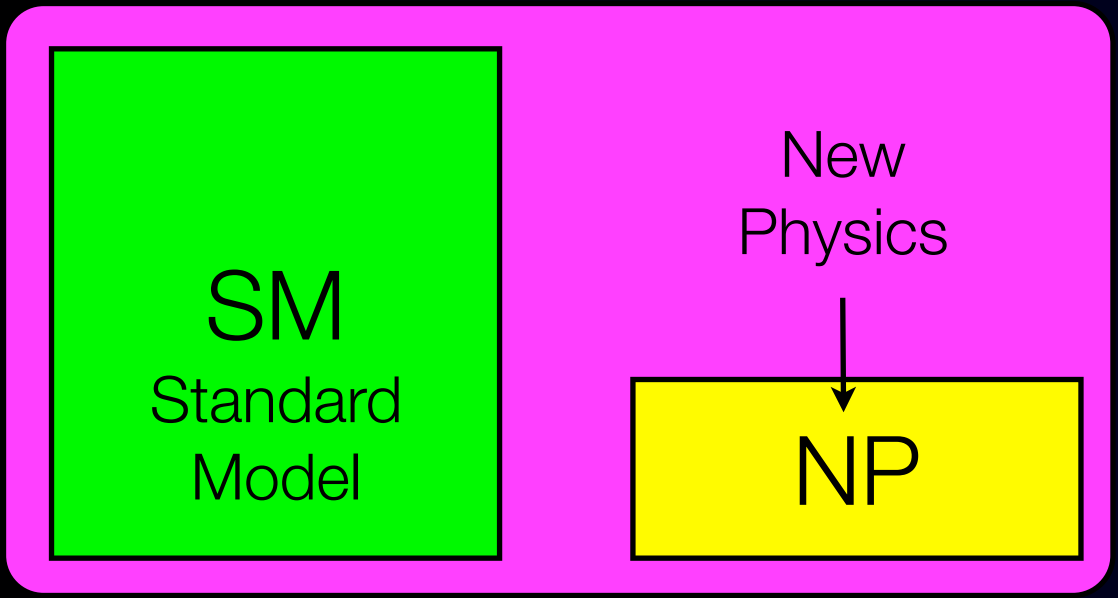

SM contribution is dominant.

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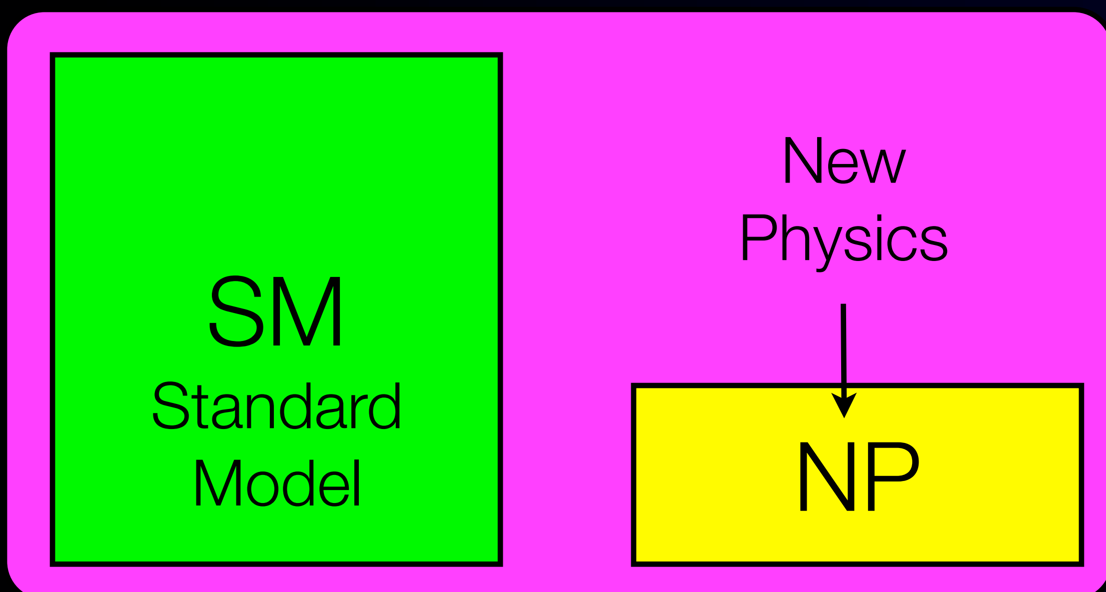

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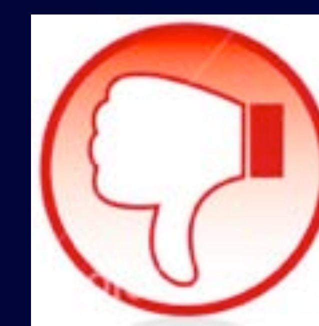

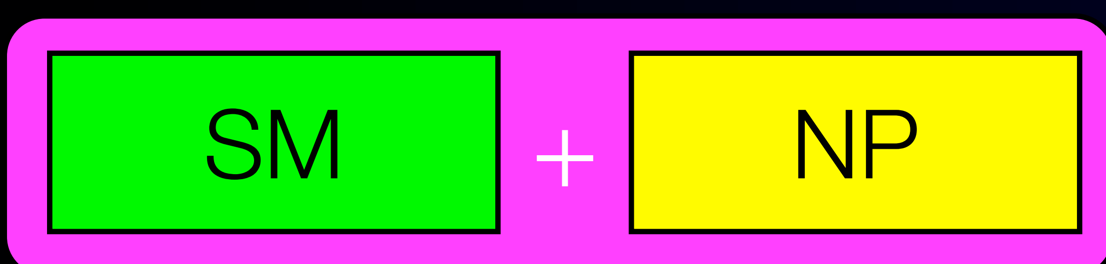

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$$B \sim \frac{1}{\sqrt{N}}$$

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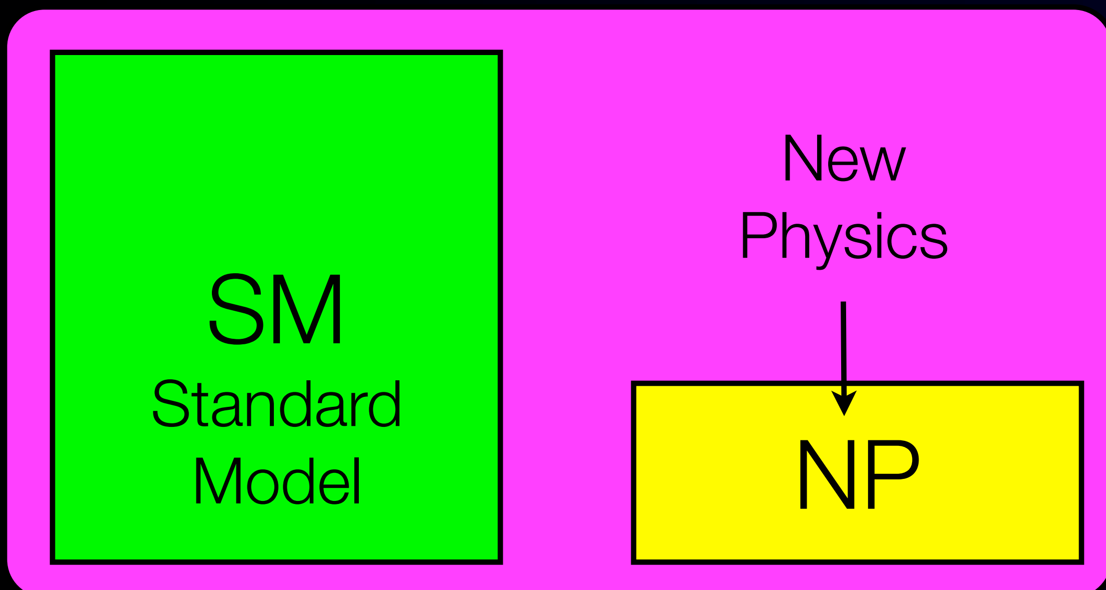

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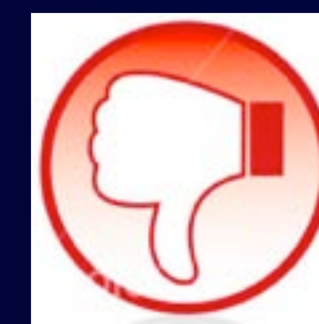

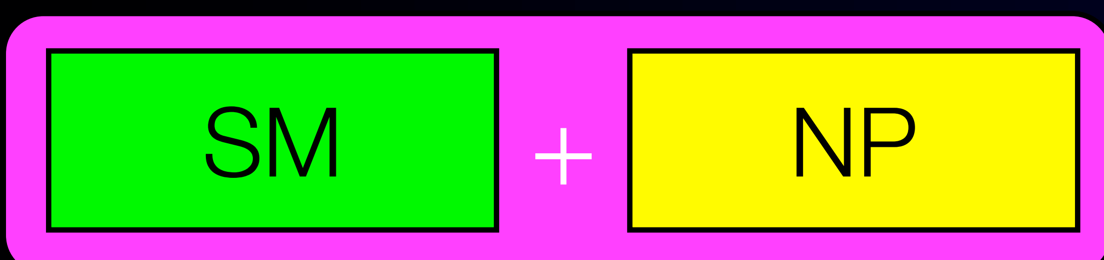

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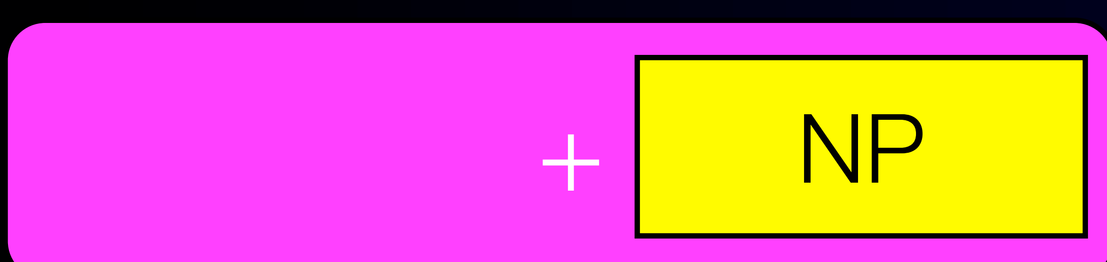

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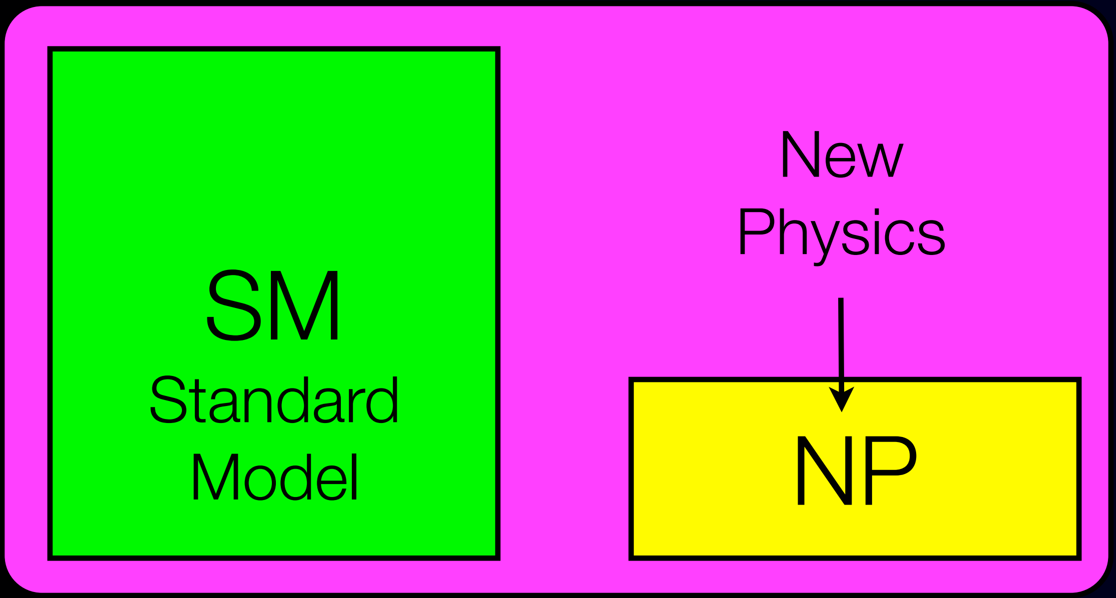

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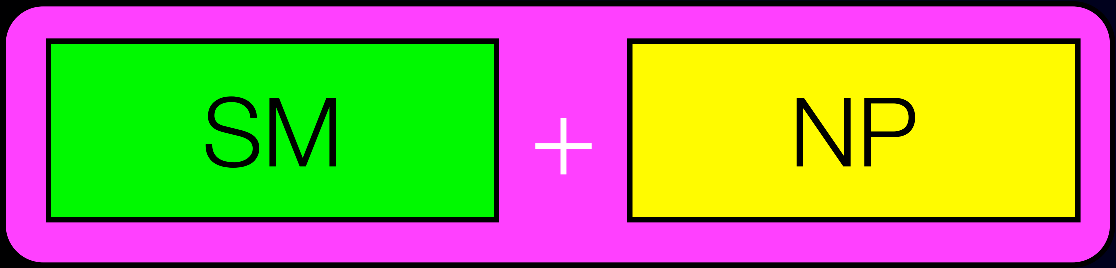

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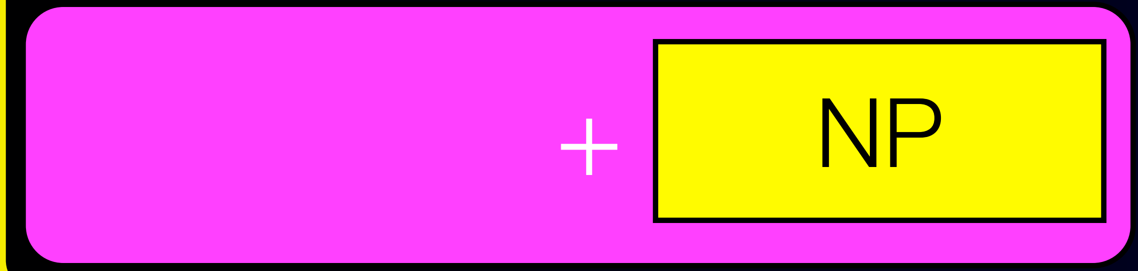

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Example : No SM Contribution in Charged Lepton Flavor Violation (CLFV)

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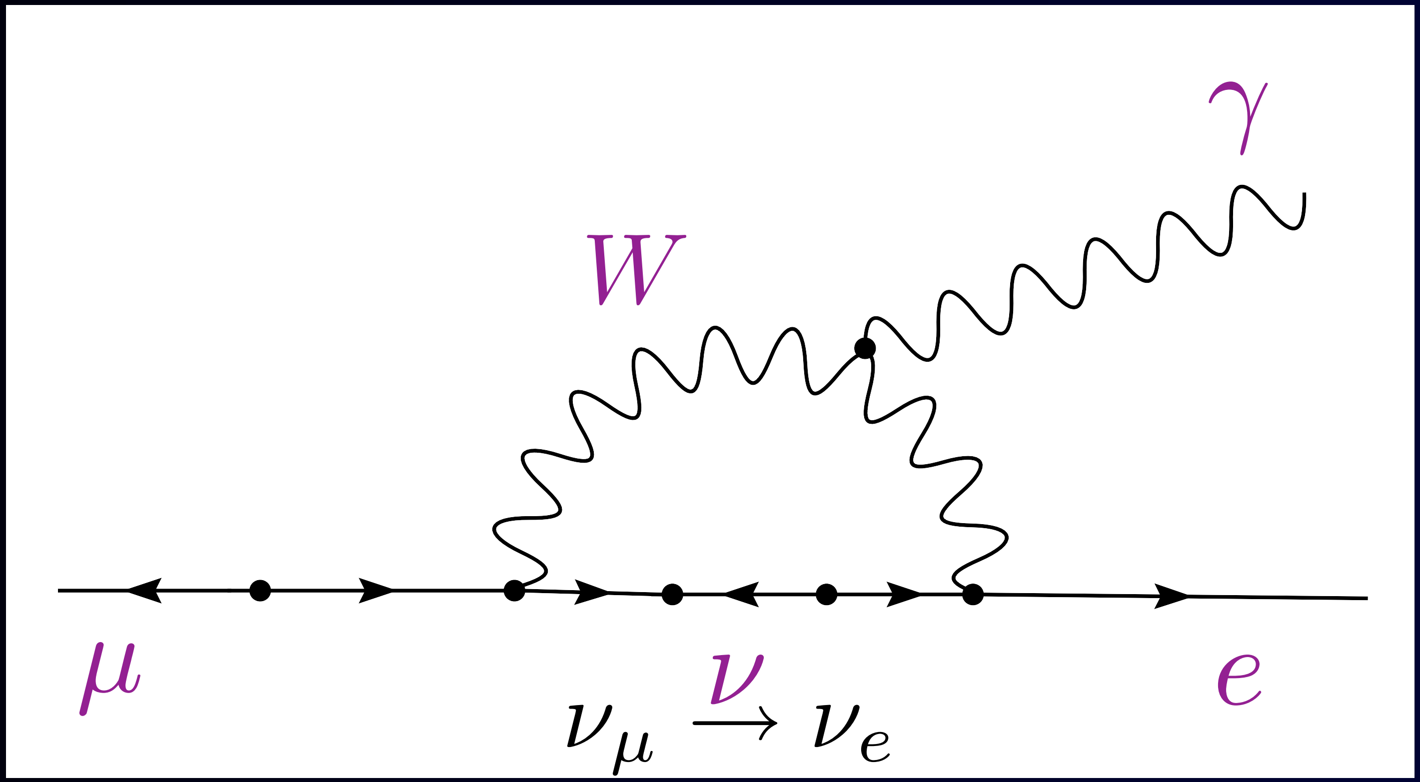
$$B(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_l (V_{MNS})^*_{\mu_l}(V_{MNS})_{el}\frac{m^2_{\nu_l}}{M^2_W}\right|^2$$



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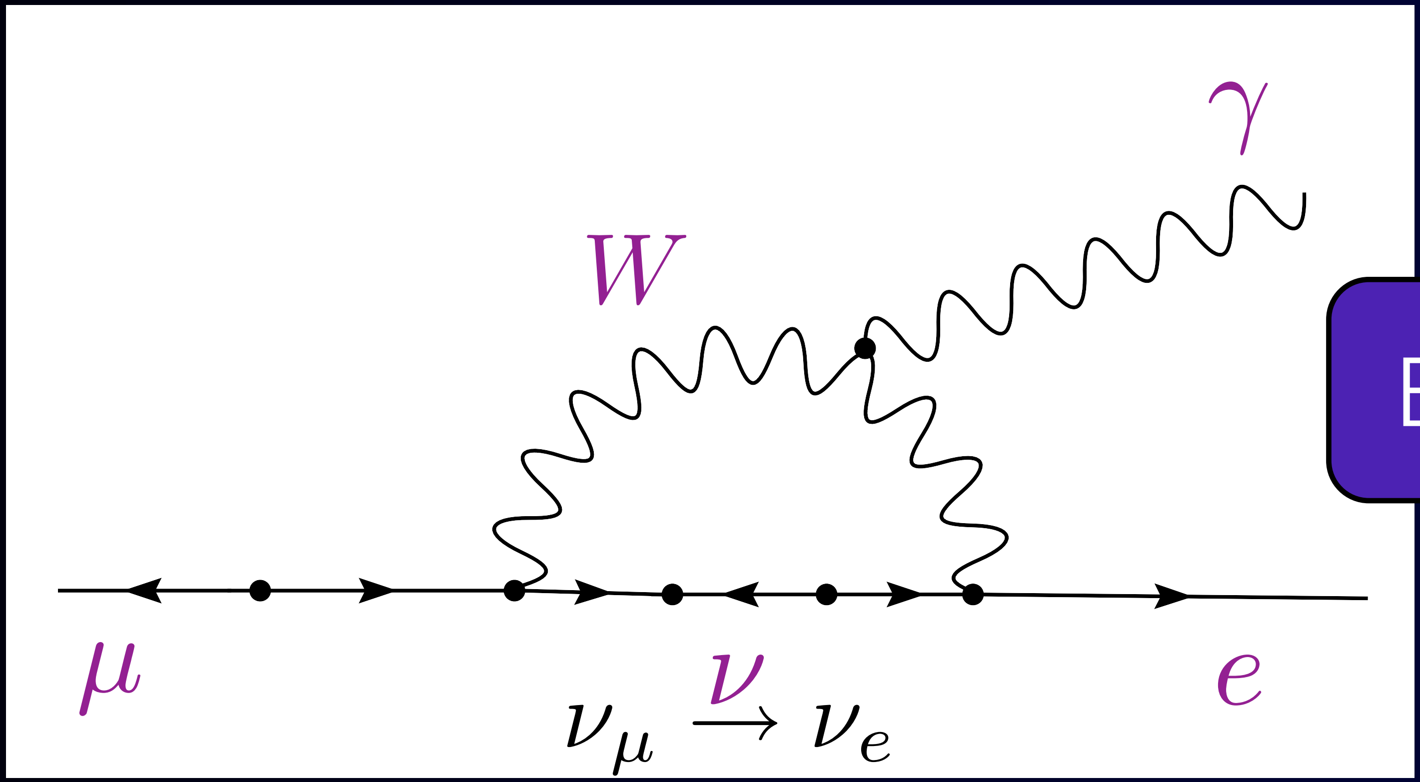

BR~O(10^{-54})

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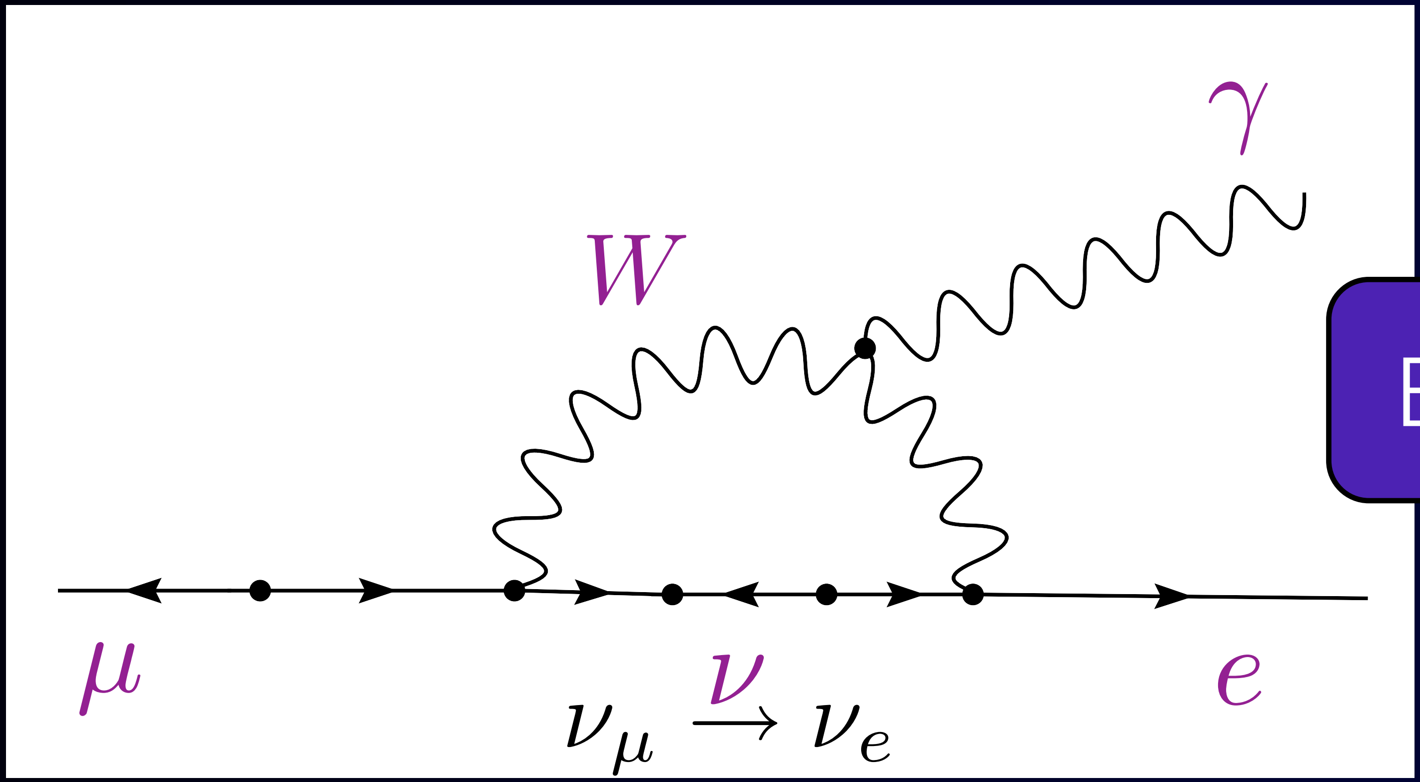

BR~O(10^{-54})

Observation of CLFV would indicate a clear signal of physics beyond the SM with massive neutrinos.

