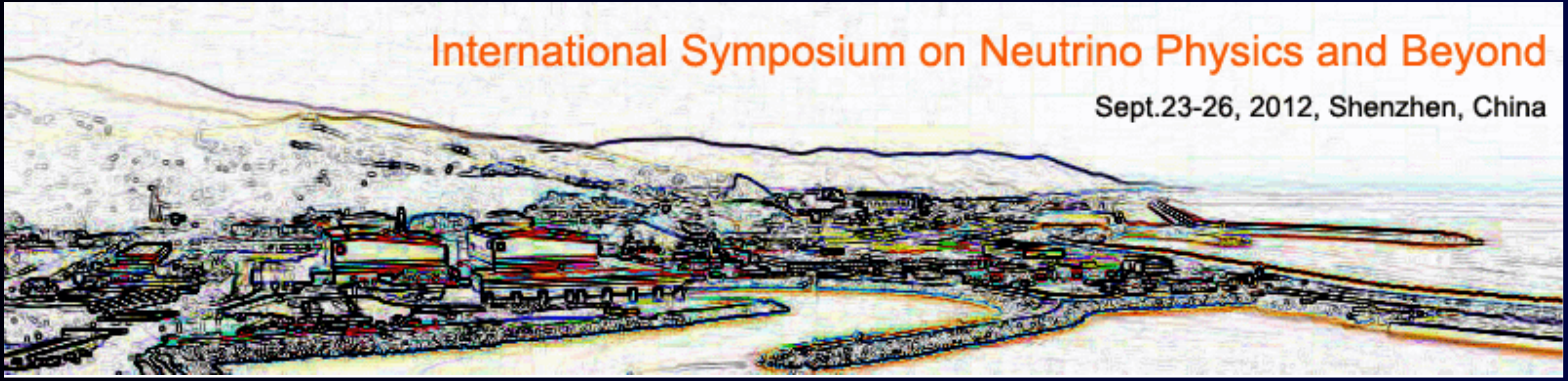
High Intensity Muon Source for Neutrino and Muon Physics

Yoshitaka Kuno
Department of Physics, Osaka University

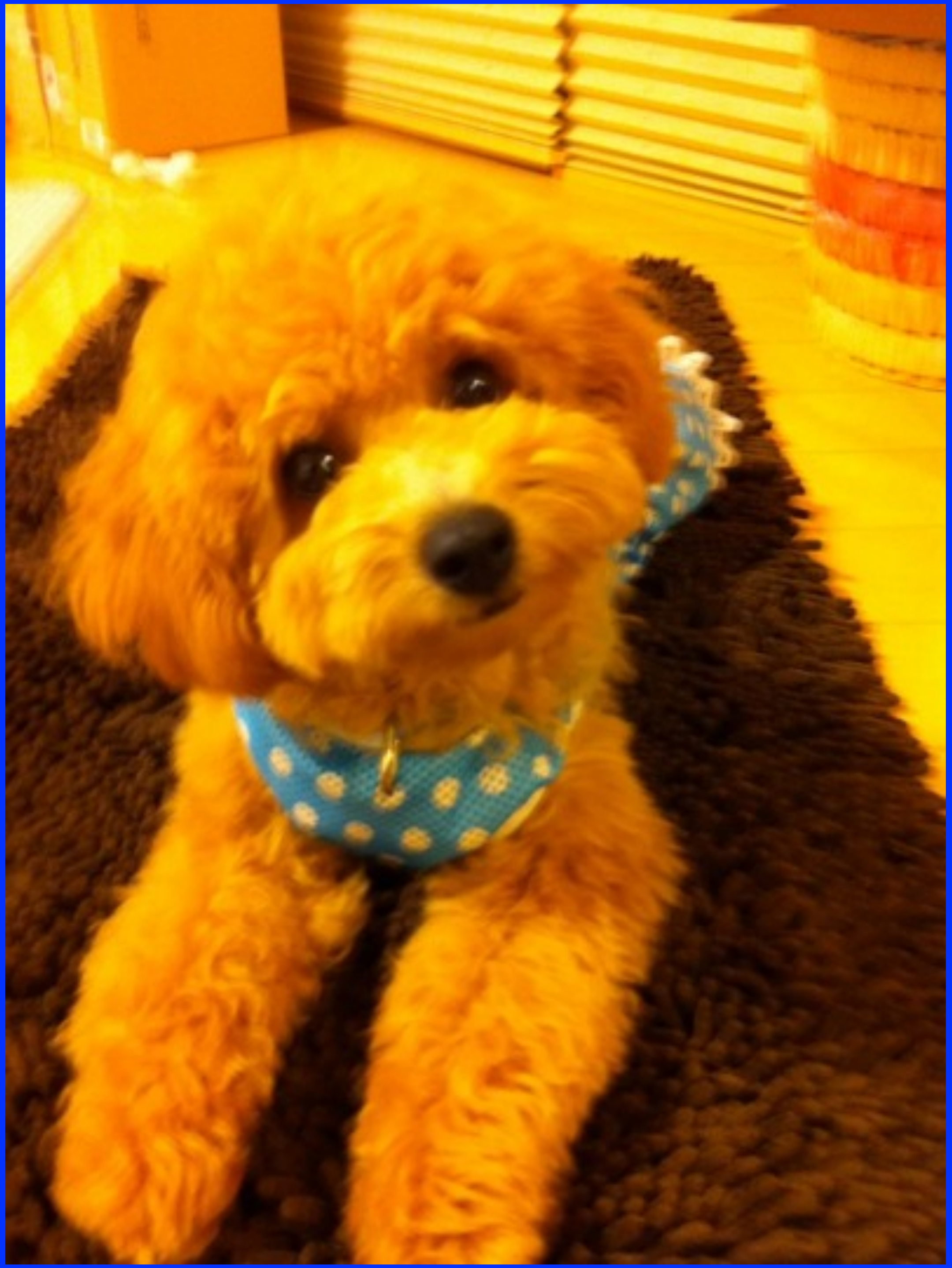
September 25, 2012
Shenzhen, China, NPB2012



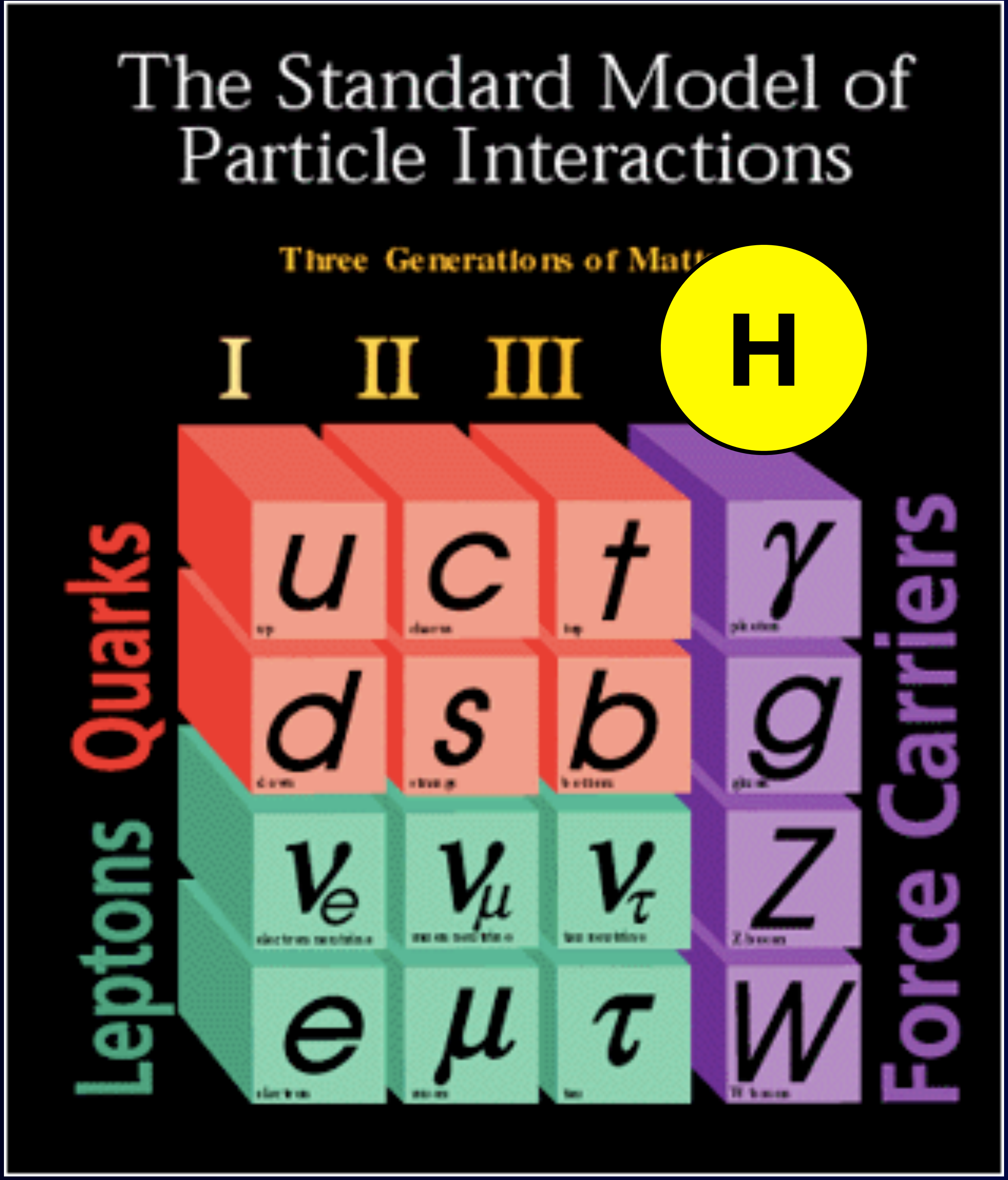
Outline

- Muon Physics
  - Charged lepton flavor violation (CLFV) with muons
  - What is μ-e conversion in a muonic atom ?
  - COMET to search for μ-e conversion at J-PARC
  - COMET staged approach (new)
  - μ-e conversion with $B<10^{-19}$ (PRISM)
- Highly intense Muon Source at Osaka University - MuSIC -
- Neutrino Physics
  - Neutrino source based on muon storage FFAG ring
- Summary

Charged Lepton Flavor Violation (CLFV) with Muons



Now, the Standard Model has the Higgs-like boson, but no new particles are found......



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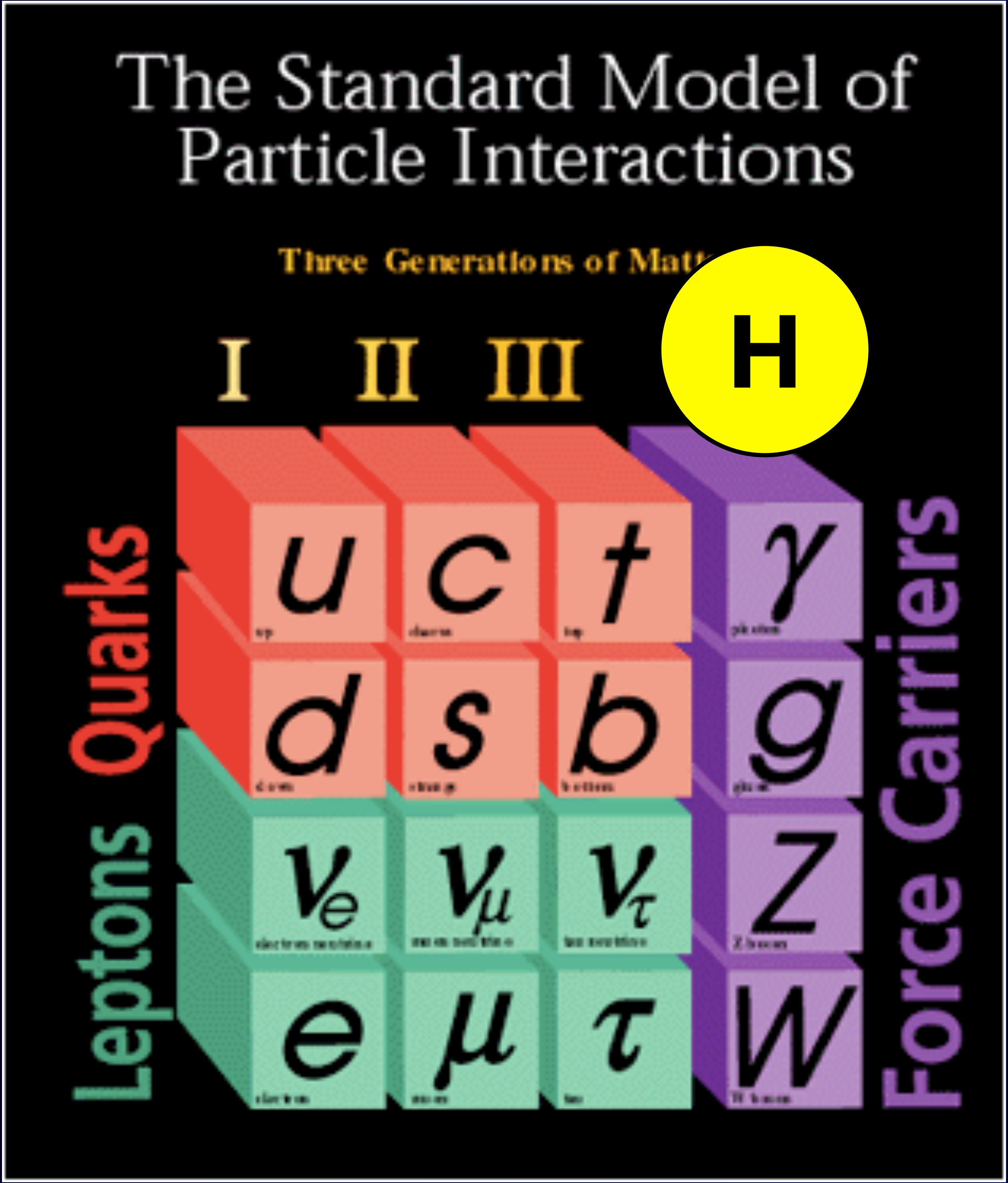
The LHC has not found any new particles so far yet, besides a Higgs-like particle.



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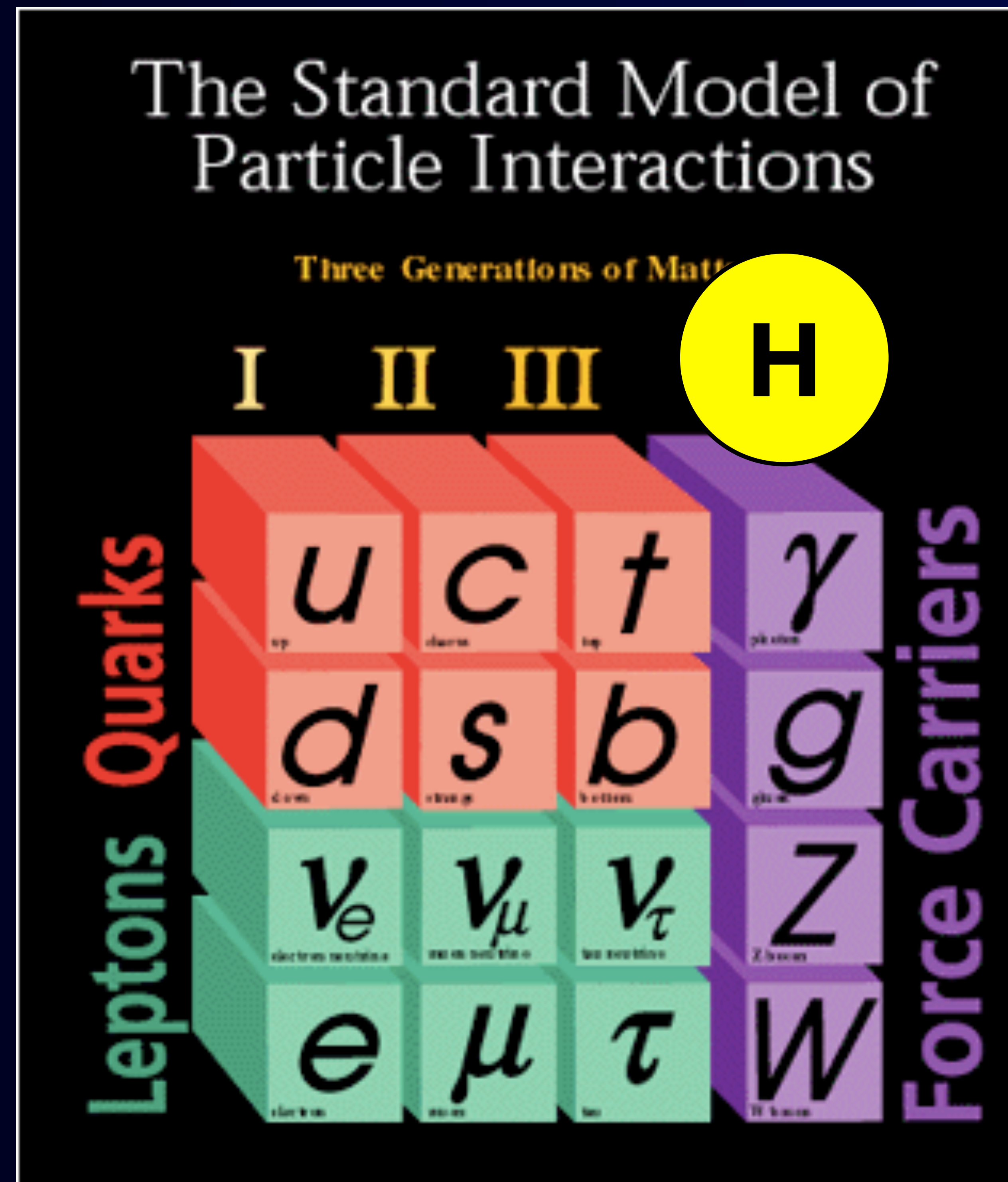

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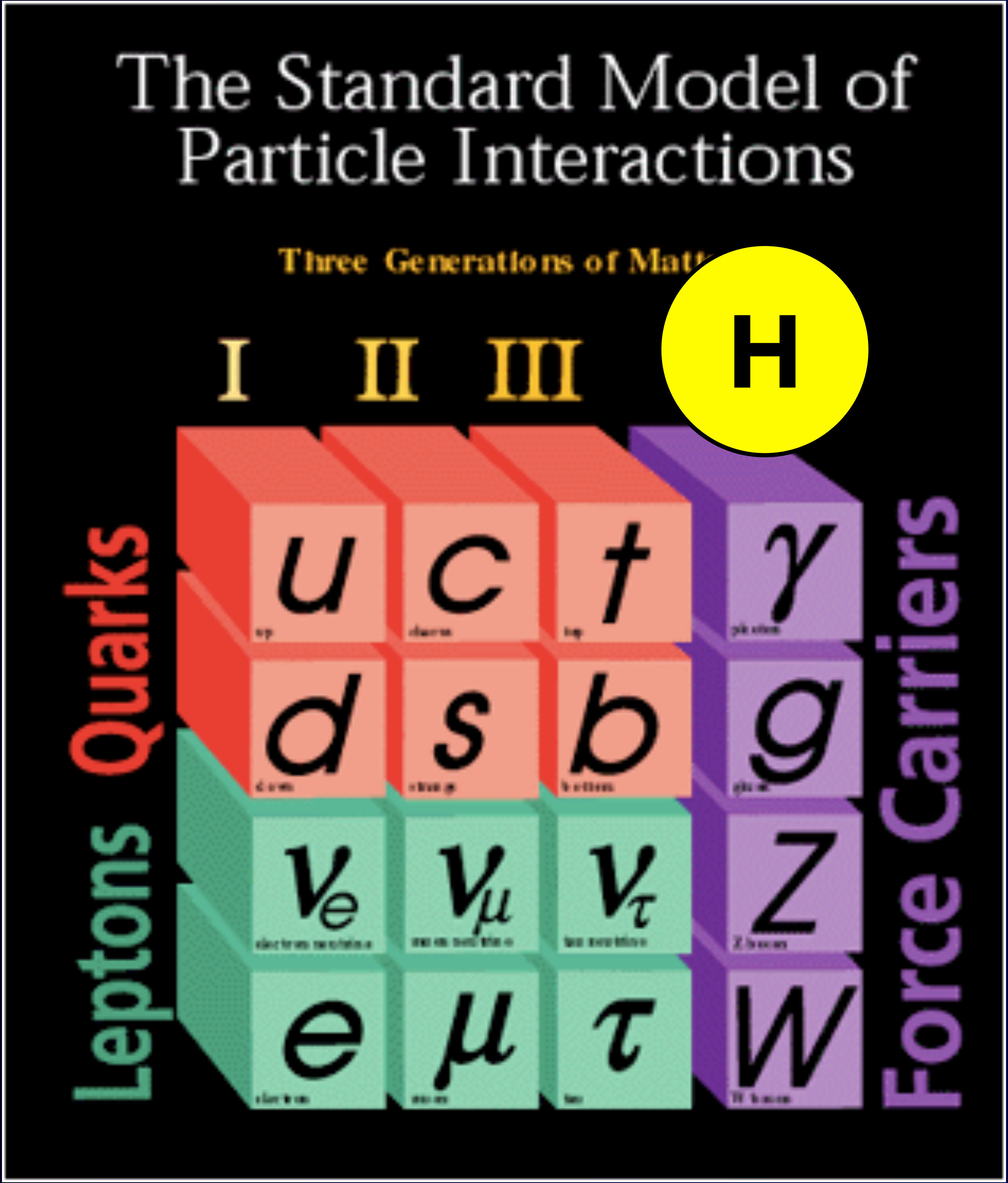
Rare Decays



Guideline for Rare Decay Searches

New physics effects may be very small.

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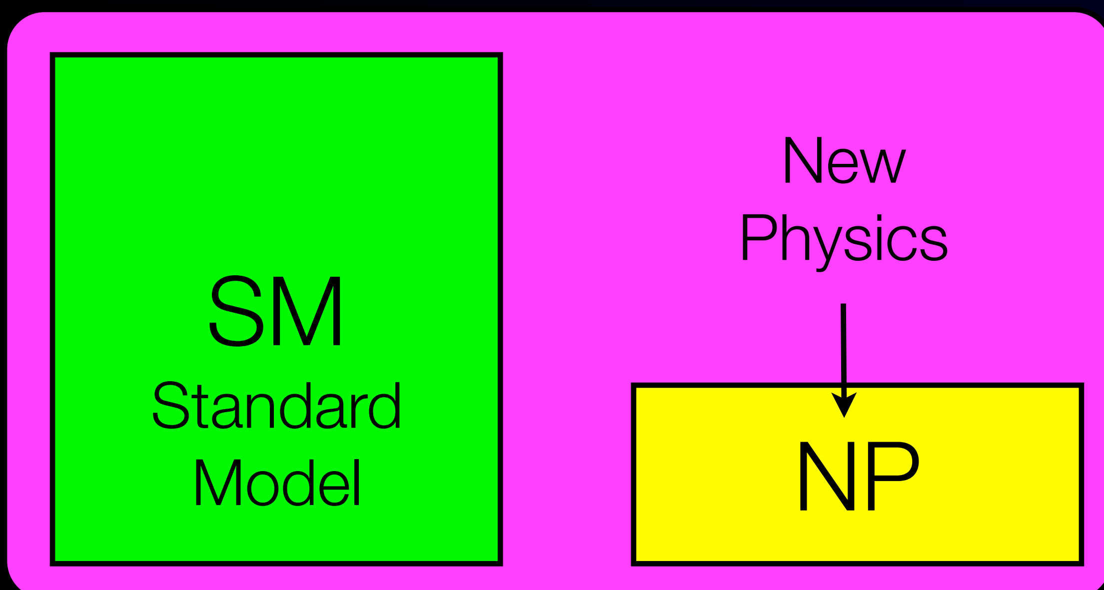
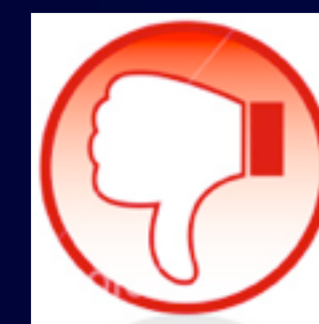


SM contribution is dominant.



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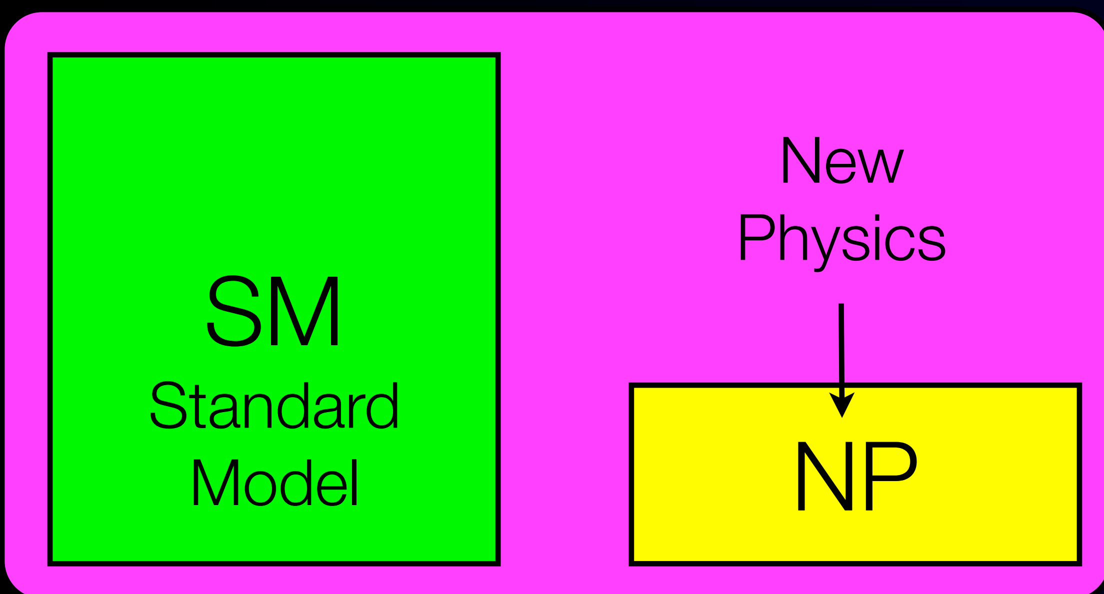

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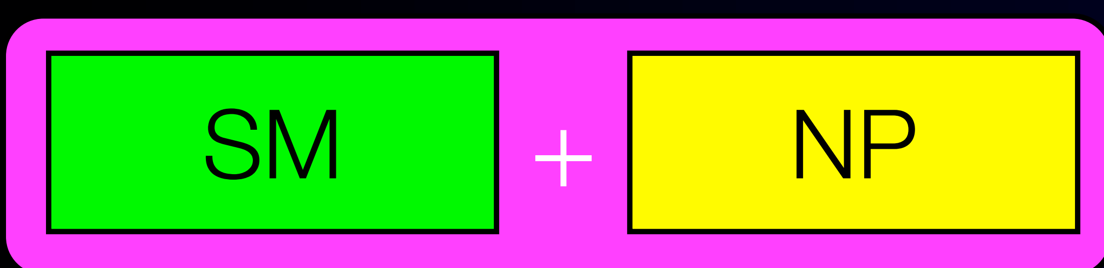

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$$B \sim \frac{1}{\sqrt{N}}$$

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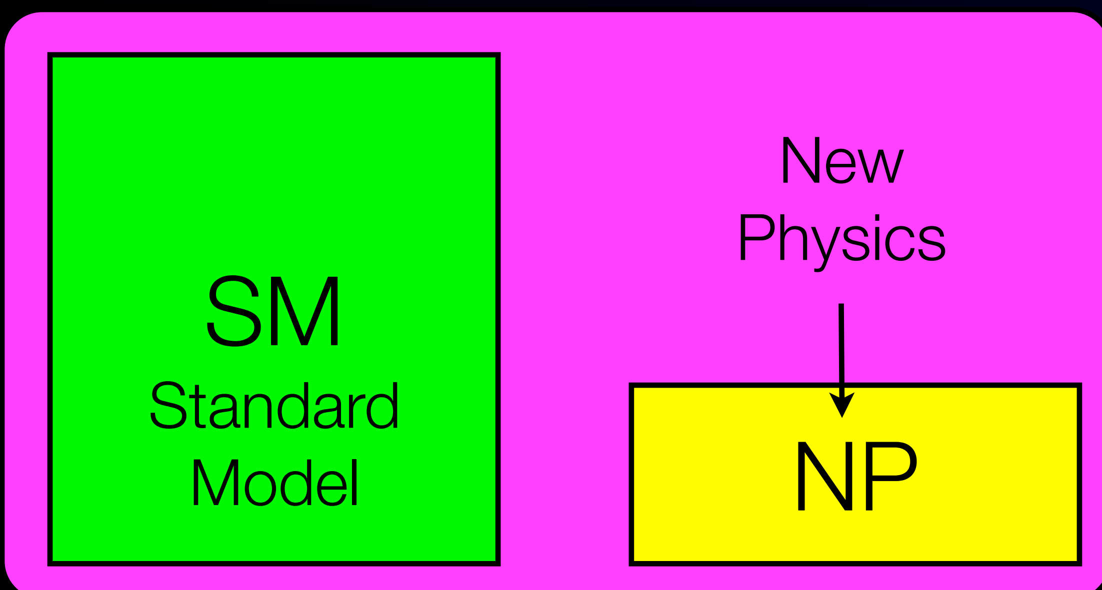

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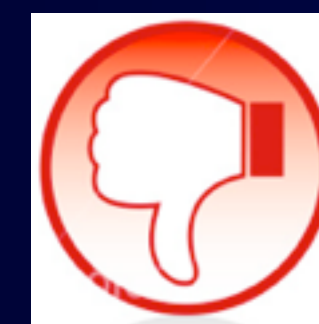

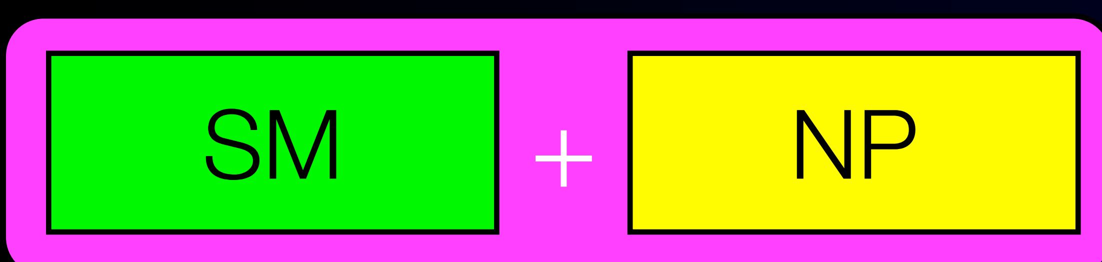

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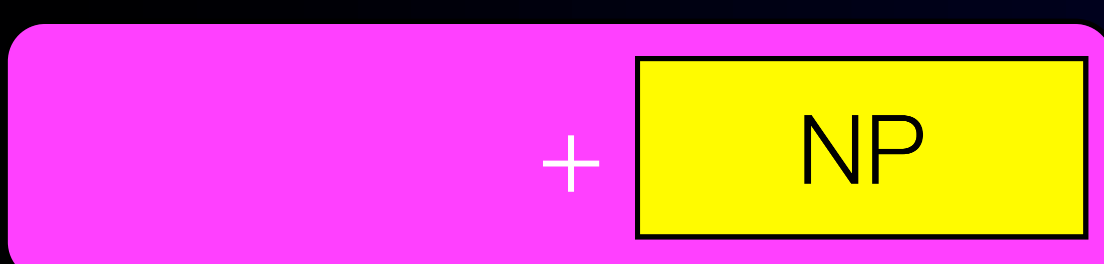

SM contribution is forbidden.