Example: Sensitivity to Energy Scale of NP

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A. de Gouvea's effective interaction for μ-e conversion

$$L_{\mathrm{CLFV}} = \frac{1}{1+\kappa}\frac{m_\mu}{\Lambda^2}\bar{\mu}_{\mathrm{R}}\sigma^{\mu\nu}e_{\mathrm{L}}F_{\mu\nu} + \frac{\kappa}{1+\kappa}\frac{1}{\Lambda^2}(\bar{\mu}_{\mathrm{L}}\gamma^{\mu}e_{\mathrm{L}})(\bar{q}_{\mathrm{L}}\gamma_{\mu}q_{\mathrm{L}})$$

Λ: energy scale of new physics

$$B(\mu \to e\gamma) < 2.4 \times 10^{-12}$$

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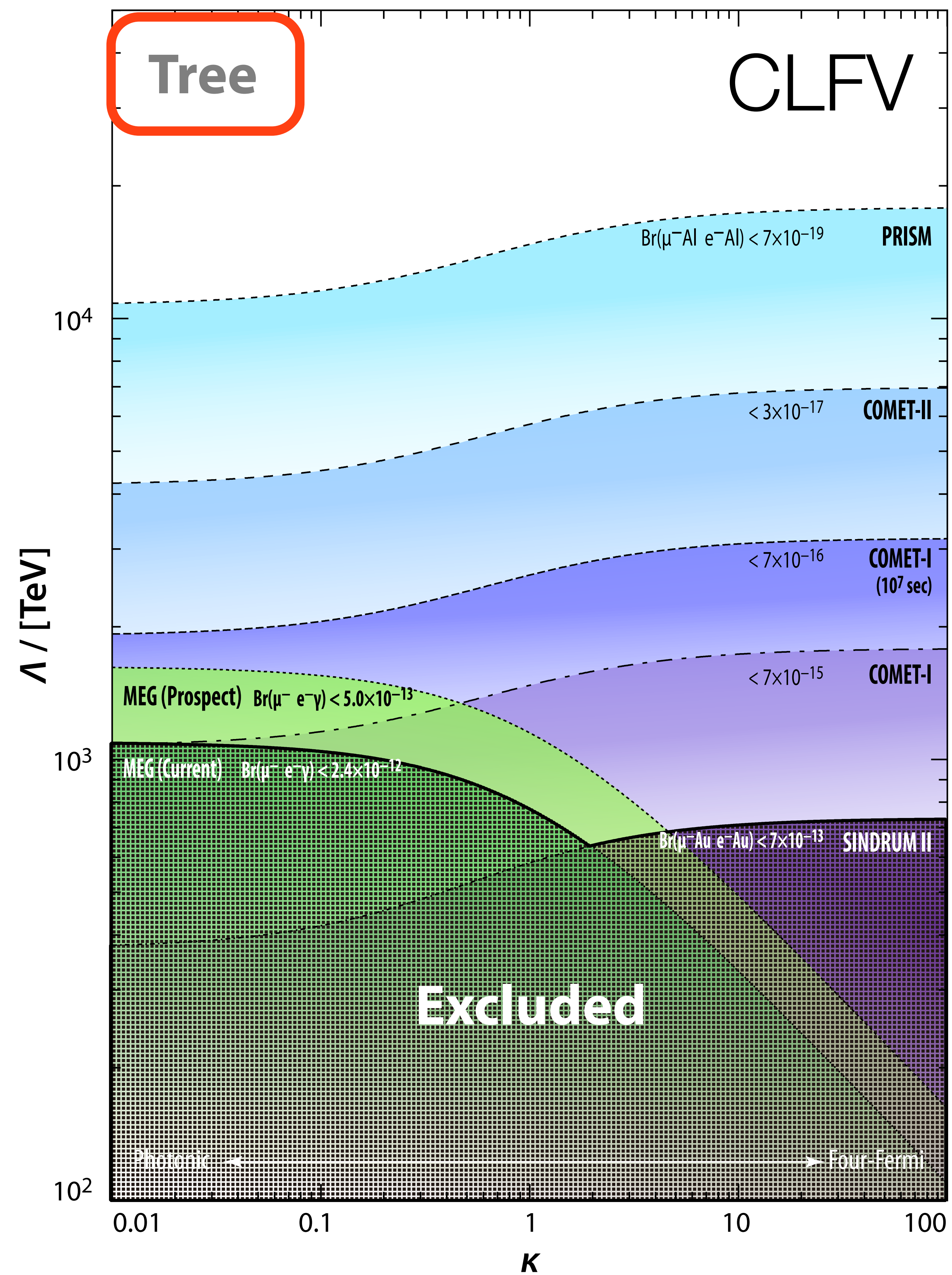

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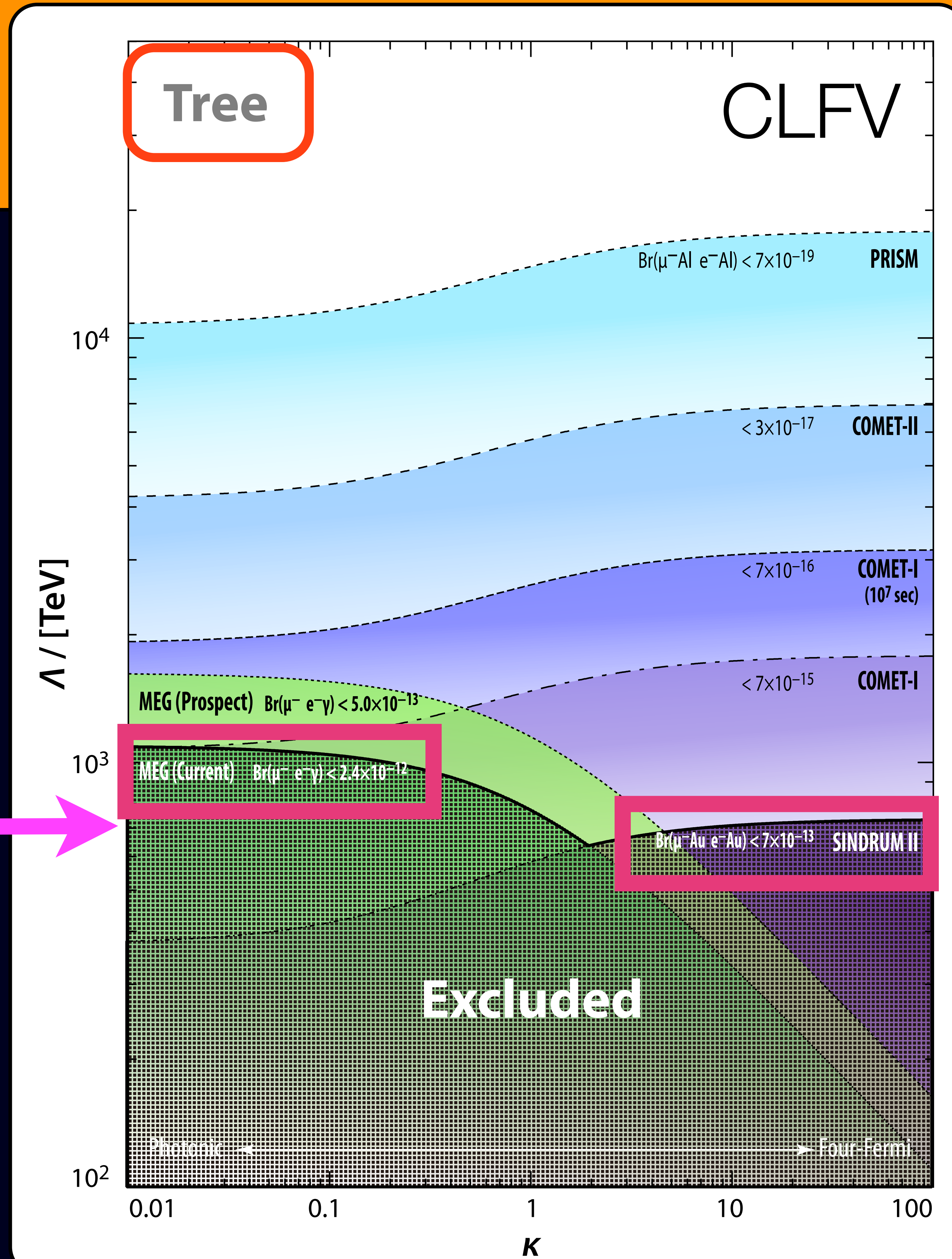
$O(10^3)$TeV



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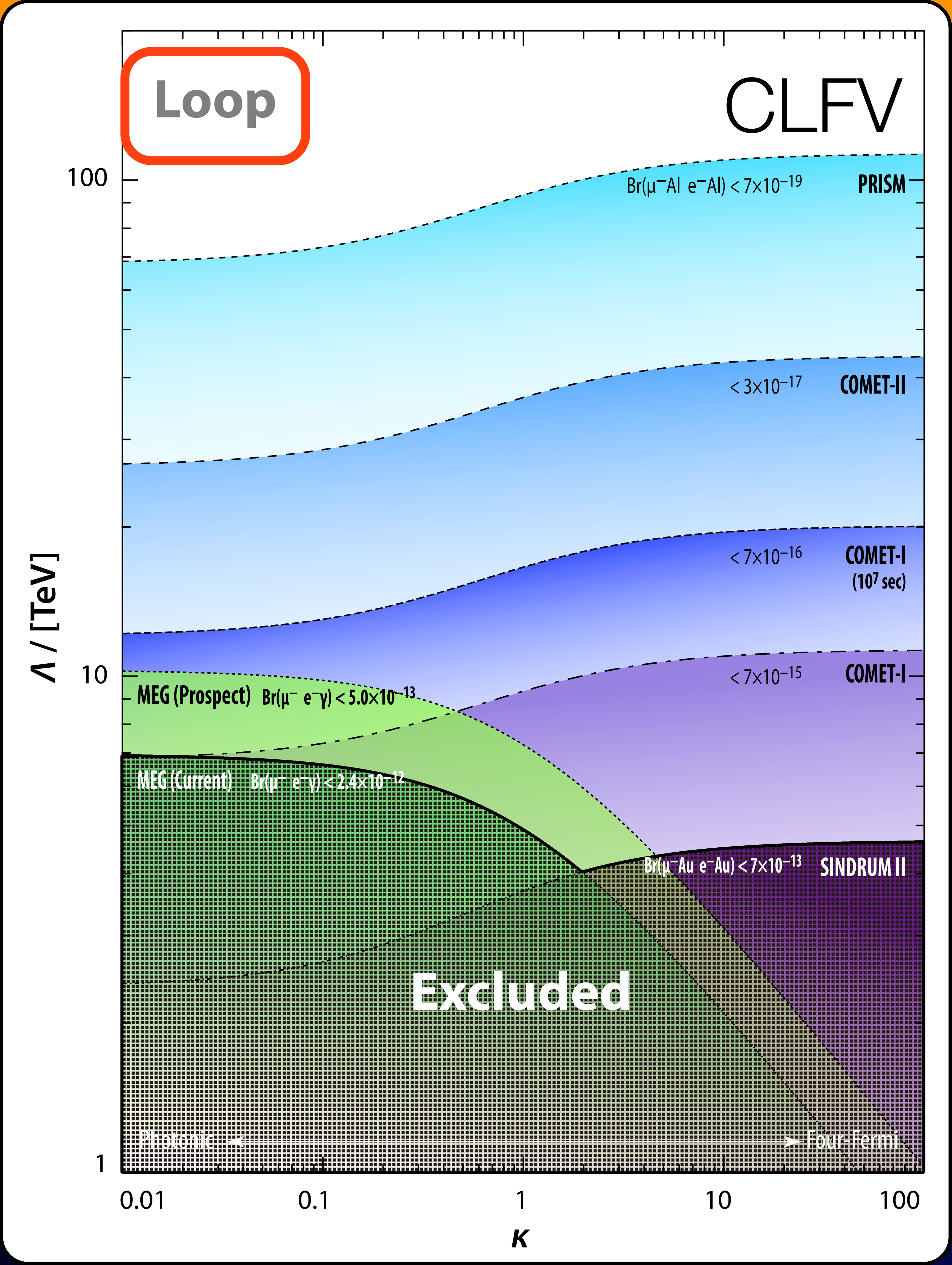
With loop suppression



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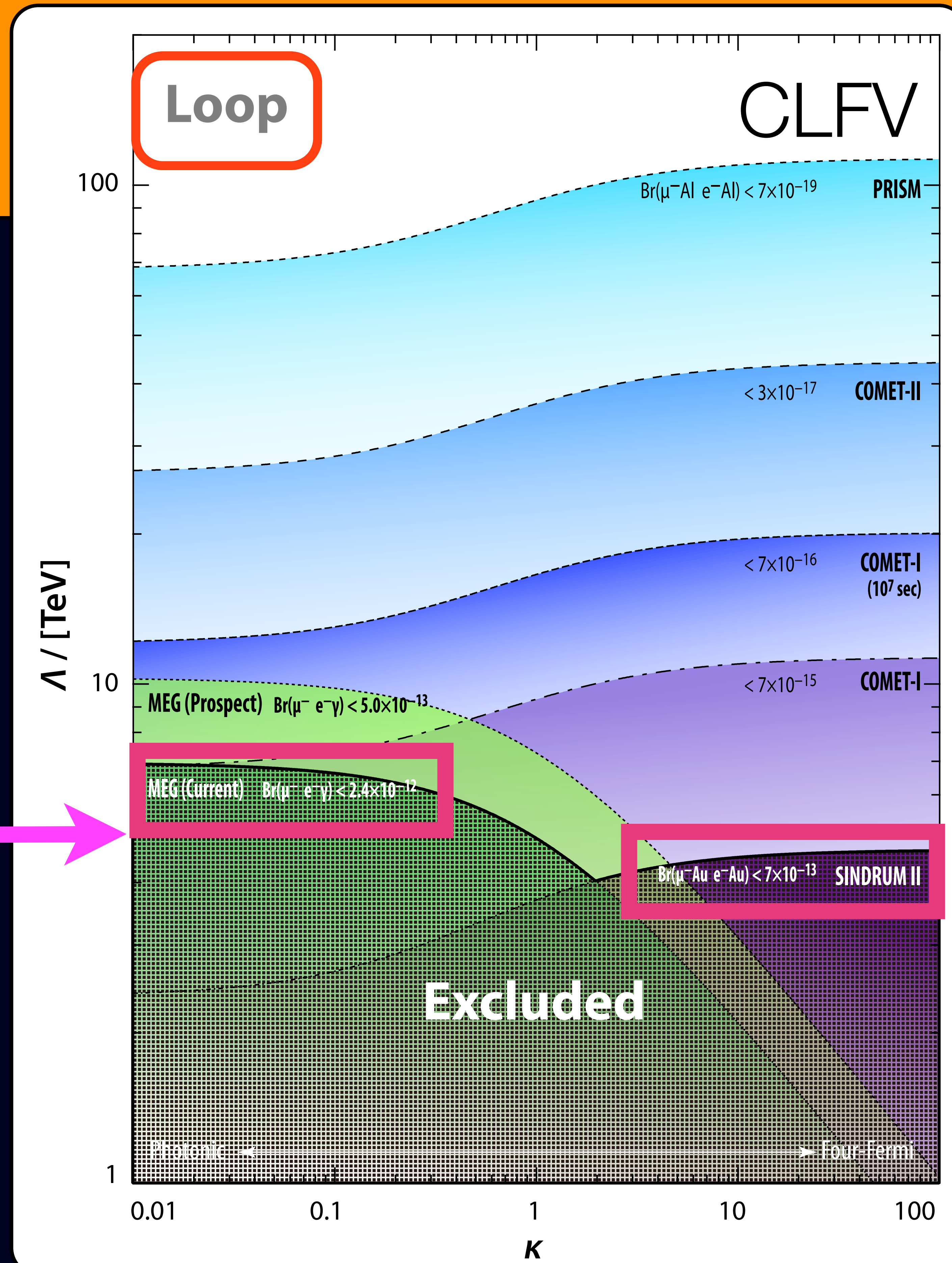

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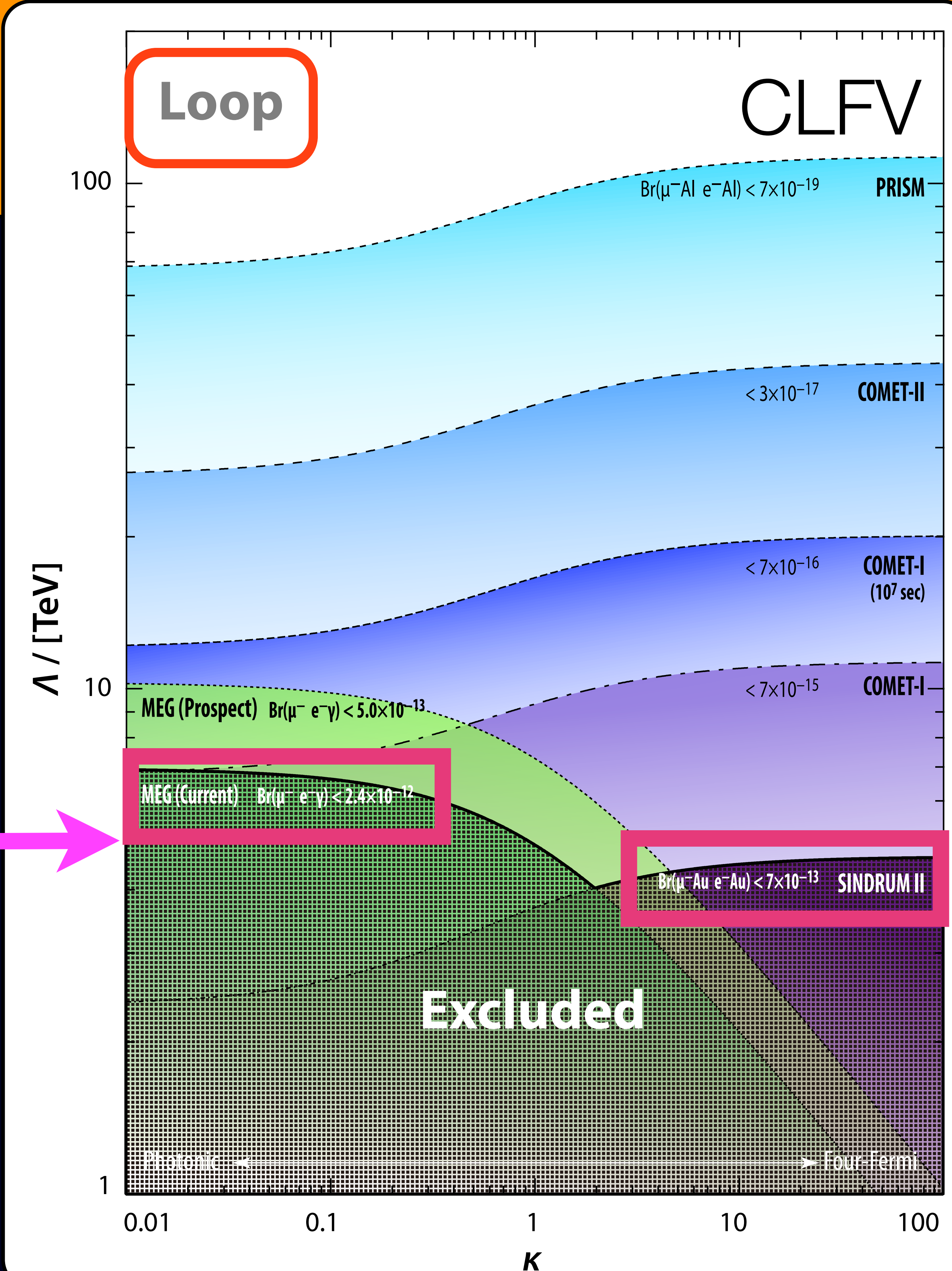
With loop suppression

Flavor mixing couplings gives additional reduction on the Λ reach.



Example: Sensitivity to Energy Scale of NP

Loop contribution in SUSY models

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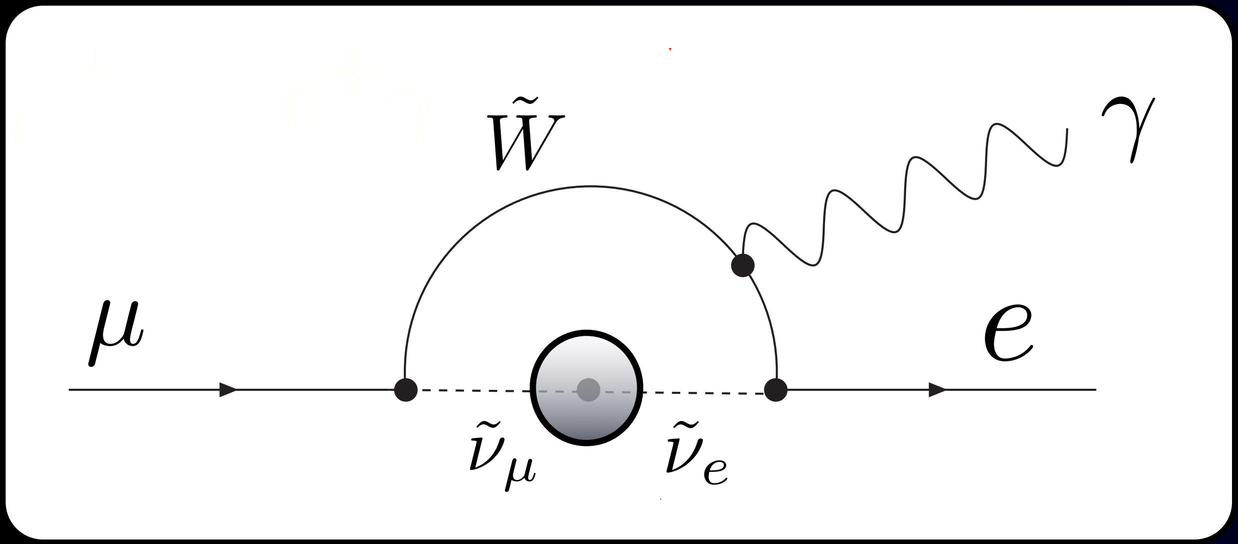
Loop contribution in SUSY models

- For loop diagrams,

$$\mathrm{BR}(\mu \to e\gamma) = 1 \times 10^{-11} \times \left(\frac{2\mathrm{TeV}}{\Lambda}\right)^4 \left(\frac{\theta_{\mu e}}{10^{-2}}\right)^2 \qquad y = \frac{g^2}{16\pi^2}\theta_{\mu e}$$

> sensitive to TeV energy scale with reasonable mixing



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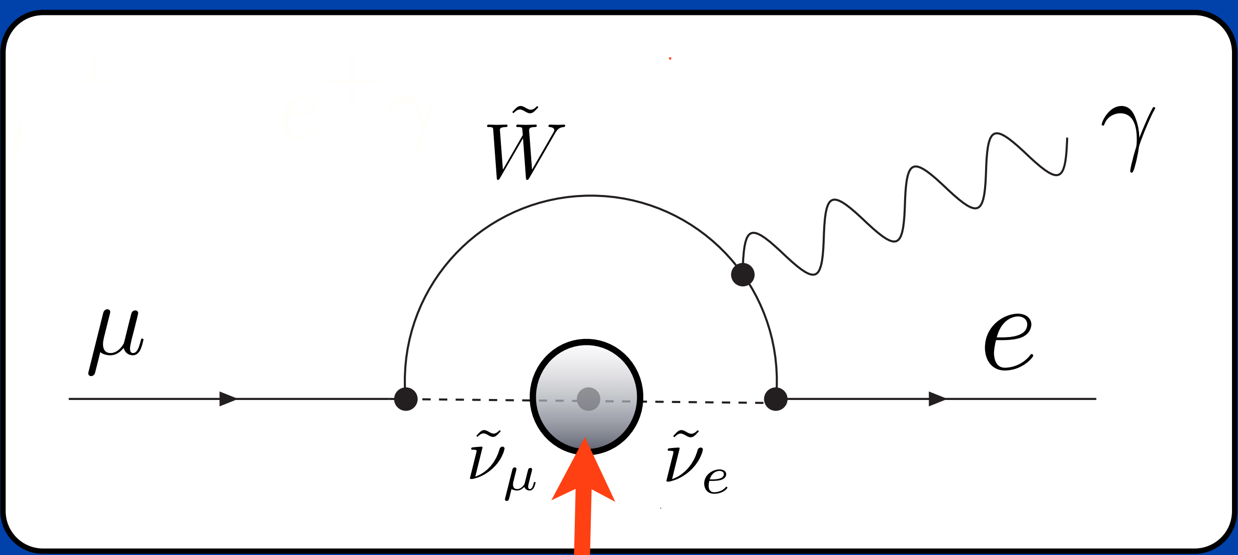

example diagram for SUSY (~TeV)

Physics at about 10^{16} GeV

slepton mixing (from RGE)

$$(m^2_{\tilde{L}})_{21} \sim \frac{3m_0^2 + A_0^2}{8\pi^2} h_t^2 V_{td} V_{ts} \ln \frac{M_{GUT}}{M_{R_s}}$$

SUSY-GUT model

$$(m^2_{L})_{21} \sim \frac{3m_0^2 + A_0^2}{8\pi^2} h_\tau^2 U_{31} U_{32} \ln \frac{M_{GUT}}{M_R}$$

SUSY neutrino seesaw model

CLFV and Neutrino Mass Generation

from Y. Okada-san's slide (2010)

CLFV and Neutrino Mass Generation

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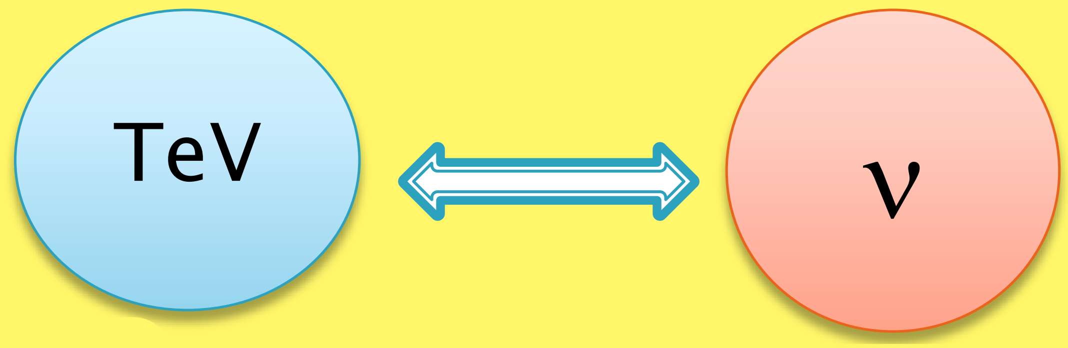
Scale of the electroweak symmetry breaking

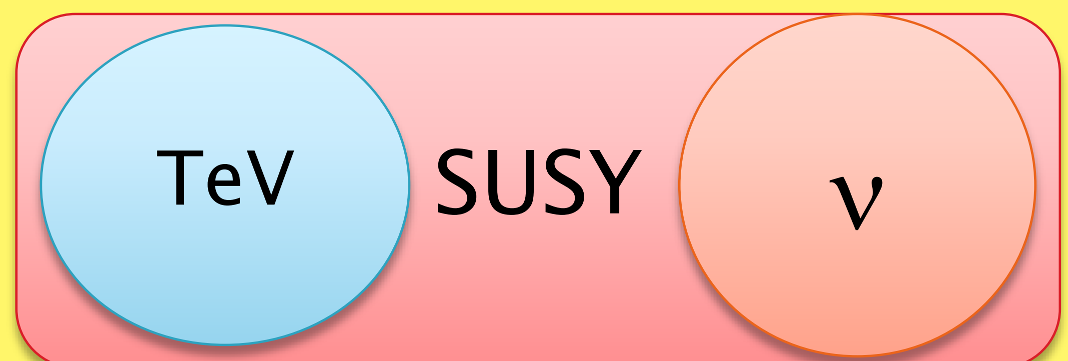
Scale of the neutrino mass generation

If two scales are well separated,
LFVs are suppressed.