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

Guideline for Rare Decay Searches

New physics effects may be very small.

SM
Standard Model

New Physics

NP

SM contribution is dominant.

SM + NP

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

+ NP

SM contribution is forbidden.

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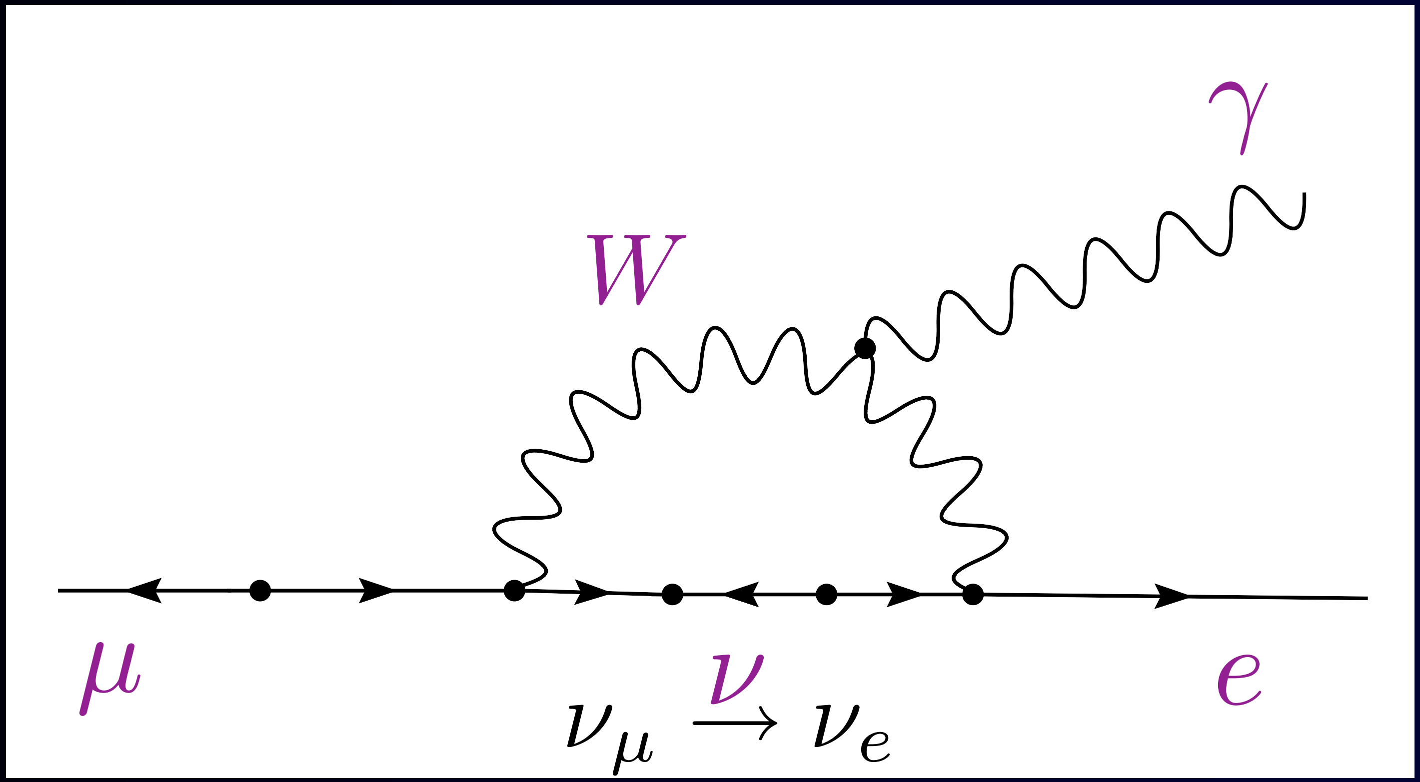
CLFV in the SM with Massive Neutrinos

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



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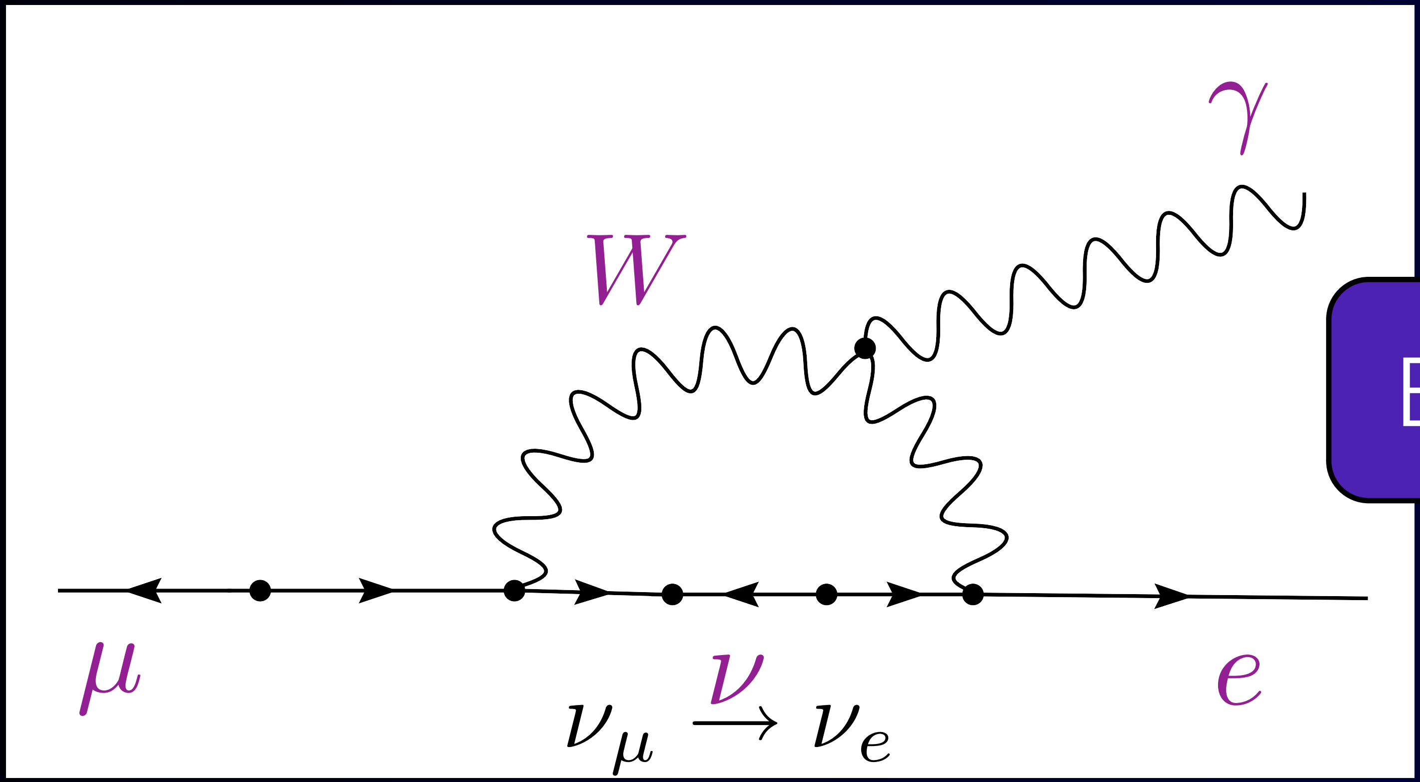

BR~O(10^{-54})

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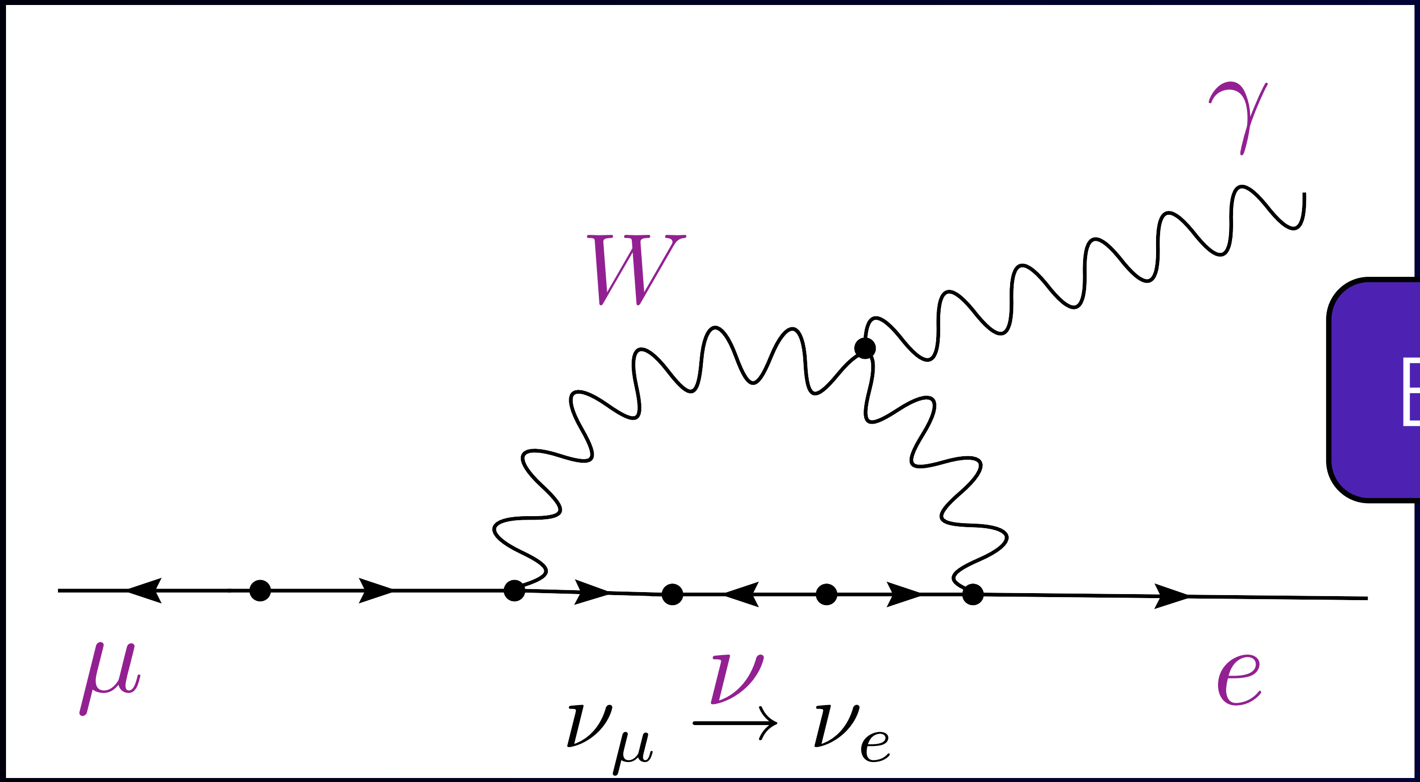

BR~O(10^{-54})

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

CLFV 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

$$B(\mu \to e\gamma) < 2.4 \times 10^{-12}$$
$$B(\mu N \to eN) < 7 \times 10^{-13}$$

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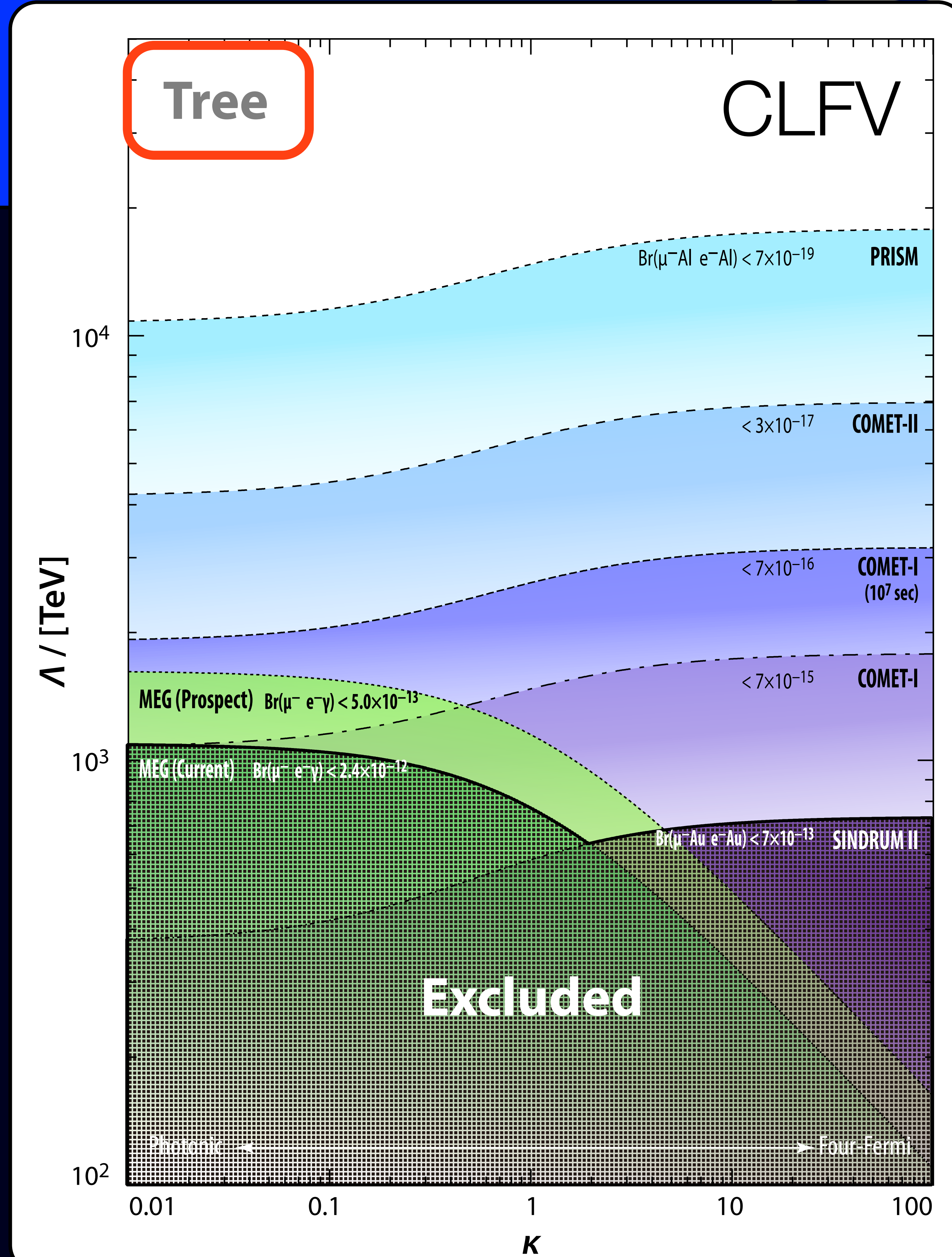

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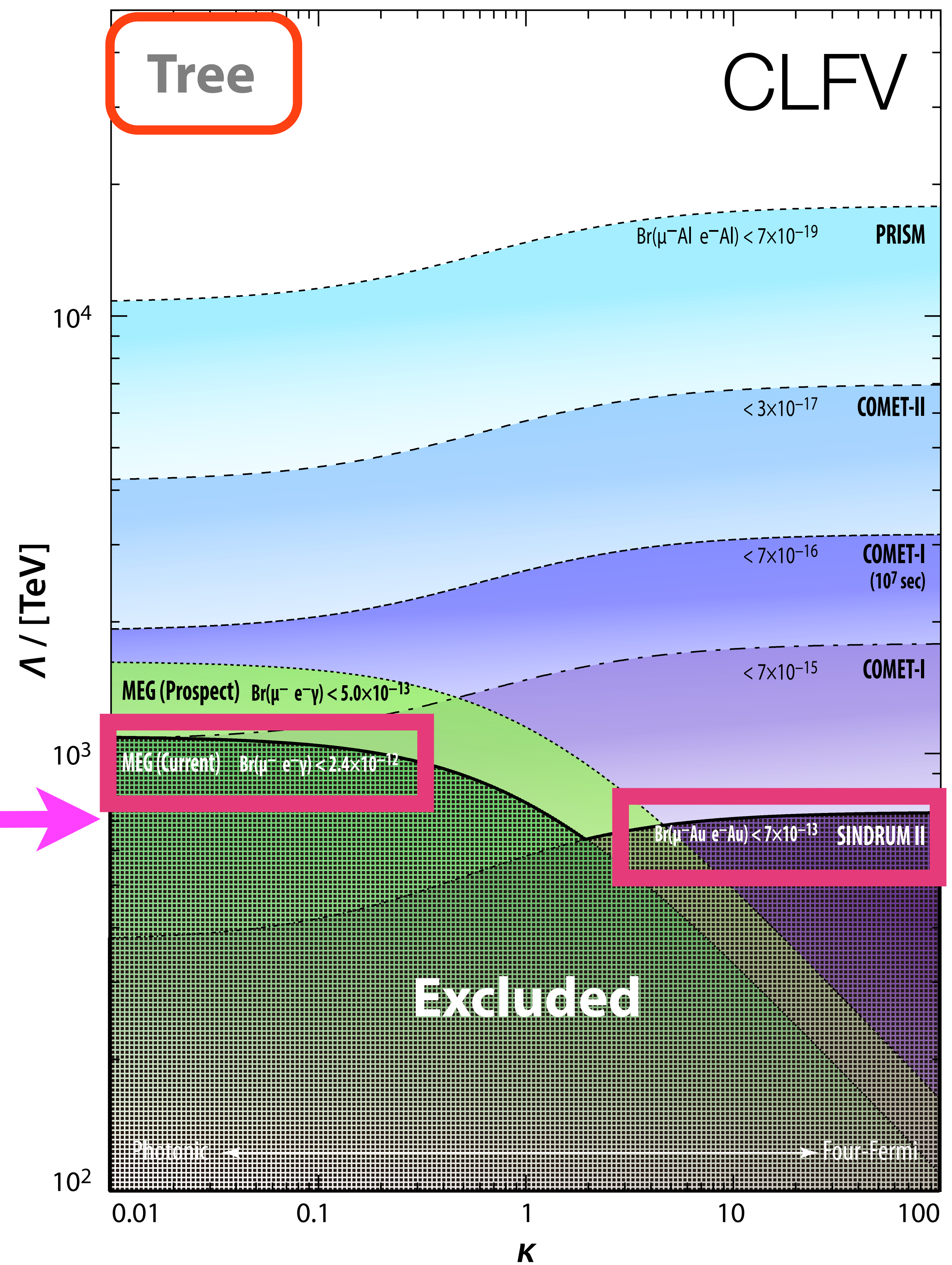
O(10^3)TeV



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CLFV and Neutrino

from Y. Okada san's slide (2010)

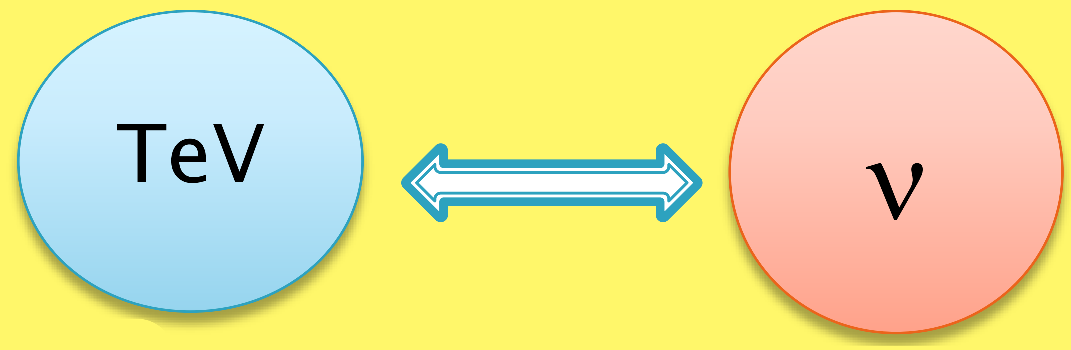
CLFV and Neutrino Mass Generation

Scale of the electroweak symmetry breaking

Scale of the neutrino mass generation

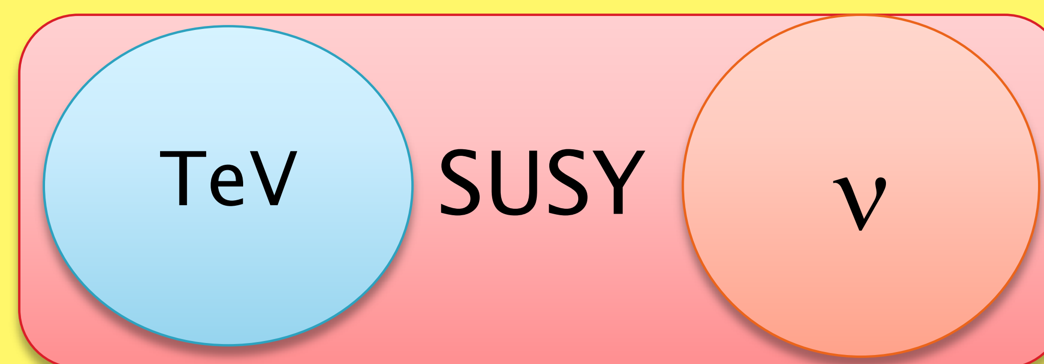
If two scales are well separated, LFVs are suppressed.

CLFV~O(10^{-54})



1

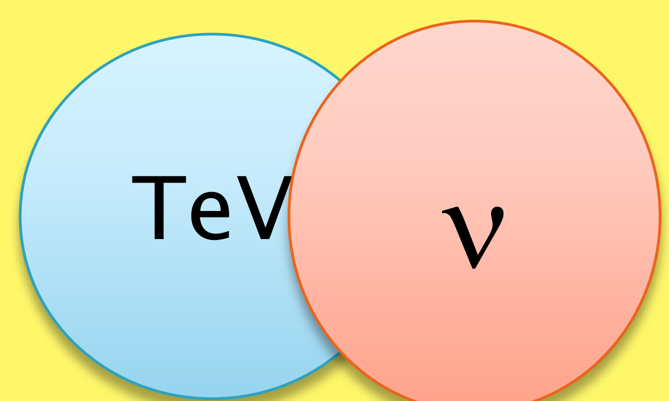
In supersymmetric models, large LFV signals are expected even if two scales are separated.



2

If two scales are close, large LFVs are expected.

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



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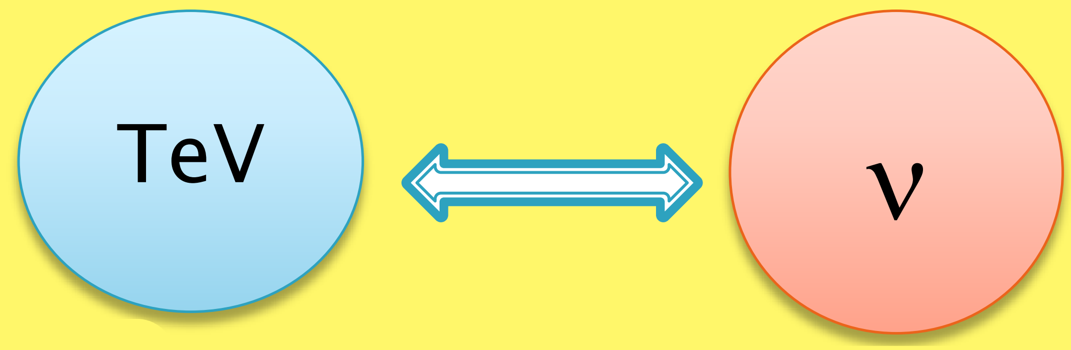

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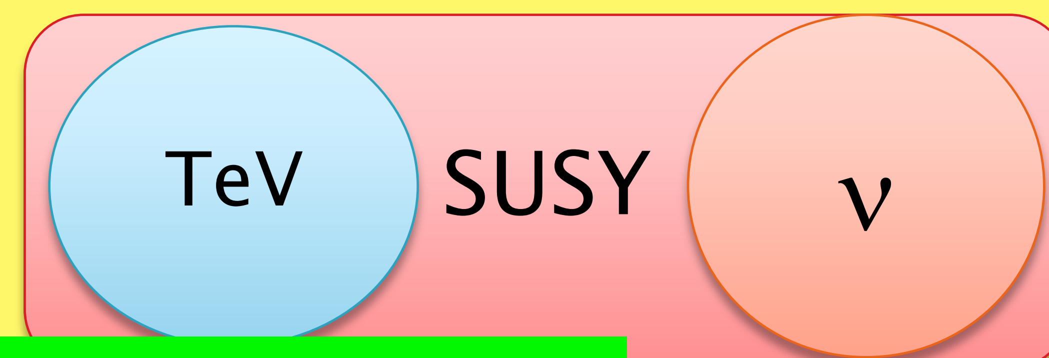

F. Borzumati and A. Masiero, PRL 57 (1986) 961

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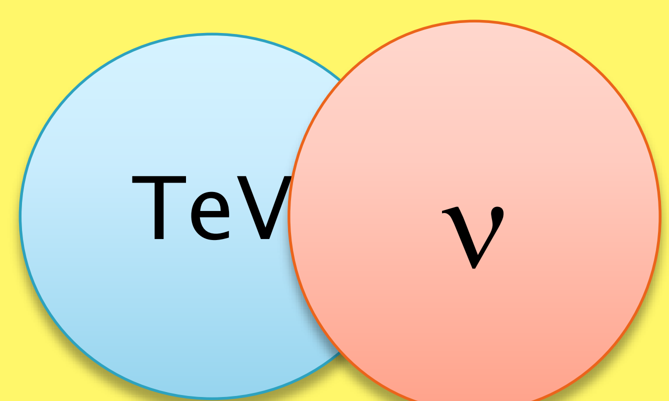


arXiv:1207.7227v1 [hep-ph] 31 Jul 2012

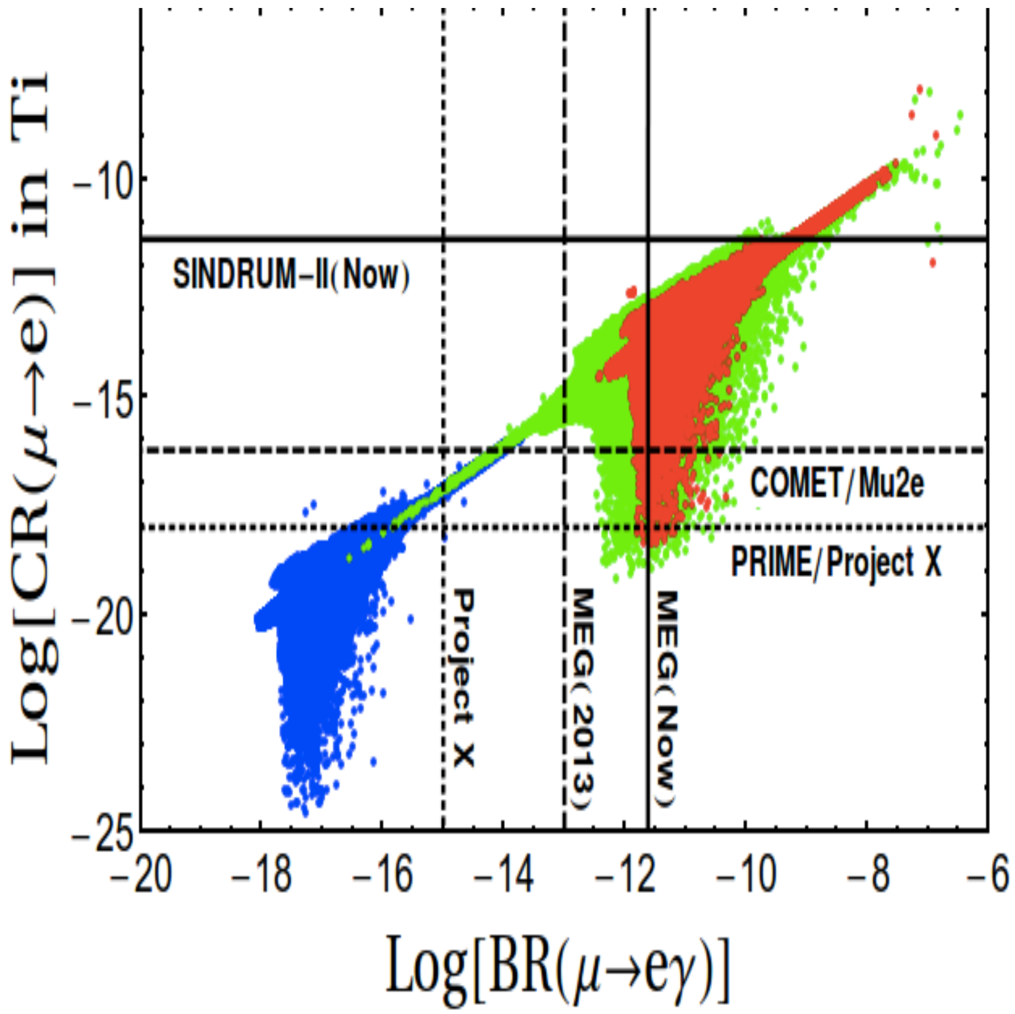
1

SUSY Predictions (a la A. Masiero)

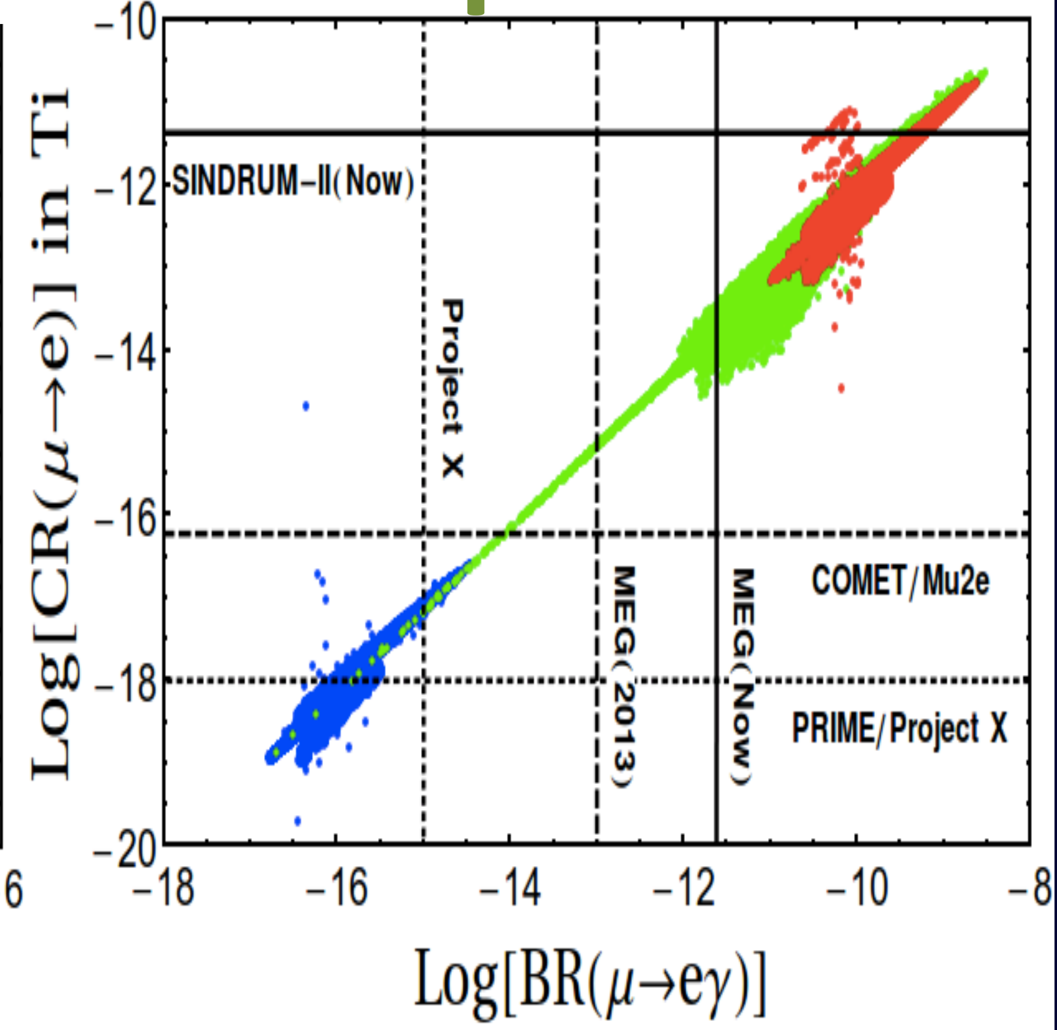
Osaka University

μ – e conversion vs μ → eγ

Tanβ = 10



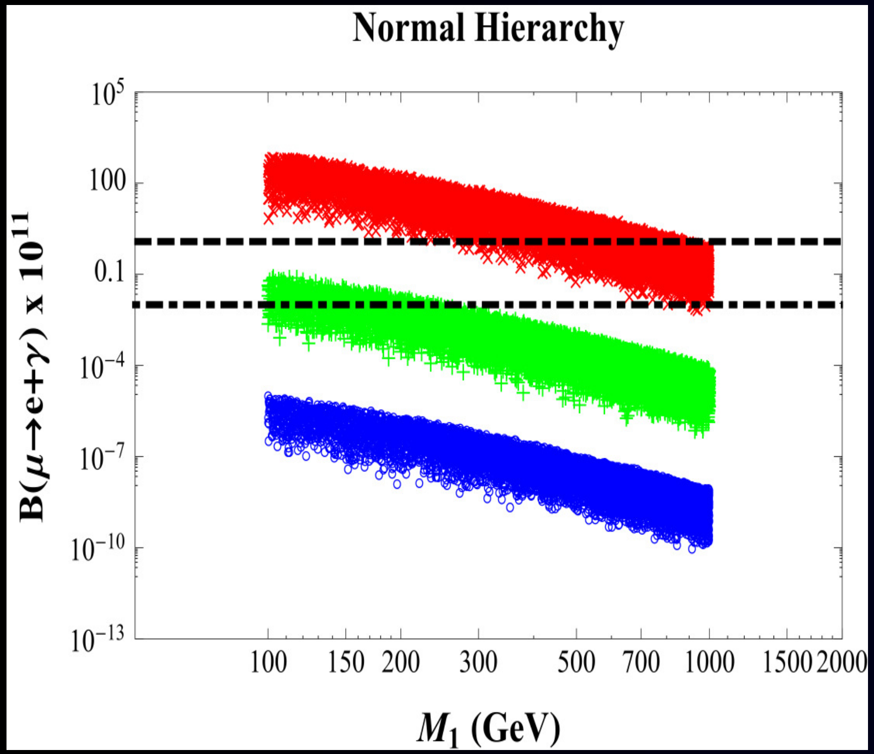
Tanβ = 40

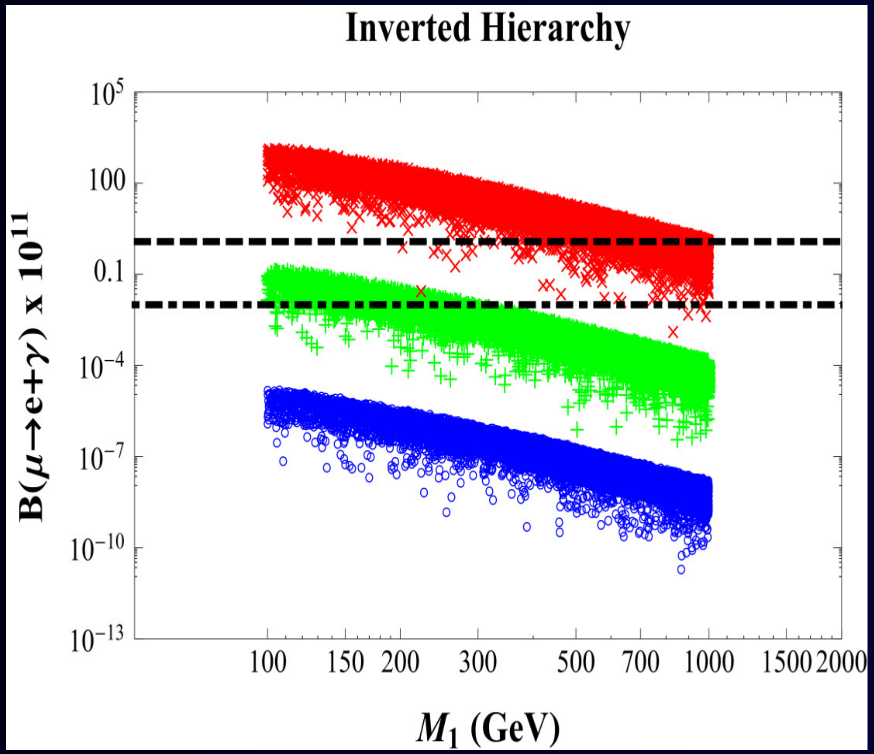


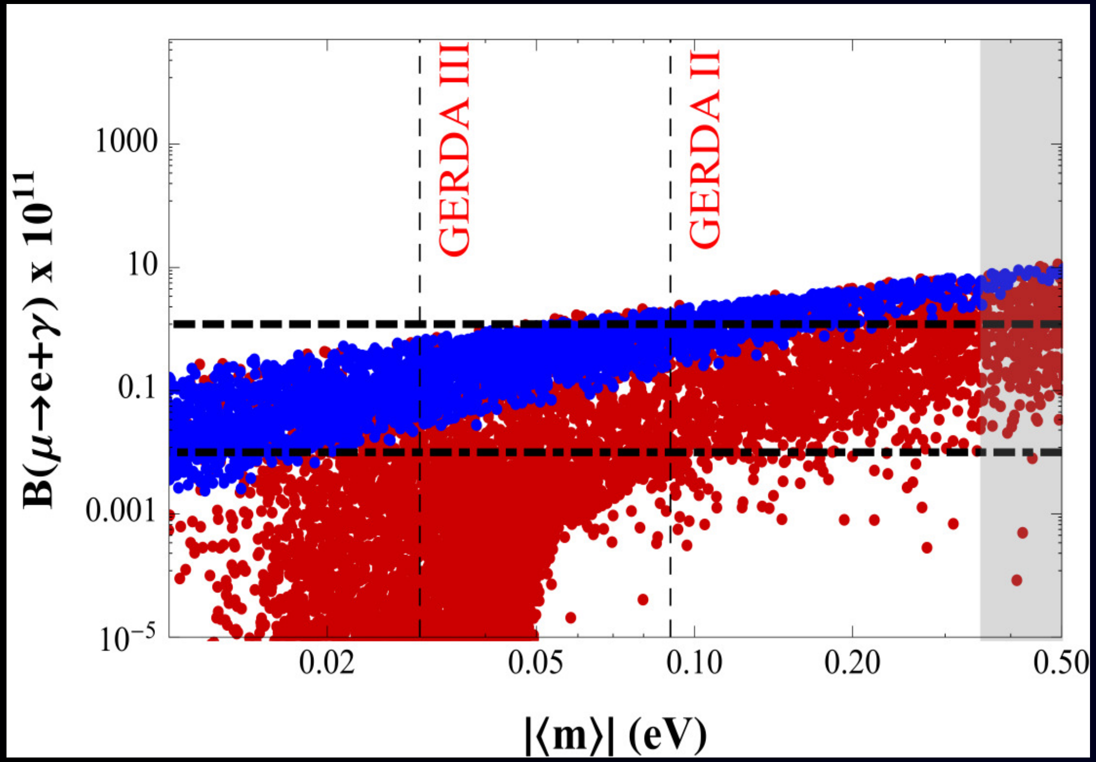
A. Ibara, E. Molinaro, S.T. Petcov, Phys. Rev. D84 (2011) 013005

2

CLFV with TeV Seesaw (Type-I)





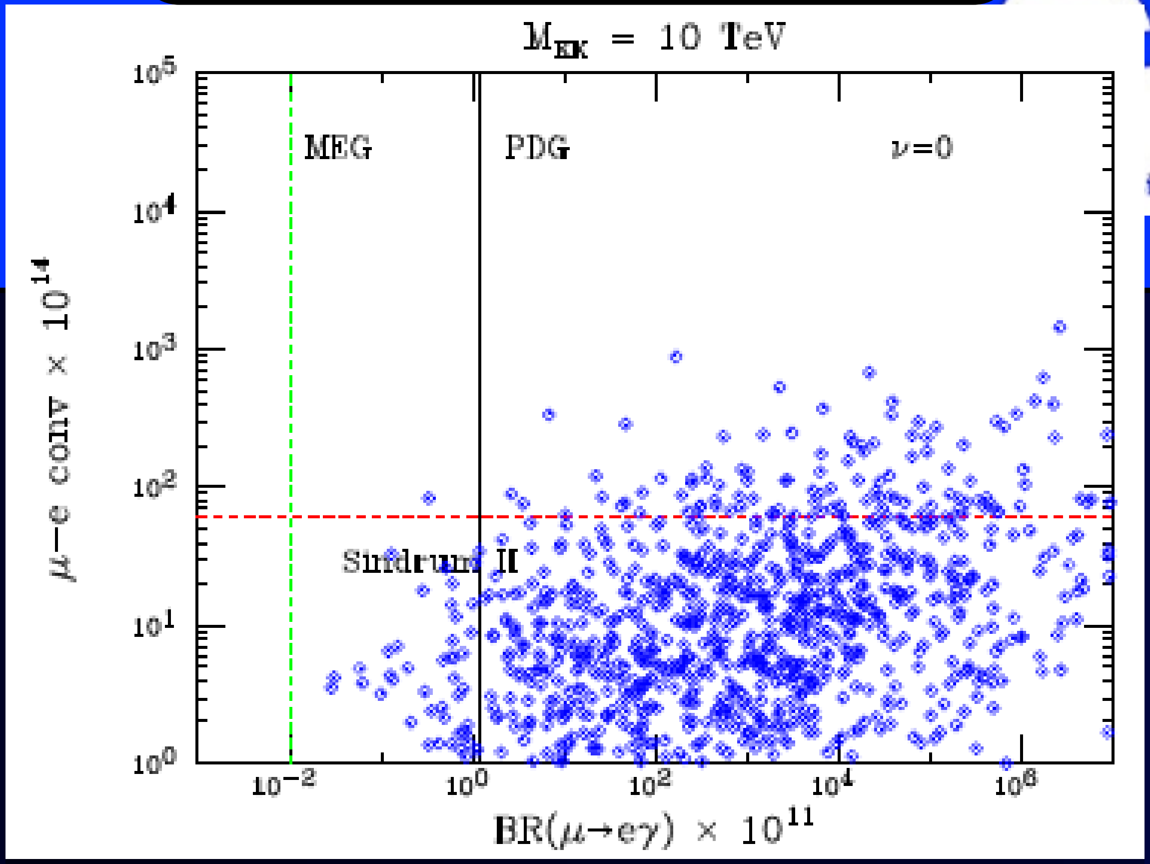


TeV seesaw type-I models predict sizable branching ratio of CLFV with right-handed neutrino mass of O(TeV).

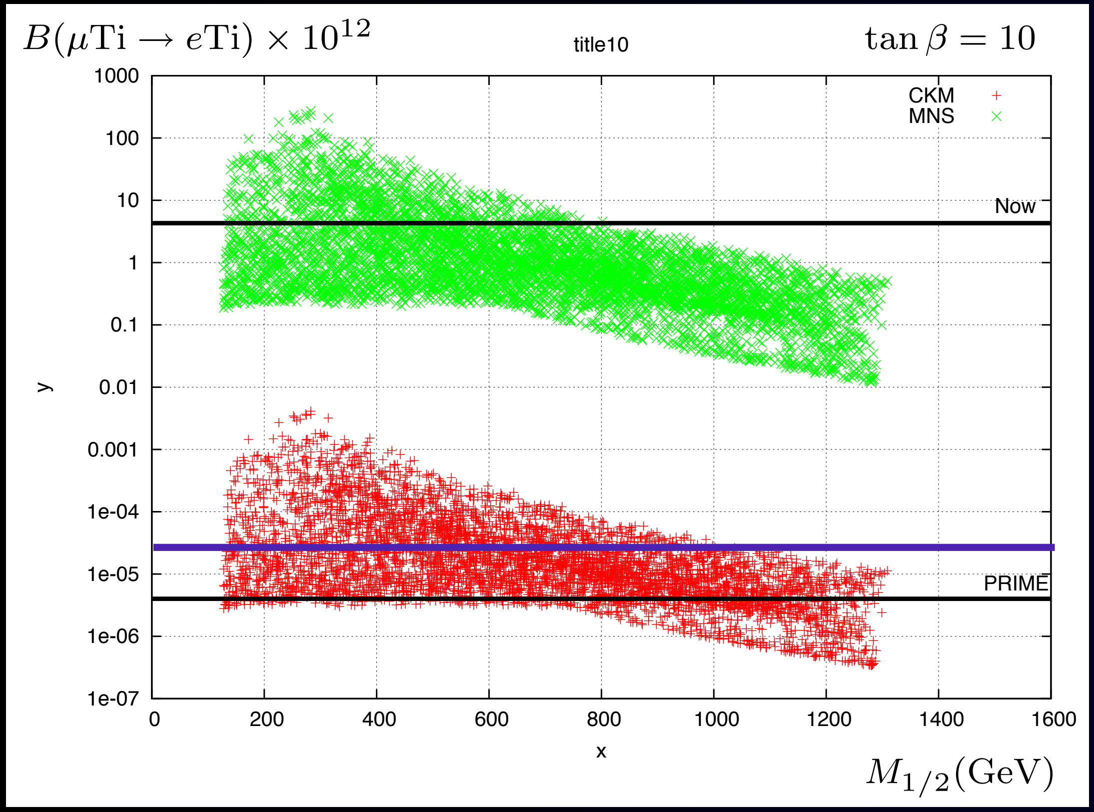
CLFV Predictions

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

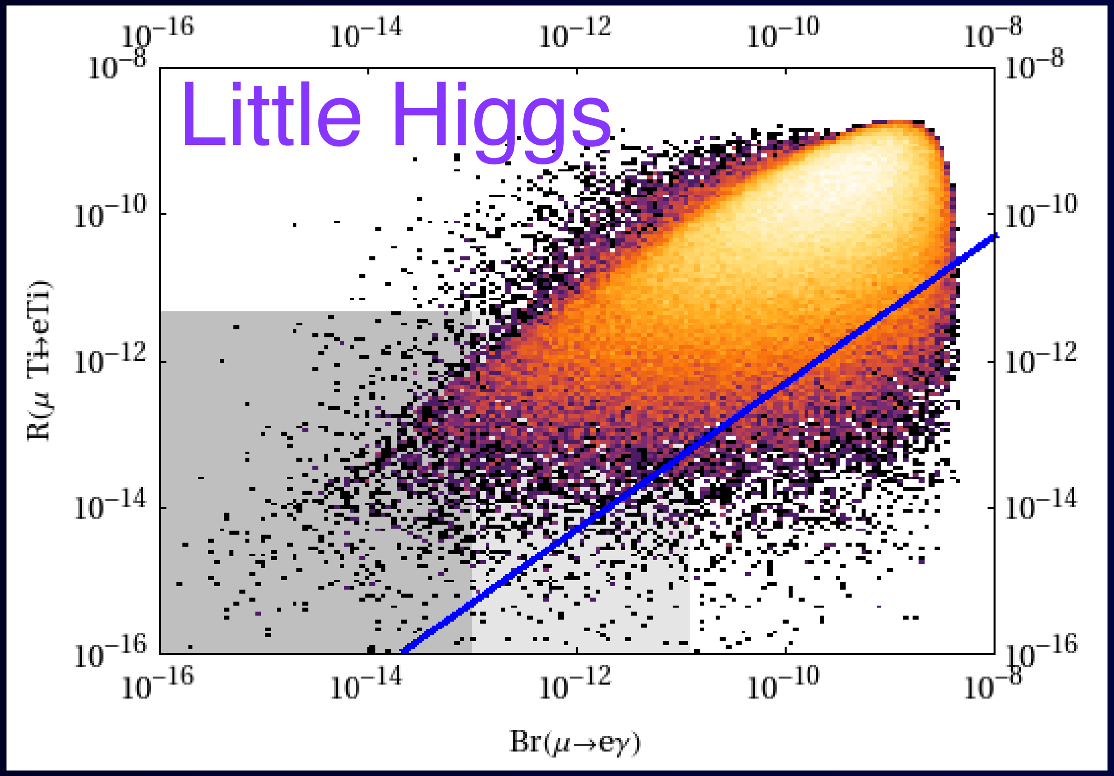
extra dimension model



SUSY model



little Higgs model



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

from D. Hitlin’s talk at ICHEP2012

Osaka University

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

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

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

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$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
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$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
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μ-e conversion
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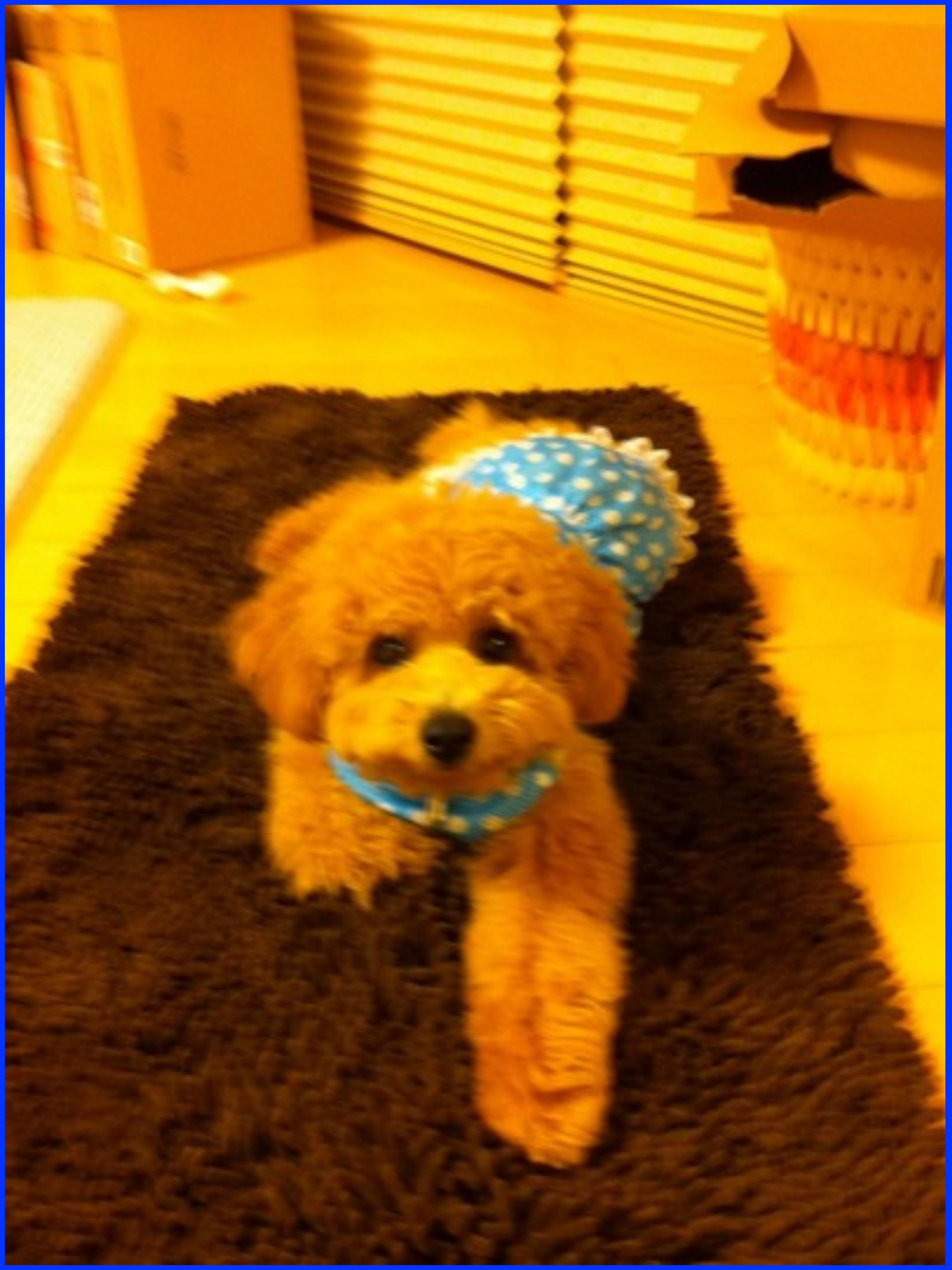

Present Limits and Future Projection

Osaka University

process	present limit	future	
$\mu \rightarrow e\gamma$	$<2.4 \times 10^{-12}$	$<10^{-14}$	MEG at PSI
$\mu \rightarrow eee$	$<1.0 \times 10^{-12}$	$<10^{-16}$	Mu3e at PSI
$\mu N \rightarrow eN$ (in Al)	none	$<10^{-16}$	Mu2e / COMET
$\mu N \rightarrow eN$ (in Ti)	$<4.3 \times 10^{-12}$	$<10^{-18}$	PRISM
$\tau \rightarrow e\gamma$	$<1.1 \times 10^{-7}$	$<10^{-9} - 10^{-10}$	super KEKB/B
$\tau \rightarrow eee$	$<3.6 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	super KEKB/B
$\tau \rightarrow \mu\gamma$	$<4.5 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	super KEKB/B
$\tau \rightarrow \mu\mu\mu$	$<3.2 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	super KEKB/B

Present Limits and Future Projection

Best because of no limitation from accidental background

process	present limit	future	
$\mu \rightarrow e\gamma$	$<2.4 \times 10^{-12}$	$<10^{-14}$	MEG at PSI
$\mu \rightarrow eee$	$<1.0 \times 10^{-12}$	$<10^{-16}$	Mu3e at PSI
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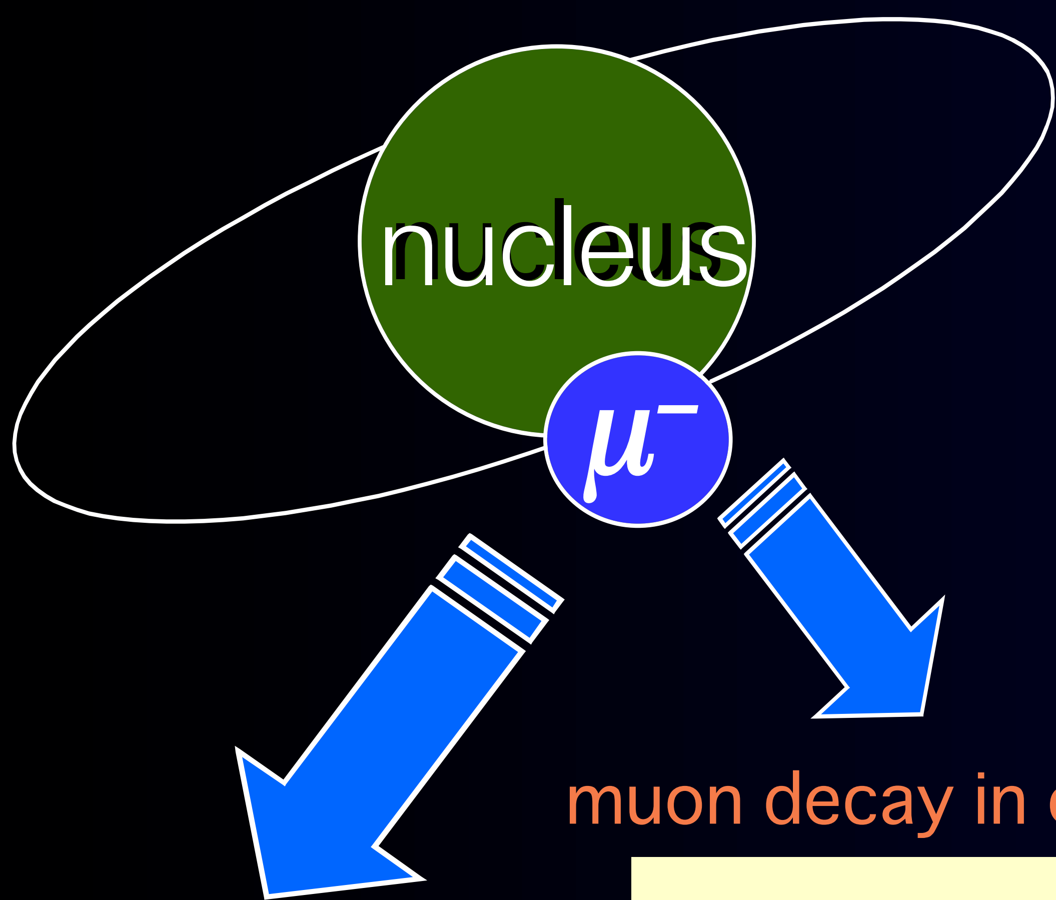
$\tau \rightarrow eee$	$<3.6 \times 10^{-8}$	$<10^{-9}$ - 10^{-10}	super KEKB/B
$\tau \rightarrow \mu\gamma$	$<4.5 \times 10^{-8}$	$<10^{-9}$ - 10^{-10}	super KEKB/B
$\tau \rightarrow \mu\mu\mu$	$<3.2 \times 10^{-8}$	$<10^{-9}$ - 10^{-10}	super KEKB/B

$\mu \rightarrow e$ conversion in a muonic atom

What is Muon to Electron Conversion?