CLFV~O(10^{-54})

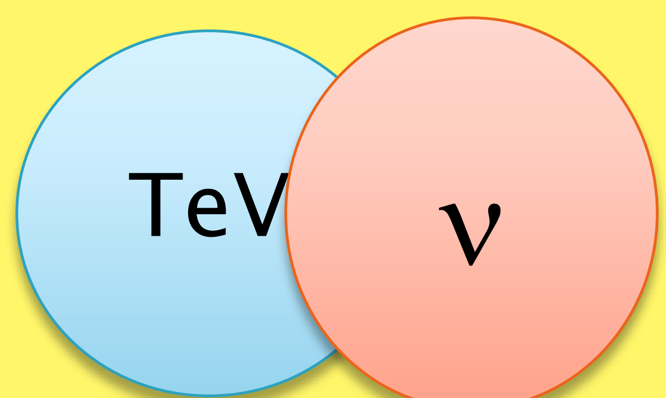


In supersymmetric models,
large LFV signals are expected
even if two scales are separated.



If two scales are close,
large LFVs are expected.

- Neutrino mass from loop
- Triplet Higgs for neutrino mass
- Left-right symmetric model



Rare Decays are indirect searches,

"DNA of New Physics" (a la Prof. Dr. A.J. Buras)

from D. Hitlin's talk [368]

W. Altmannshofer, A.J. Buras, S. Gori, P. Paradisi and D.M. Straub

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

The pattern of measurement:
★★★ large effects
★★ visible but small effects
★ unobservable effects
is characteristic,
often uniquely so,
of a particular model

GLOSSARY	
AC [10]	RH currents & U(1) flavor symmetry
RVV2 [11]	SU(3)-flavored MSSM
AKM [12]	RH currents & SU(3) family symmetry
δLL [13]	CKM-like currents
FBMSSM [14]	Flavor-blind MSSSM
LHT [15]	Little Higgs with T Parity
RS [16]	Warped Extra Dimensions

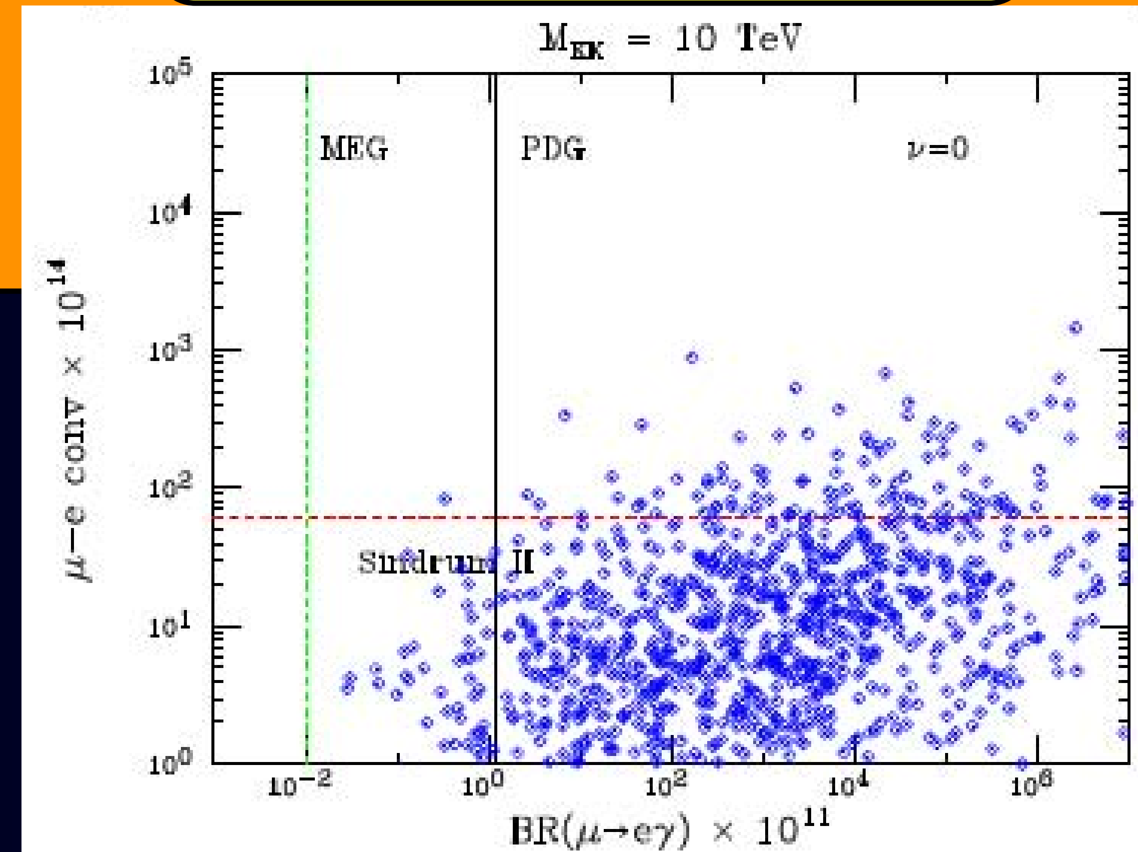
These are a subset of a subset listed by Buras and Girrbach MFV, CMFV, $2HDM_{\overline{MFV}}$, LHT, SM4, SUSY flavor. SO(10) – GUT, $SSU(5)_{HN}$, FBMSSM, RHMFV, L-R, RS_0, gauge flavor, ……….

Rare Muon Decays

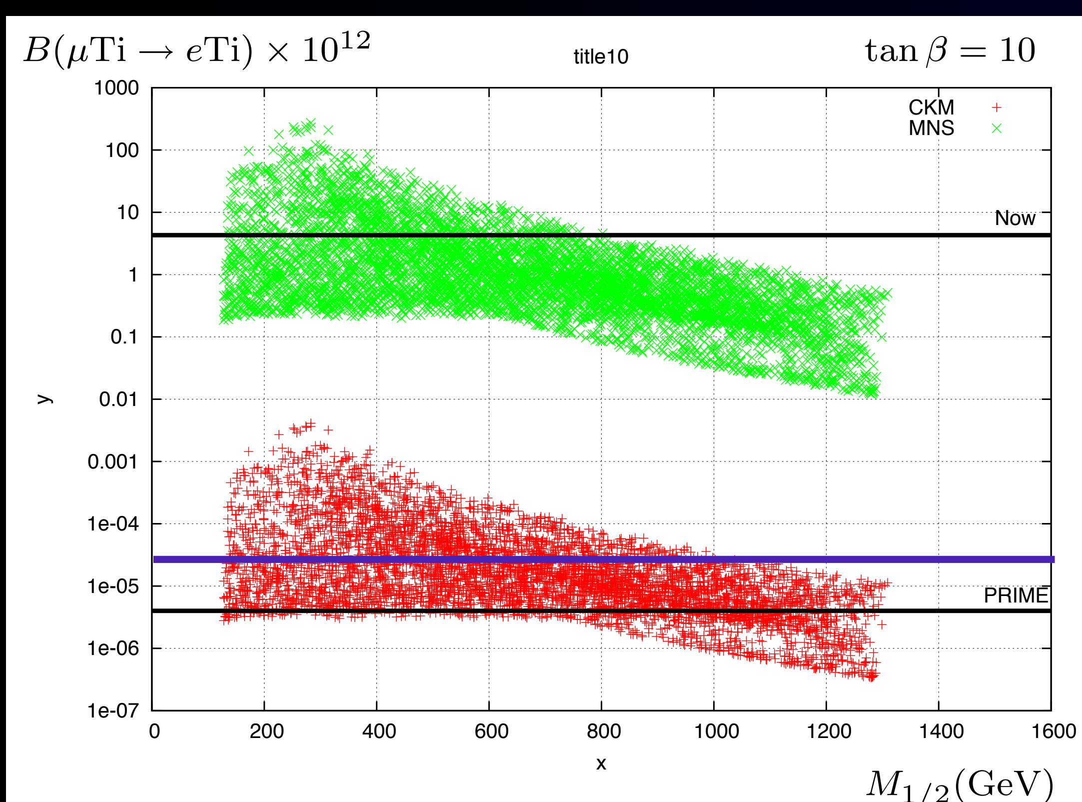
CLFV Predictions

Various BSM models predict sizable muon CLFV, as well as tau CLFV.

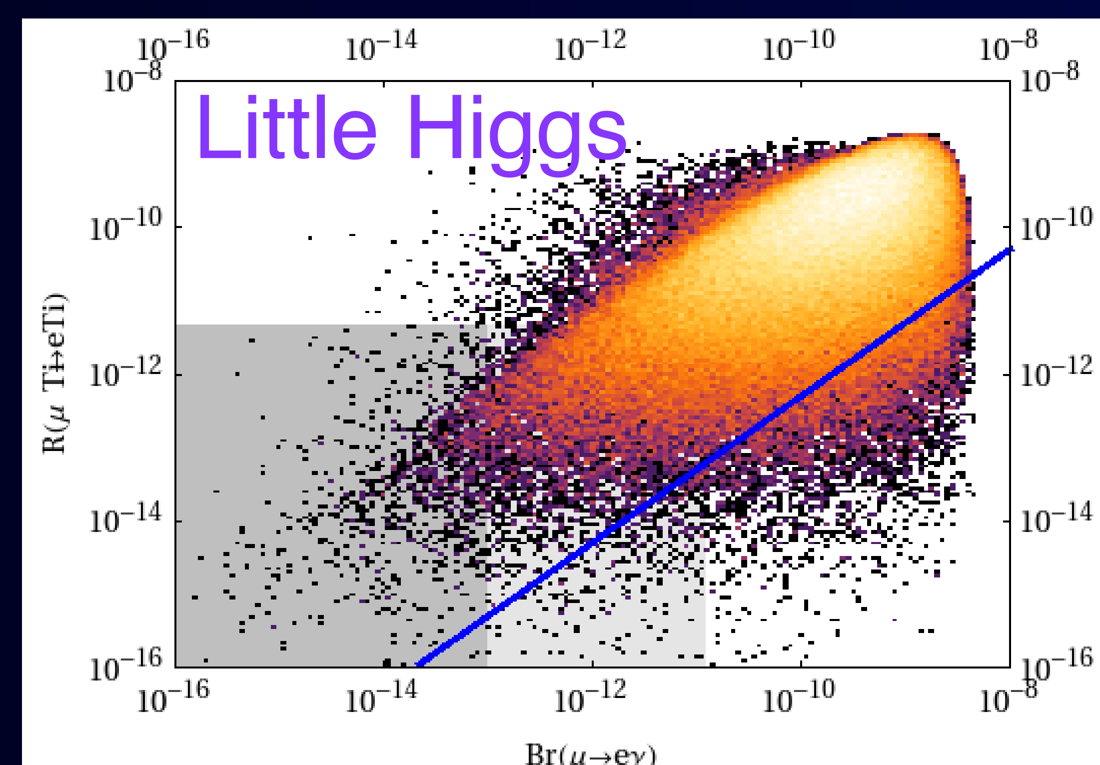
extra dimension model



SUSY model



little Higgs model



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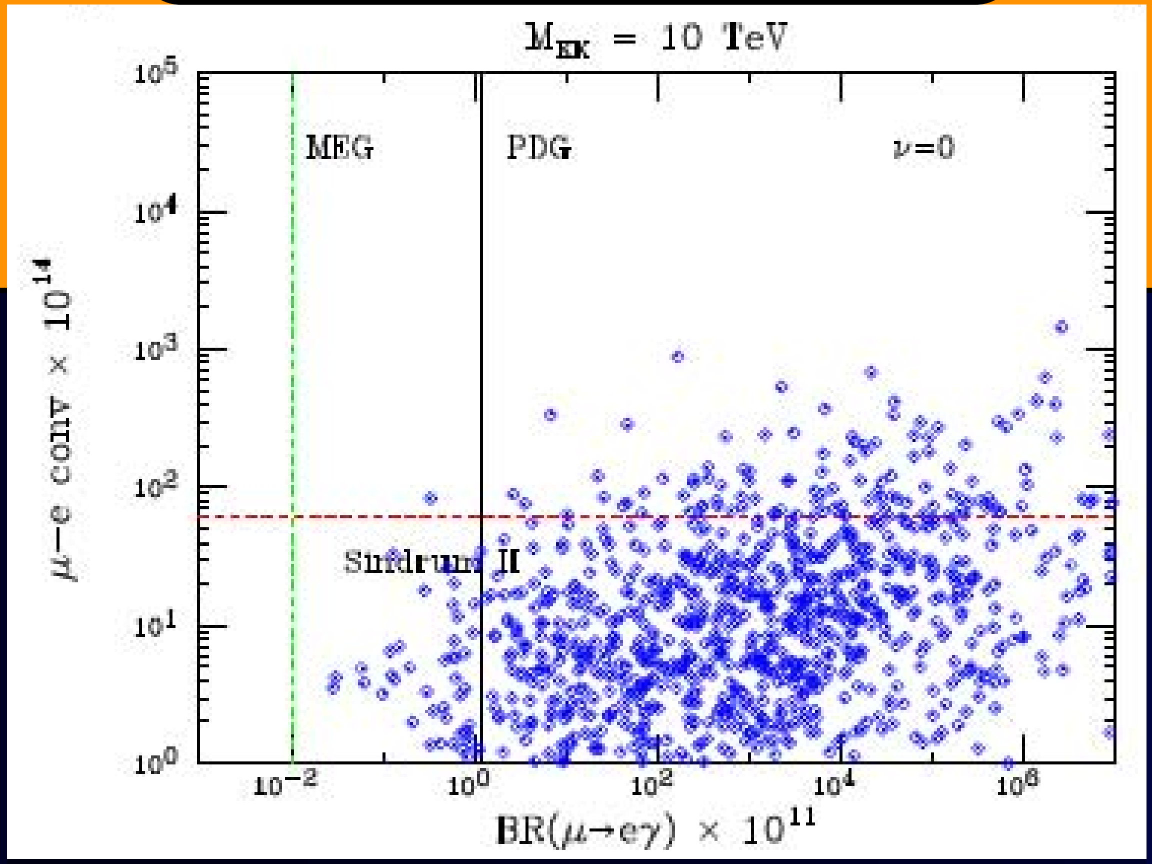

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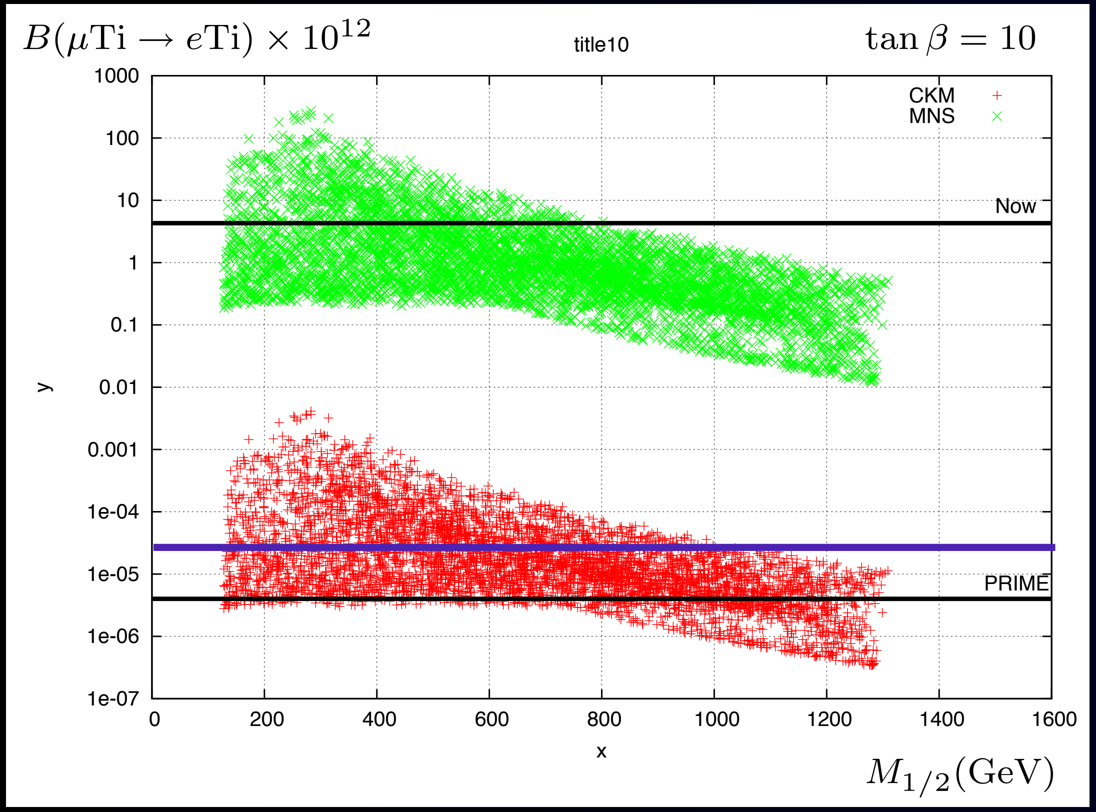
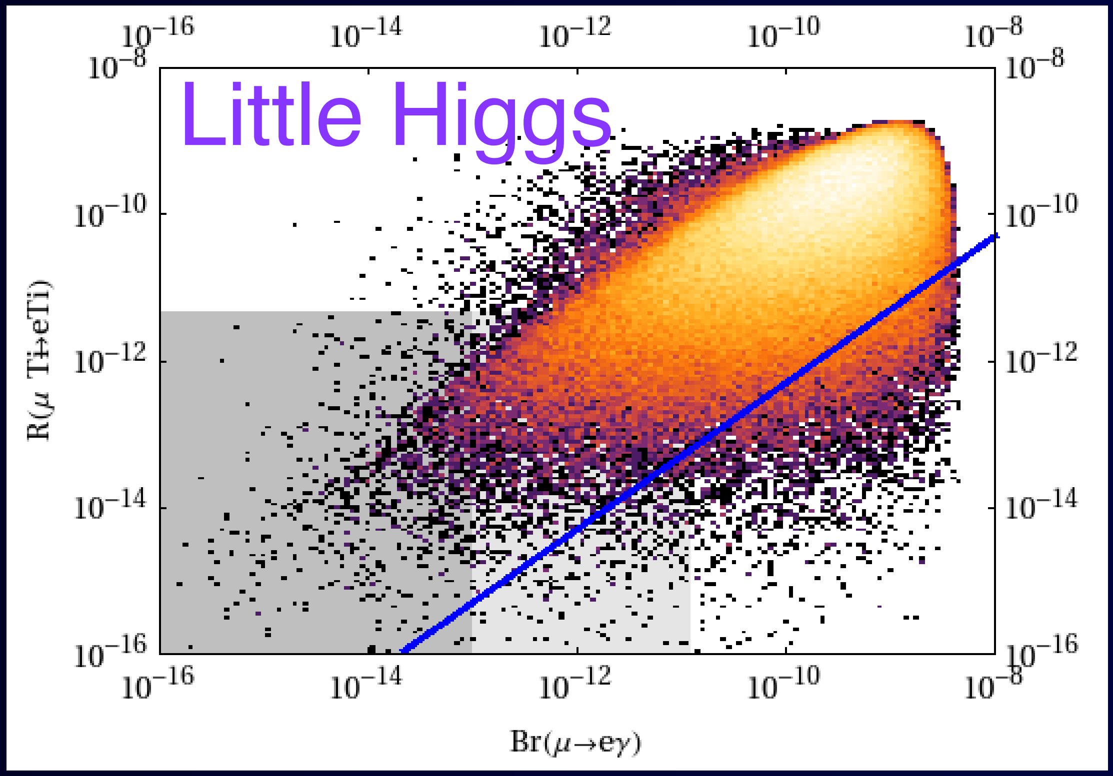


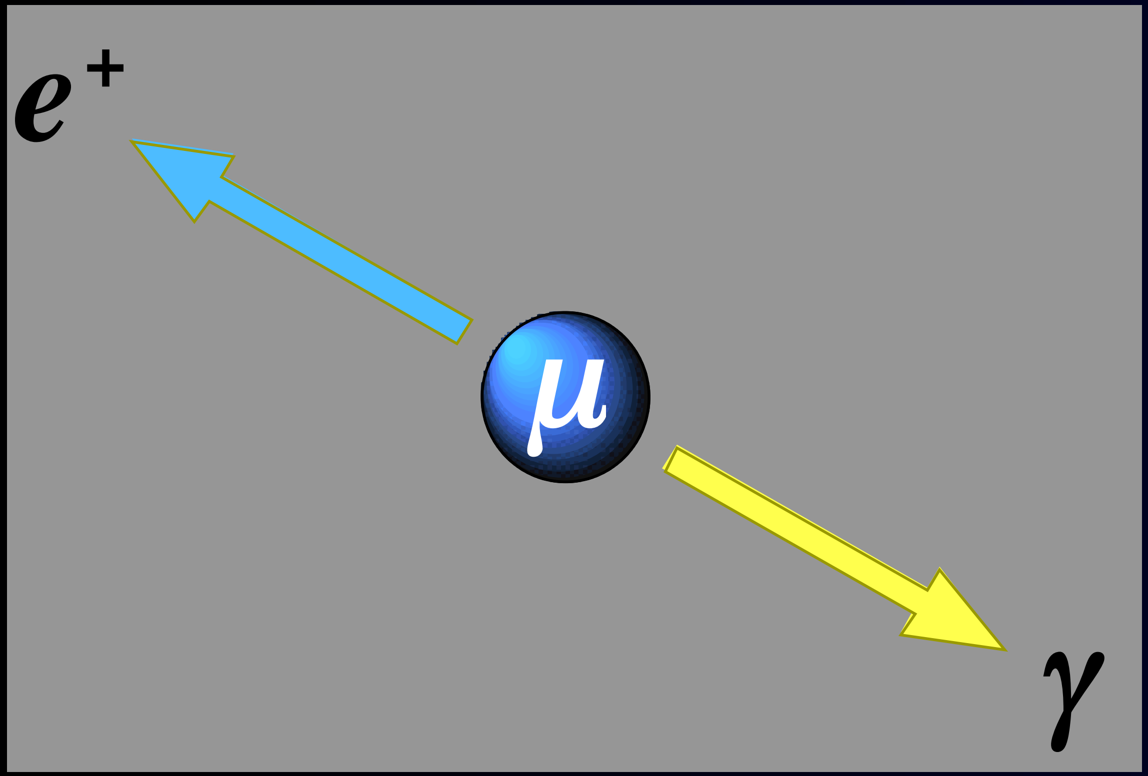
10^4

little Higgs model



What is $\mu \to e\gamma$?