1s state in a muonic atom



muon decay in orbit

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

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

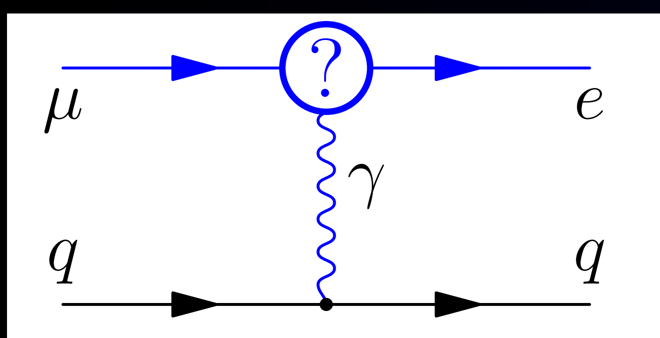
Backgrounds:
(1) physics backgrounds
ex. muon decay in orbit (DIO)
(2) beam-related backgrounds
ex. radiative pion capture, muon decay in flight,
(3) cosmic rays, false tracking

Physics Sensitivity: μ→eγ vs. μ-e conversion

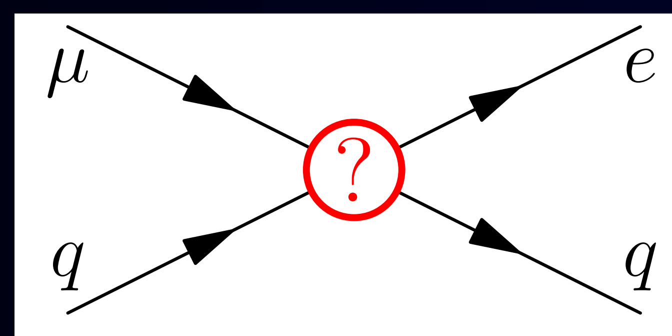
constructive

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

Photonic (dipole) interaction



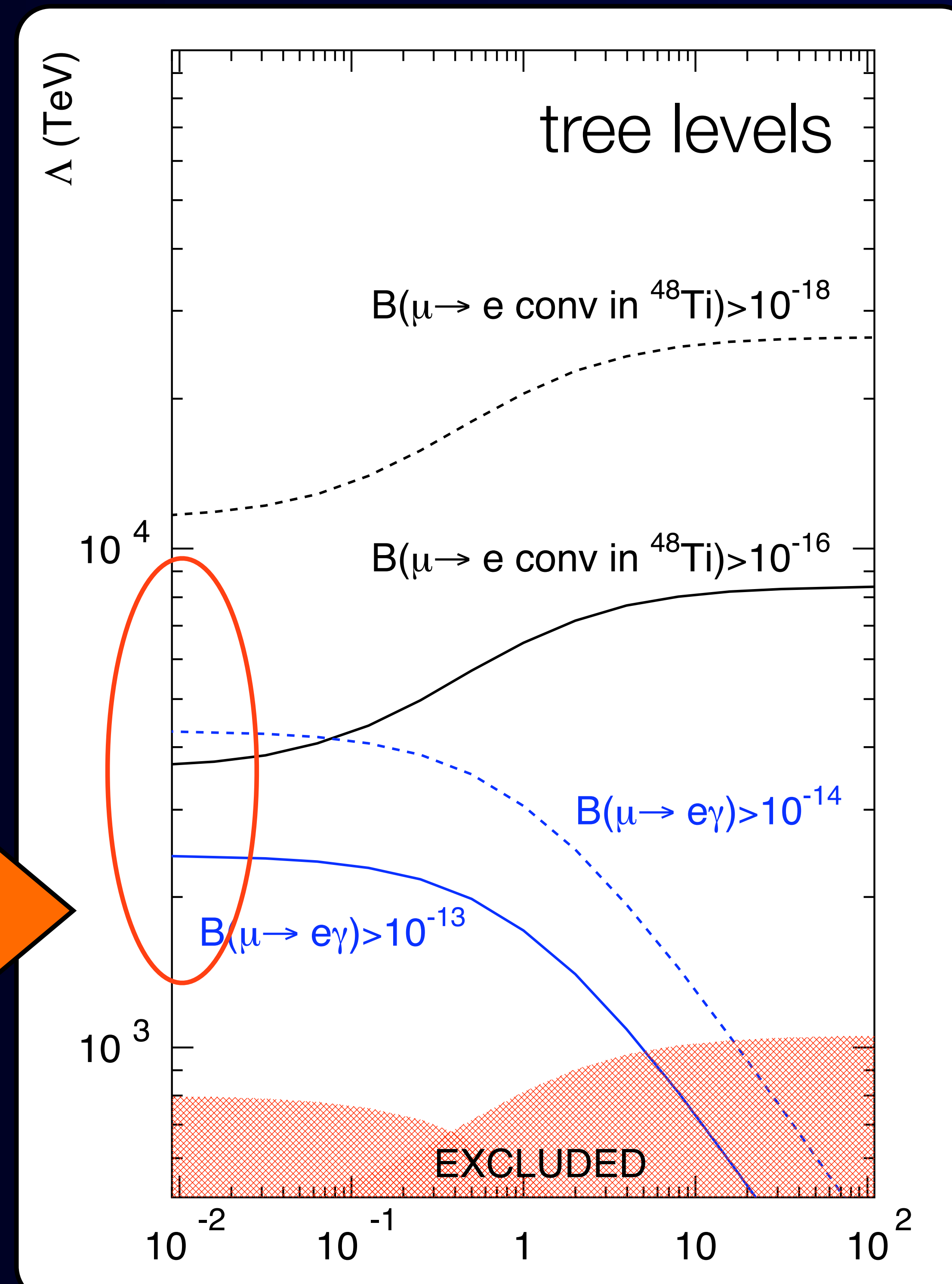
Contact interaction



if photonic contribution dominates,

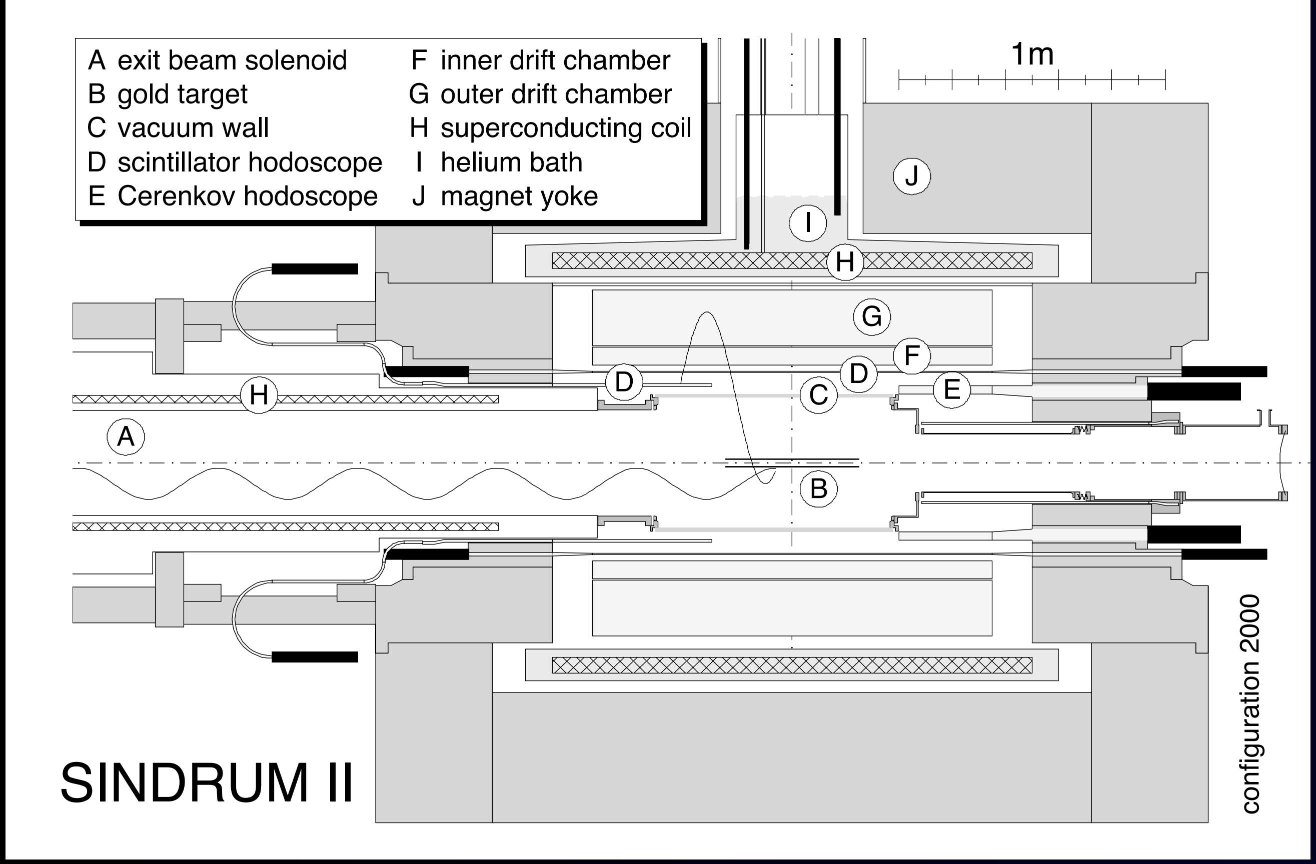
$$\frac{B(\mu N \to eN)}{B(\mu \to e\gamma)} = \frac{G_F^2 m_\mu^4}{96\pi^3\alpha} \times 3 \times 10^{12} B(A,Z) \sim \frac{B(A,Z)}{428}$$

- for aluminum, about 1/390~0.003
- for titanium, about 1/230



Previous Measurements

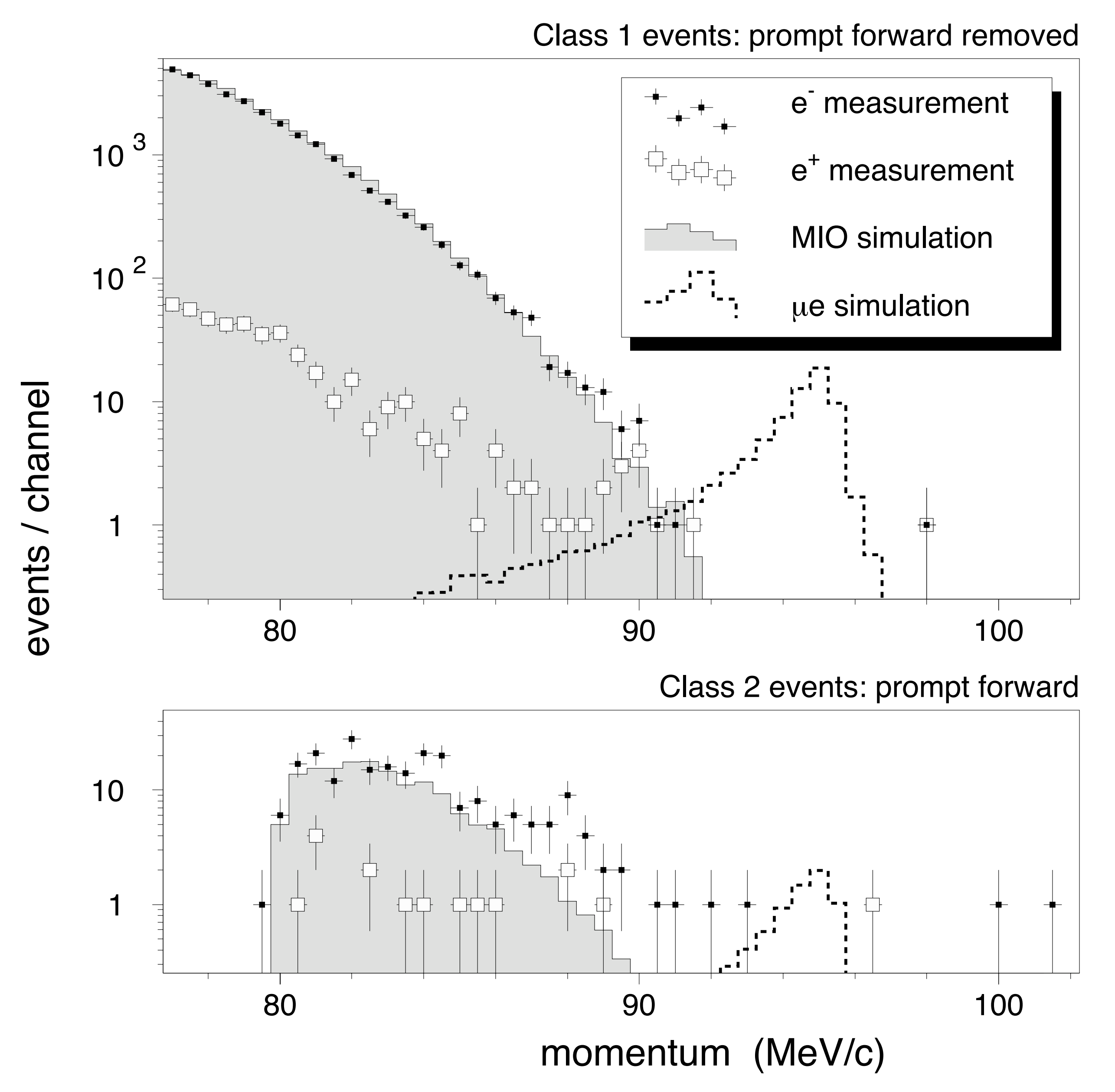
SINDRUM-II (PSI)



PSI muon beam intensity ~ $10^{7\text{-}8}$/sec beam from the PSI cyclotron. To eliminate beam related background from a beam, a beam veto counter was placed. But, it could not work at a high rate.

Published Results (2004)

$$B(\mu^- + Au \rightarrow e^- + Au) < 7 \times 10^{-13}$$



COMET at J-PARC

Improvements for Signal Sensitivity

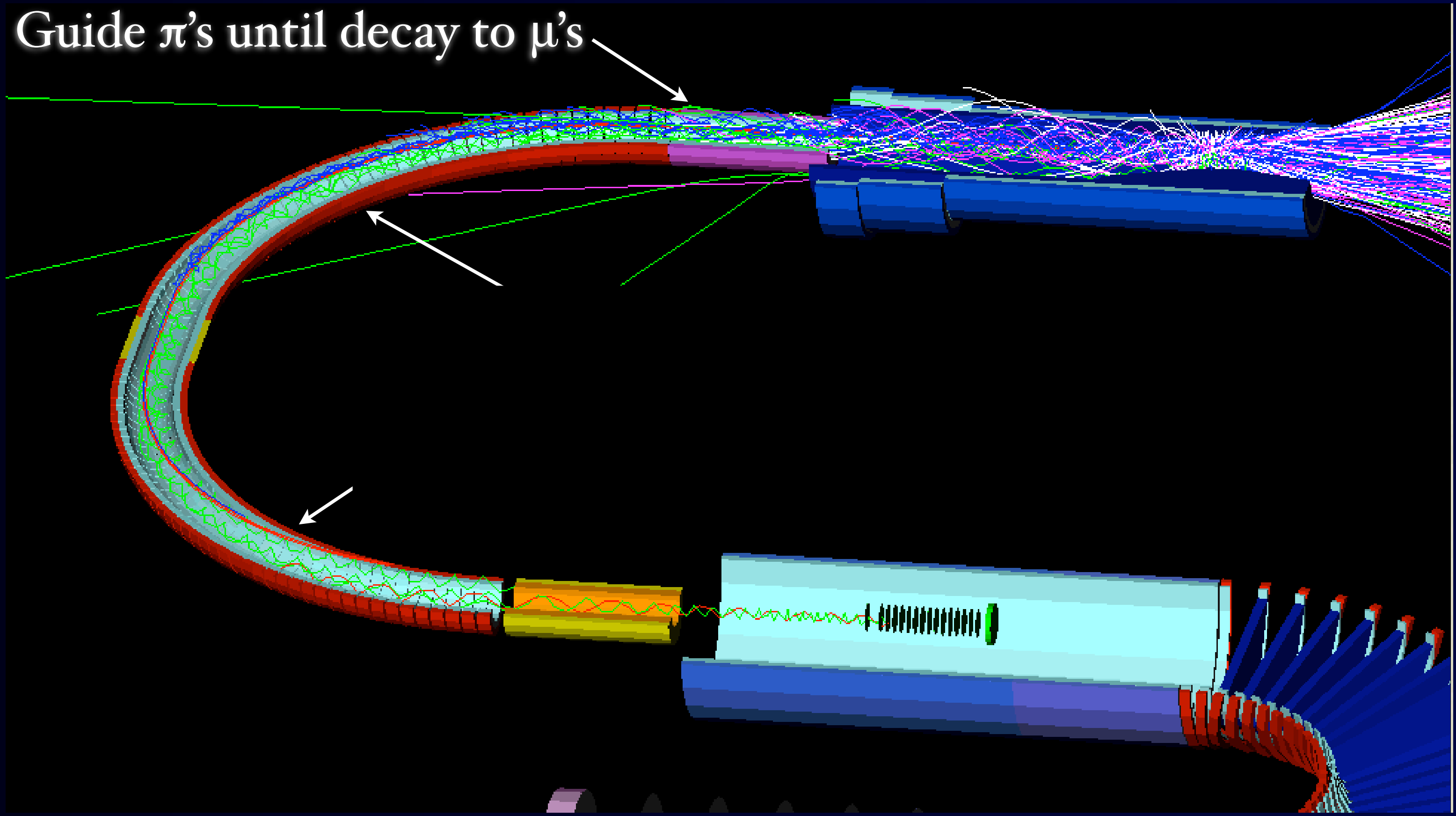
To achieve a single sensitivity of 10^{-17}, we need

10^{11} muons/sec (with 10^{7} sec running)

whereas the current highest intensity is 10^{8}/sec at PSI.

Pion Capture and Muon Transport by Superconducting Solenoid System

(10^{11} muons for 50 kW beam power)



Improvements for Background Rejection

Beam-related backgrounds → Beam pulsing with separation of 1μsec

measured between beam pulses

proton extinction = #protons between pulses/#protons in a pulse < 10^{-9}

Muon DIO background → low-mass trackers in vacuum & thin target

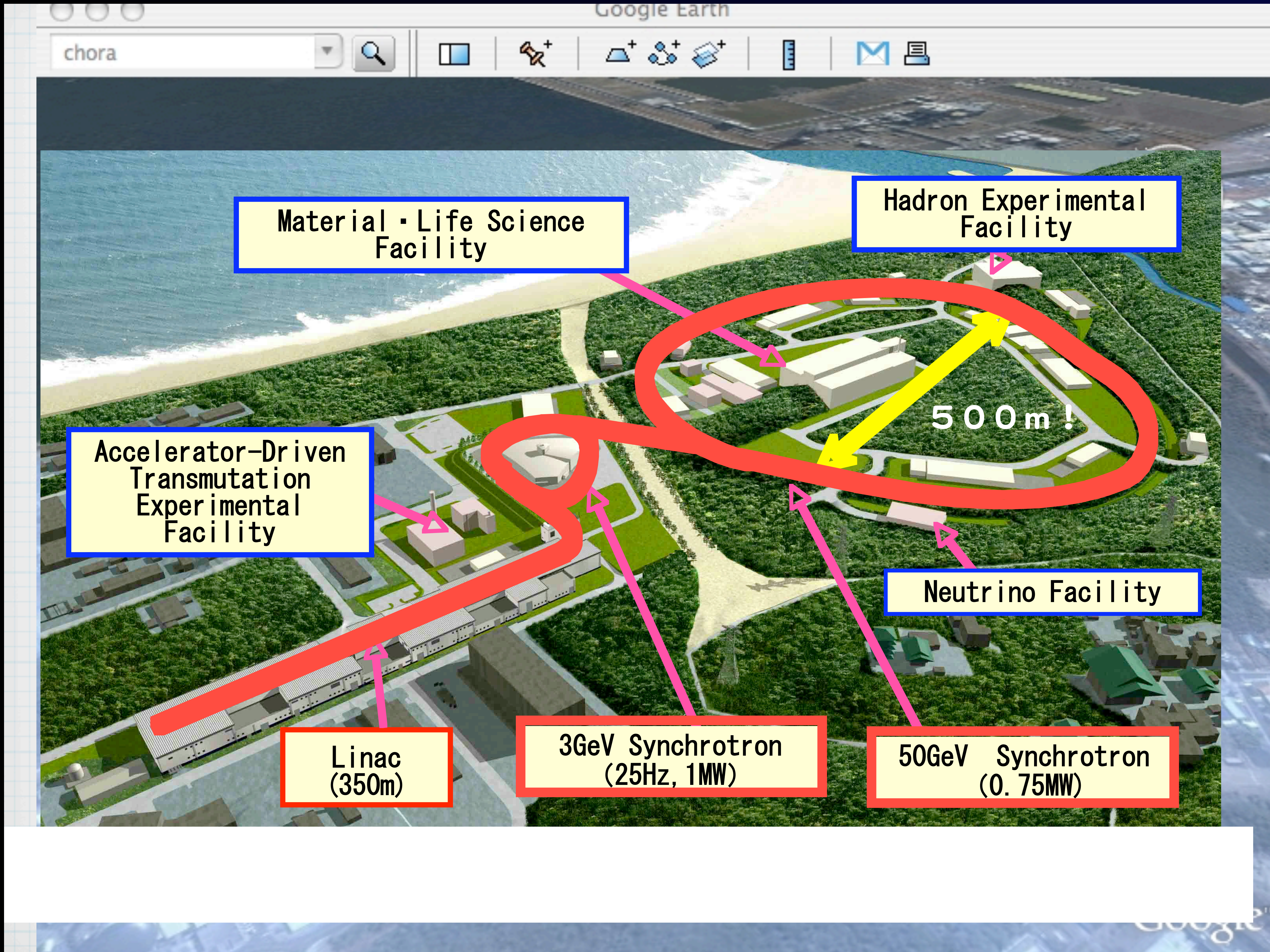
improve electron energy resolution

Muon DIF background → curved solenoids for momentum selection

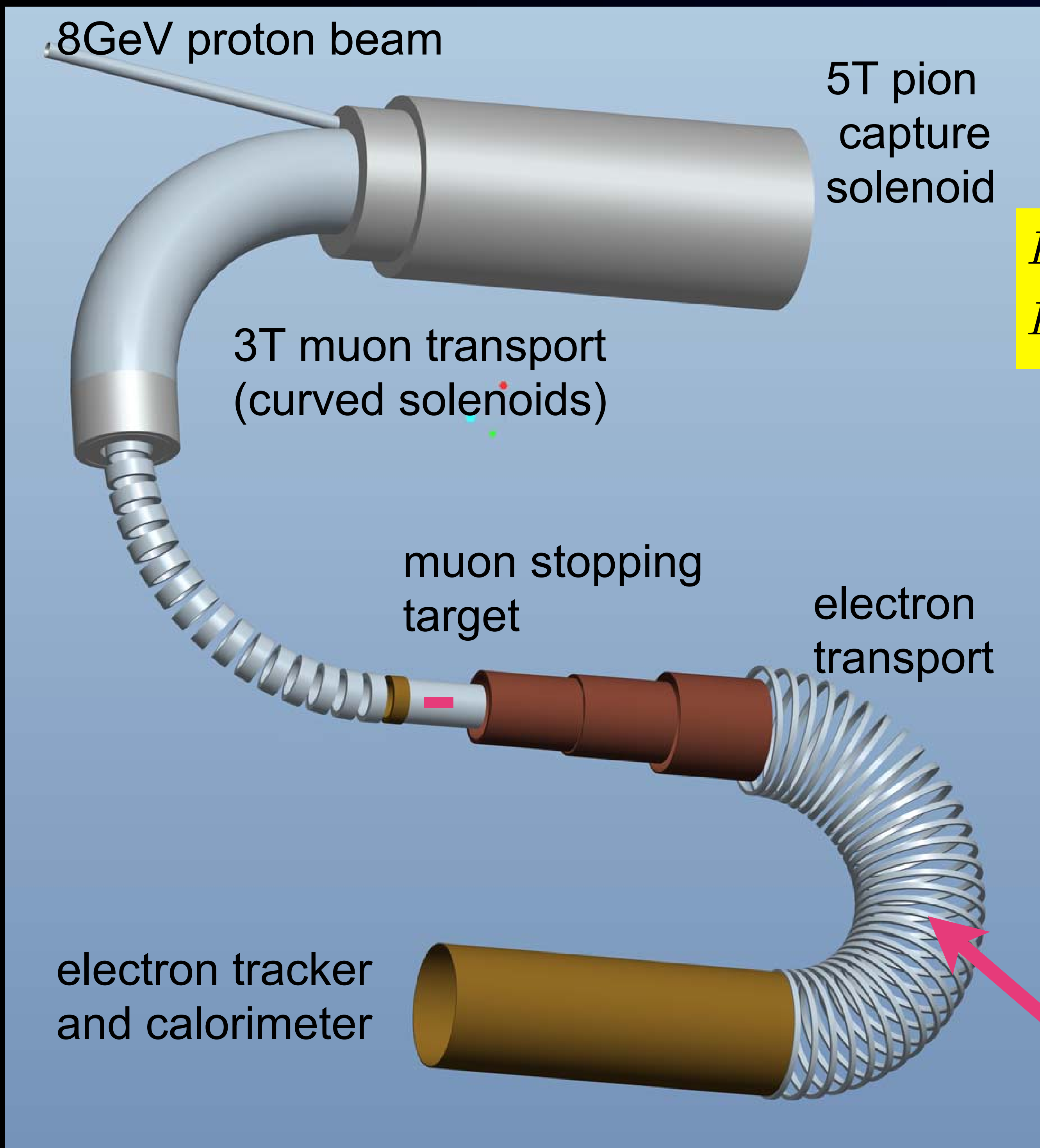
eliminate energetic muons (>75 MeV/c)

base on the MELC proposal at Moscow Meson Factory

J-PARC at Tokai, Japan



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



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.

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

COMET Collaboration

The COMET Collaboration

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from IHEP

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Charged Particle Trajectory in Curved Solenoid

- A center of helical trajectory of charged particles in a curved solenoidal field is drifted by

$$D = \frac{p}{qB}\theta_{bend}\frac{1}{2}\left(\cos\theta + \frac{1}{\cos\theta}\right)$$

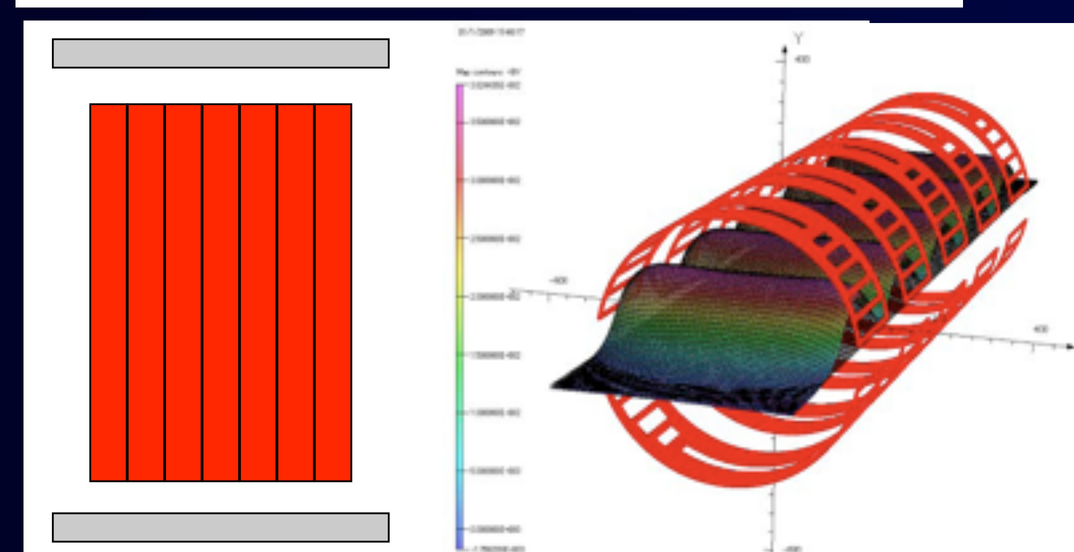
D : drift distance
B : Solenoid field
θ_{bend} : Bending angle of the solenoid channel
p : Momentum of the particle
q : Charge of the particle
θ : atan(P_T/P_L)

- This can be used for charge and momentum selection.