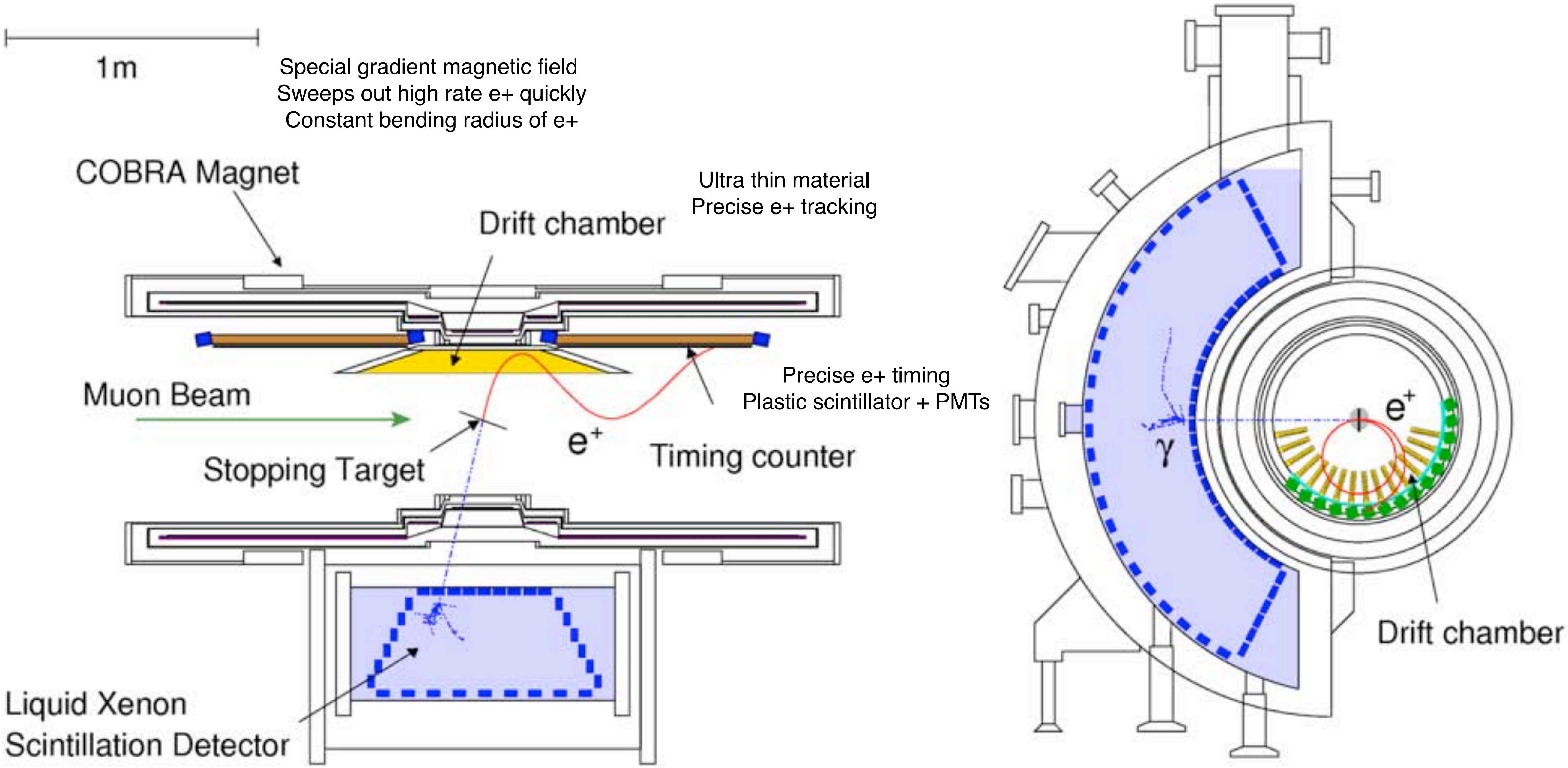
- Event Signature
  - $E_e = m_\mu/2$, $E_\gamma = m_\mu/2$ (=52.8 MeV)
  - angle $\theta_{\mu e}$=180 degrees (back-to-back)
  - time coincidence



- Backgrounds
  - prompt physics backgrounds
    - radiative muon decay $\mu \to e\nu\nu\gamma$ when two neutrinos carry very small energies.
  - accidental backgrounds
    - positron in $\mu \to e\nu\nu$
    - photon in $\mu \to e\nu\nu\gamma$ or photon from e^+e^- annihilation in flight.

MEG Experiment

$3x10^7 \mu/s$@PSI, Switzerland

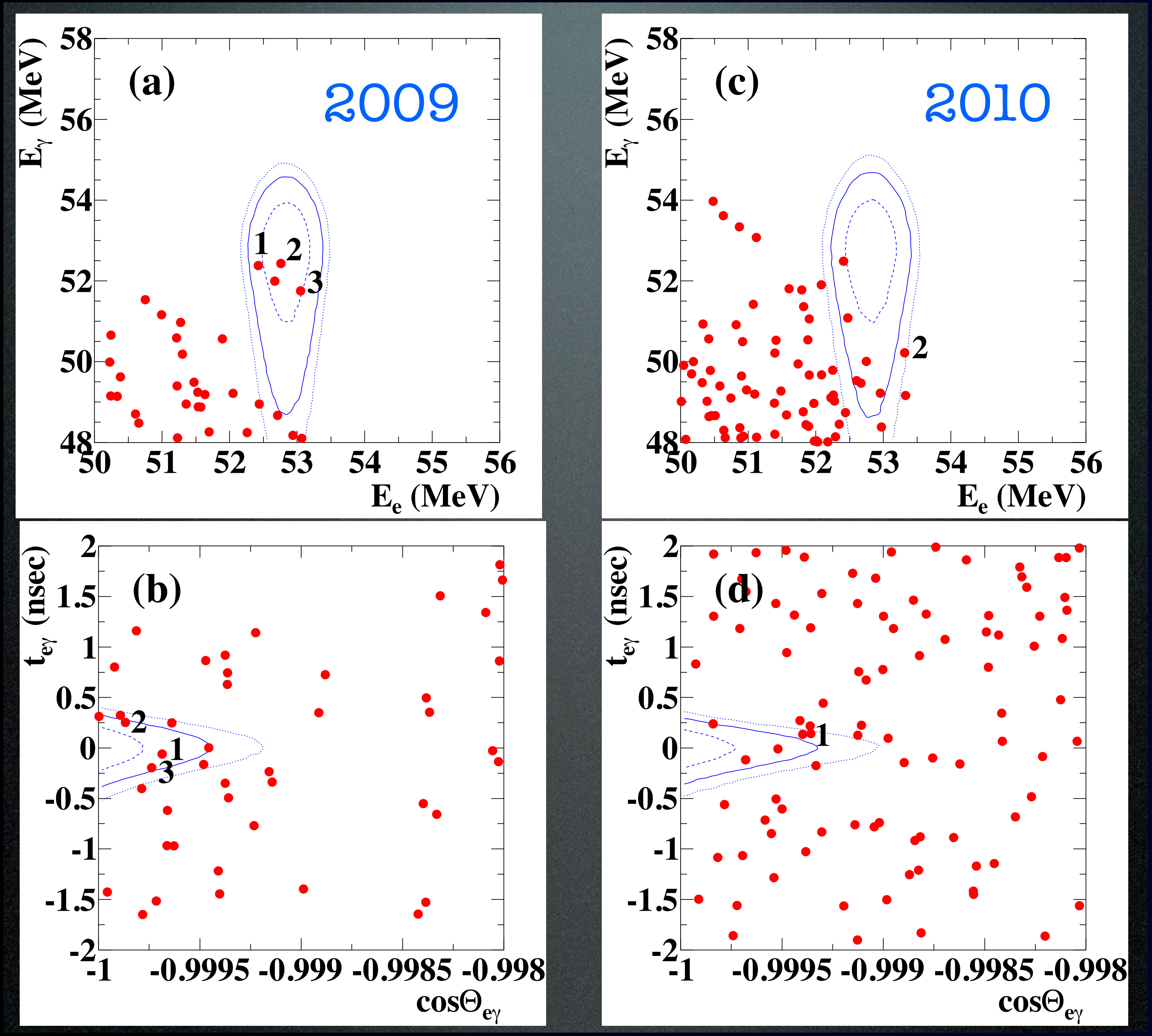


2.7 ton of liquid xenon
Homogeneous detector
Good time, position, energy resolution

Waveform digitizer for all detectors

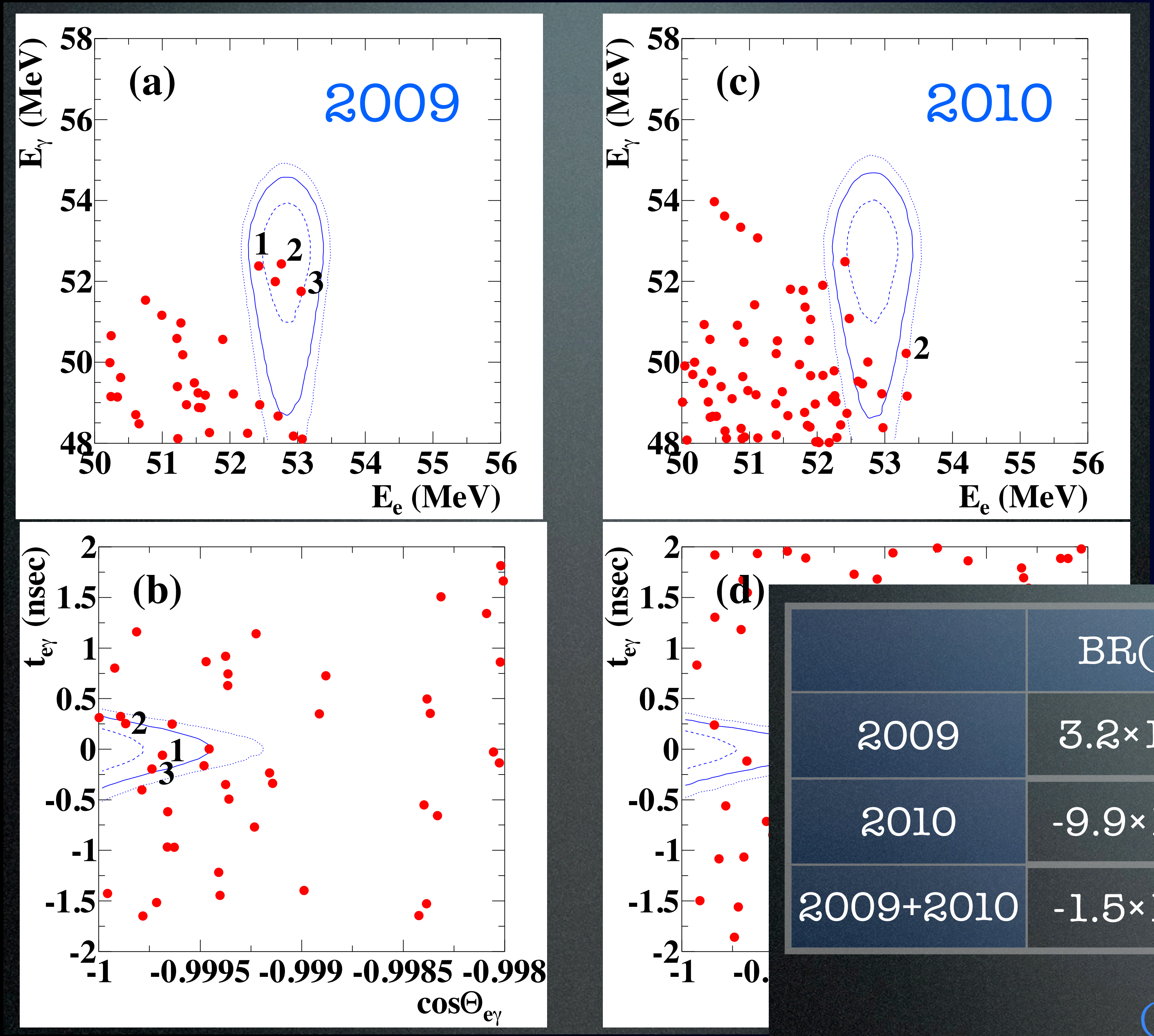
MEG Result (2009+2010)

from H. Nishiguchi's talk [829]



MEG Result (2009+2010)

from H. Nishiguchi's talk [829]



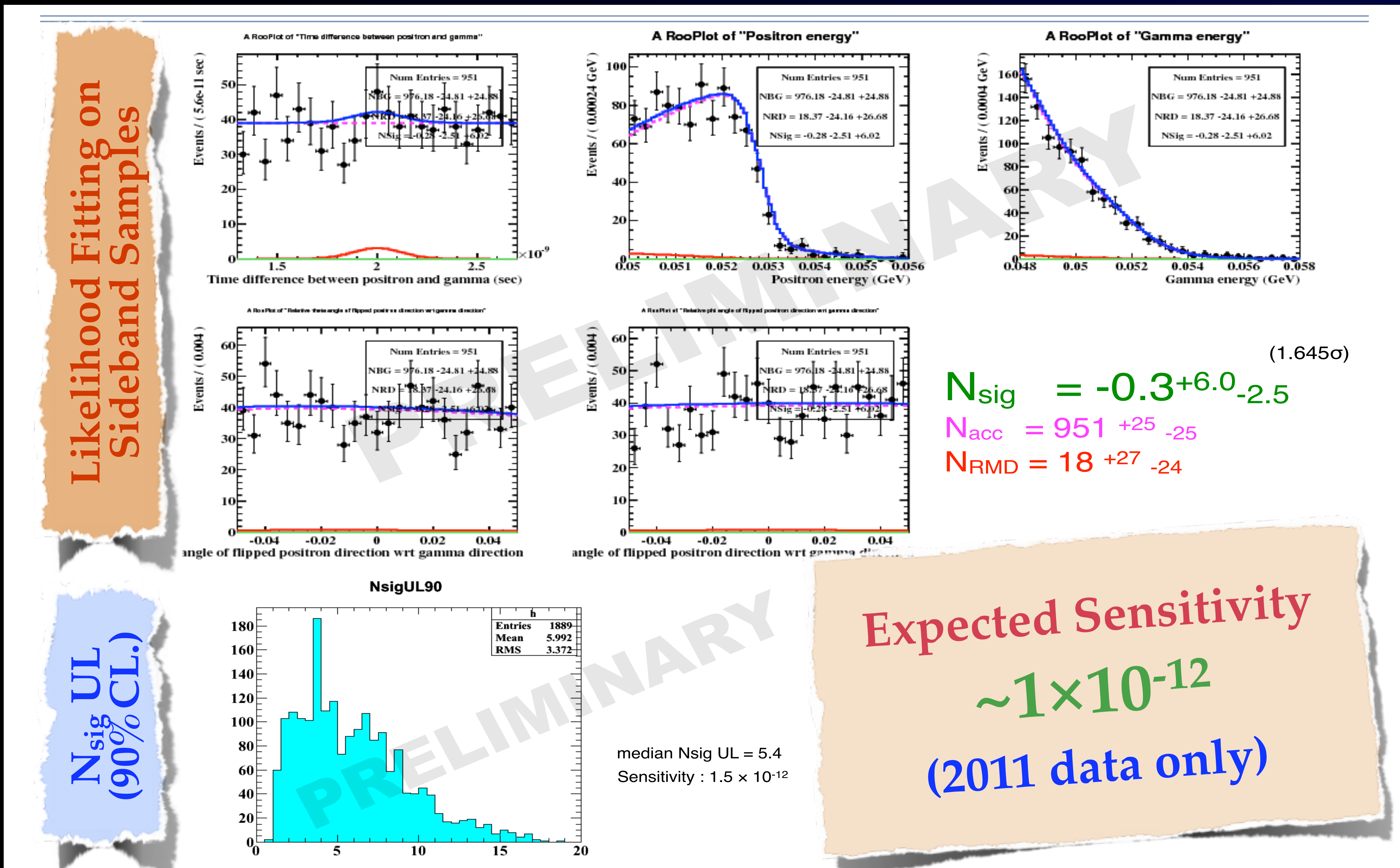
	BR(fit)	LL 90%	UL 90%
2009	3.2×10^{-12}	1.7×10^{-13}	9.6×10^{-12}
2010	-9.9×10^{-13}	--	1.7×10^{-12}
2009+2010	-1.5×10^{-13}	--	2.4×10^{-12}

combined result

(2009+2010expected UL = 1.6×10^{-12})

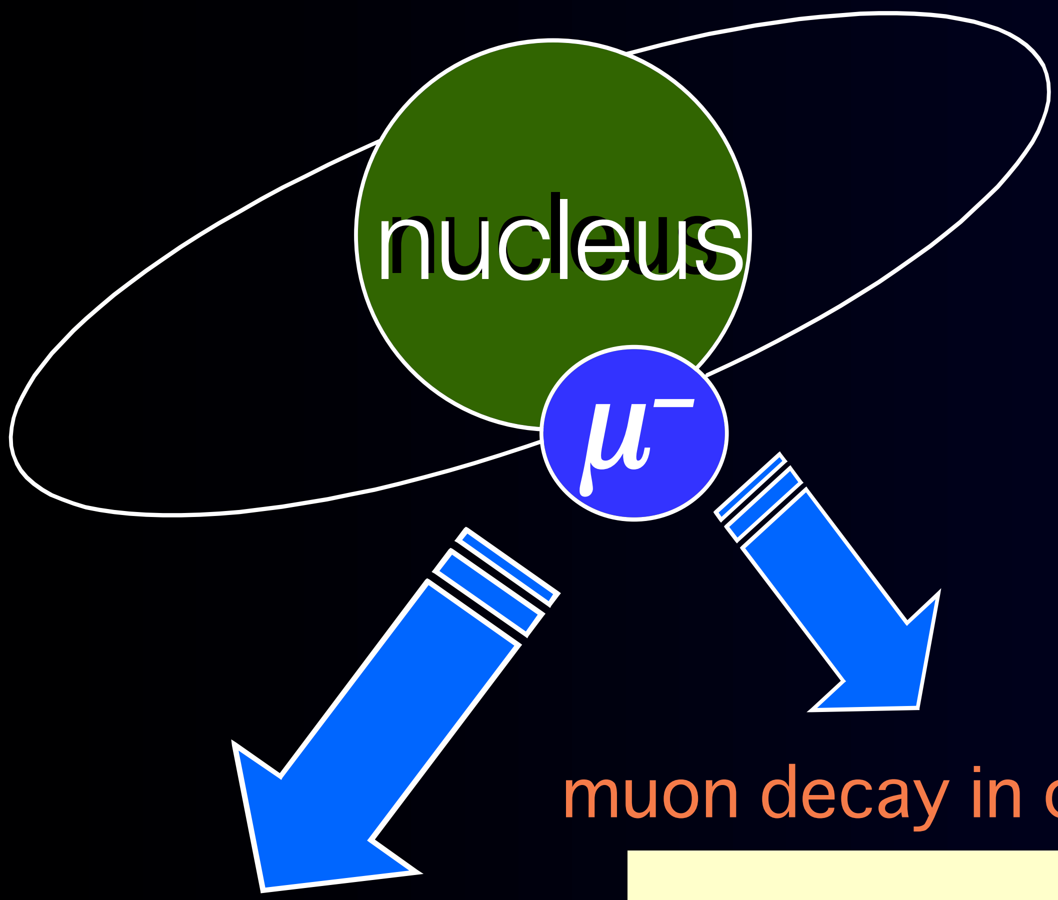
MEG Results (2011)
Signal box is not opened yet....

from H. Nishiguchi's talk [829]



What is Muon to Electron Conversion?

1s state in a muonic atom



muon decay in orbit

$$\mu^- \rightarrow e^- \nu \overline{\nu}$$

nuclear muon capture

$$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$$

Neutrino-less muon nuclear capture

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

Event Signature :
a single mono-energetic electron of 100 MeV

Backgrounds:

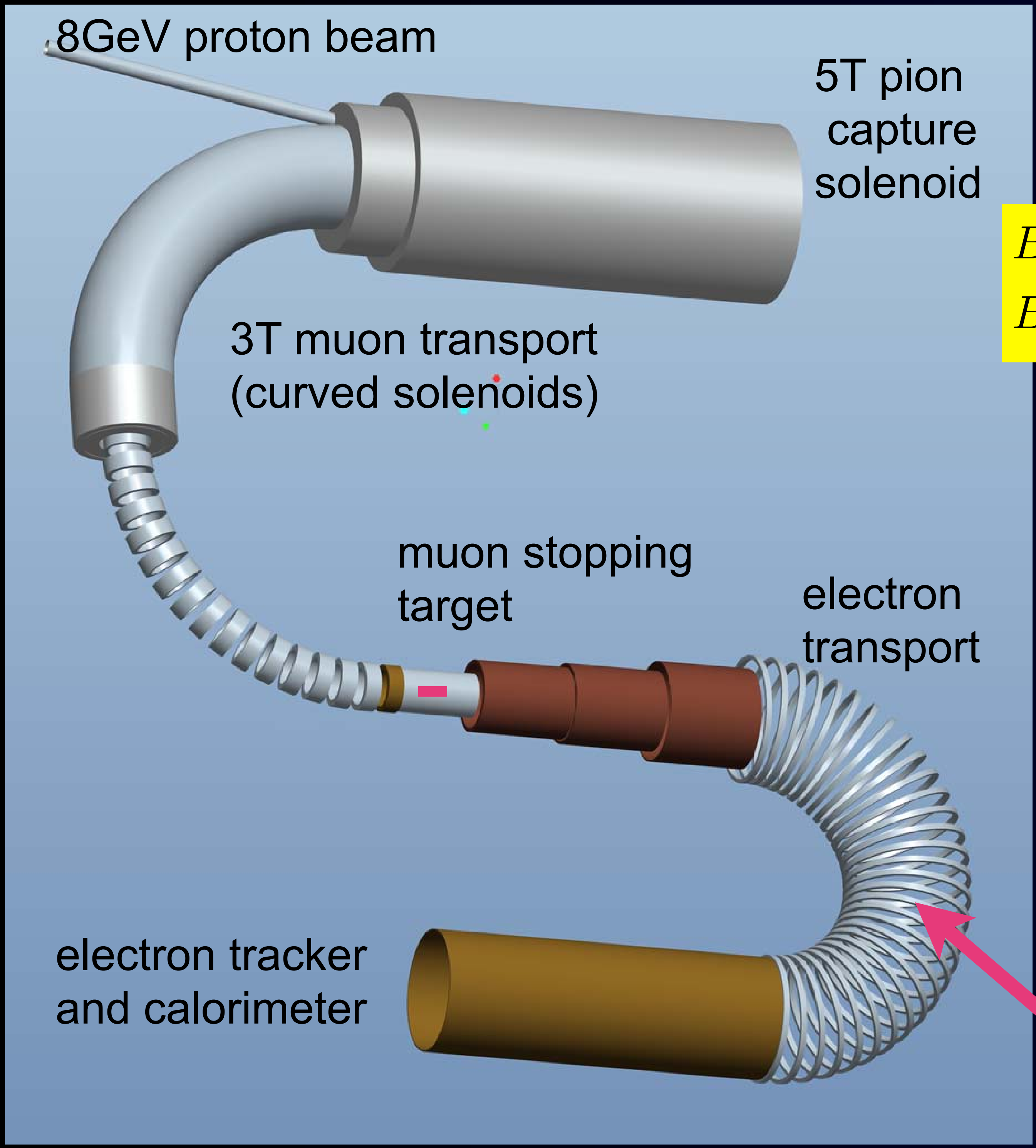
(1) physics backgrounds
  ex. muon decay in orbit (DIO)

(2) beam-related backgrounds
  ex. radiative pion capture, muon decay in flight,

(3) cosmic rays, false tracking

μ-e conversion : COMET (E21) at J-PARC

from YK poster presentation



Experimental Goal of COMET

$$B(\mu^- + Al \rightarrow e^- + Al) = 2.6 \times 10^{-17}$$
$$B(\mu^- + Al \rightarrow e^- + Al) < 6 \times 10^{-17} \quad (90\% C.L.)$$

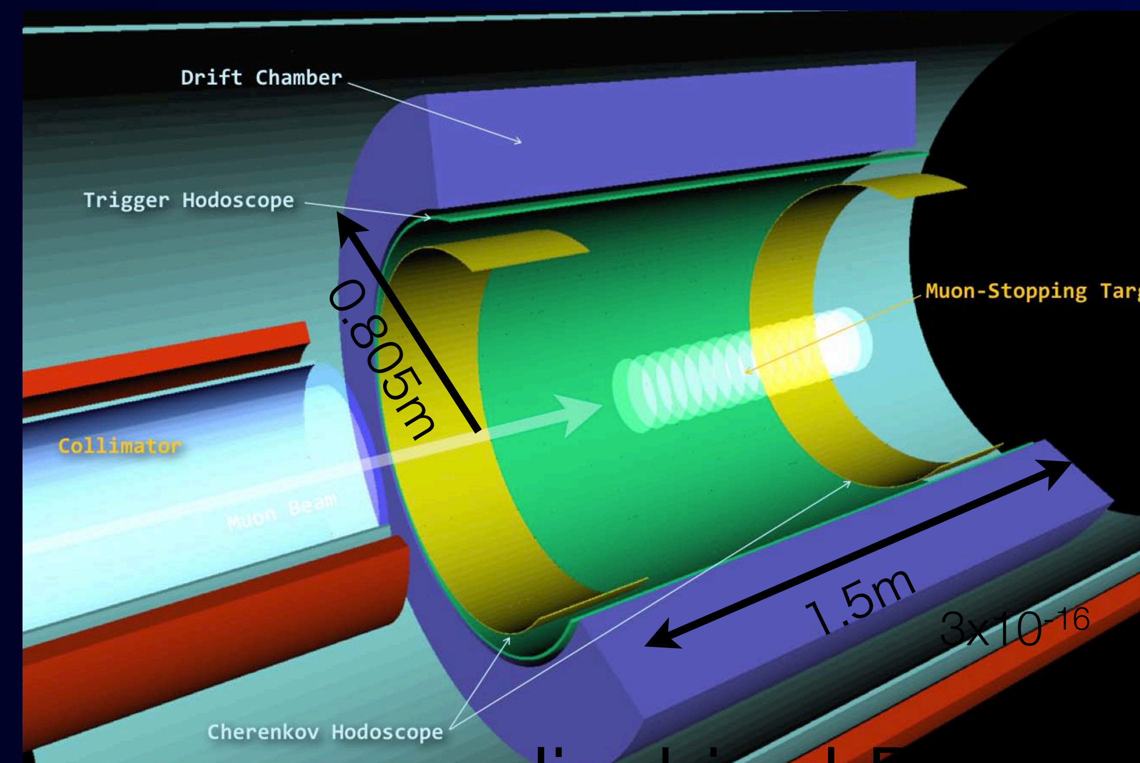
- 10^{11} muon stops/sec for 56 kW proton beam power.
- C-shape muon beam line and C-shape electron transport followed by electron detection system.
- Stage-1 approved in 2009.
- Aim to start in 2020.