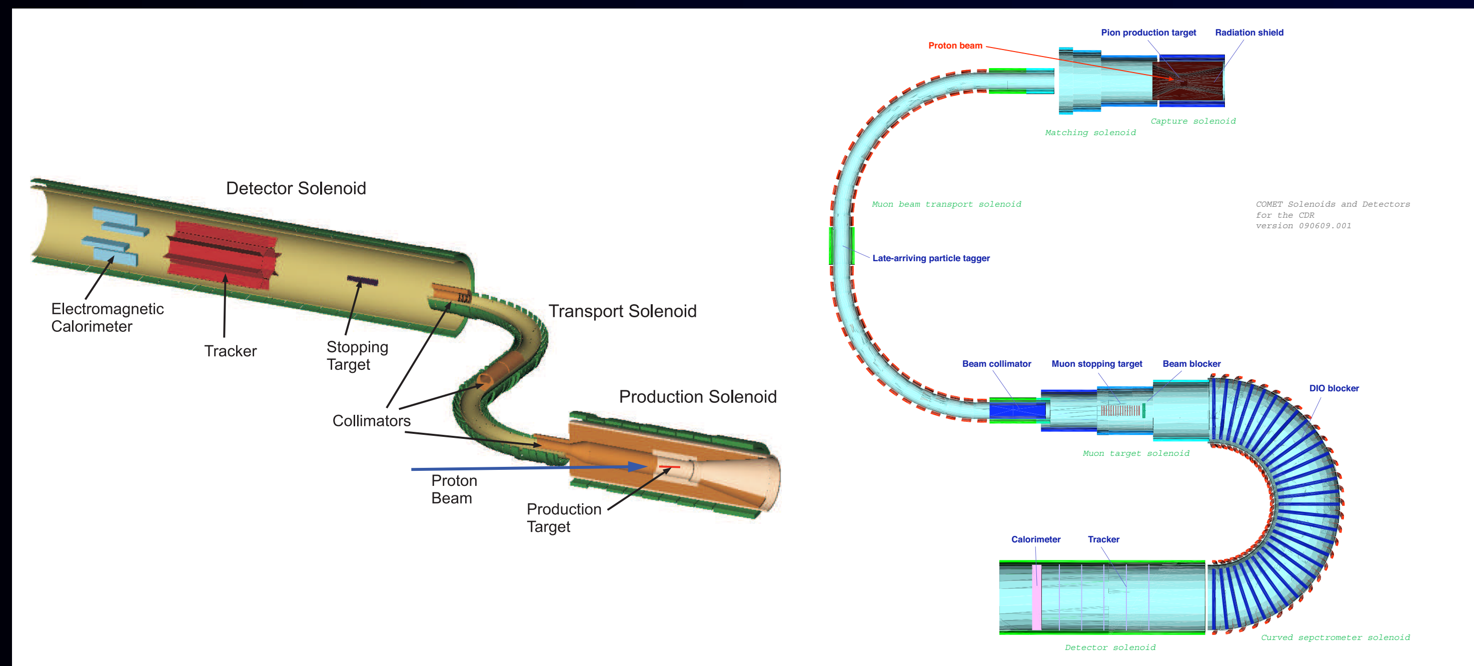
- This drift can be compensated by an auxiliary field parallel to the drift direction given by

$$B_{comp} = \frac{p}{qr}\frac{1}{2}\left(\cos\theta + \frac{1}{\cos\theta}\right)$$

p : Momentum of the particle
q : Charge of the particle
r : Major radius of the solenoid
θ : atan(P_T/P_L)

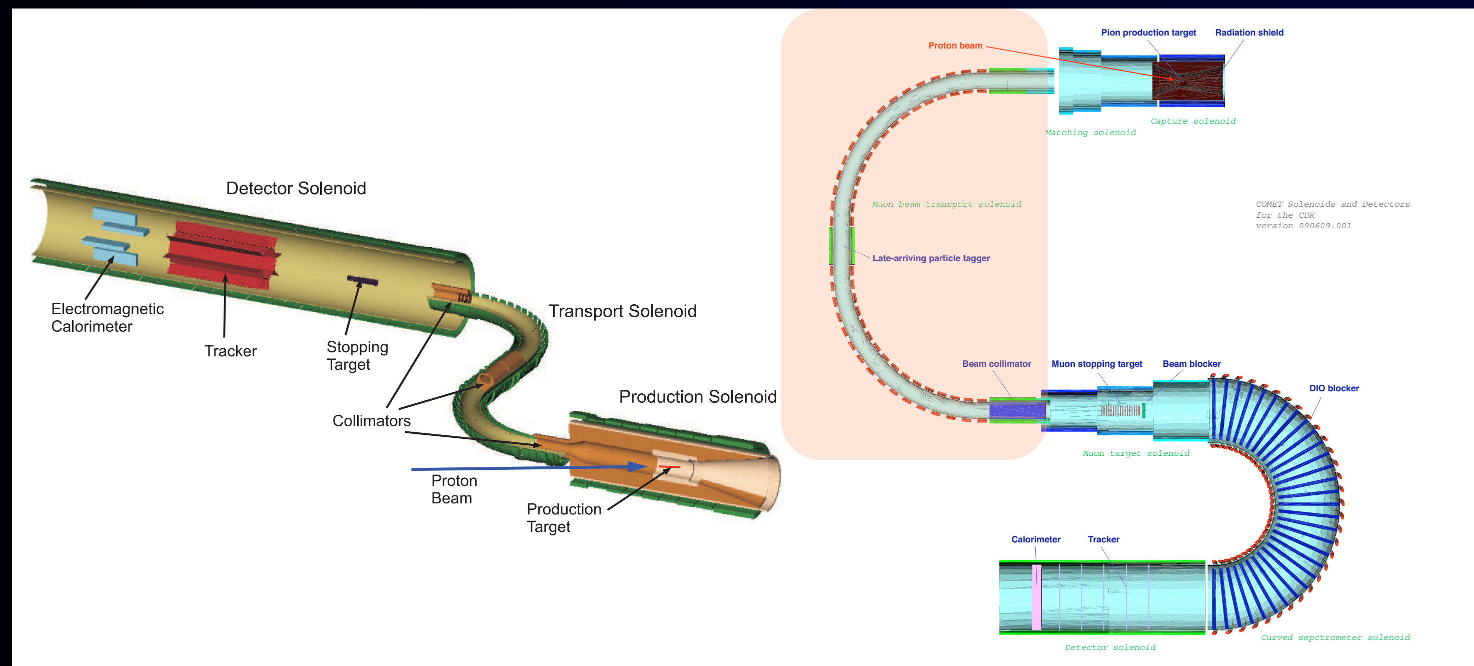


Comparison : COMET vs. Mu2e



	Mu2e@FNAL	COMET@J-PARC
muon beamline	S-shape	C-shape
electron spectrometer	Straight solenoid	Curved solenoid

Comparison : COMET vs. Mu2e

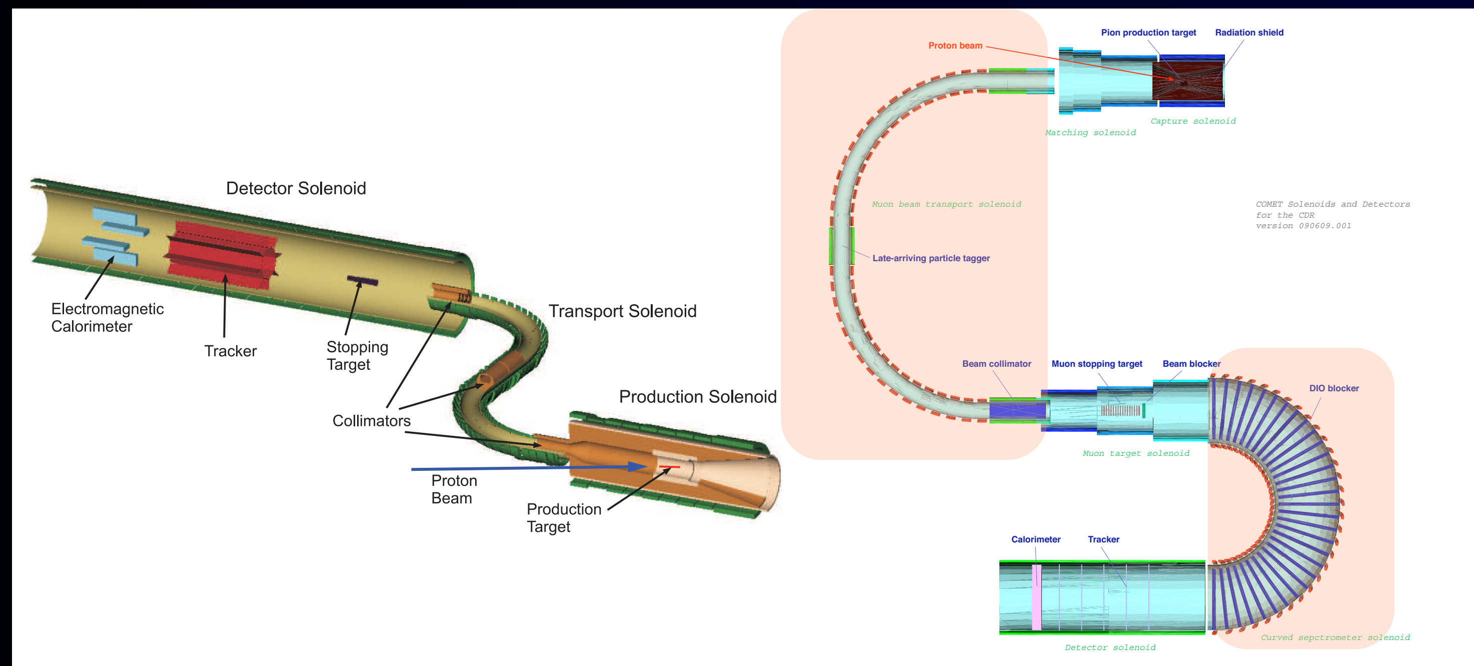


	Mu2e@FNAL	COMET@J-PARC
muon beamline	S-shape	C-shape
electron spectrometer	Straight solenoid	Curved solenoid

Selection of low momentum muons

eliminate background from muon decay in flight

Comparison : COMET vs. Mu2e



	Mu2e@FNAL	COMET@J-PARC
muon beamline	S-shape	C-shape
electron spectrometer	Straight solenoid	Curved solenoid

Selection of low momentum muons

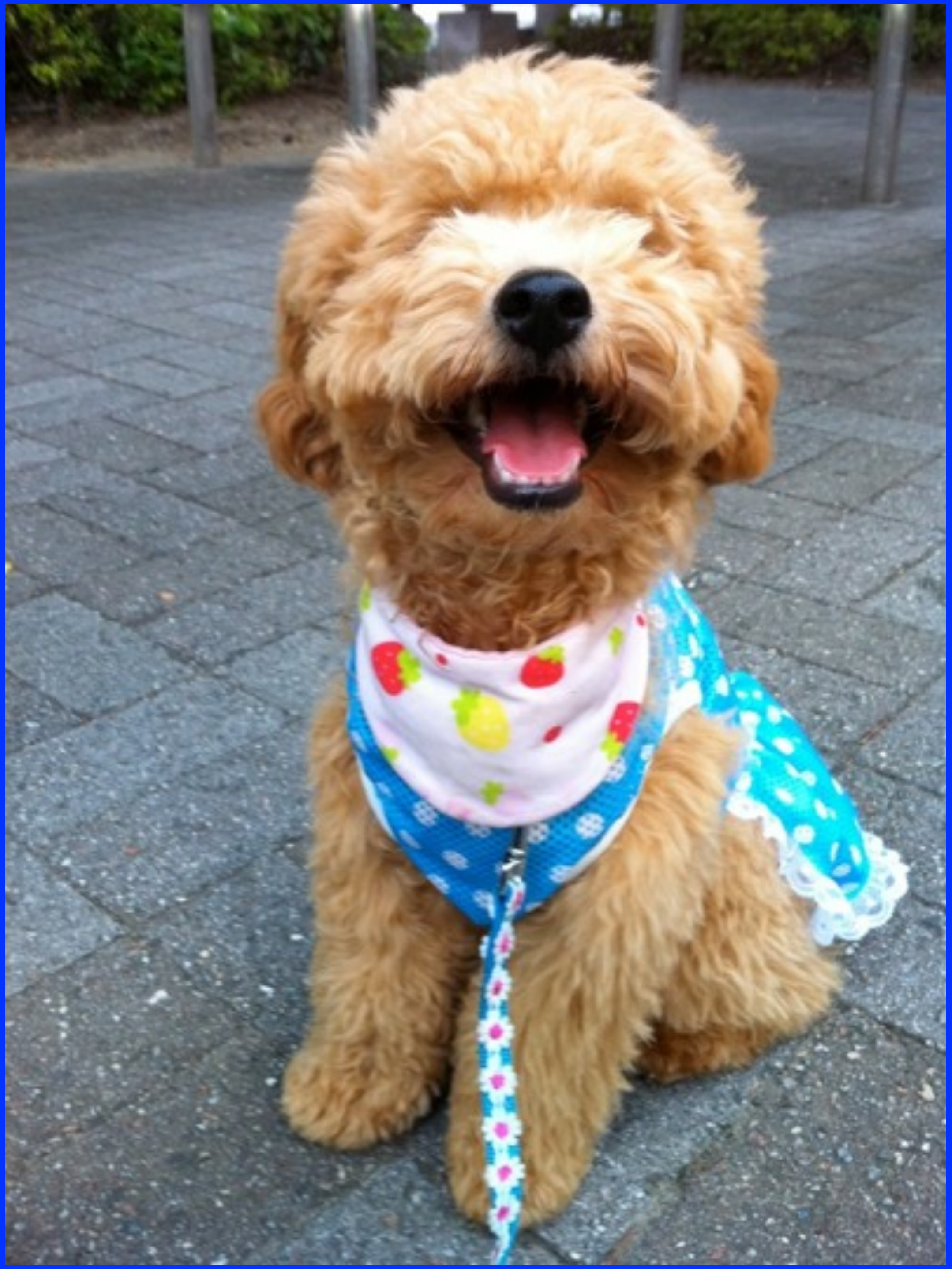
eliminate background from muon decay in flight

Selection of 100 MeV electrons

eliminate protons from nuclear muon capture.

eliminate low energy events to make the detector quiet.

COMET Staged Approach



COMET Phase-I (staged scenario)
- from J-PARC PAC report, March 2012

COMET Phase-I (staged scenario) - from J-PARC PAC report, March 2012

Osaka University

Reflecting the PAC's high evaluation of the physics associated with the COMET experiment and the positive results in the report recently published by a sub-committee of Japanese Association on High Energy Physics (JAHEP) on the future high energy physics projects, the COMET experiment is a high priority component for the J-PARC program. Considering that this high-priority experiment needs a large investment in infrastructure and hence a long time to realize, it is important to start the construction of the COMET beam line in the next 5 years.

The IPNS proposes, as the first priority item in the next five-year plan, that the upstream part of the high-p beam line be constructed and co-used by the COMET experiment and that the first half of the muon capture solenoid be constructed simultaneously.

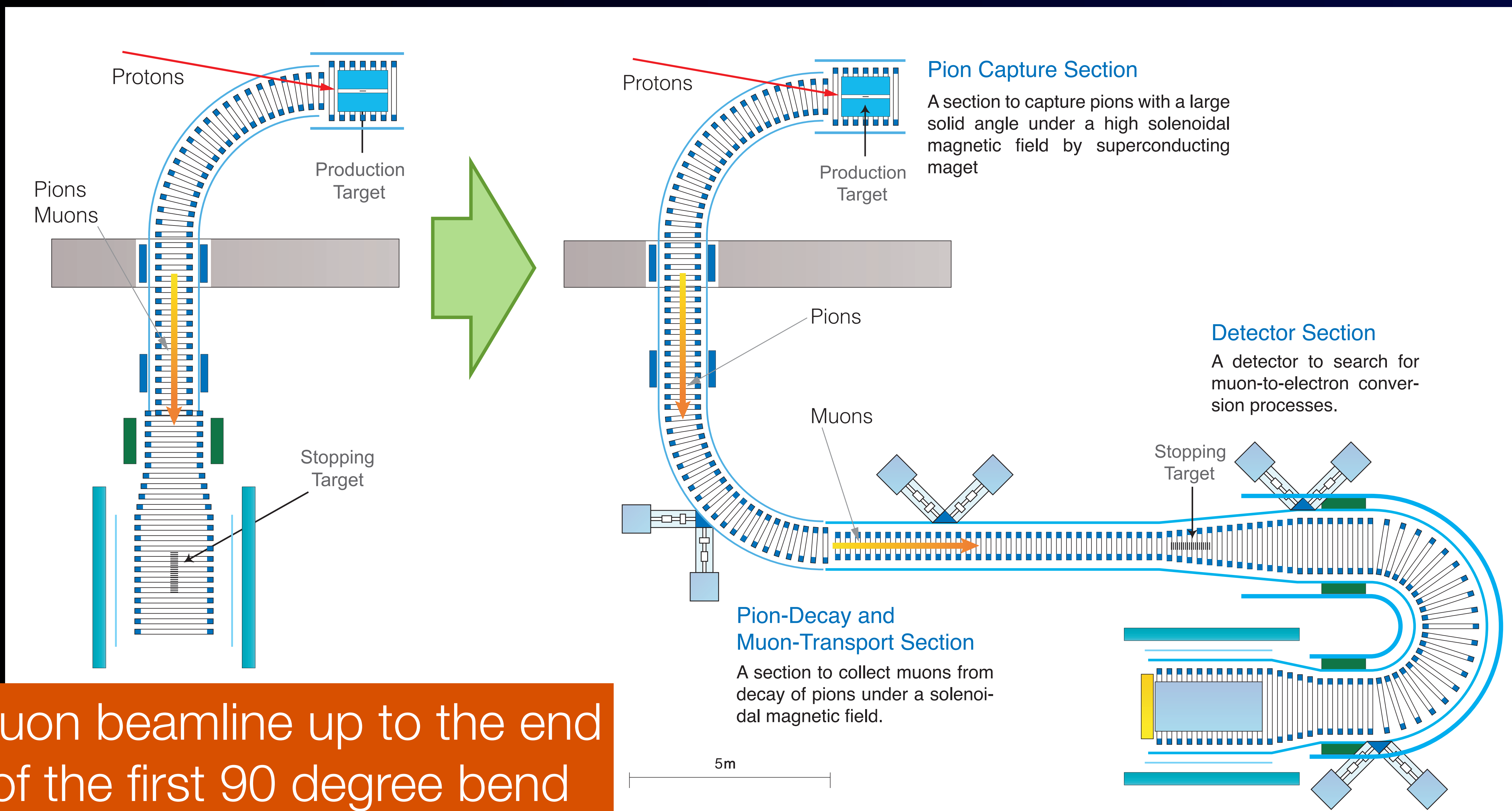
A consequence of this plan is that the K1.1BR beam line will not be usable after the installation of the production target of COMET. This conflict, as was pointed out by the PAC in the last meeting, will have a serious impact on the TREK experiments (E06 and P36). The PAC is requested to consider and comment on this in its evaluation during the meeting.

COMET Staged Approach

COMET Staged Approach

COMET Phase-I

COMET Phase-II



muon beamline up to the end of the first 90 degree bend

Goals of COMET Phase-I

1 Background Study for COMET Phase-II

direct measurement of potential background sources for the full COMET experiment by using the actual COMET beamline constructed at Phase-I

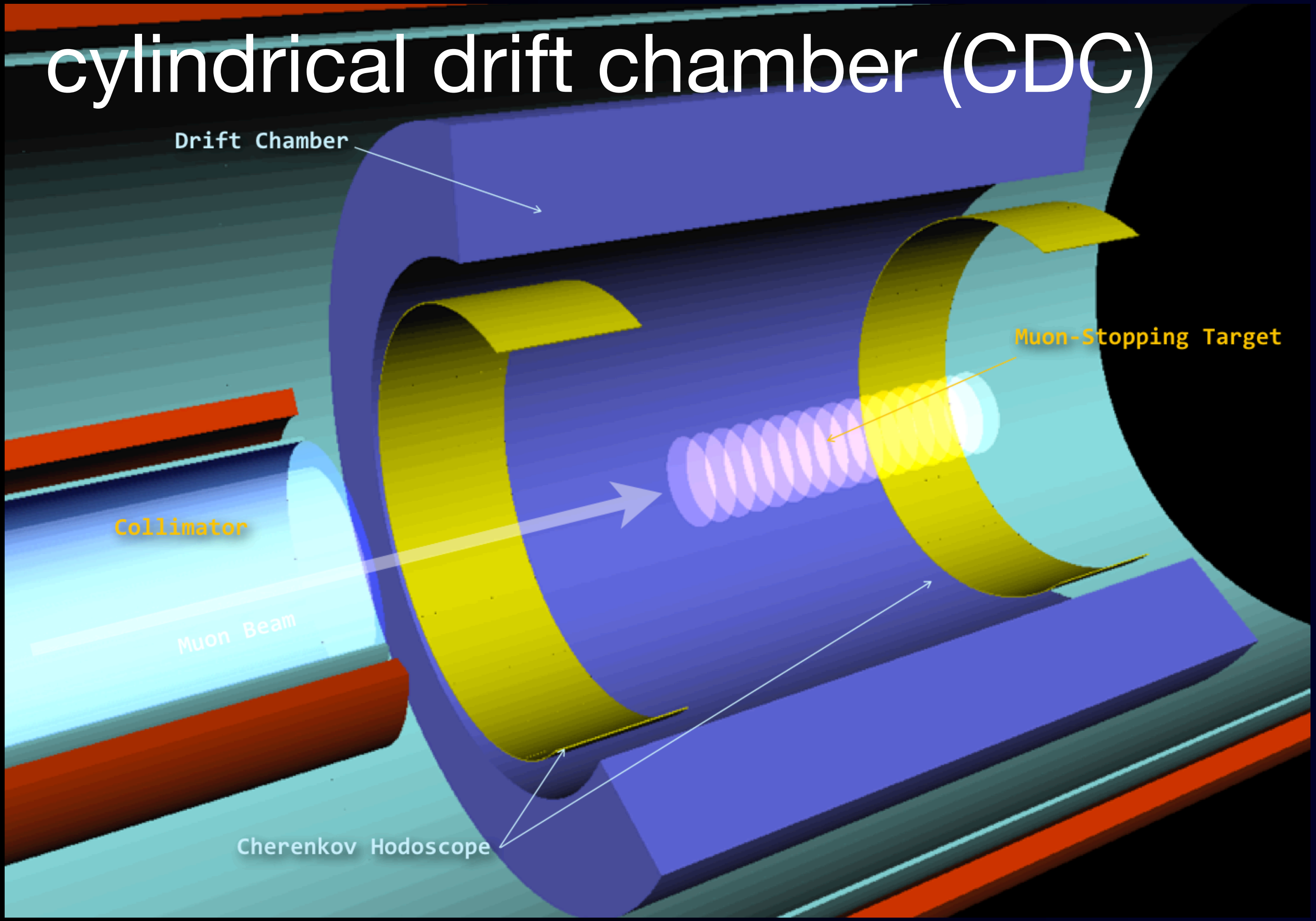
2 Search for μ-e conversion

a search for μ^-–e^- conversion at intermediate sensitivity which would be more than 100 times better than the SINDRUM-II limit

Search for μ-e conversion at Intermediate Sensitivity (CDC)

Osaka University

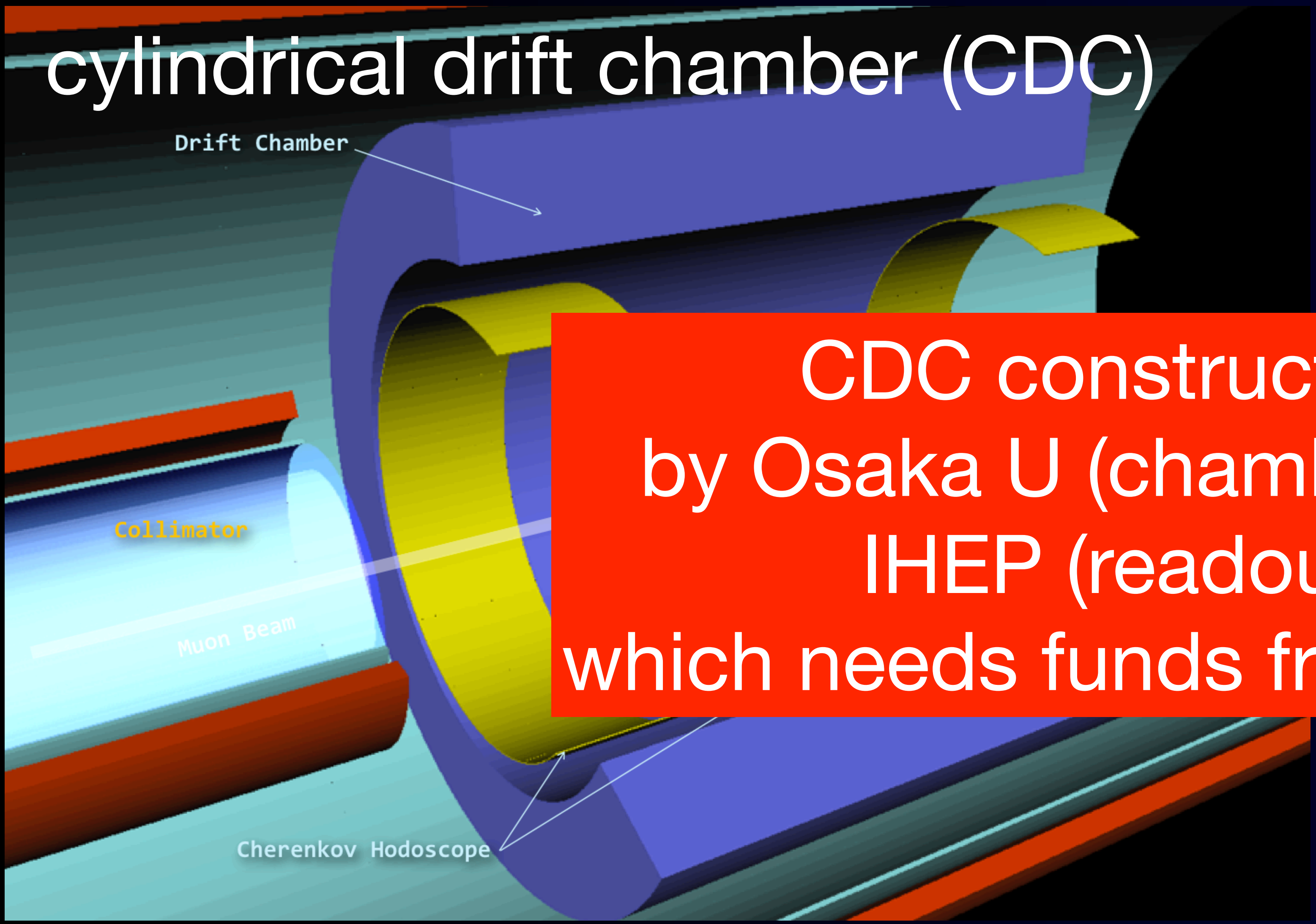
cylindrical drift chamber (CDC)



Design Philosophy
by keeping an open end in a solenoid geometry, beam particles continue downstream and escape the detector.

- CDC design is based on Belle II CDC (small cell part)
- Design difference (from LOI)
  - He:C_2H_6 (=50:50) gas
  - trigger counters at the both ends (smaller acceptance)
  - no proton absorber
- CDC hit rates
  - 40 kHz/wire at the innermost layer by proton emission from muon capture (0.15 per capture)
- CDC trigger rate
  - 270 Hz from DIO

Search for μ-e conversion at Intermediate Sensitivity (CDC)



CDC construction by Osaka U (chamber) and IHEP (readout) which needs funds from China!

- CDC design is based on Belle II CDC (small cell part)
- Design difference (from LOI)
  - ... (=50:50) gas
  - ...ounters at the ...ds (smaller ...nce)
  - ...n absorber
- CDC hit rates
  - 40 kHz/wire at the innermost layer by proton emission from muon capture (0.15 per capture)
- CDC trigger rate
  - 270 Hz from DIO

Design Philosophy

by keeping an open end in a solenoid geometry, beam particles continue downstream and escape the detector.