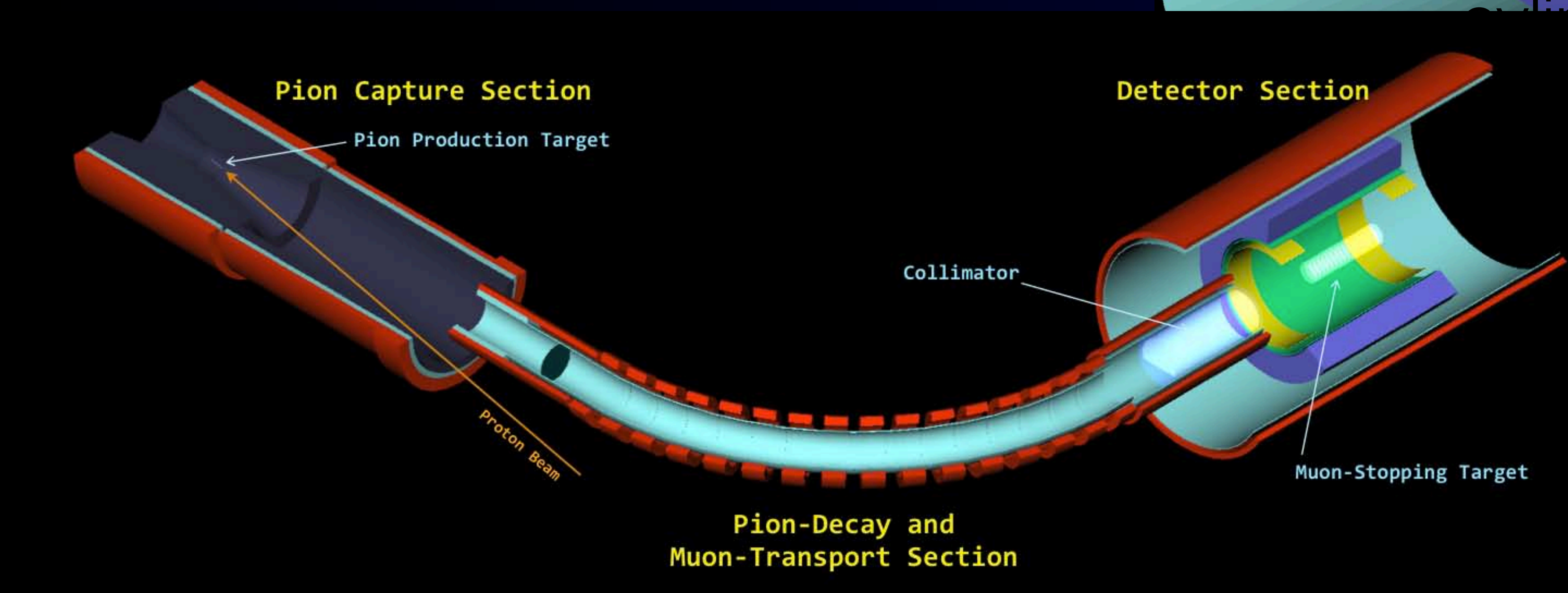
Electron transport with curved solenoid would make momentum and charge selection.

μ-e conversion : COMET Phase-I

from YK poster presentation

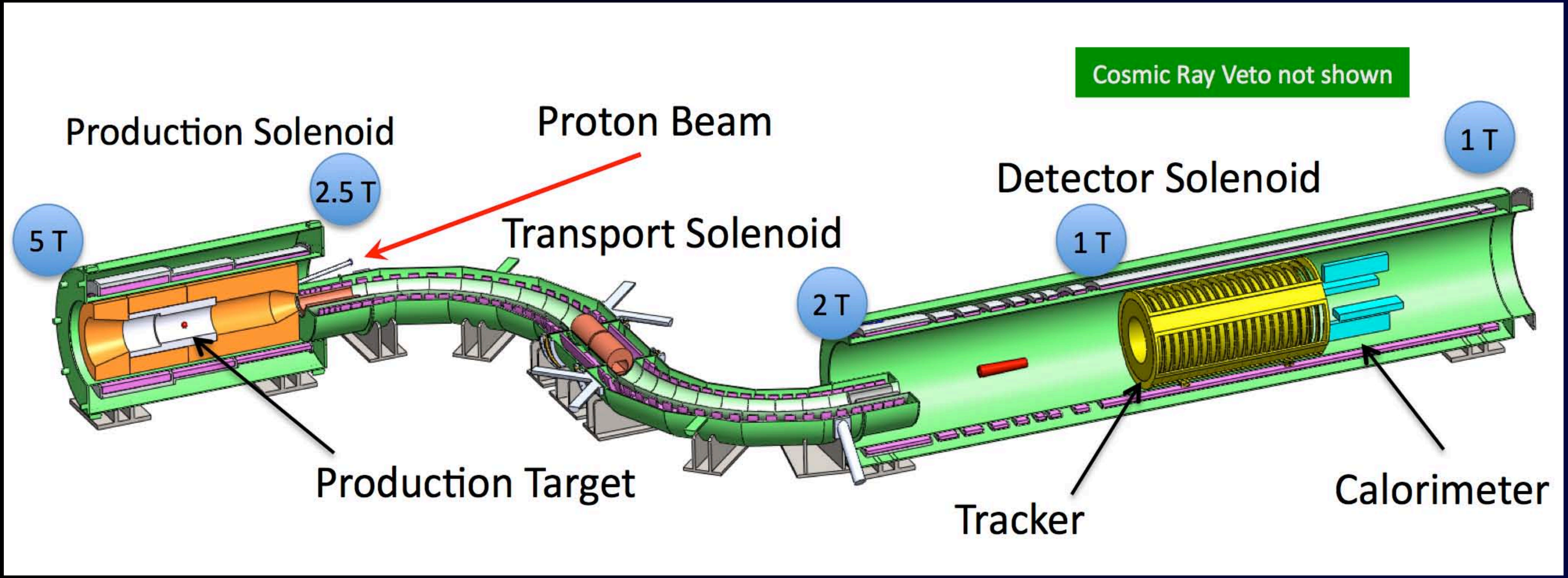
- COMET Phase-I (LOI) aims ....
  - BG studies for Phase-II
  - intermediate sensitivity
    - SE sensitivity~3×10^{-15} for 10^6 s (12 days) with 3 kW proton beam power (with 5×10^9 stopped μ/s).
- Aim to start in 2016.





cylindrical drift chamber

μ-e conversion : Mu2e at Fermilab



$$B(\mu^- + Al \to e^- + Al) = 5 \times 10^{-17} \quad \text{(S.E.)}$$
$$B(\mu^- + Al \to e^- + Al) < 10^{-16} \quad \text{(90\%C.L.)}$$

- Reincarnation of MECO at BNL.
- Antiproton buncher ring is used to produce a pulsed proton beam.
- Approved in 2009, and CD0 in 2009, and CD1 review underway.
- Data taking starts in about 2019.

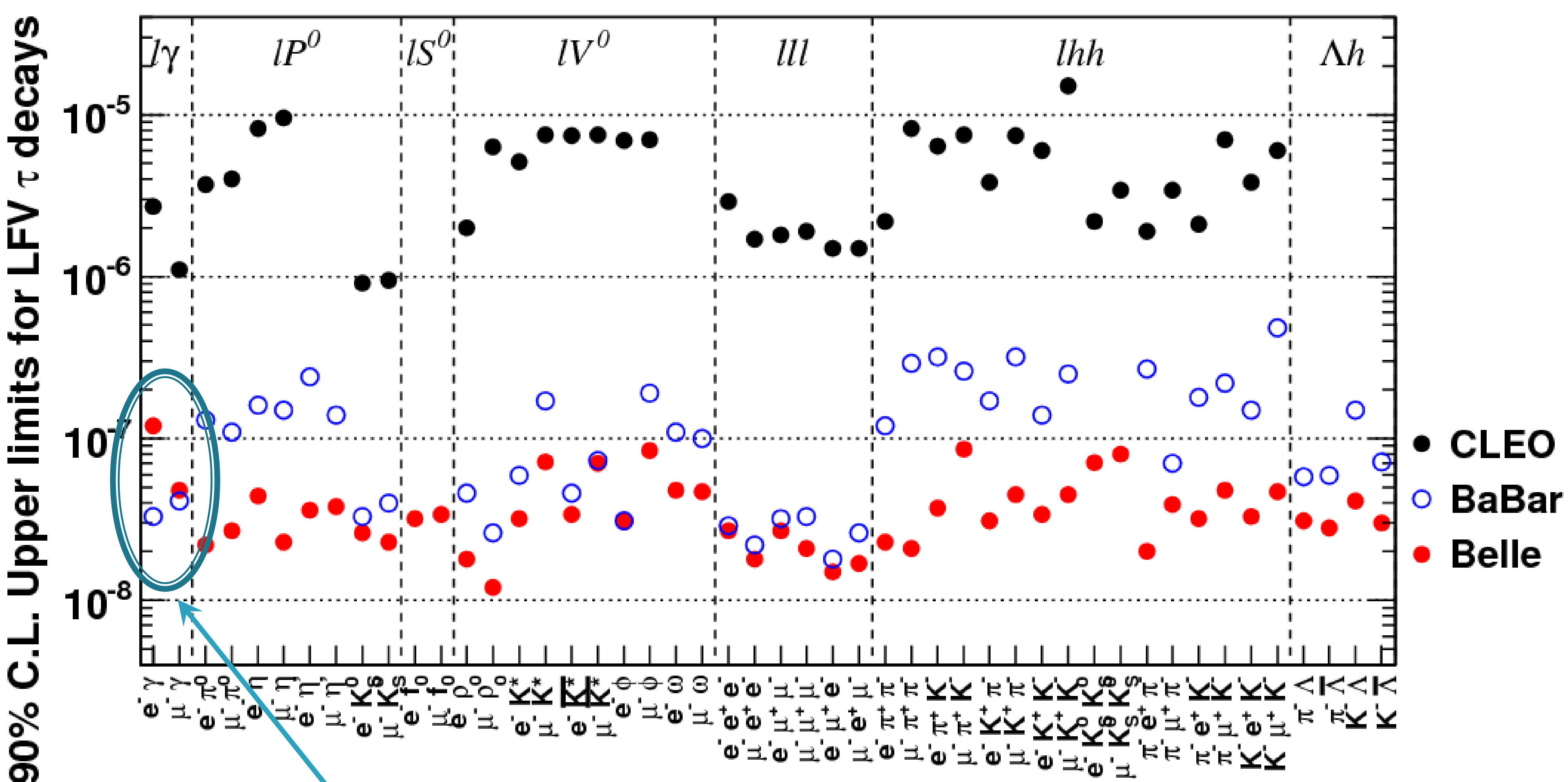
Tau Rare Decays

tau CP violation not included.

Tau CLFV Decays at Belle

from K. Hayasaka's talk [742]

Upper Limits on τ LFV Decays



The remaining mode are $\tau \to \mu\gamma$ and $e\gamma$!

Previously, a 545 fb^{-1} data subsample was analyzed.

- 980 fb^{-1} data (about 10^9 taus) at Belle
- Signal box is still blinded, but $<5\times10^{-8}$ level is expected.

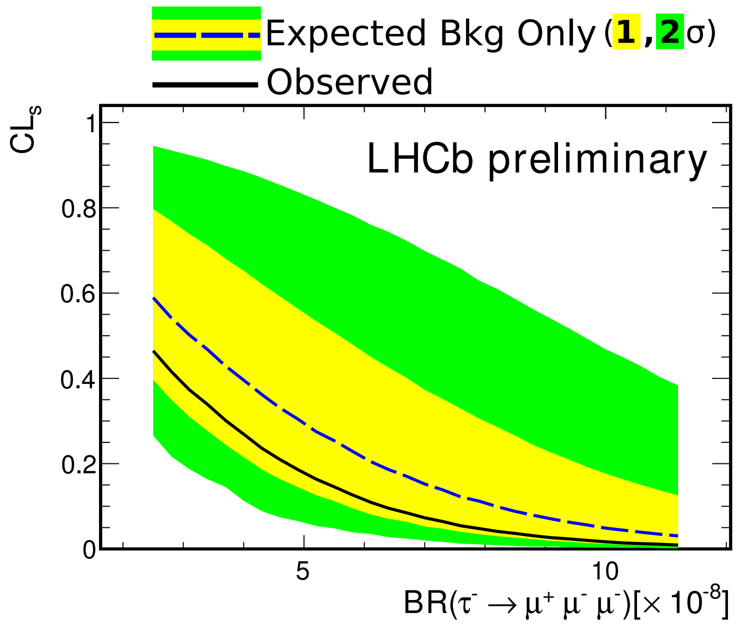
τ→μμμ at LHCb (preliminary)

from M. Perrin-Terrin's talk [559]

Results

- Preliminary upper limits 95 (90)% C.L. extracted using the $\mathrm{CL_s}$ method

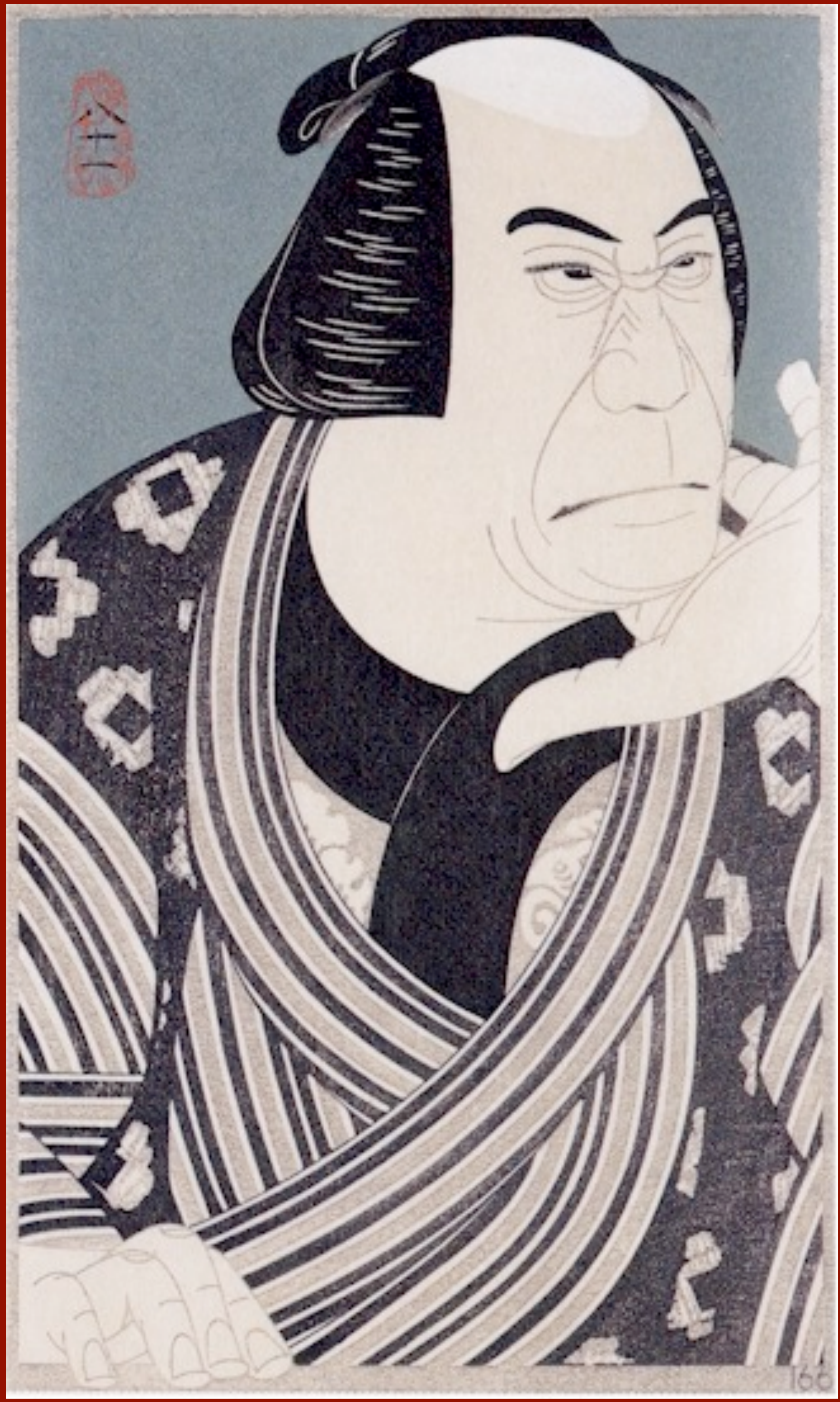
$$\mathcal{B}(\tau^- \to \mu^+\mu^-\mu^-) < 7.8\ (6.3) \times 10^{-8}$$



- Results comparable with Belle PLB 687 (2010) 139, arXiv:1001.3221
  $\mathcal{B}(\tau^- \to \mu^+\mu^-\mu^-) < 2.1 \times 10^{-8}$ at 90% C.L.

- All analyses performed with 1 $\mathrm{fb^{-1}}$,
- Outlook for 2012: another 1.5 $\mathrm{fb^{-1}}$

Kaon Rare Decays



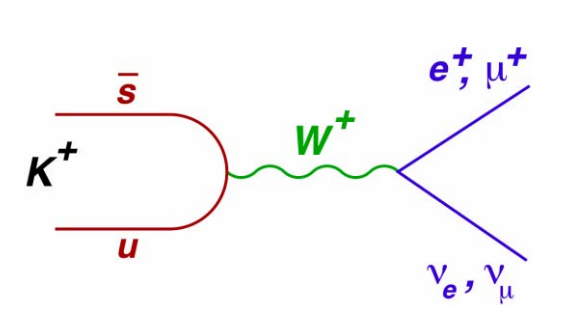
B(K⁺→eν)/B(K⁺→μν) at NA48/2-NA62

from V. Kekelidze's talk [152]

$R_K^{SM} = \Gamma(K^\pm \to e^\pm \nu)/\Gamma(K^\pm \to \mu^\pm \nu)$

$= (m_e^2/m_\mu^2) \times (m_K^2 - m_e^2)^2/(m_K^2 - m_\mu^2)^2 \times (1+\delta R_K^{rad})$

$= (2.477 \pm 0.001) \times 10^{-5}$



- in-flight K⁺ decays
- excellent test of μ-e universality
- hadronic uncertainty is canceled in ratio.
- good μ/e separation below 30 GeV/c

beyond SM:

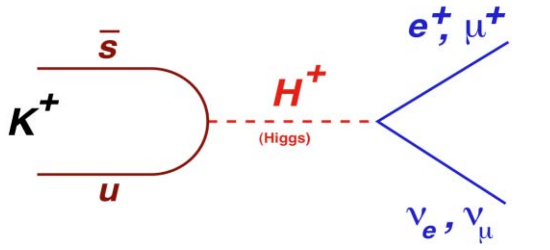
*2HDM → presence of extra charged Higgs introduces **LFV** at one-loop level*

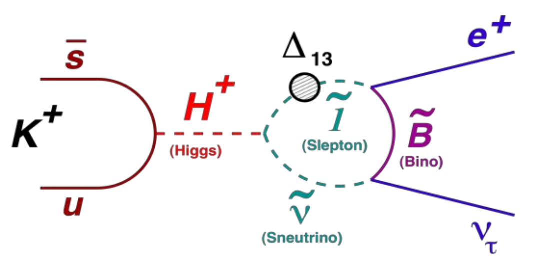
$R_K^{LFV} = R_K^{SM}\,[1 + (m_K/m_{H^\pm})^4) \times (m_\tau/m_e)^2\,|\Delta_{13}|^2) \times \tan^6\beta]$

[Masiero, Paradisi, Petronzio, PRD 74 (2006) 011701 ; JHEP 0811 (2008) 042]

MSSM: *1% effect*

[Girrbach, Nierste, arXiv: 1202.4906]





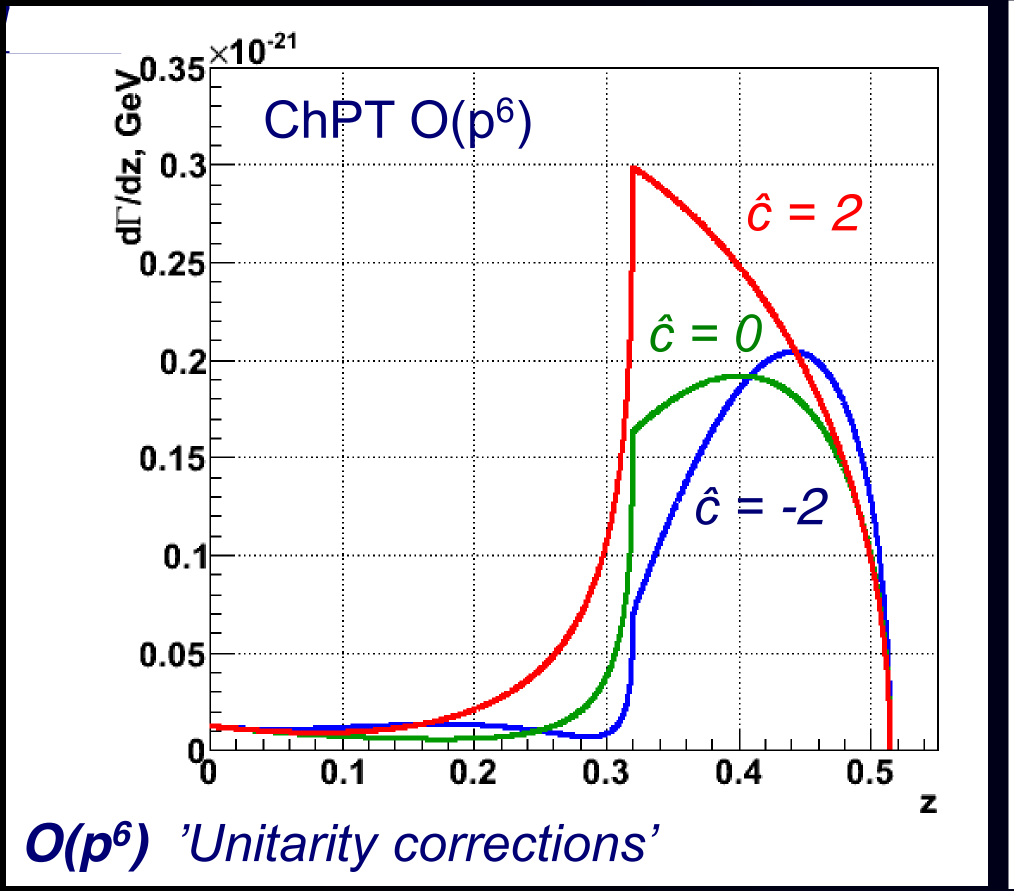
$R_K = (2.488 \pm 0.007_{stat} \pm 0.007_{syst}) \times 10^5$

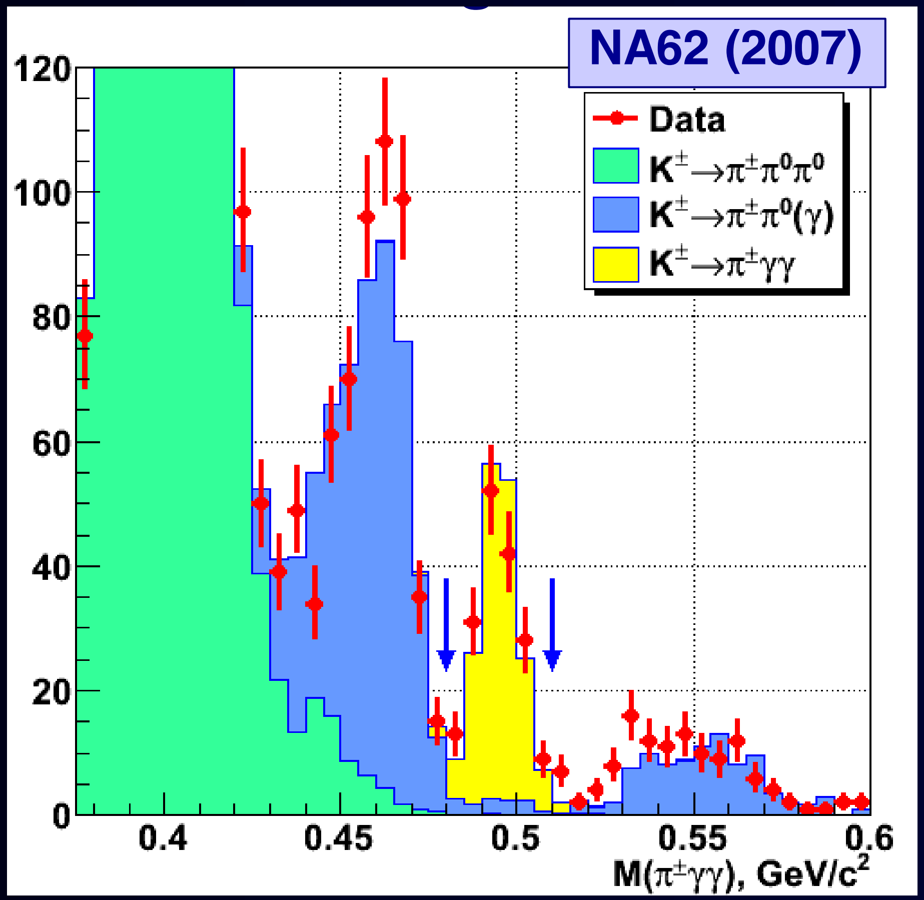
$= (2.488 \pm 0.010) \times 10^5$

	$R_K \times 10^5$	*precision*
PDG 2008	2.447 ± 0.109	4.5 %
PDG 2010	2.493 ± 0.031	1.3 %
now	2.488 ± 0.009	0.4 %
SM	2.477 ± 0.001	0.04 %

K→πγγ at NA48/2-NA62

from
V. Kekelidze's
talk [152]





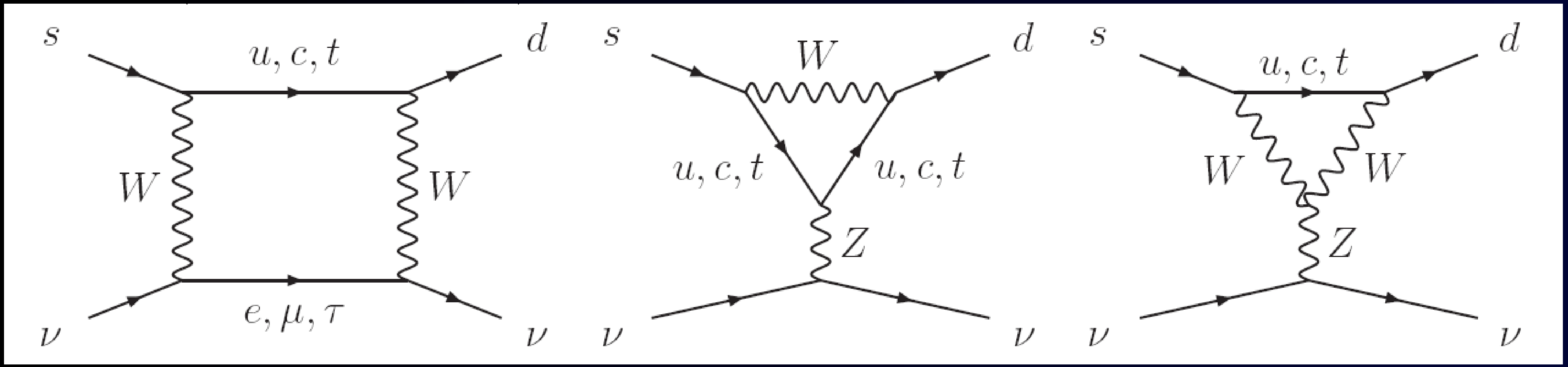
- in-flight K^+ decays
- test of chiral perturbation theory up to $O(P^6)$

ChPT **O(p6) combined BR fit:** **BR = (1.01 ± 0.06)×10⁻⁶**

- ***PDG (= BNL E787): BR = (1.10 ± 0.32)×10⁻⁶***

$K^+ \to \pi^+ \nu\nu$ and $K_L \to \pi^0 \nu\nu$ decays

- Golden modes of rare K decays (FCNC)

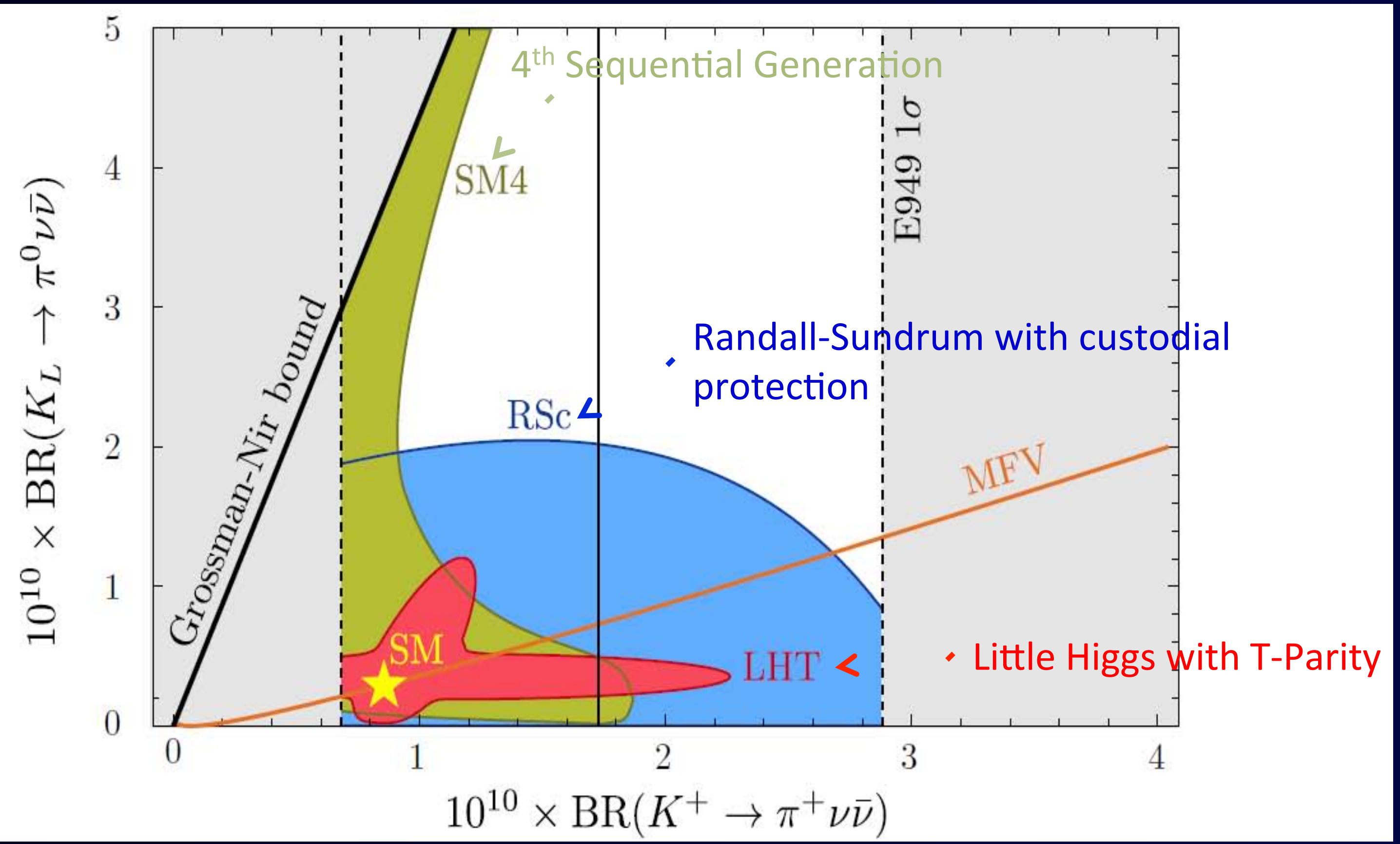


$$B_{SM}(K^+ \to \pi^+ \nu\bar{\nu}) = (7.2 \pm 0.8) \times 10^{-11}$$

$$B_{SM}(K_L^0 \to \pi^0 \nu\bar{\nu}) = (2.8 \pm 0.4) \times 10^{-11}$$

E787/E949 Final: 7 events observed

$$B\left(K^+ \to \pi^+ \nu\bar{\nu}\right) = 17.3^{+11.5}_{-10.5} \times 10^{-11}$$

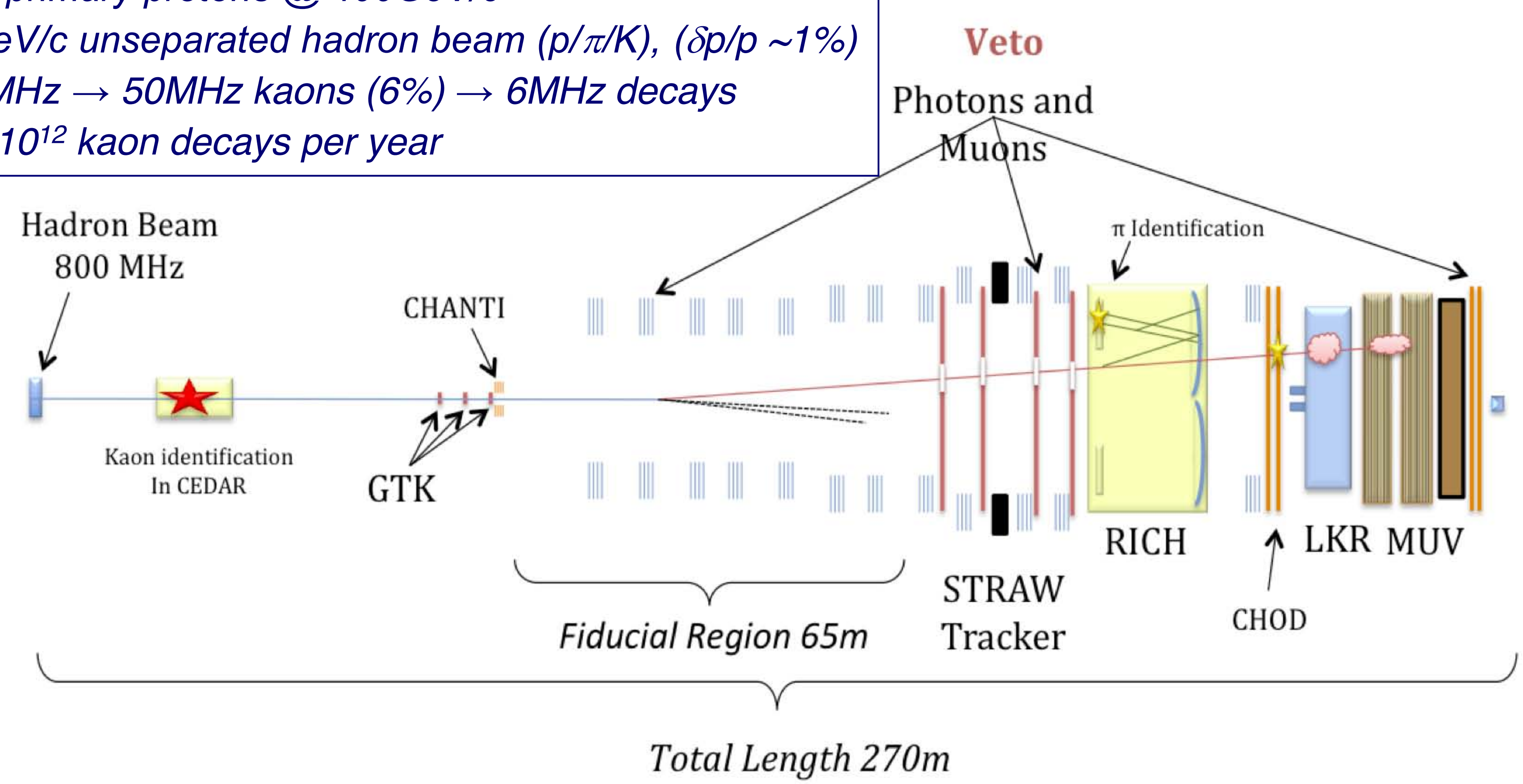


$K^+ \rightarrow \pi^+ \nu\nu$: NA62 at CERN

[152]
V. Kekelidze's talk

The NA62 detector for $K^\pm \rightarrow \pi^\pm \nu\bar{\nu}$

- *SPS primary protons @ 400GeV/c*
- *75GeV/c unseparated hadron beam (p/π/K), (δp/p ~1%)*
- *750MHz → 50MHz kaons (6%) → 6MHz decays*
- *4.8×10^{12} kaon decays per year*



NA62 timeline:

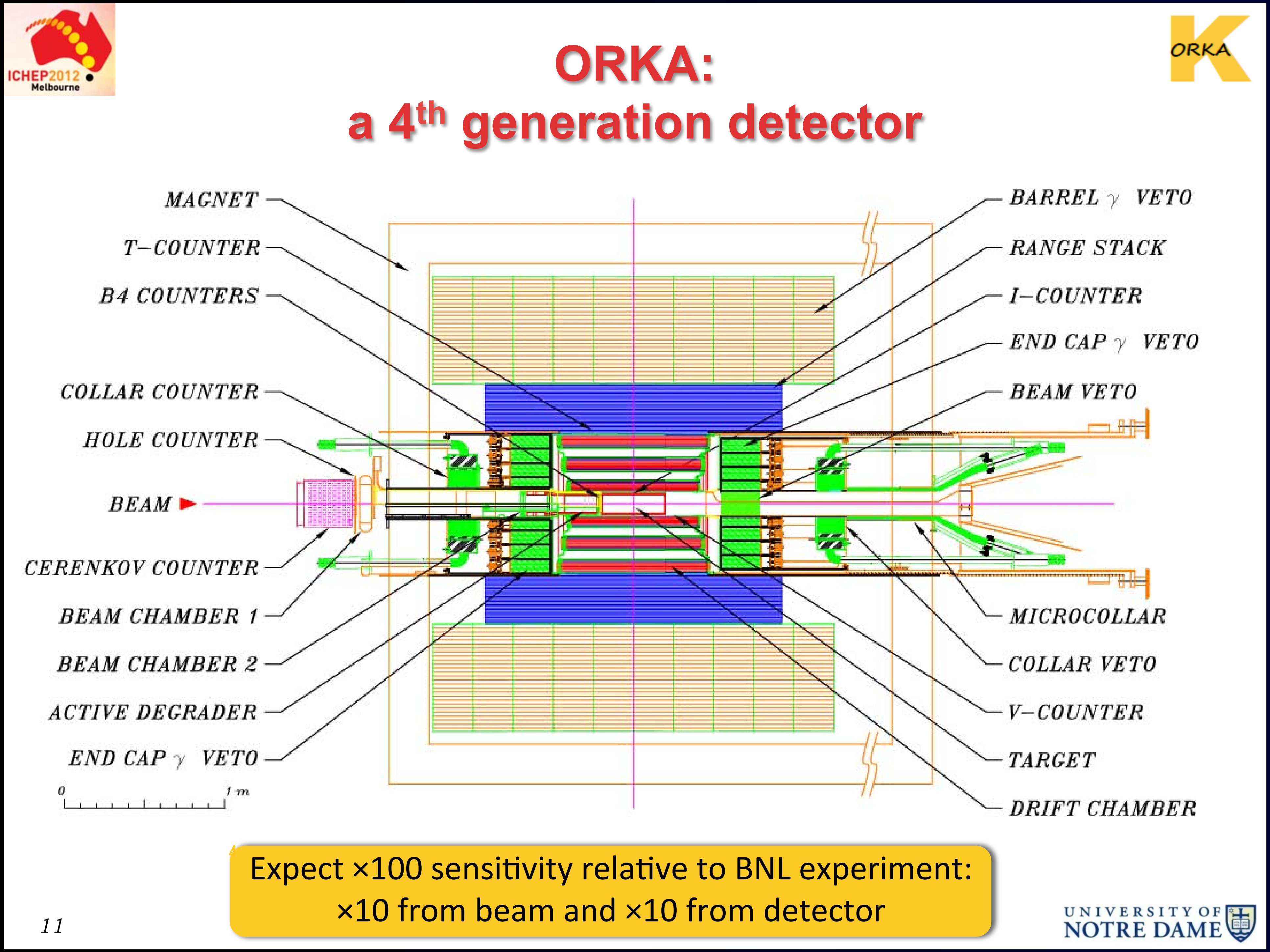
- *first technical run in autumn 2012 including many parts of the experiment*
- *2013: complete detector installation*
- *2014-?: data taking with full detector*

(driven by CERN accelerator schedule)

- 10% in BR with ~100 events

$K^+ \to \pi^+ \nu\nu$: ORKA at FNAL

[78]
M. Hildreth's talk



- 5% in BR with ~1000 events in 5 years
- 53 M USD
- Wish timeline, construction by 2014, data taking by 2017.

Charm Rare Decays

charm CP violation not included.

$D^0 \to \mu^+\mu^-$

- $D^0 \to \mu^+\mu^-$ is FCNC process,, highly suppressed in the SM ($\sim 10^{-13}$) , but could be enhanced by NP.
  - SM short distance contribution ~ 10^{-18}
  - SM long distance contribution
    - two photon contribution dominate

$$\mathcal{BR}^{(\gamma\gamma)}(D^0 \to \mu^+\mu^-) \simeq 2.7 \times 10^{-5} \mathcal{BR}(D^0 \to \gamma\gamma)$$ Phys.Rev. D66 (2002) 014009

present best UL on $D^0 \to \gamma\gamma$ is from Babar: $2.2 \cdot 10^{-6}$ @90% C.L. Phys.Rev. D85 (2012091107

so the UL to the two-photon contribution to $BR(D^0 \to \mu\mu)$is $6 \cdot 10^{-11}$ @90% C.L.

$D^0 \to \mu^+\mu^-$

from
M. Bonivento's talk
K. Ulmer's talk [634]

LHCb

$\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.3\ (1.1) \cdot 10^{-8}$ at 95 (90)%CL

Preliminary (LHCb-CONF 2012-005)

0.9 fb^{-1} data

CMS

$B(D^0 \to \mu^+\mu^-) \leq 5.4 \times 10^{-7}$ (90% CL).

Event in signal region = 23, predicted BG = 23

BELLE

Belle $< 1.4 \times 10^{-7}$ PRD, 81 091102

best published result

$D^0 \rightarrow \mu^+\mu^-$ at BarBar

from R. Godang talk

Search for $D^0 \longrightarrow \ell^{\mp}\ell^{(\prime)\pm}$ **Submitted to PRD: arXiv 1206.5419**

- No statistically significant excess over the background
- Observed 1 event for $D^0 \rightarrow e^+e^-$ with expected bkg 1.0 ± 0.5
- Observed 2 events for $D^0 \rightarrow e^{\pm}\mu^{\mp}$ with expected bkg 1.4 ± 0.3
- Observed 8 events for $D^0 \rightarrow \mu^+\mu^-$ with expected bkg 3.9 ± 0.6
- Set Upper Limit on the Branching Fraction at 90% CL:

  $D^0 \rightarrow e^+e^- < 1.7 \times 10^{-7}$ $\longrightarrow$ (best electron channel)

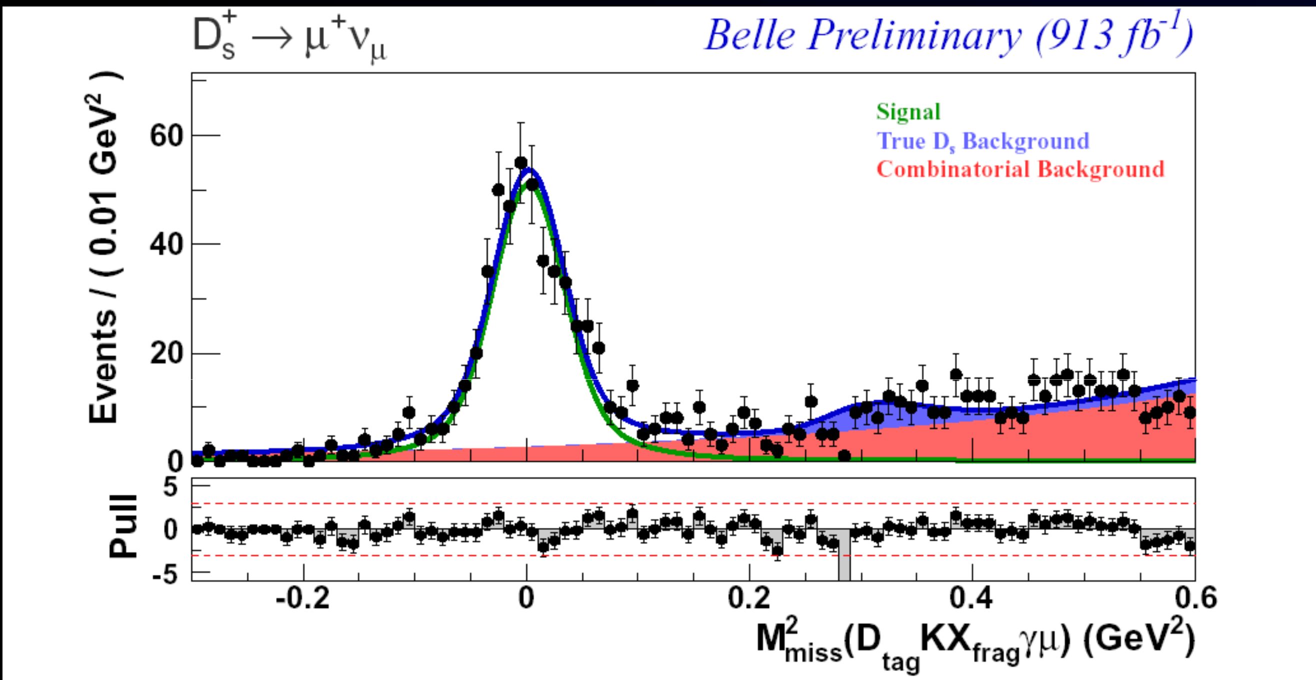
  $D^0 \rightarrow e^{\pm}\mu^{\mp} < 3.3 \times 10^{-7}$

  $D^0 \rightarrow \mu^+\mu^- = [0.6, 8.1] \times 10^{-7}$

- LHCb: $D^0 \rightarrow \mu^+\mu^- < 1.3 \times 10^{-8}$ at 95% CL (LHCb-CONF-2012-005)

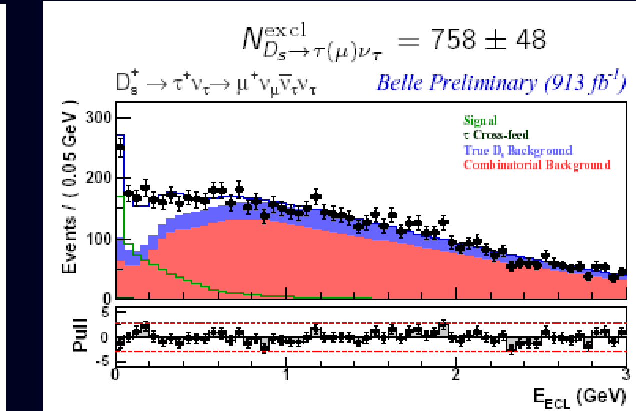
$D_s \to \mu\nu$ and $D_s \to \tau\nu$ at Belle

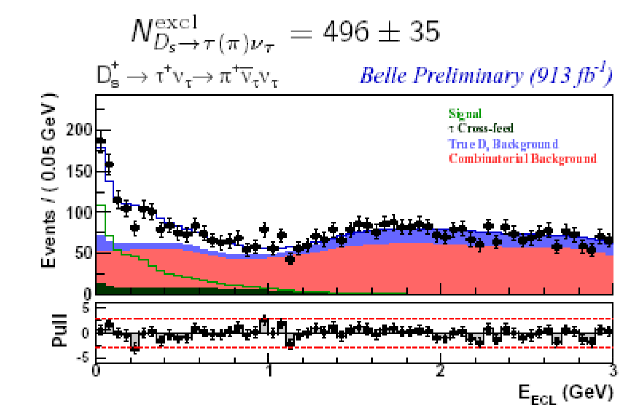
from M.-Z. Wang's talk [718]