Signal Event Sensitivity (SES) for COMET Phase-I CDC

Event selection	Value	Comments
Geometrical acceptance	0.24	tracking efficiency included
Momentum selection	0.74	104.1 MeV/c < P_e <106 MeV/c
Timing selection	0.39	same as COMET
Trigger and DAQ	0.9	same as COMET
Total	0.06	

- Single event sensitivity

$$B(\mu^- + Al \to e^- + Al) \sim \frac{1}{N_\mu \cdot f_{cap} \cdot A_e},$$

  - N_μ is a number of stopping muons in the muon stopping target. It is 8.7×10^{15} muons.
  - 5.8×10^9 stopped μ/s with 3 kW proton beam power, with 1.5×10^6 sec running.
  - f_{cap} is a fraction of muon capture, which is 0.6 for aluminum.
  - A_e is the detector acceptance, which is 0.06.

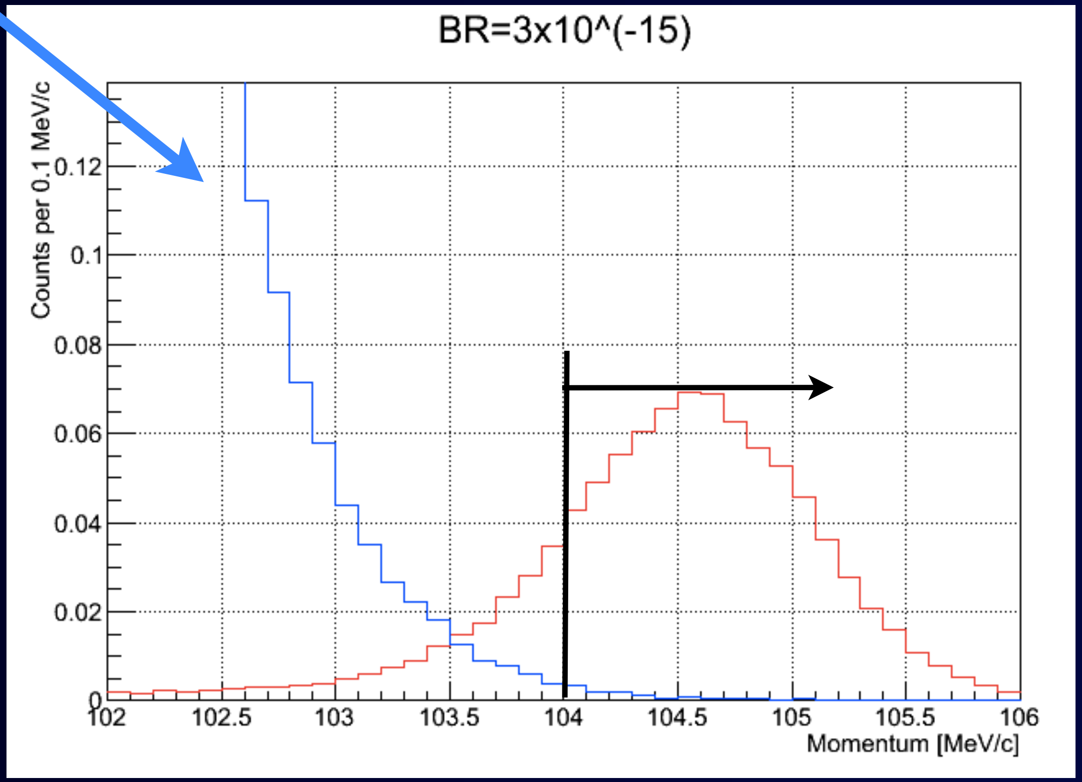
$$B(\mu^- + Al \to e^- + Al) = 3.1 \times 10^{-15}$$

$$B(\mu^- + Al \to e^- + Al) < 7 \times 10^{-15} \quad (90\% C.L.)$$

Background Estimation for COMET Phase-I CDC

Background	estimated events
Muon decay in orbit	0.01
Radiative muon capture	< 0.001
Neutron emission after muon capture	< 0.001
Charged particle emission after muon capture	< 0.001
Radiative pion capture	0.0096*
Beam electrons Muon decay in flight Pion decay in flight	< 0.00048*
Neutron induced background	~ 0*
Delayed radiative pion capture	0.002
Anti-proton induced backgrounds	0.007
Electrons from cosmic ray muons	< 0.0002
Total	0.03

DIO



with proton extinction factor of 3×10^{-11}

Expected BG events are about 0.03 at S.E.S. of 3×10^{-15}.

Background Estimation for COMET Phase-I CDC

studied by a IHEP student

Background	estimated events
Muon decay in orbit	0.01
Radiative muon capture	< 0.001
Neutron emission after muon capture	< 0.001
Charged particle emission after muon capture	< 0.001
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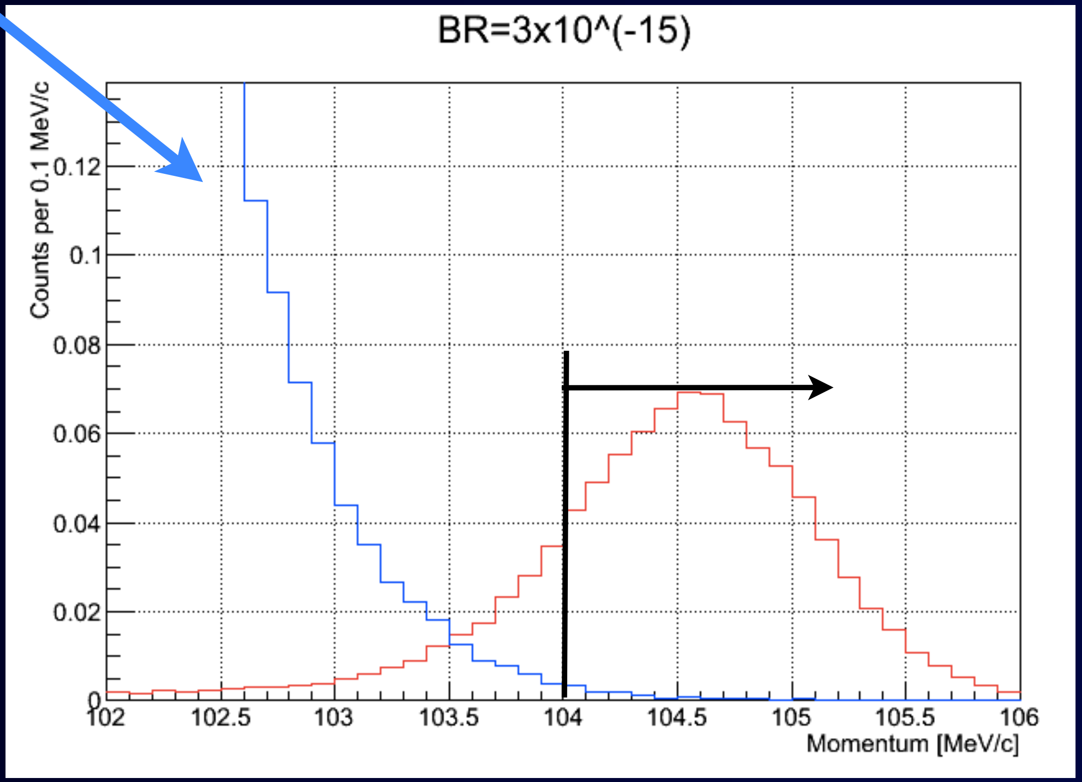
DIO

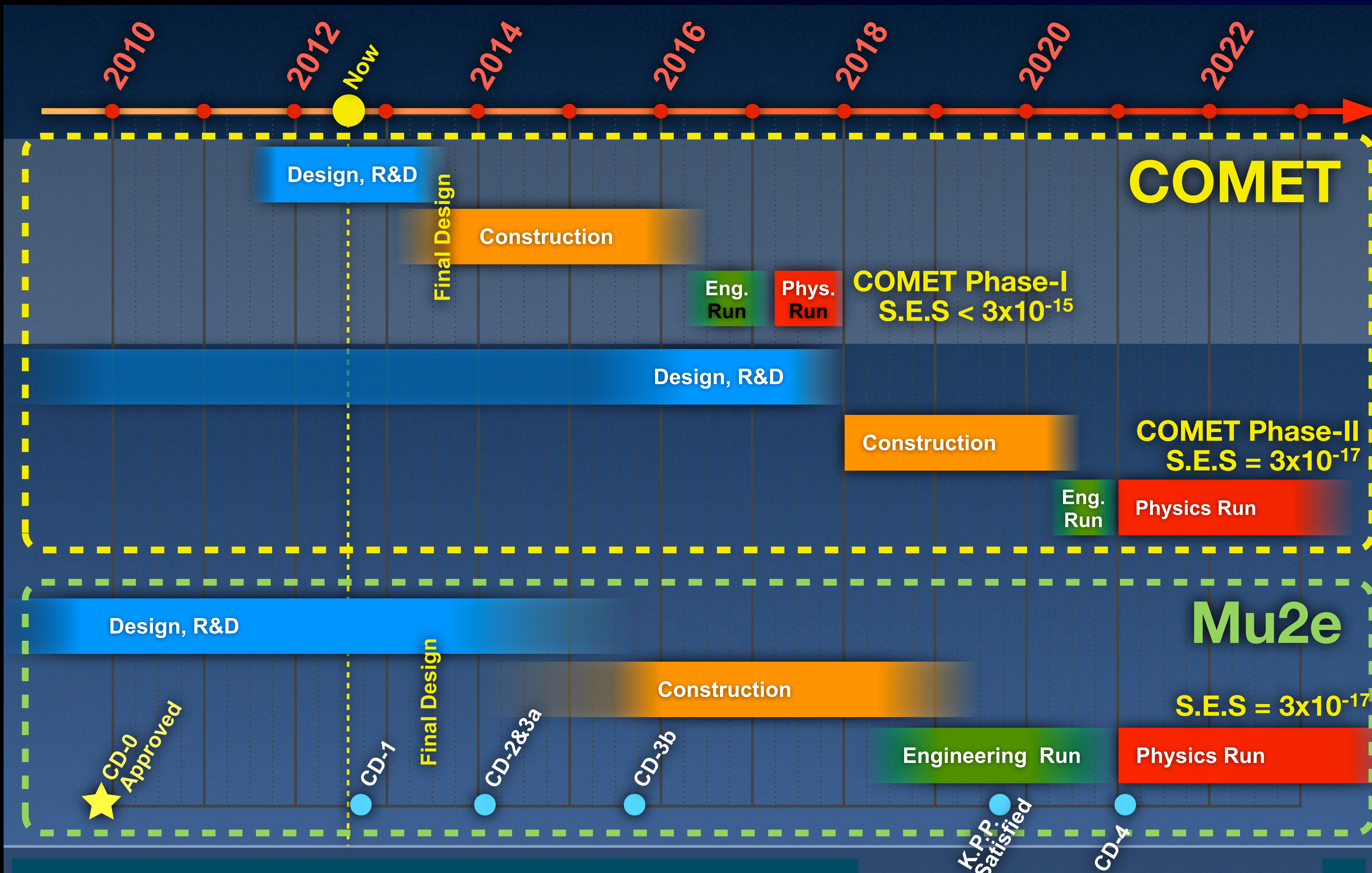


with proton extinction factor of $3\text{x}10^{-11}$

Expected BG events are about 0.03 at S.E.S. of $3\text{x}10^{-15}$.

Schedule of COMET and Mu2e

Schedule of COMET and Mu2e



Comparison of COMET Phase-I / Phase-II and Mu2e

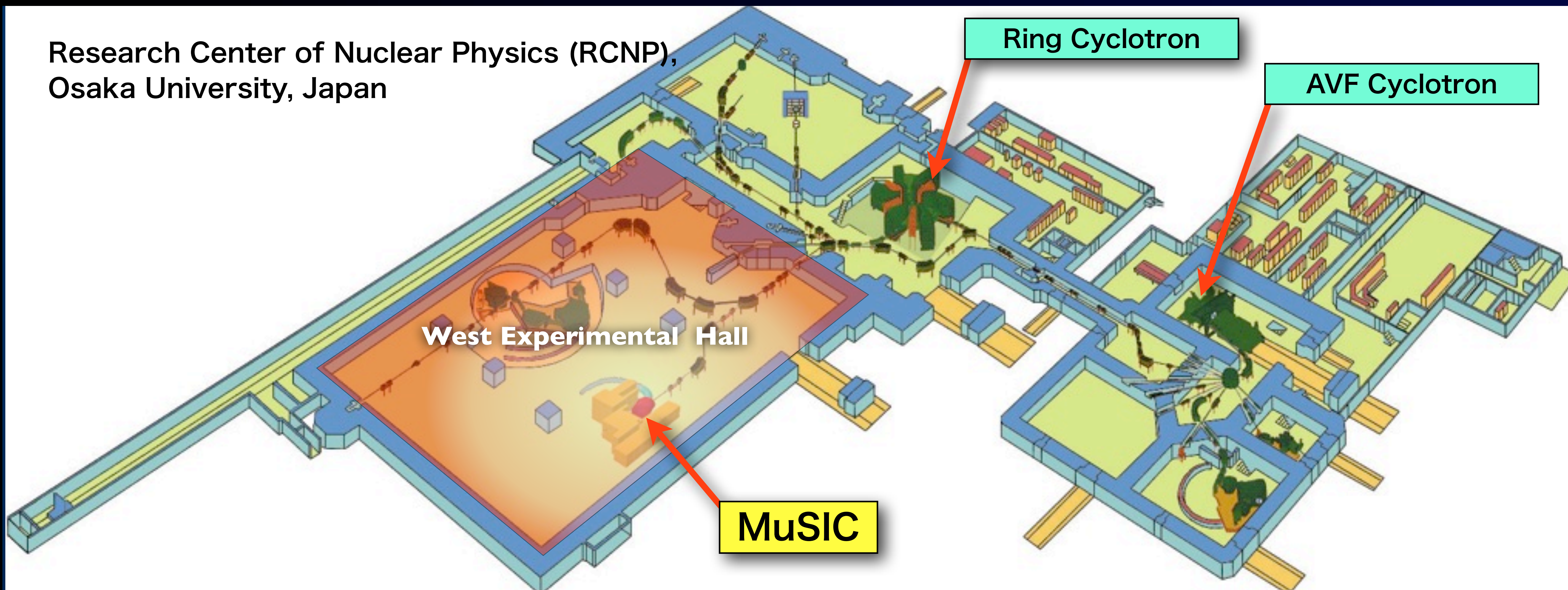
Comparison of COMET Phase-I / Phase-II and Mu2e

90% C.L. upper limit is 7×10^{-13} (SINDRUM)

	S.E. sensitivity	BG events at aimed sensitivity	running time (sec)	Year	Comments
COMET Phase-I	3×10^{-15}	0.03	1.5×10^{6}	~2016	from Proposal (2012)
COMET Phase-II	3×10^{-17}	0.34	2×10^{7}	~2020	from CDR (2009)
Mu2e	3×10^{-17}	0.4	3x (2×10^{7})	~2020	J. Miller's talk at SSP2012

MuSIC
- Highly Intense Muon Source

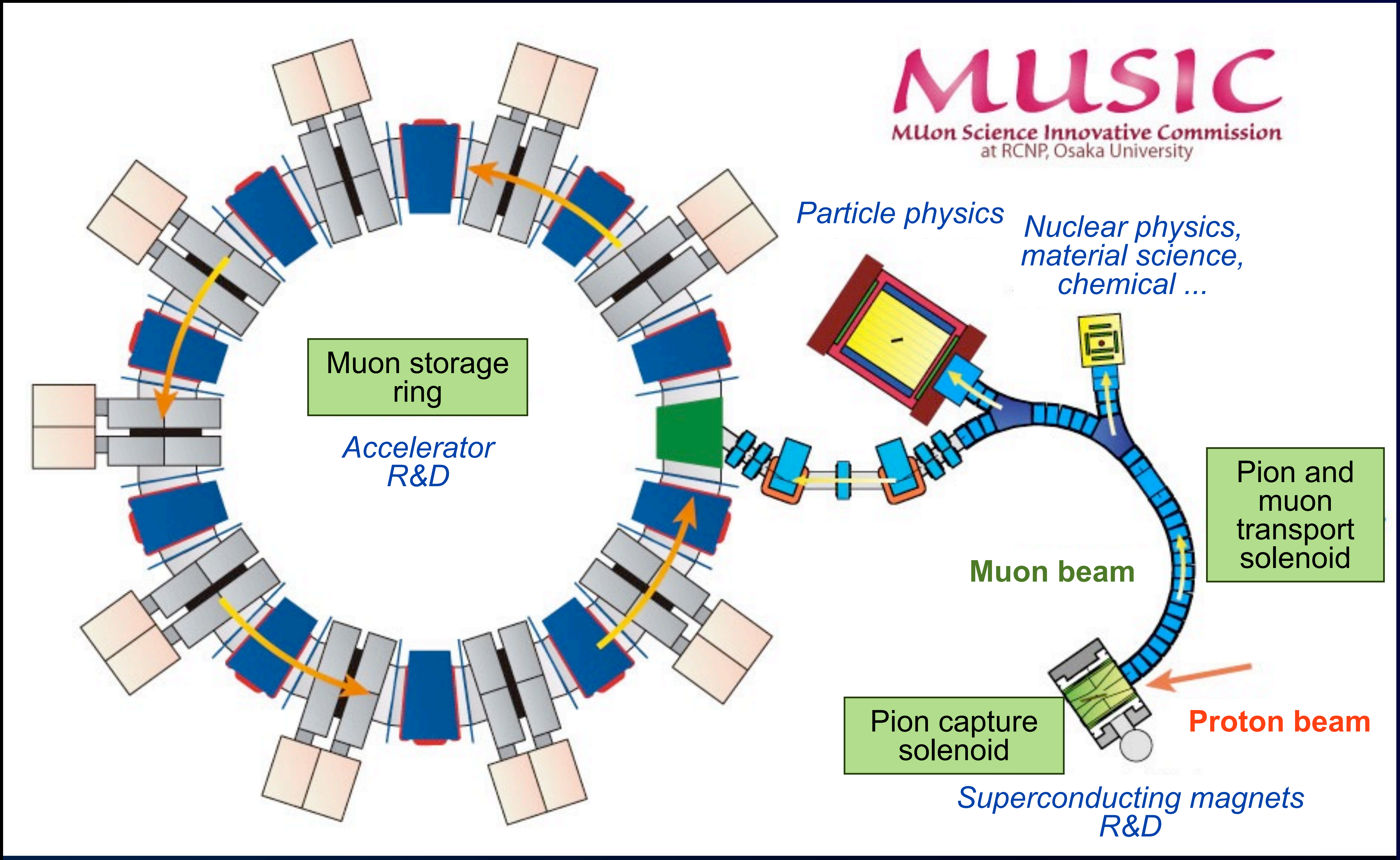
MuSIC@RCNP, Osaka University



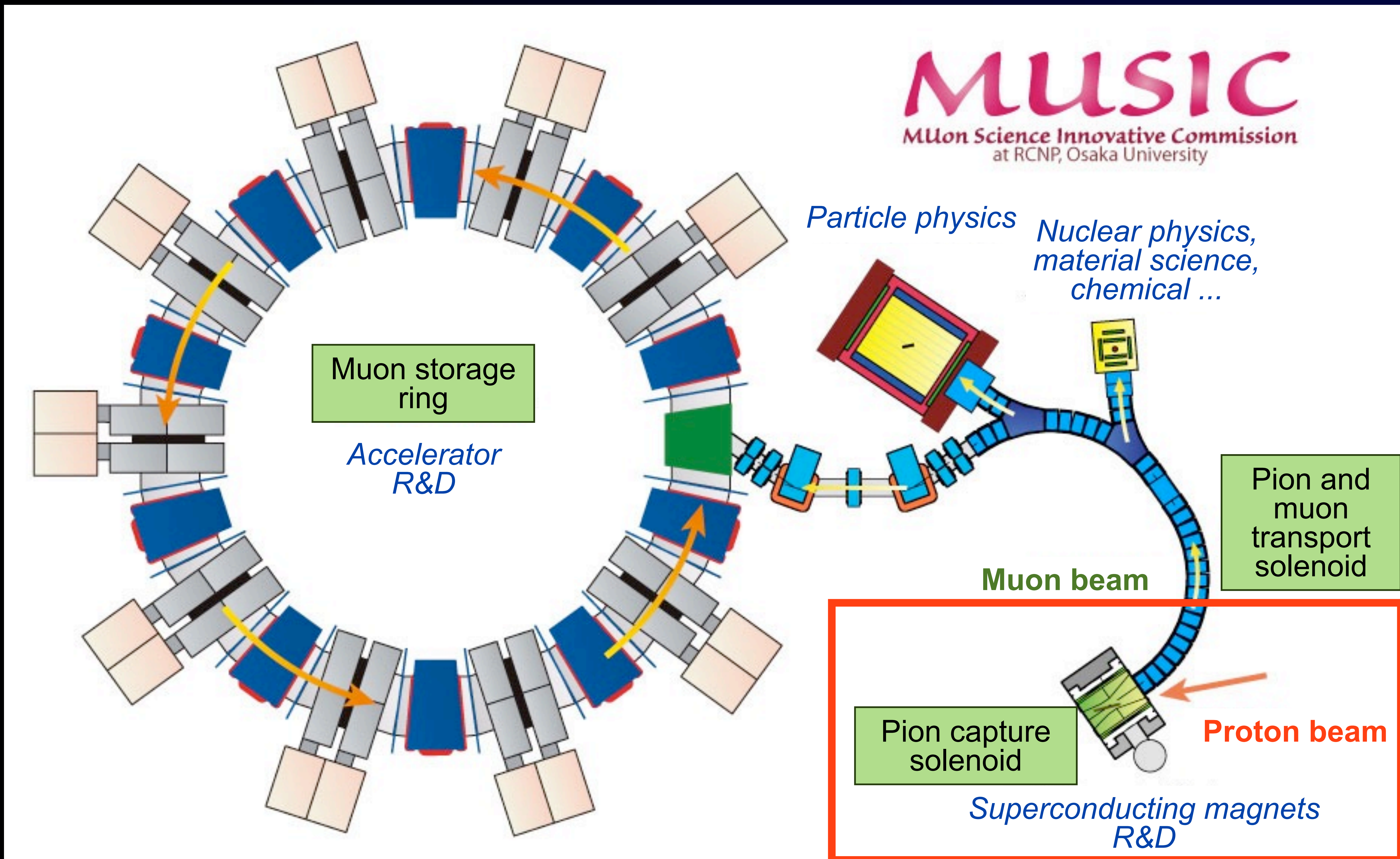
RCNP has two cyclotrons. A proton beam with 392MeV, 1μA is provided from the Ring Cyclotron (up to 5μA in near future).

The MuSIC is in the largest experimental hall, the west experimental hall.

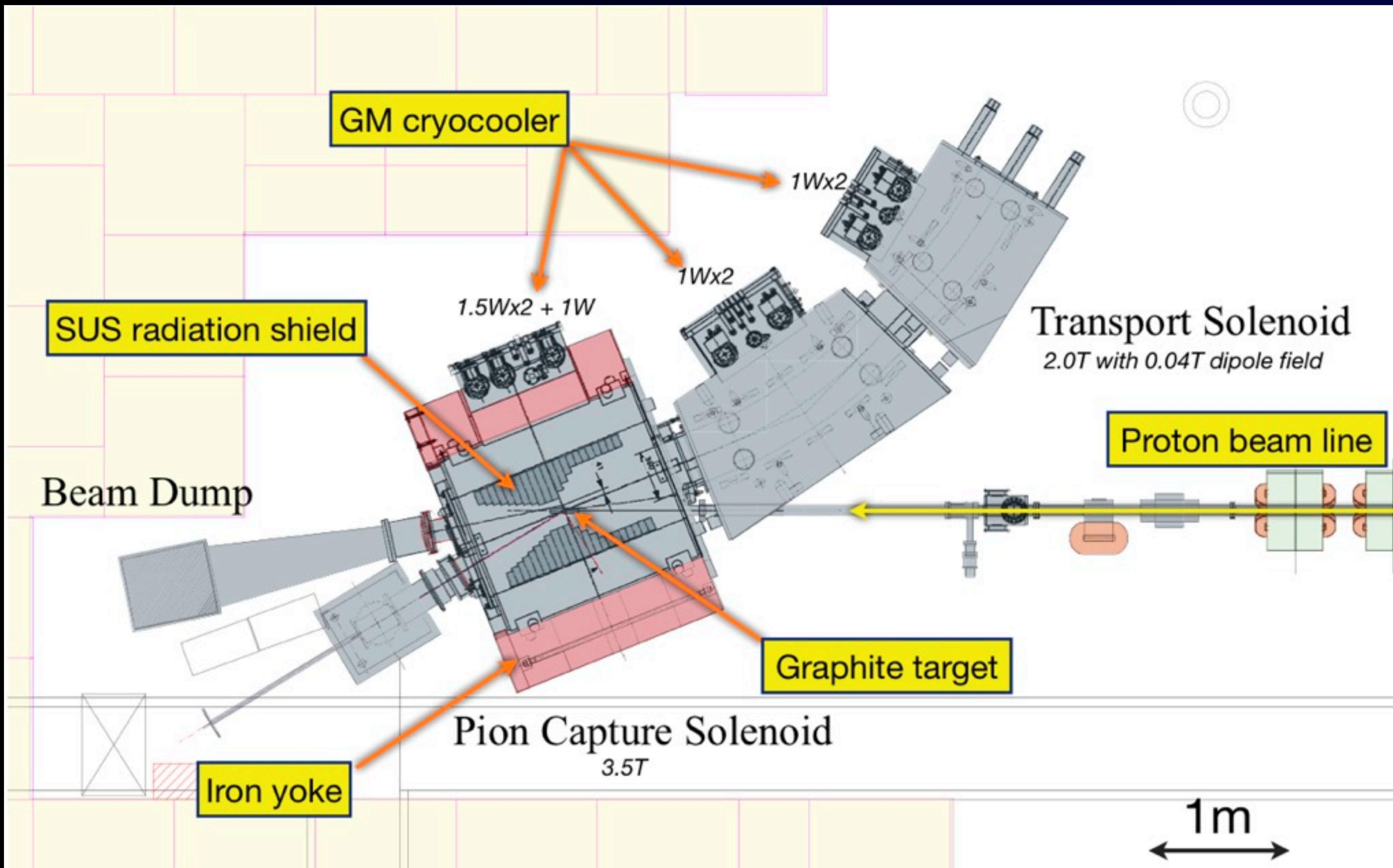
MuSIC Layout



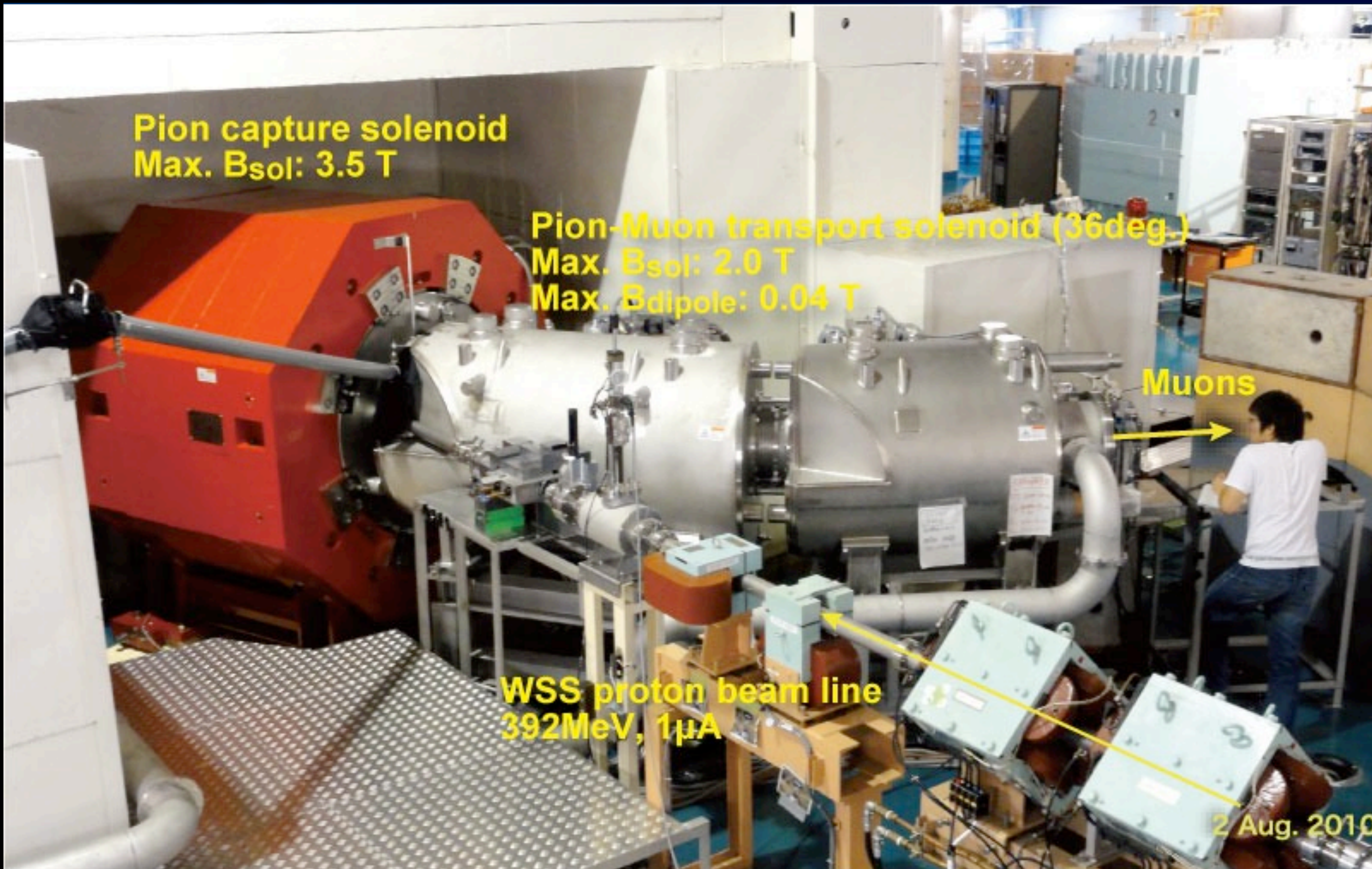
MuSIC Layout



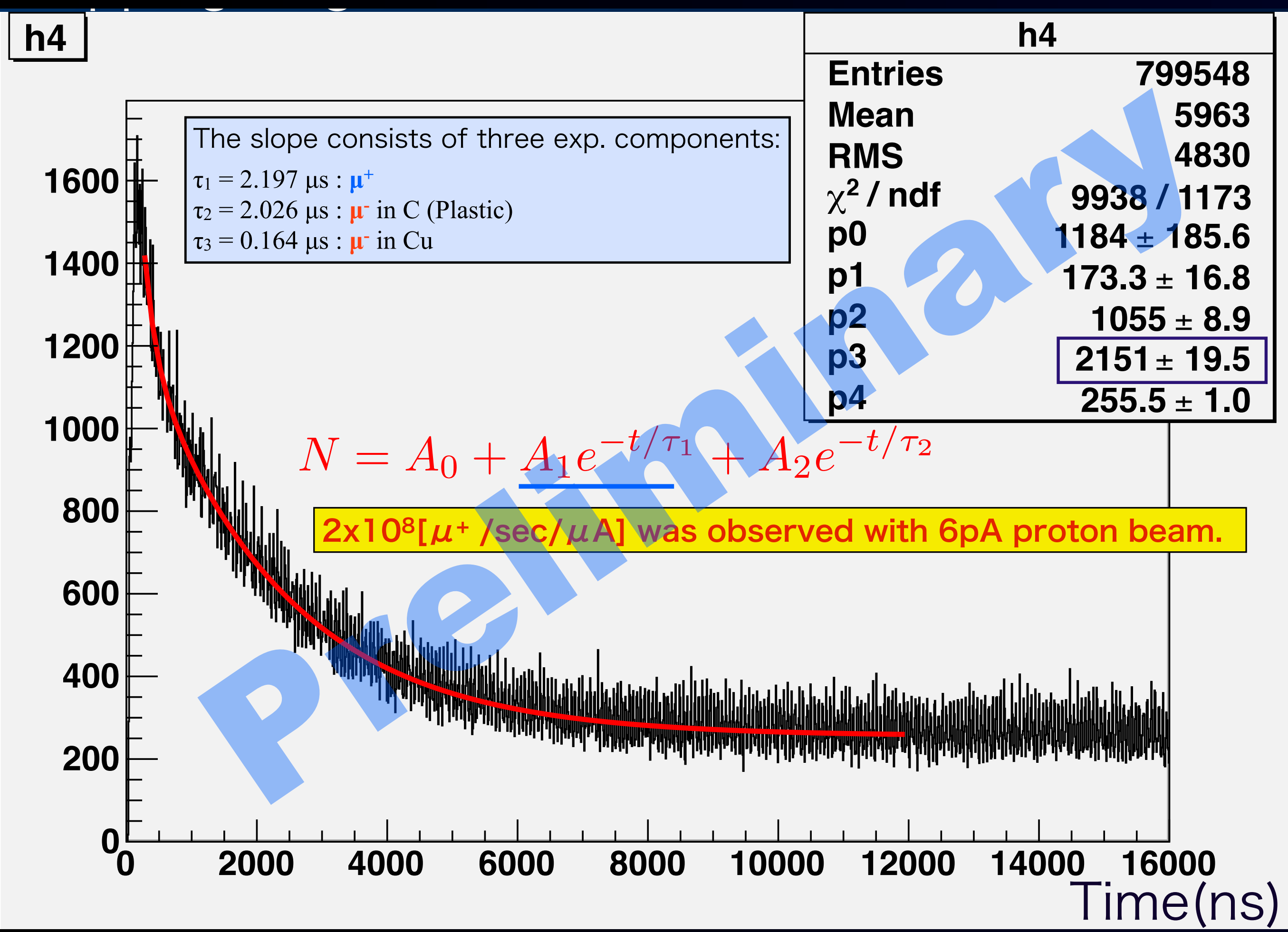
MuSIC Present Layout



MuSIC at RCNP, Osaka University

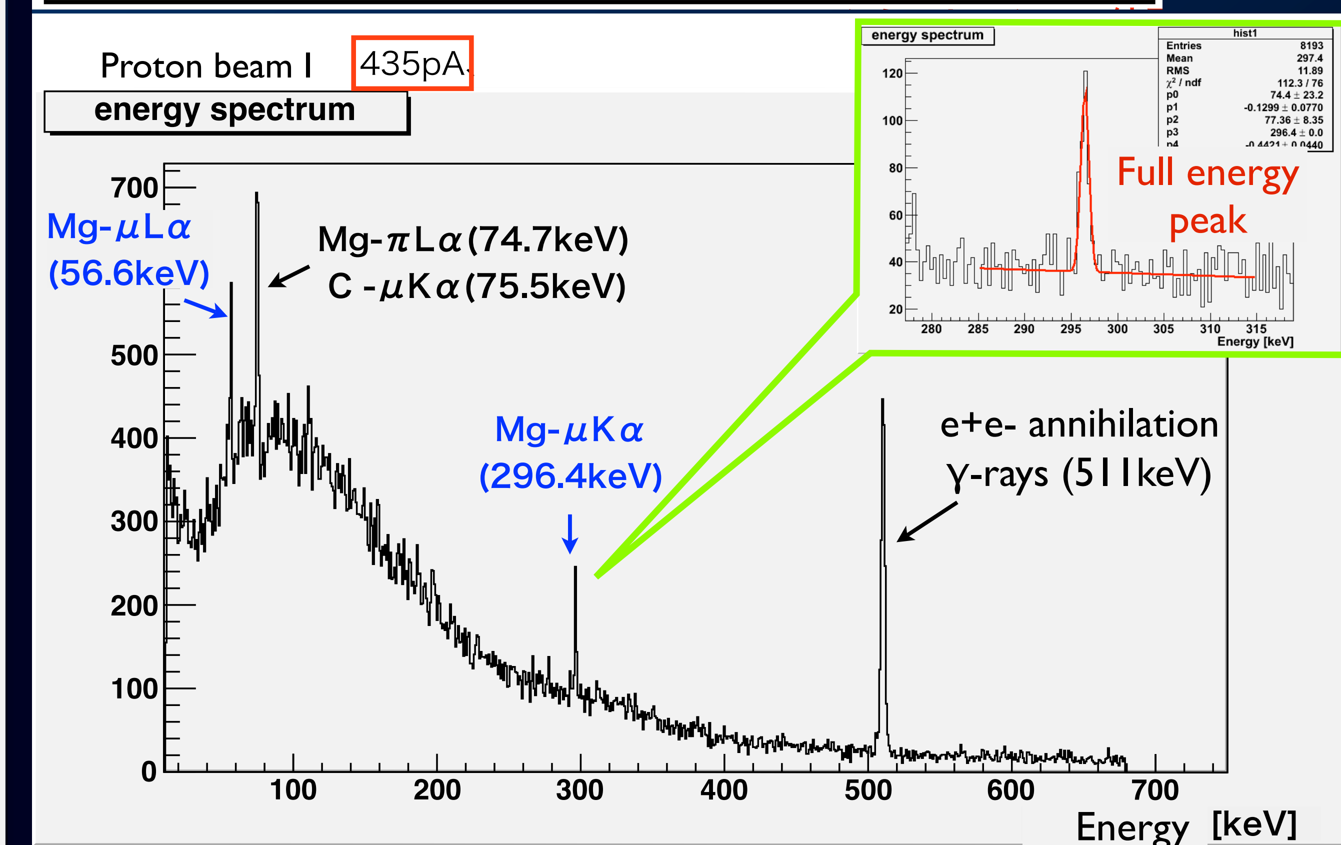


MuSIC Muon Yields (Measured)

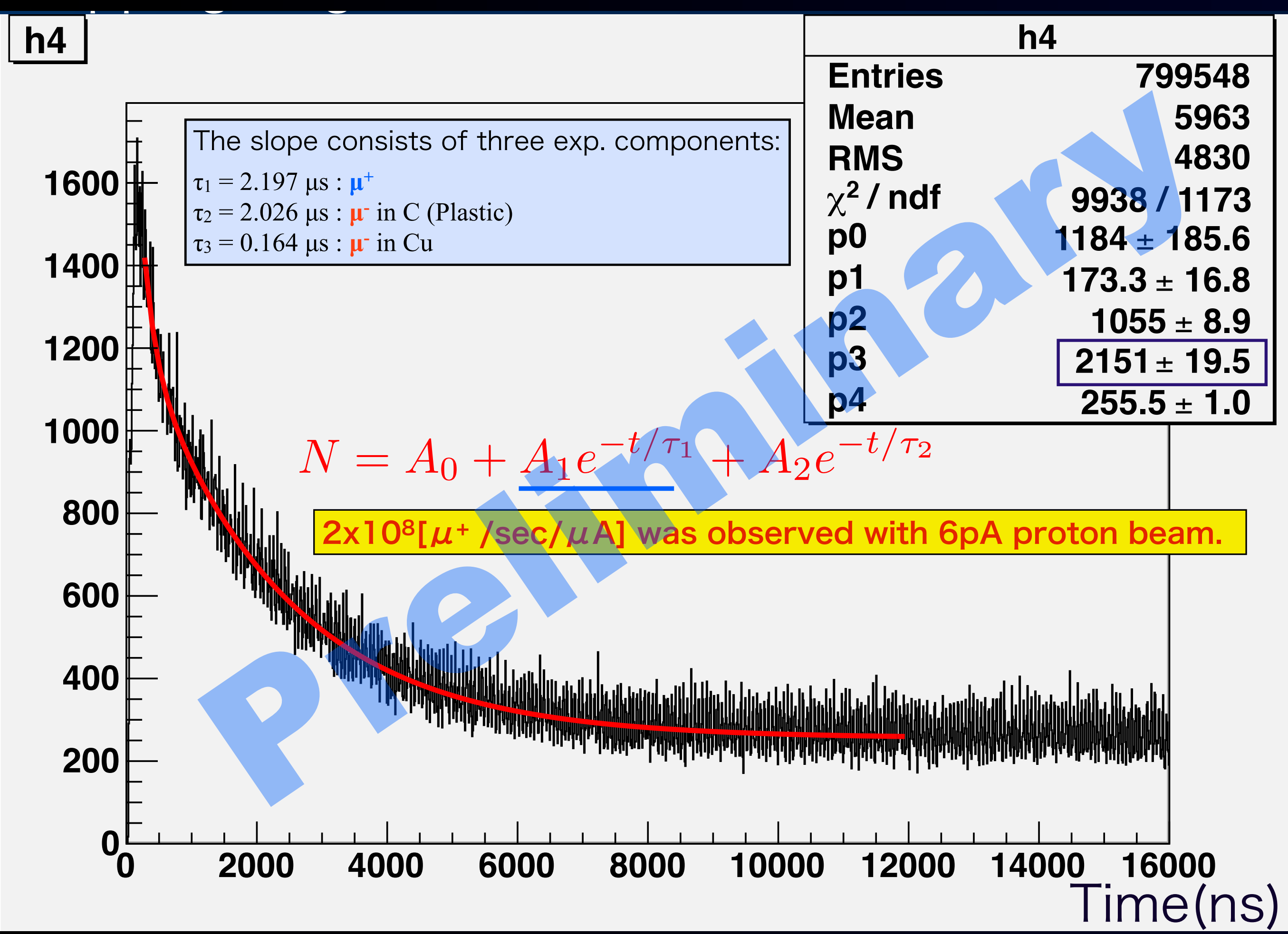


Number of negative muons at the 36 deg exit for 1μA proton beam

	beam test	simulation
Num. of muons [1/sec]	$(1.7\pm0.3)\times10^8$	1.4×10^8

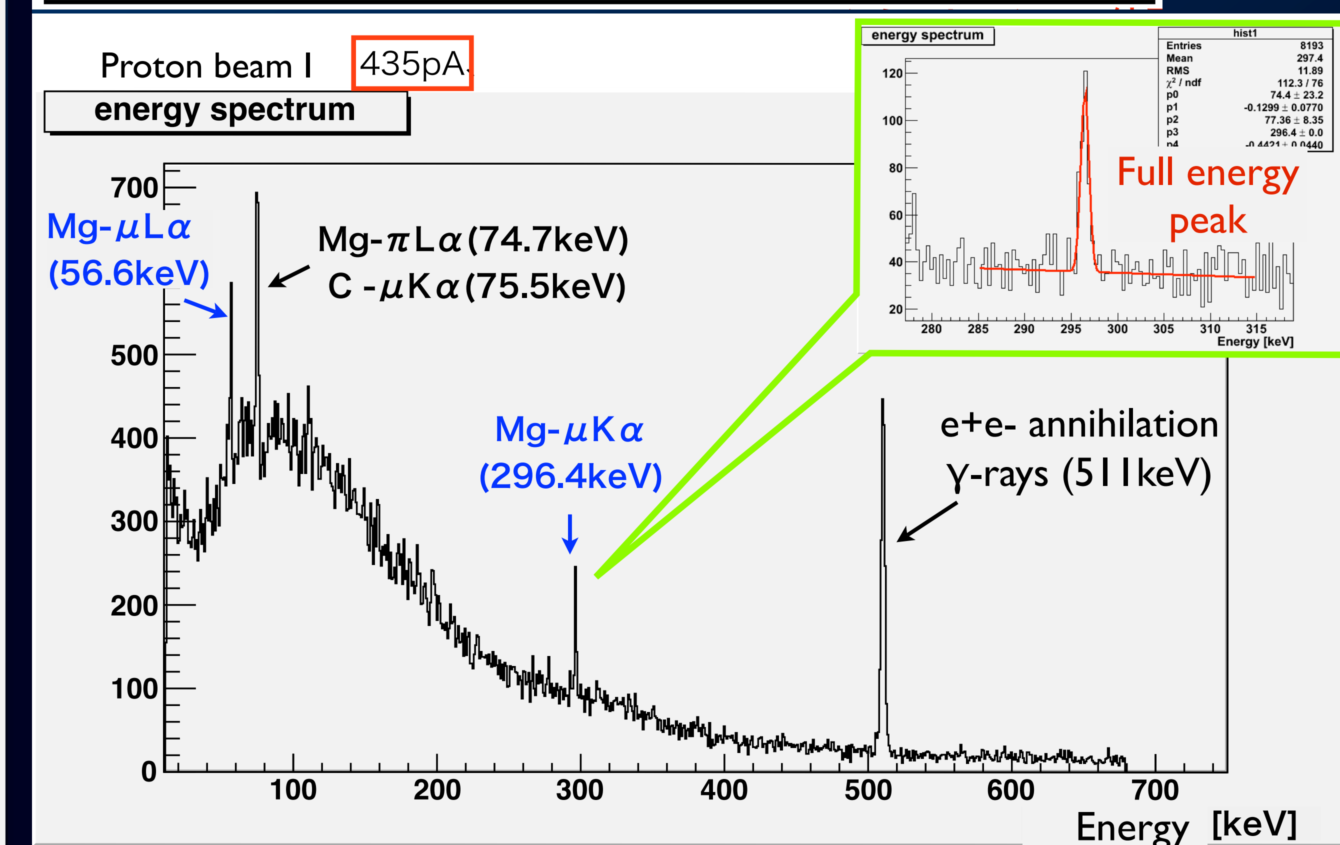


MuSIC Muon Yields (Measured)



Number of negative muons at the 36 deg exit for 1μA proton beam

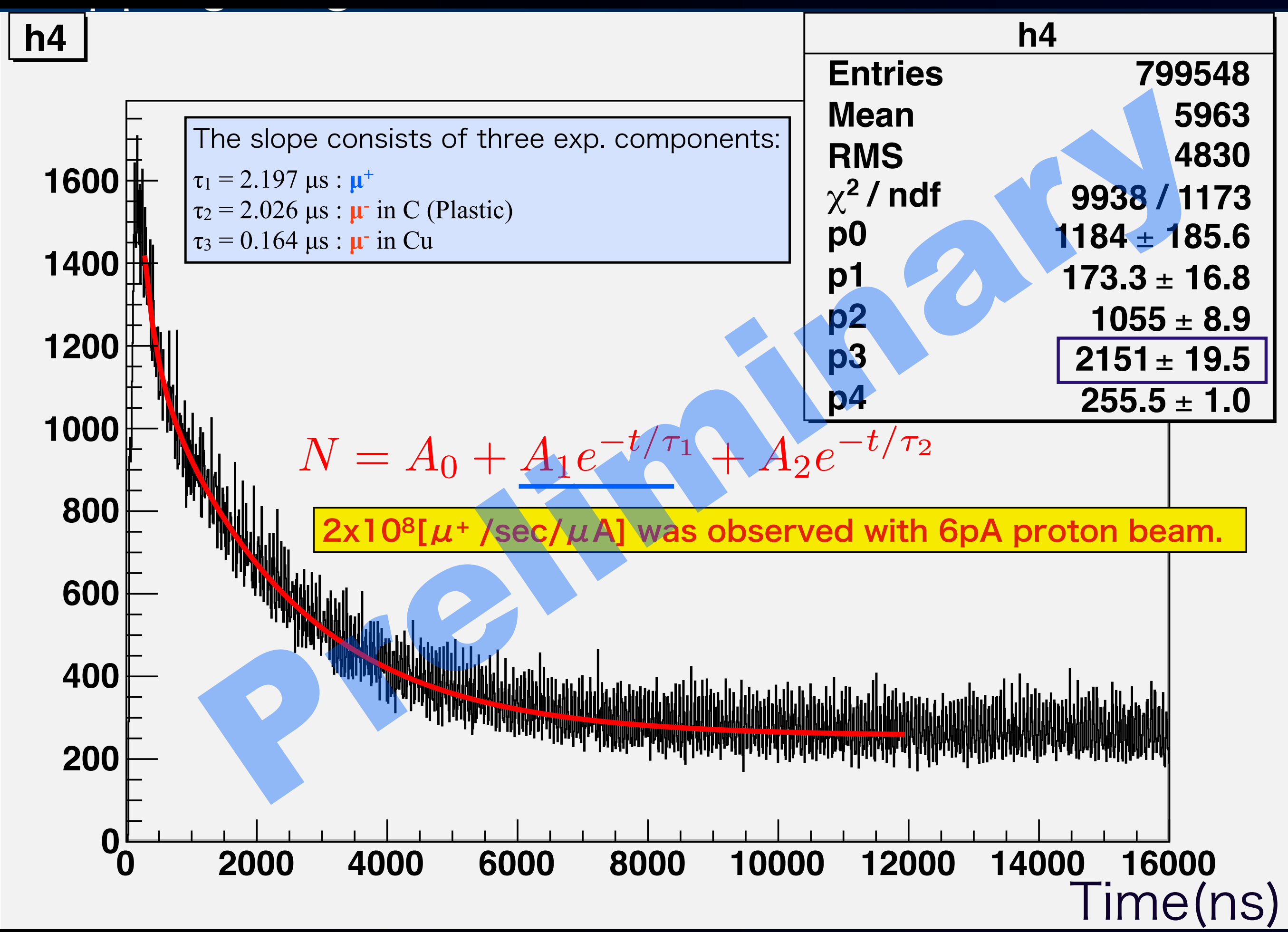
	beam test	simulation
Num. of muons [1/sec]	$(1.7\pm0.3)\times10^8$	1.4×10^8



10^8 muons/sec with 400 W at MuSIC

eg. 10^8 muons/s with 1.2 MW at PSI

MuSIC Muon Yields (Measured)



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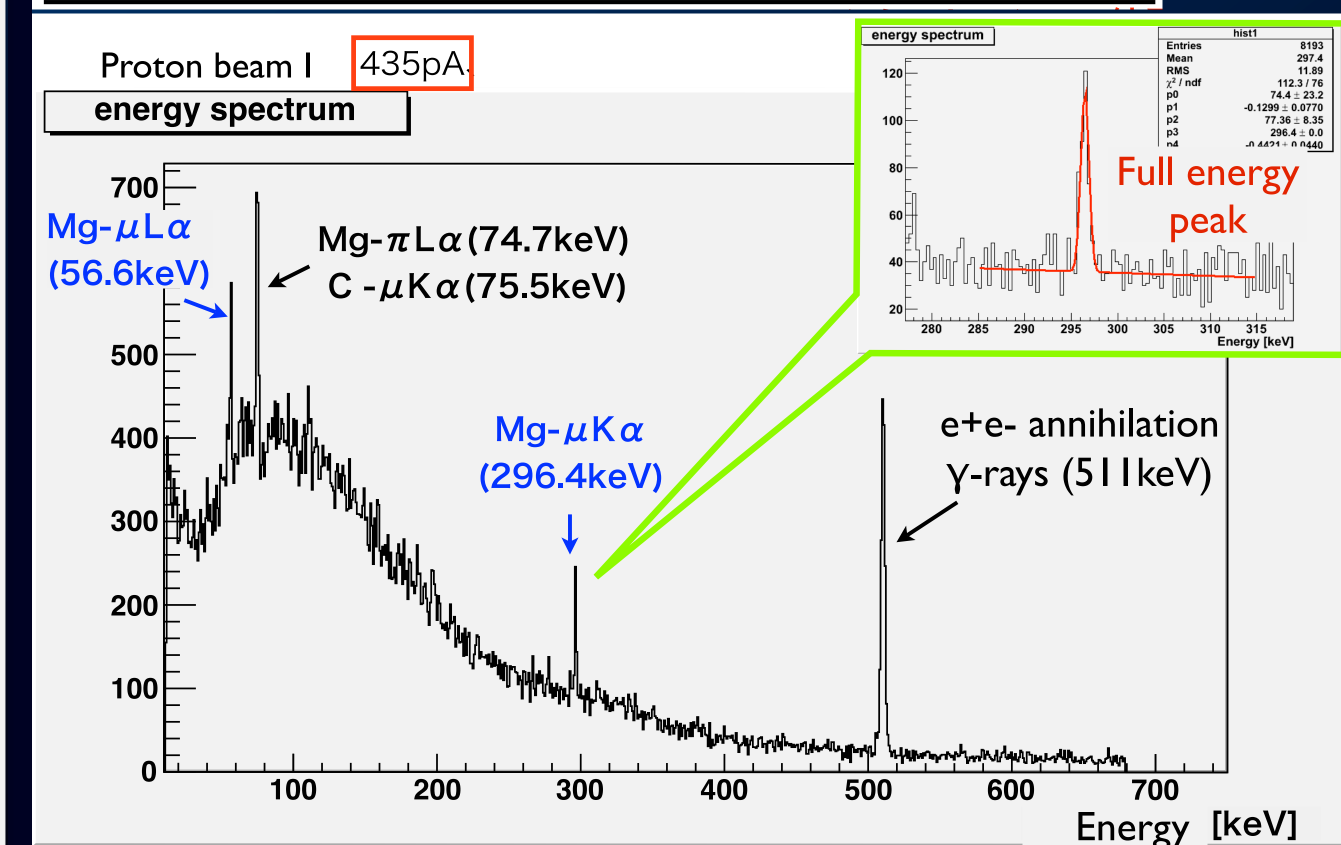

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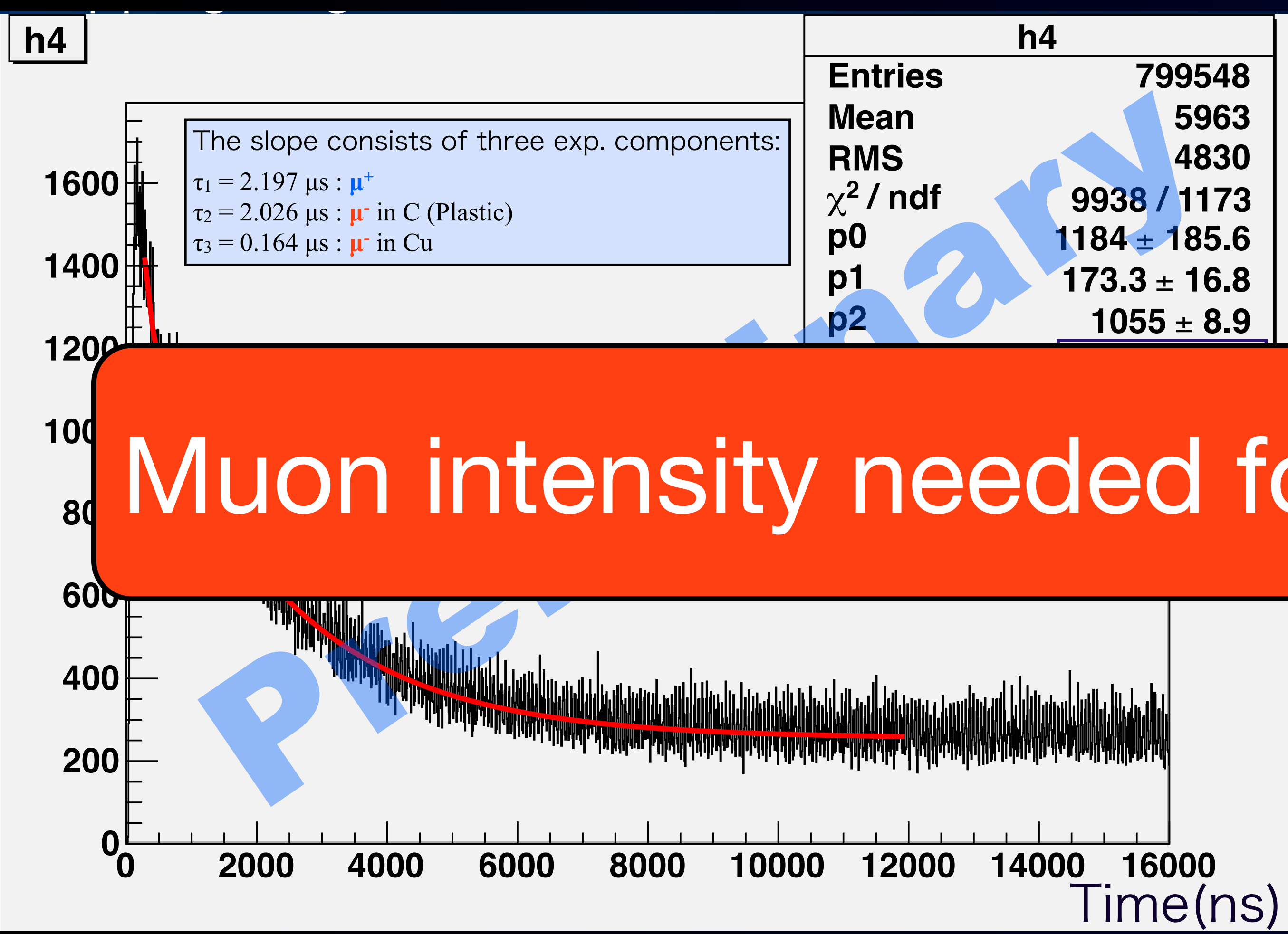

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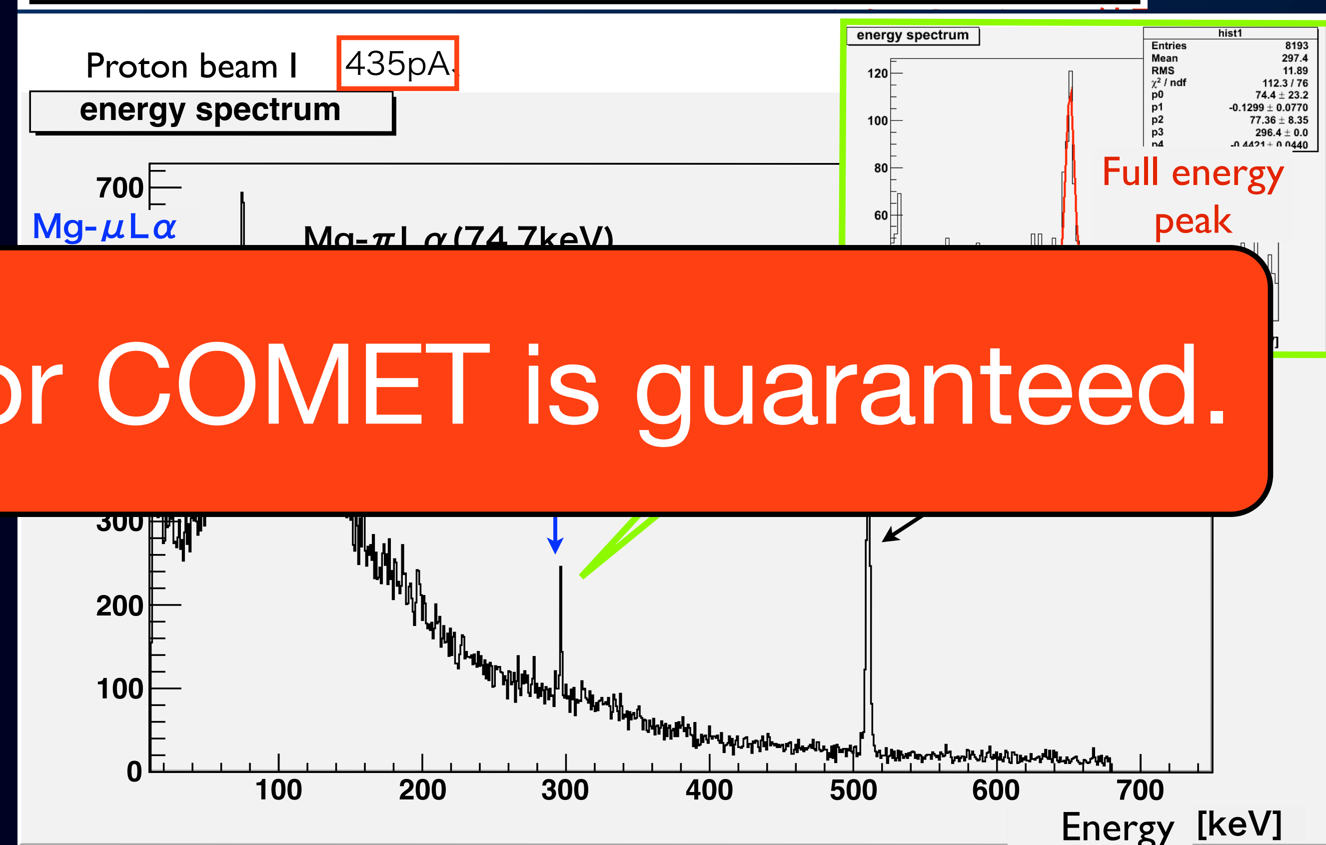


Muon intensity needed for COMET is guaranteed.