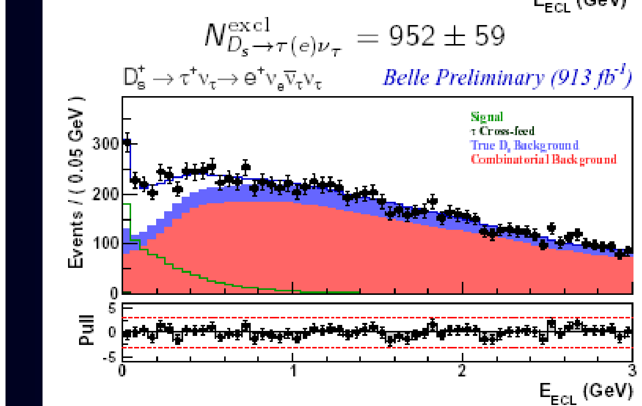


$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.528 \pm 0.028(\text{stat.}) \pm 0.019(\text{syst.}))\%$$

PDG value : (0.590±0.033)%

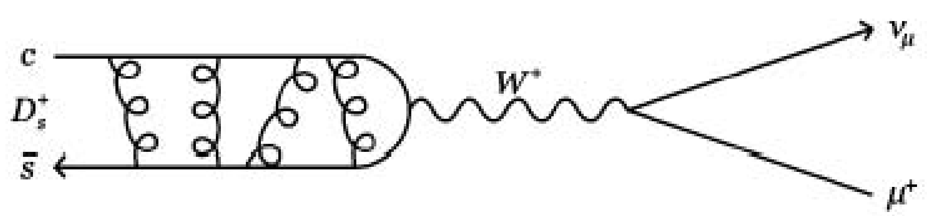




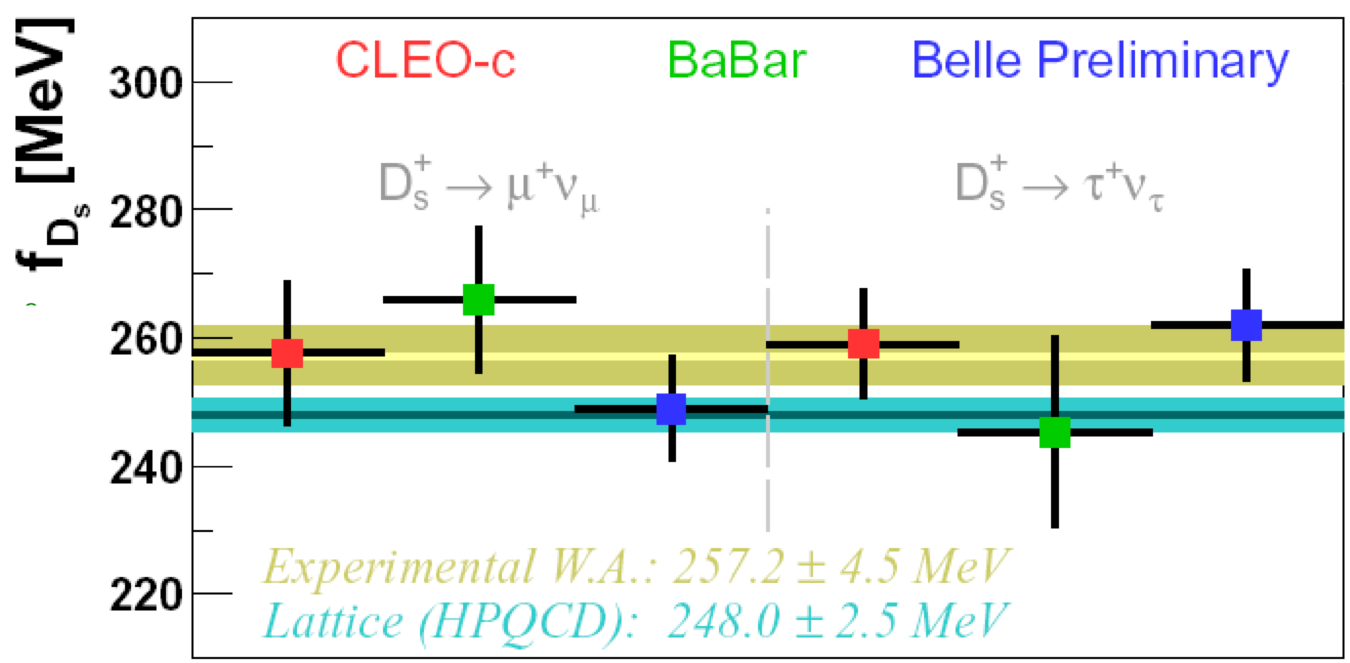


τ decay mode	$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)$ [$\times 10^{-2}$]
$e\nu\nu$	$5.37 \pm 0.33^{+0.35}_{-0.30}$
$\mu\nu\nu$	$5.88 \pm 0.37^{+0.34}_{-0.58}$
$\pi\nu$	$5.96 \pm 0.42^{+0.45}_{-0.39}$
Combination	$5.70 \pm 0.21^{+0.31}_{-0.30}$

PDG value : (5.43±0.31)%



$$\mathcal{B}(D_s^+ \to \ell^+\nu_\ell) = \frac{G_F^2}{8\pi} f_{D_s}^2 |V_{cs}|^2 \tau_{D_s} M_{D_s} m_\ell^2 \left(1 - \frac{m_\ell^2}{M_{D_s}^2}\right)^2$$



sensitive to NP

Particle Sources (Facility)

Towards Higher Energy Scale for NP in Rare Decays

Towards Higher Energy Scale for NP in Rare Decays

$$R \sim \frac{1}{\Lambda^4}$$

Λ: energy scale of new physics

Towards Higher Energy Scale for NP in Rare Decays

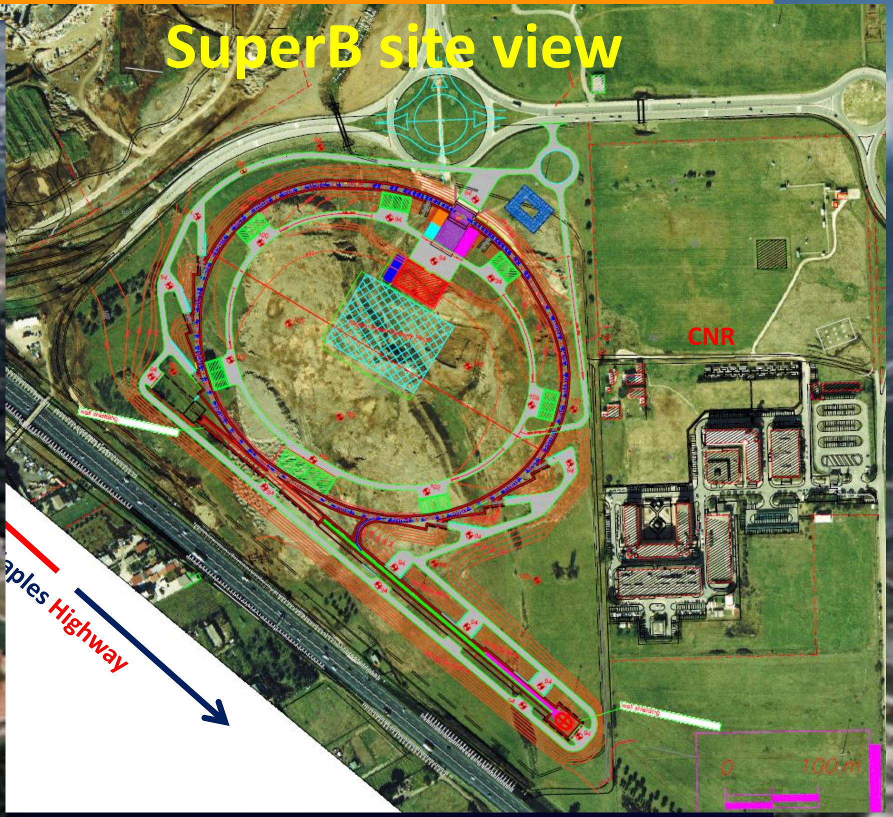
$$R \sim \frac{1}{\Lambda^4}$$

Λ: energy scale of new physics

Can we improve the Λ reach by an order of magnitude ?

must have at least 10^4 times the number of parent particles in rare decays.

Super KEKB and SuperB Factories (for taus and charms)

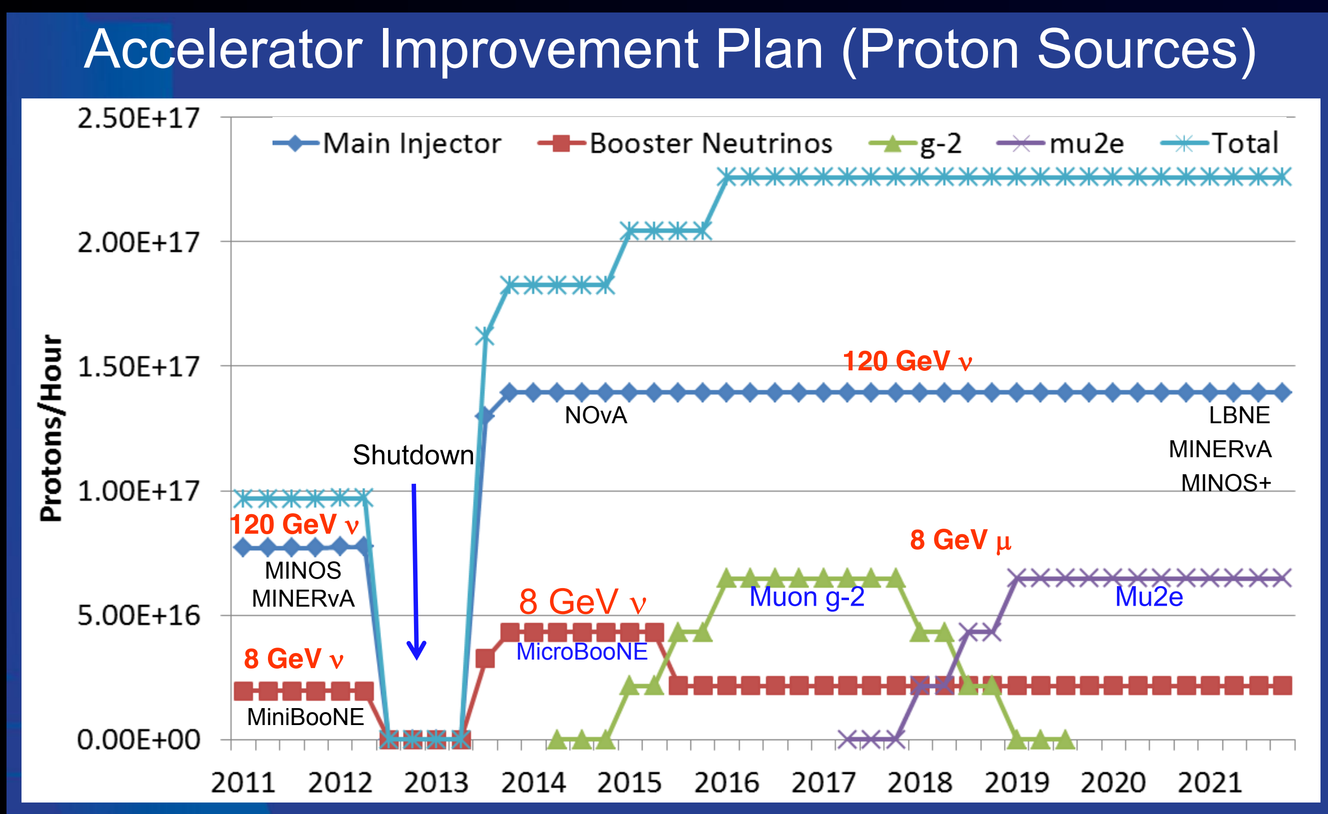


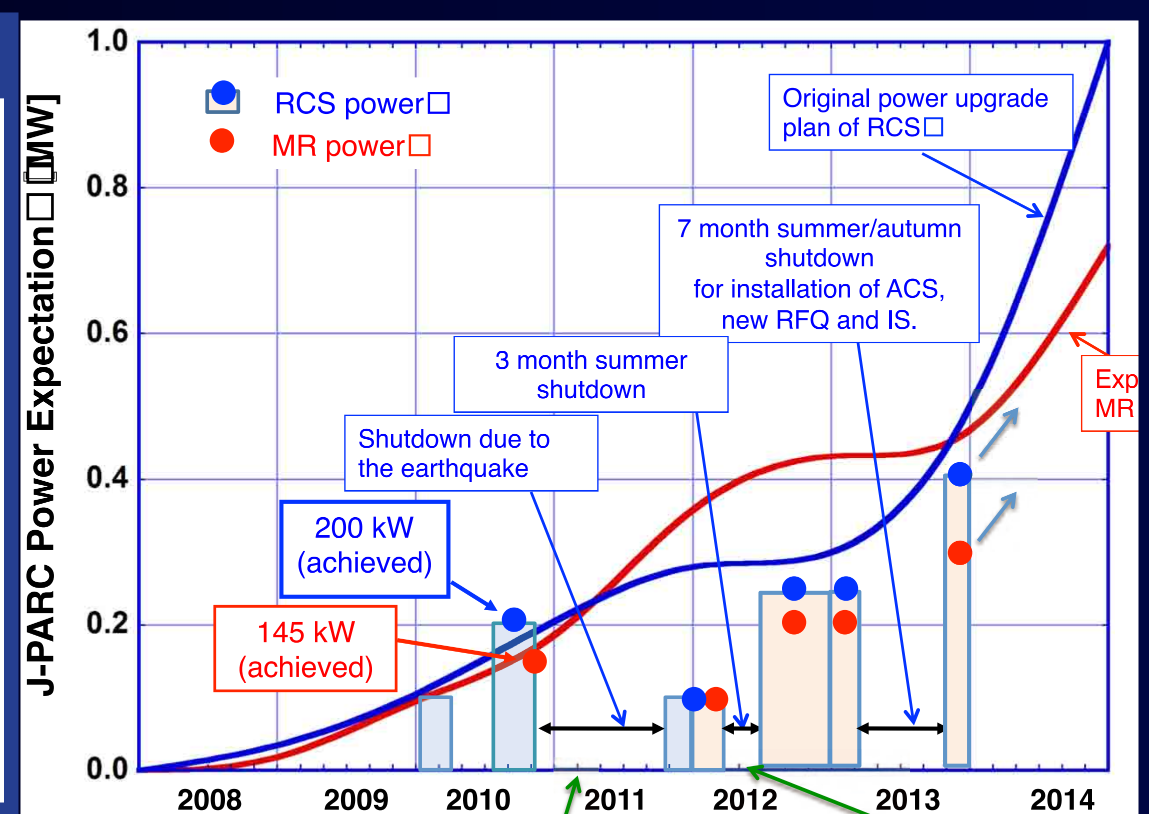
aim at
10 ab^{-1} by 2018
50 ab^{-1} by 2022

aim at
75 ab^{-1} for 5 years

LHC luminosity
upgrade

Proton Accelerators (for muons and kaons)





Improvement of Particle Collection Efficiency

from Y. Hino's talk [634]

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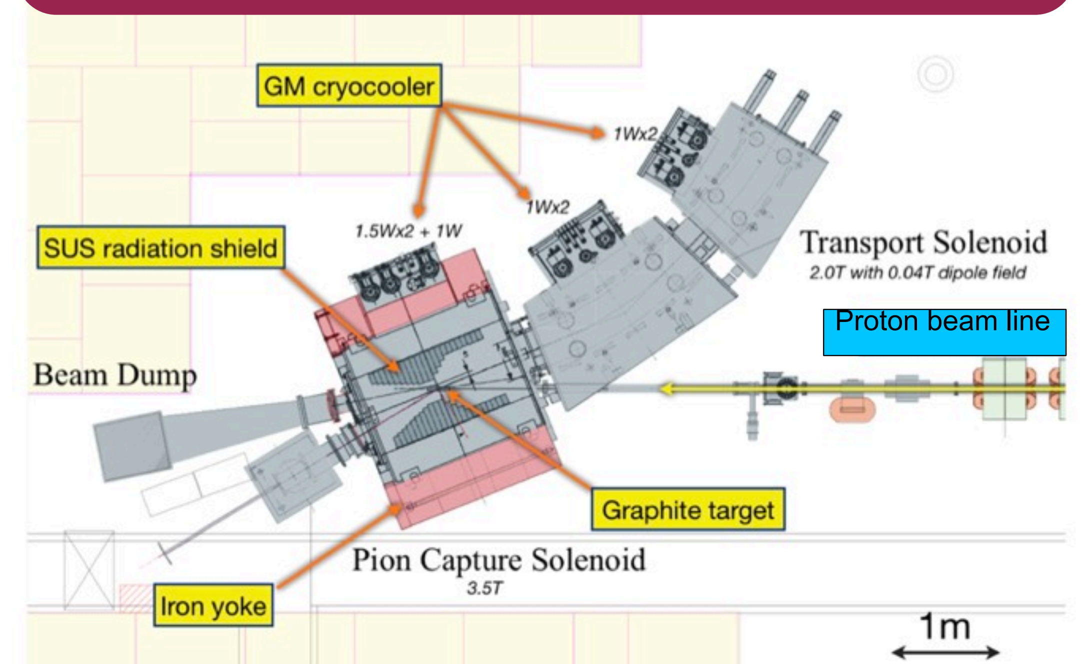
MuSIC@Osaka-U



RCNP cyclotron
400 MeV, 1μA

Improvement of Particle Collection Efficiency

from Y. Hino's talk [634]

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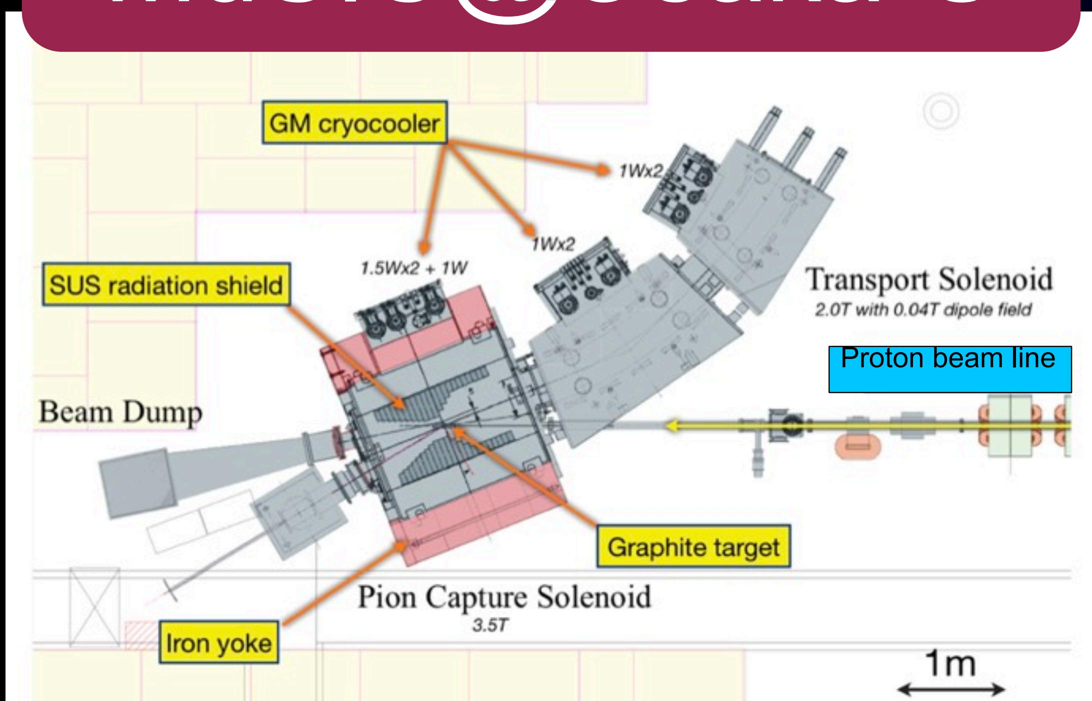
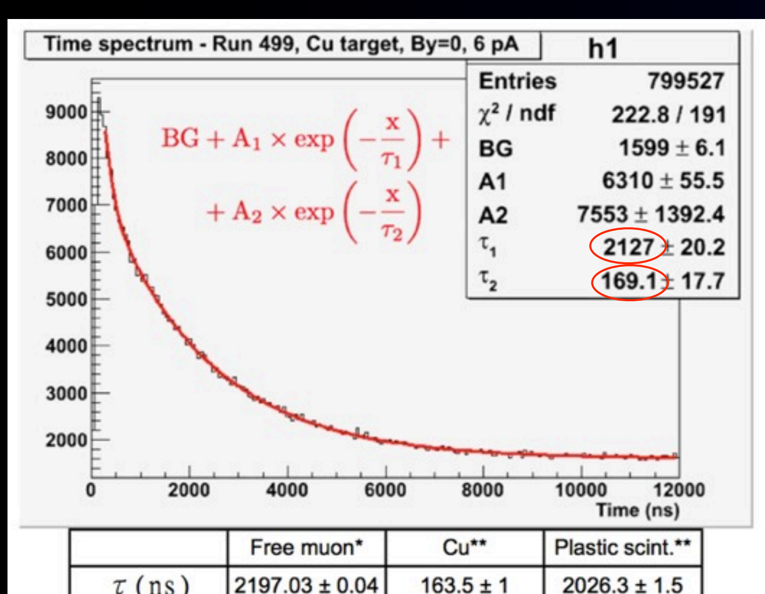
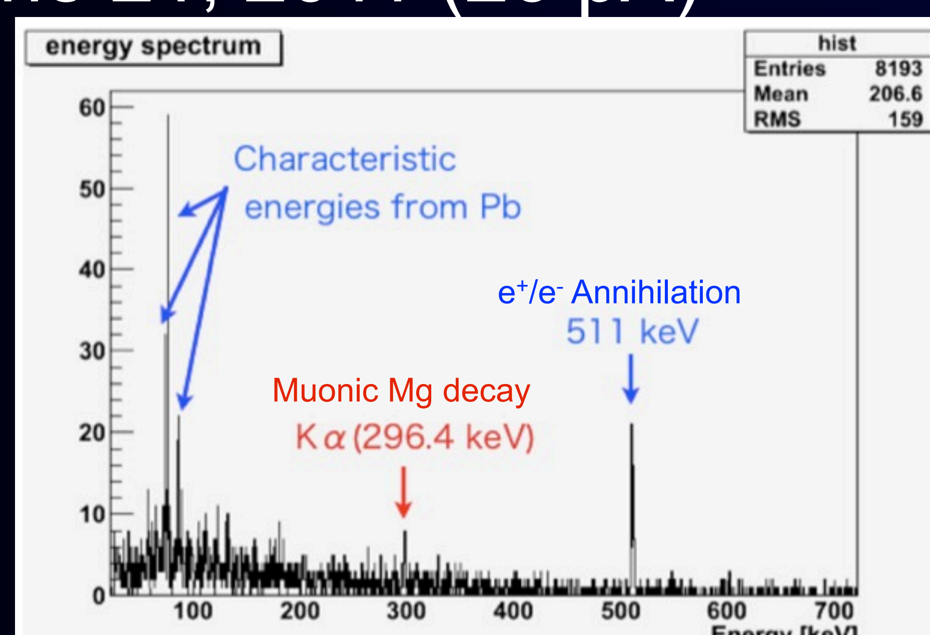


RCNP cyclotron
400 MeV, 1μA

preliminary

Measurements on June 21, 2011 (26 pA)





MuSIC muon yields

μ^+ : 3x10^8/s for 400W

μ^- : 1x10^8/s for 400W

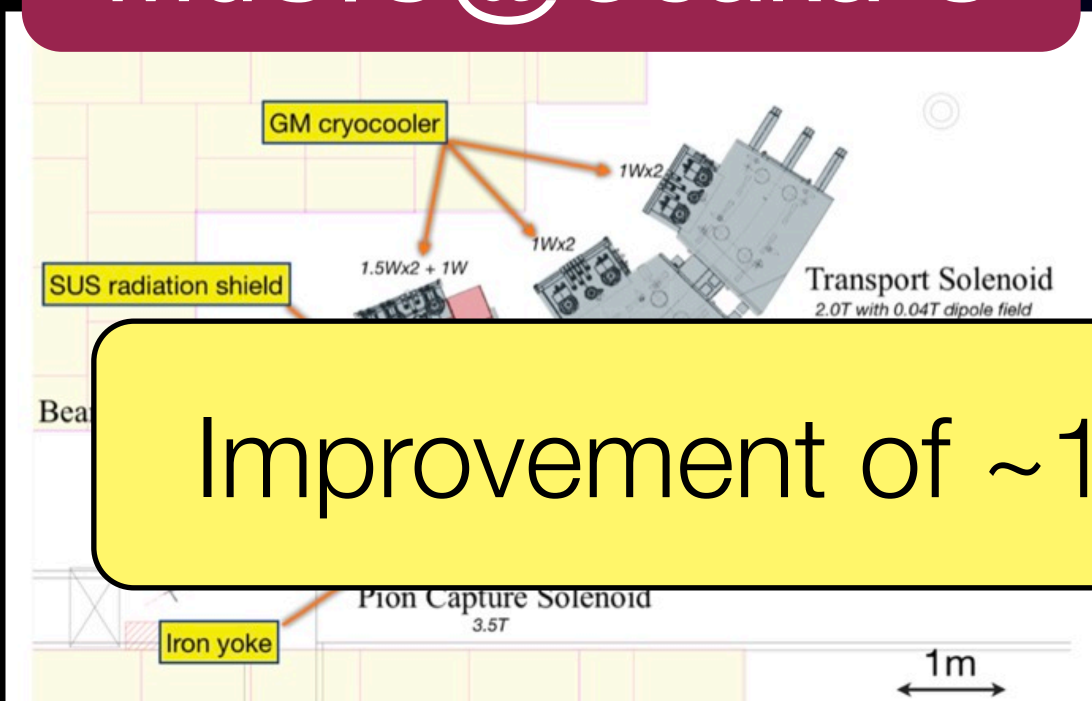
cf. 10^8/s for 1MW @PSI

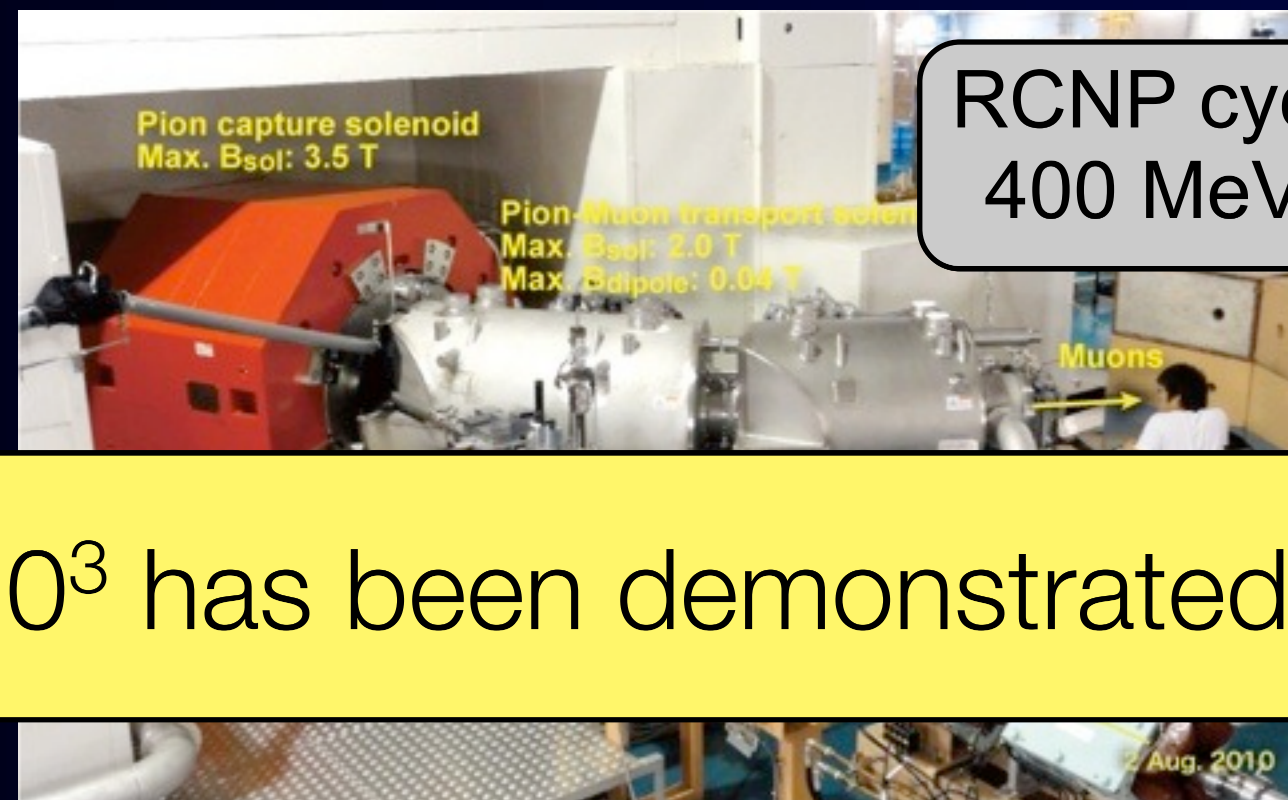
Req. of x10^3 achieved...

Improvement of Particle Collection Efficiency

from Y. Hino's talk [634]

MuSIC@Osaka-U



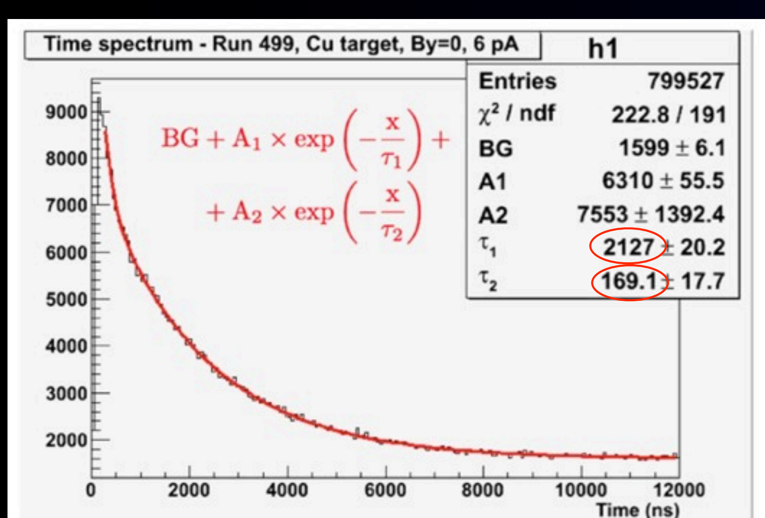


RCNP cyclotron
400 MeV, 1μA

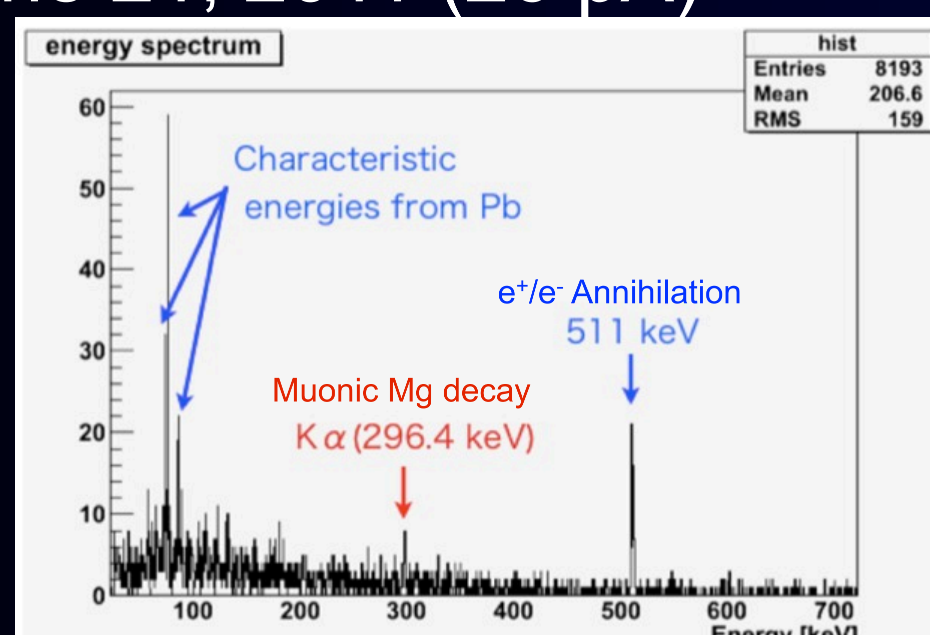
Improvement of ~10^3 has been demonstrated.

preliminary

Measurements on June 21, 2011 (26 pA)



	Free muon*	Cu**	Plastic scint.**
τ (ns)	2197.03 ± 0.04	163.5 ± 1	2026.3 ± 1.5



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μ^+ : 3×10^8/s for 400W

μ^- : 1×10^8/s for 400W

cf. 10^8/s for 1MW @PSI

Req. of x10^3 achieved...

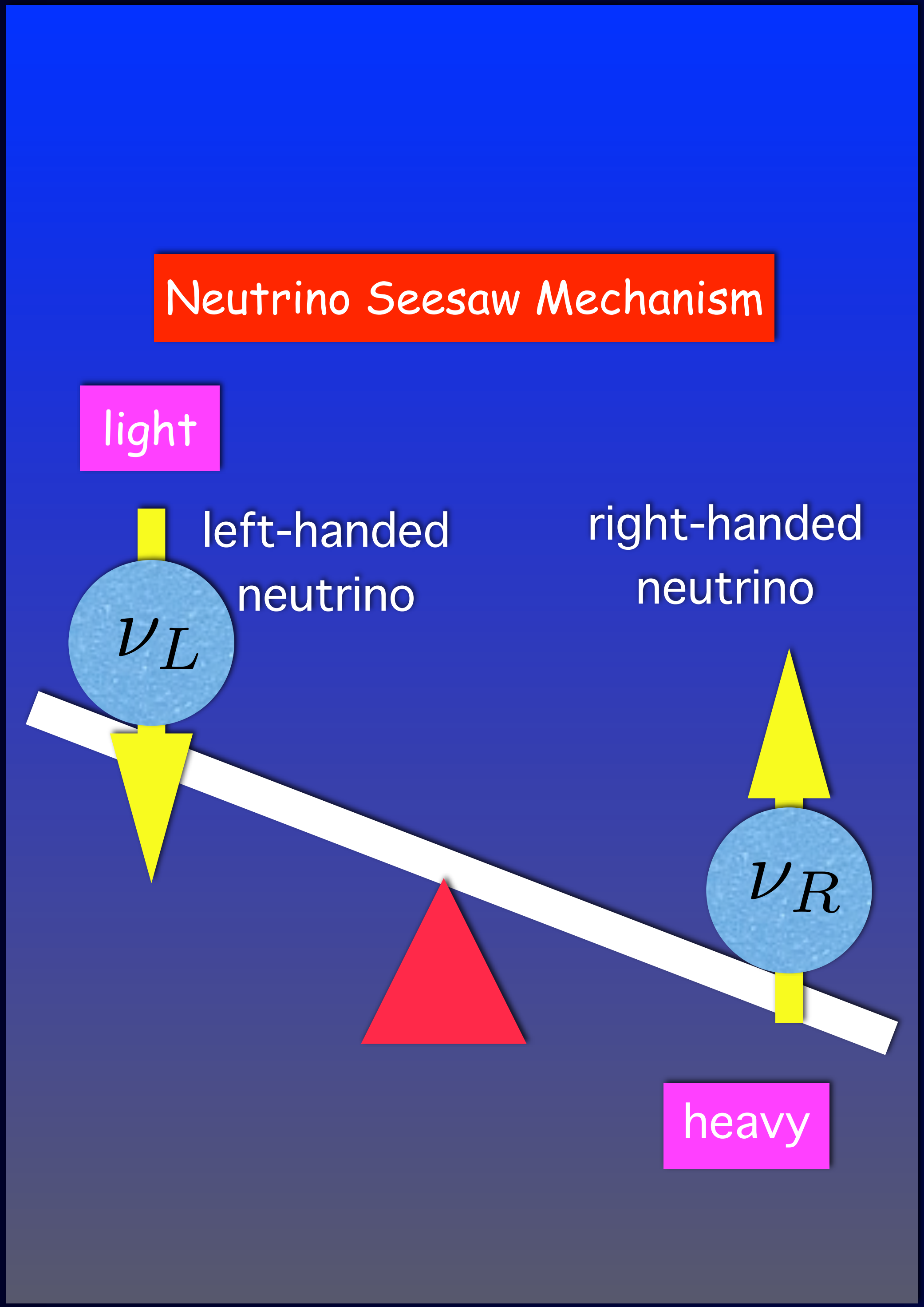
Summary

Summary

- Searches for rare decays of charged leptons (muons and taus) and light mesons (kaons and charms) are quite active.
- Rare decays have potential of great discoveries of new physics beyond the SM at high energy scale.
- Search for rare decays would be complementary to the high energy frontier.

Backup

How to Validate Neutrino Seesaw Mechanism?
SUSY-Seesaw ?

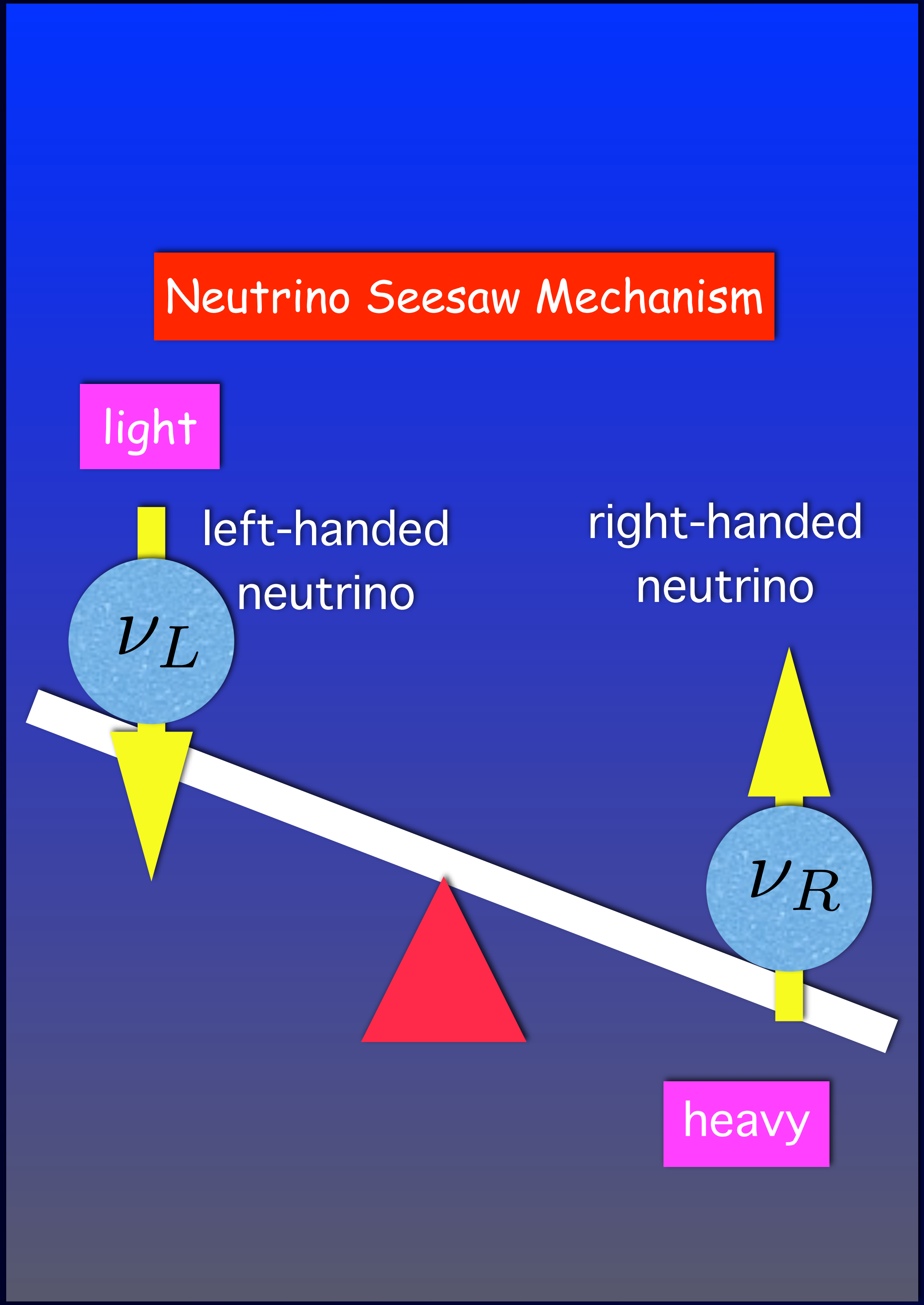


How to Validate Neutrino Seesaw Mechanism? SUSY-Seesaw ?

1 **Majorana Nature of Neutrinos**

Neutrinoless Double Beta Decays

Neutrinoless double beta decays address whether neutrinos are Majorana-type or not?



How to Validate Neutrino Seesaw Mechanism? SUSY-Seesaw ?

1 Majorana Nature of Neutrinos

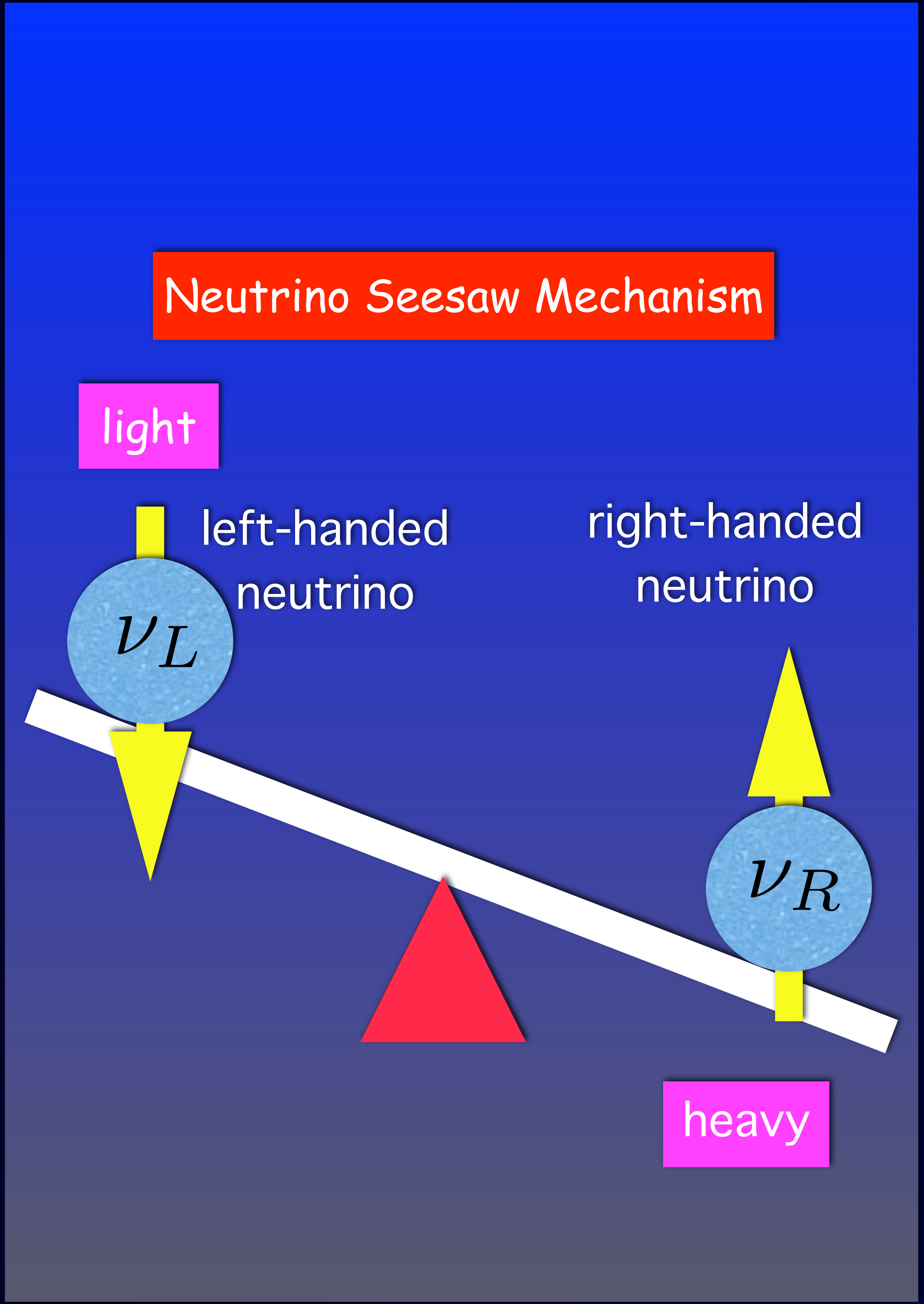
Neutrinoless Double Beta Decays

Neutrinoless double beta decays address whether neutrinos are Majorana-type or not?

2 Heavy Partner of Neutrinos

CLFV

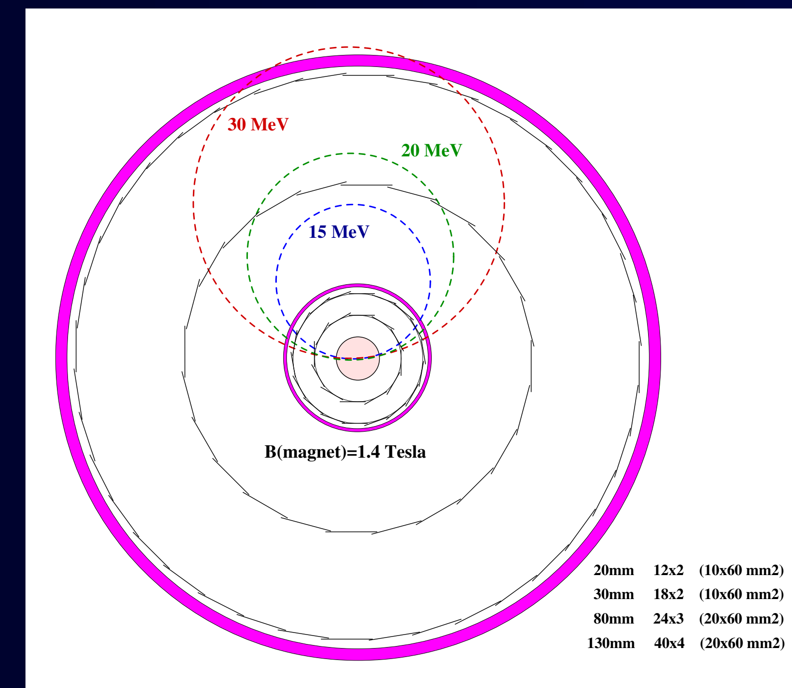
Search for CLFV is sensitive to the energy scale of heavy right-handed neutrinos in the neutrino seesaw models.

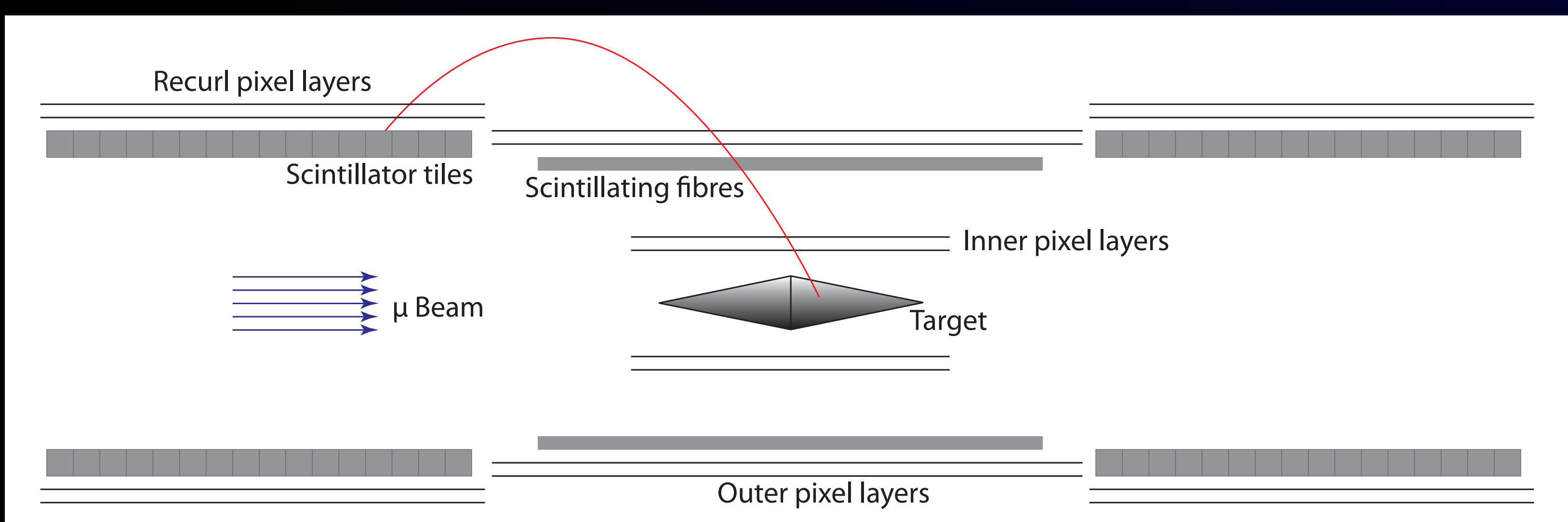


Mu3e at PSI (LOI)

New

- thin silicon pixel detectors (<50μm thick) with high position resolution
  - high voltage monolithic active pixel (HVMAPS)
  - three (two) cylinders with double layers
- SciFi hodoscopes with high timing resolution.
- Stage-I (2014-2017)
  - $B \sim 10^{-15}$ with 2×10^{8} μ/s at πE5
- Stage-2 (2018-)
  - $B < 10^{-16}$ with 2×10^{9} μ/s at new muon source





HVMAPS