10^8 muons/sec with 400 W at MuSIC
eg. 10^8 muons/s with 1.2 MW at PSI

1000 times improvement

μ-e conversion with $B<10^{-19}$

μ-e conversion at S.E. sensitivity of 3×10^{-19} PRISM/PRIME (with muon storage ring)

PRIME detector

momentum slit

extract kickers

PRISM beamline

injection kickers

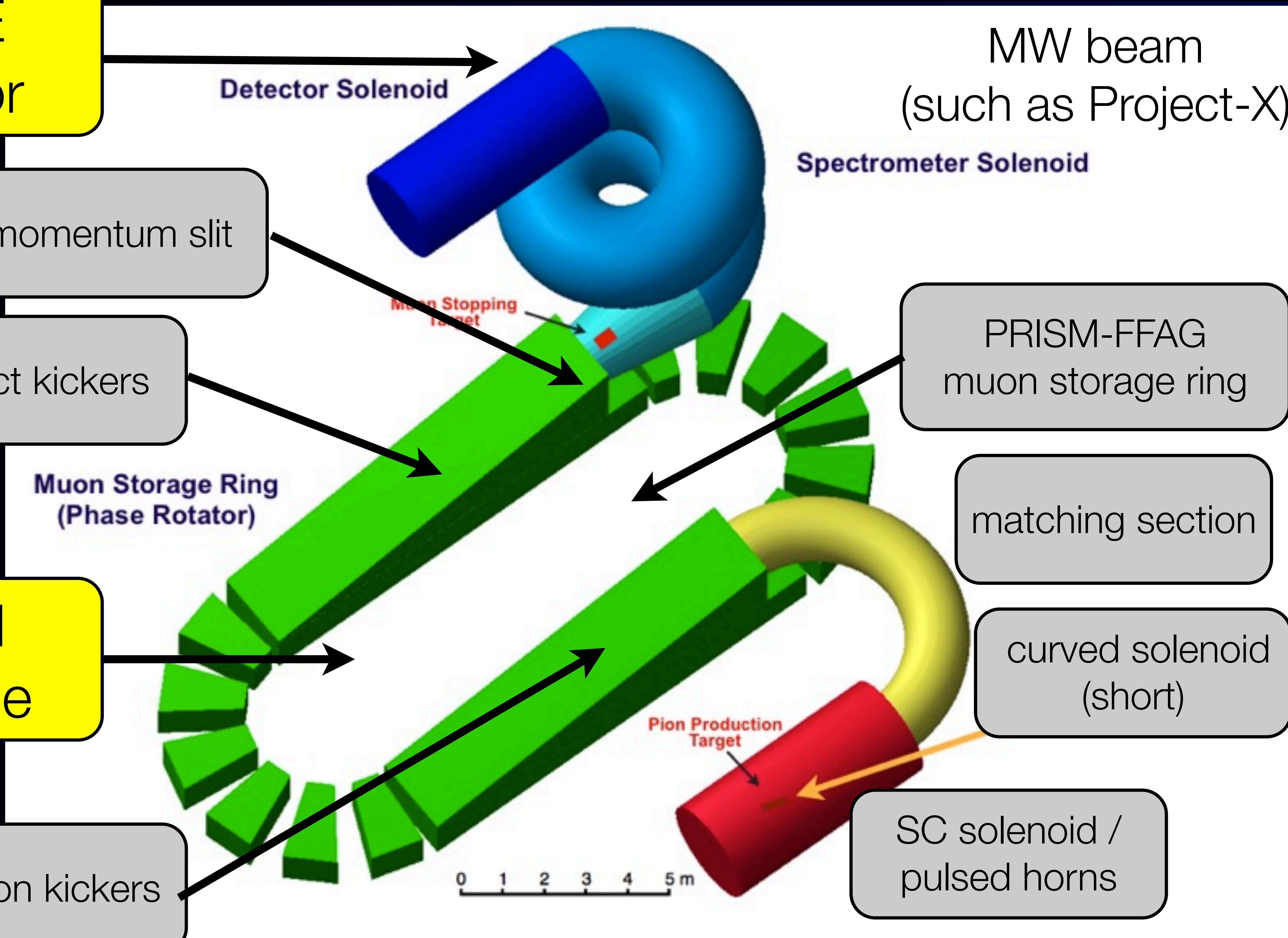
MW beam (such as Project-X)

PRISM-FFAG muon storage ring

matching section

curved solenoid (short)

SC solenoid / pulsed horns



R&D on the PRISM-FFAG Muon Storage Ring at Osaka University

Phase rotation has been demonstrated.
PRISM Task Force (UK&Japan) is active for desgn.

Neutrino Source based on Muon Storage Ring

EUROnu: Conclusion

Input for CERN Strategy Review:

EUROnu has made a physics performance and cost comparison between
a 4 MW CERN to Frejus Super Beam,
a 10 GeV Neutrino Factory
and a γ=100 Beta Beam, all based at CERN.

The physics comparison has demonstrated that the Neutrino Factory has the best physics reach for CP-violation and the mass hierarchy,
while a combination of the Super Beam and Beta Beam is required to be competitive.

Although far advanced, the cost comparison is not yet at the stage where it can be made public. Nevertheless, it has been demonstrated that there is not a significant cost advantage in building the Super Beam and Beta Beam combination, rather than the Neutrino Factory.

As a result, the recommendation of EUROnu is the construction and operation of a 10 GeV Neutrino Factory as soon as possible, implemented using a staged approach.

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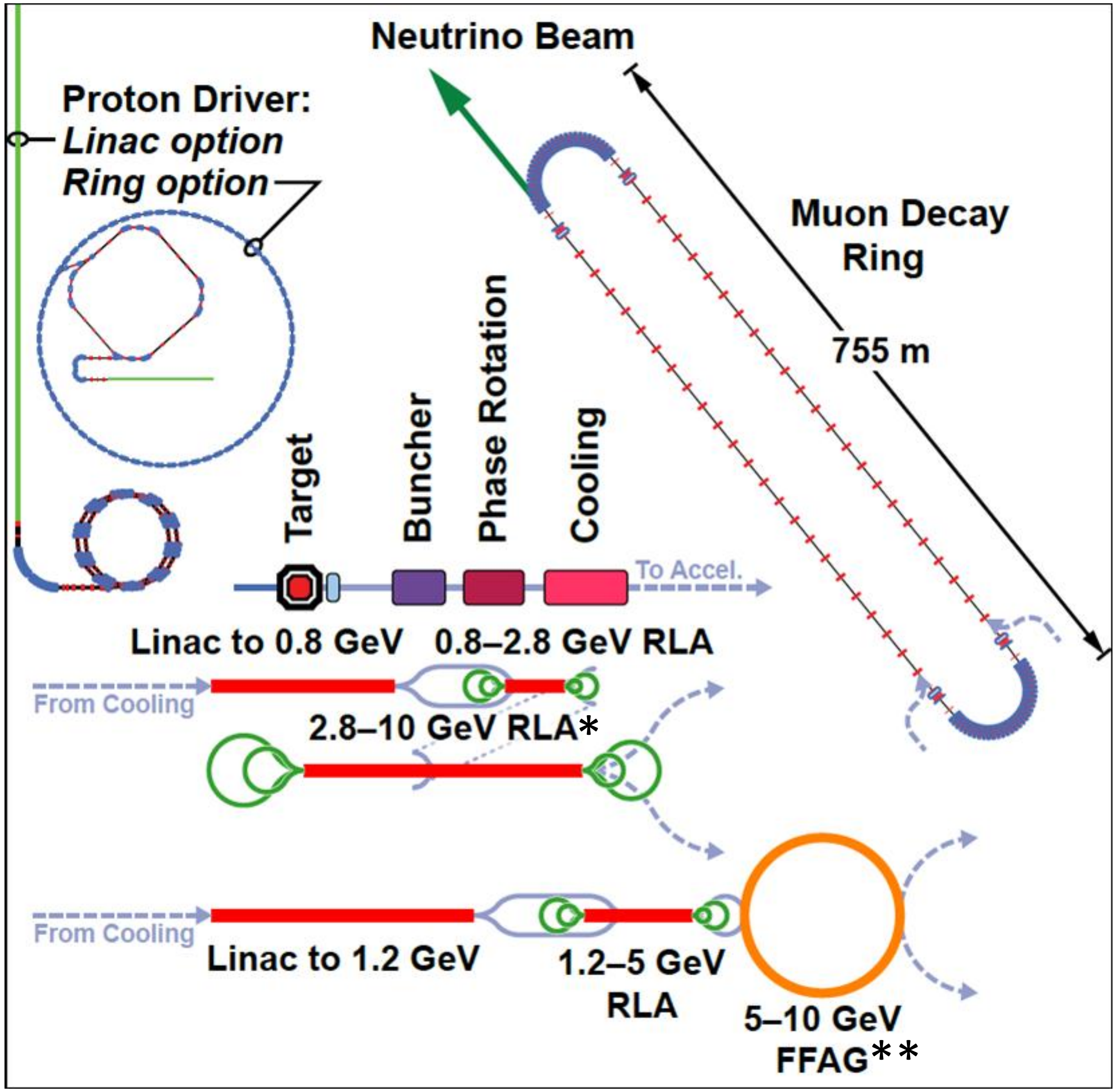
International Design Study for a Neutrino Factory (IDS-NF)

- Targeting a Reference Design Report on 2013 timescale

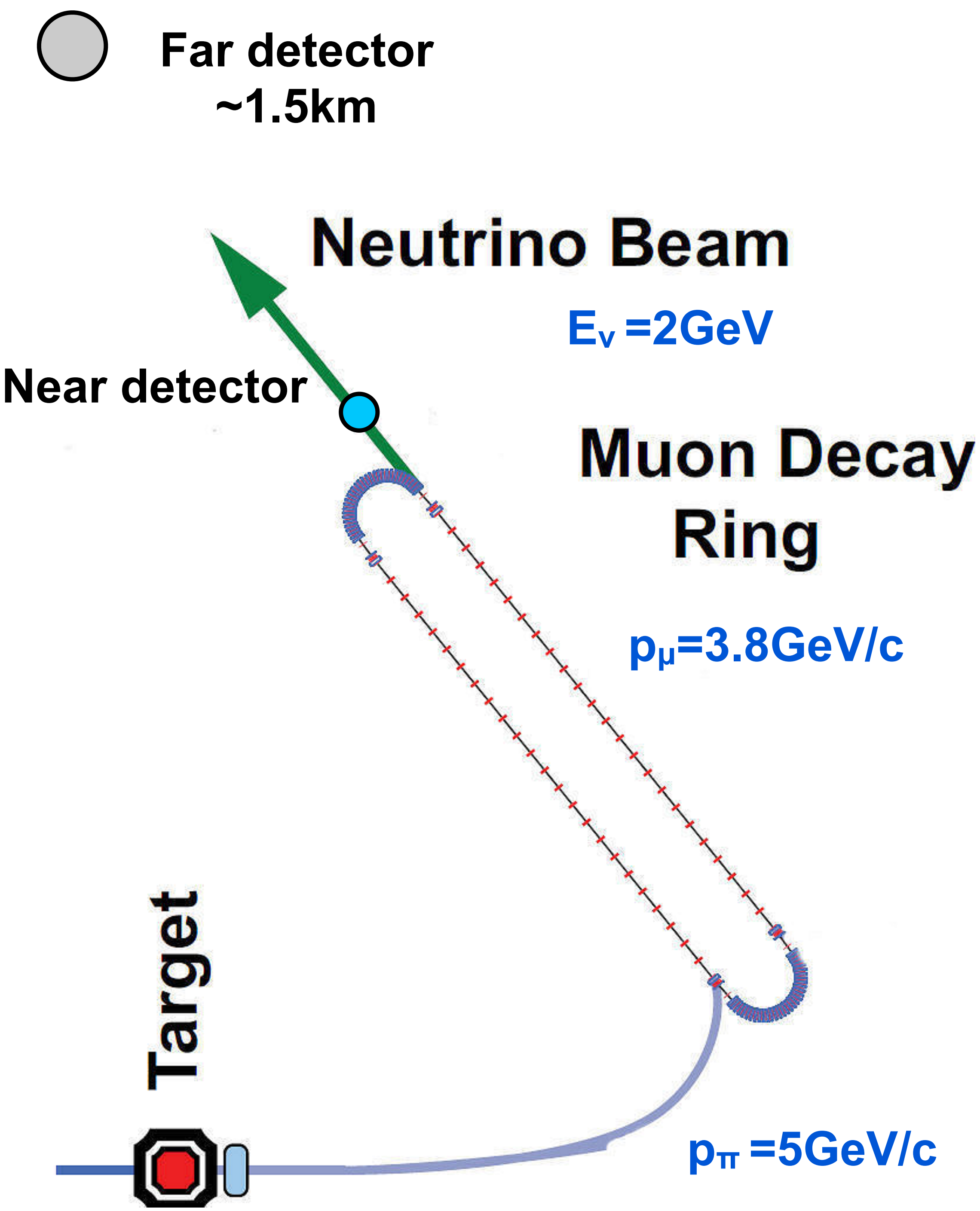
Updated baseline design:
10GeV muons,
100kt MIND @ 2000km,
10^{21} useful decays/y



*) RLA: recirculating linear accelerator
**) FFAG: fixed-field alternating gradient accelerator

νSTORM

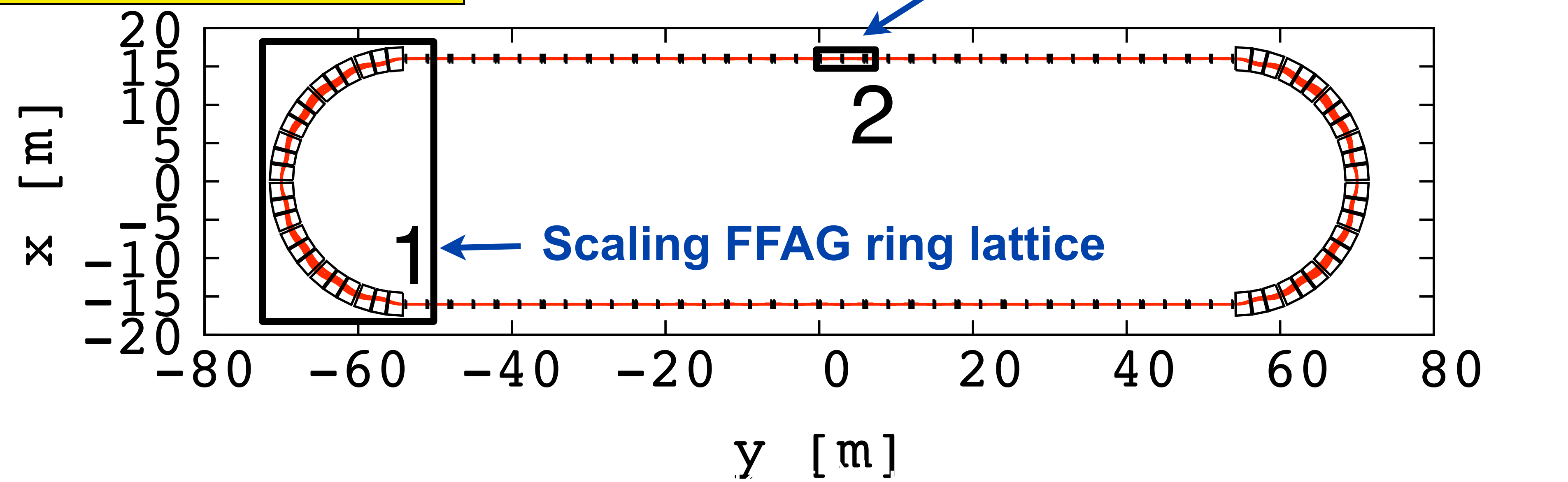
- A new LoI of a short-baseline neutrino experiment has been submitted to FNAL-PAC.
  - Physics:
    - study of sterile neutrinos
    - precise measurement of neutrino-nucleon scattering cross sections.
- A production of neutrino beams from a muon storage ring without any cooling section.
- For the decay ring,
    - large transverse acceptance
    - large momentum acceptance
  - are required to increase the intensity of the ν beam.
- Two candidates
  - FODO racetrack
  - **FFAG racetrack**



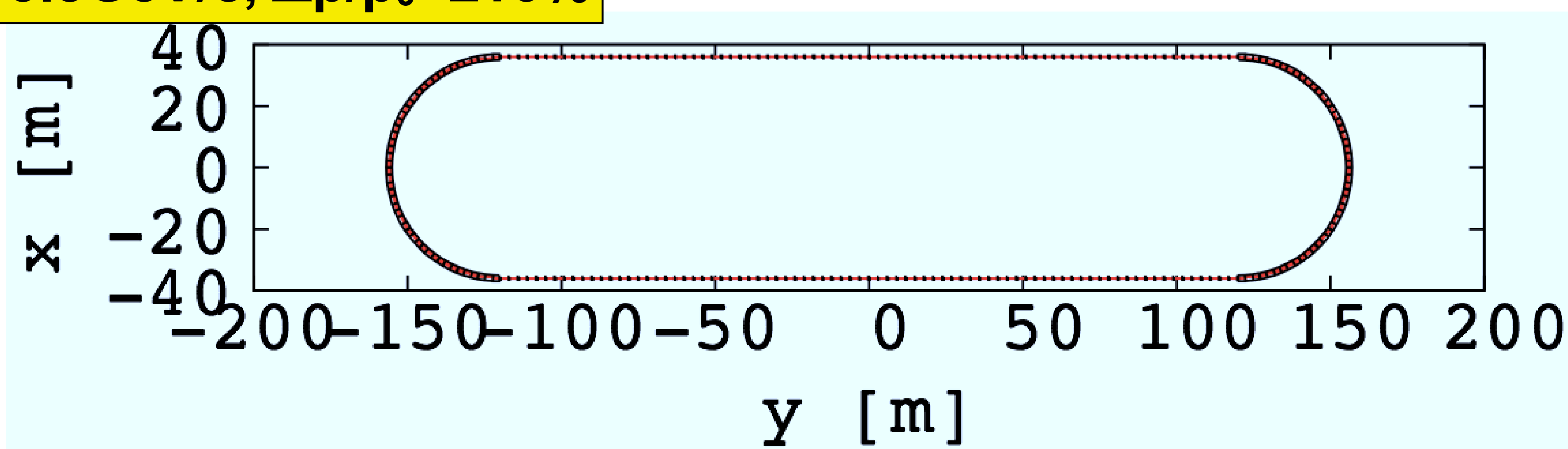
Study of Racetrack FFAGs for νSTORM

- J.B.Lagrange and Y.Mori proposed two racetrack FFAG for the decay ring.

E_μ=2GeV, $\Delta p/p_0$=±16%



p_μ=3.8GeV/c, $\Delta p/p_0$=±16% in the νSTORM LoI



- They studied performance of these FFAGs by their original tracking code, which cannot study decay of muon.

from A. Sato talk at NuFACT2012

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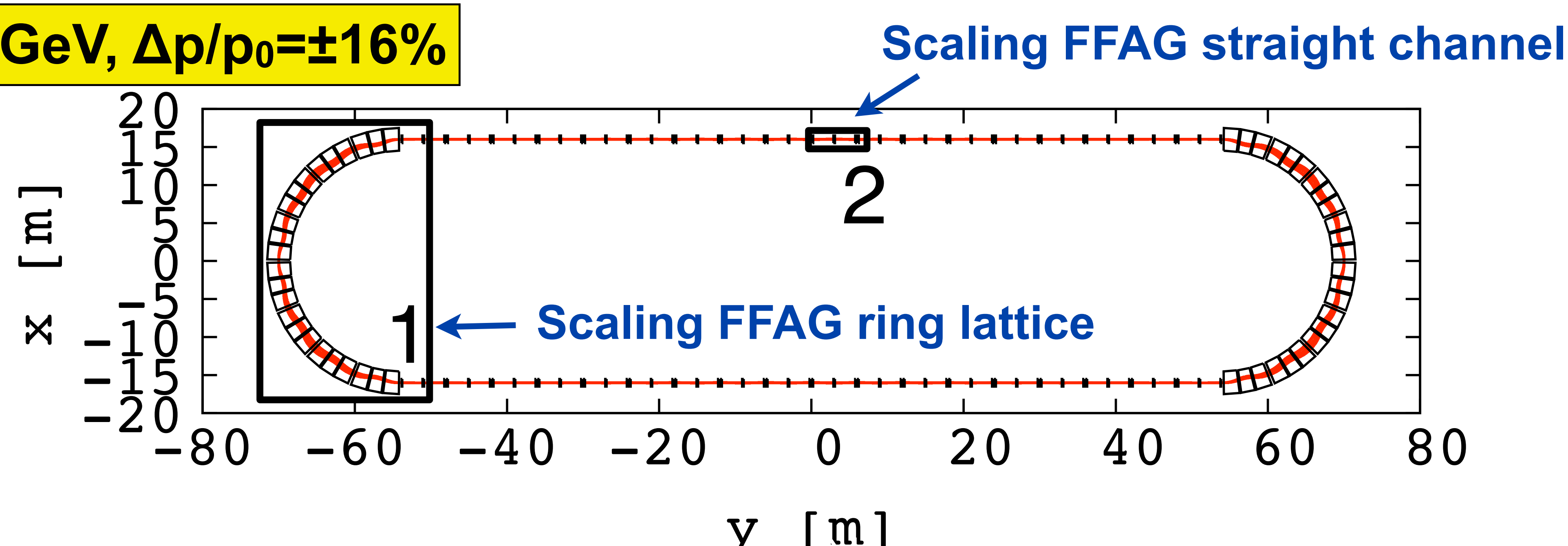

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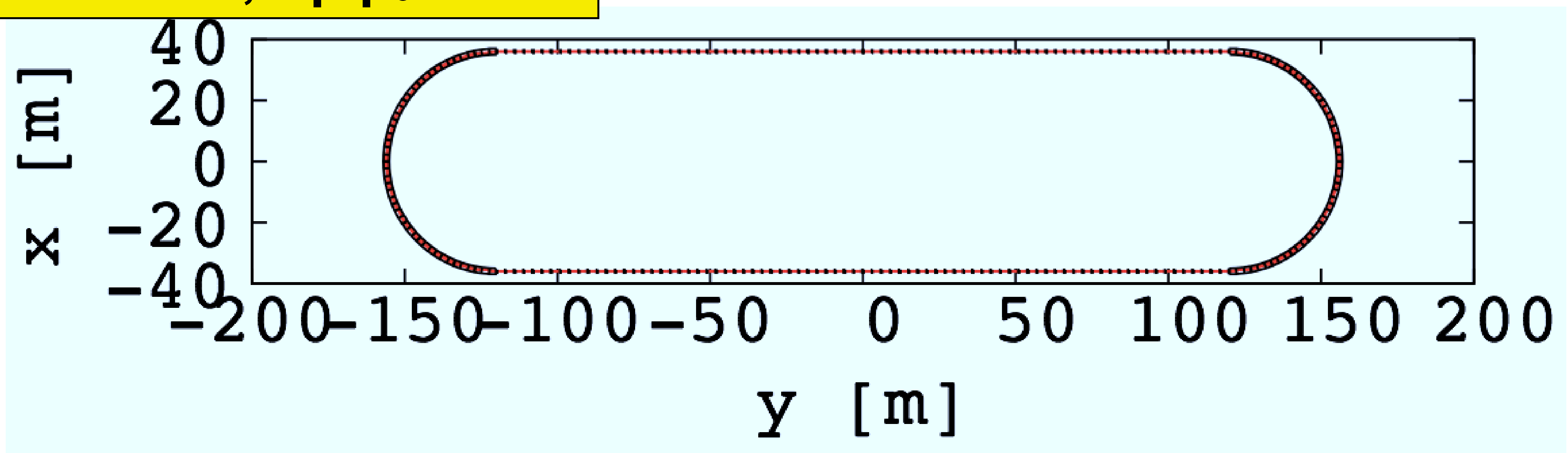

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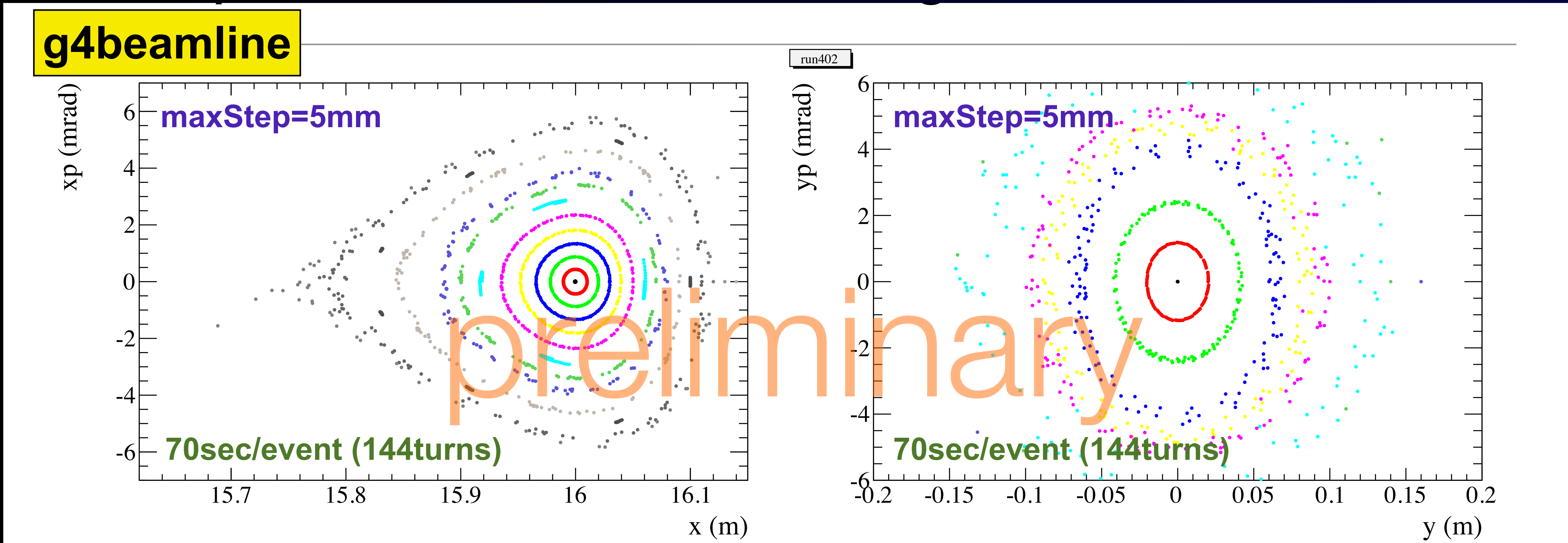
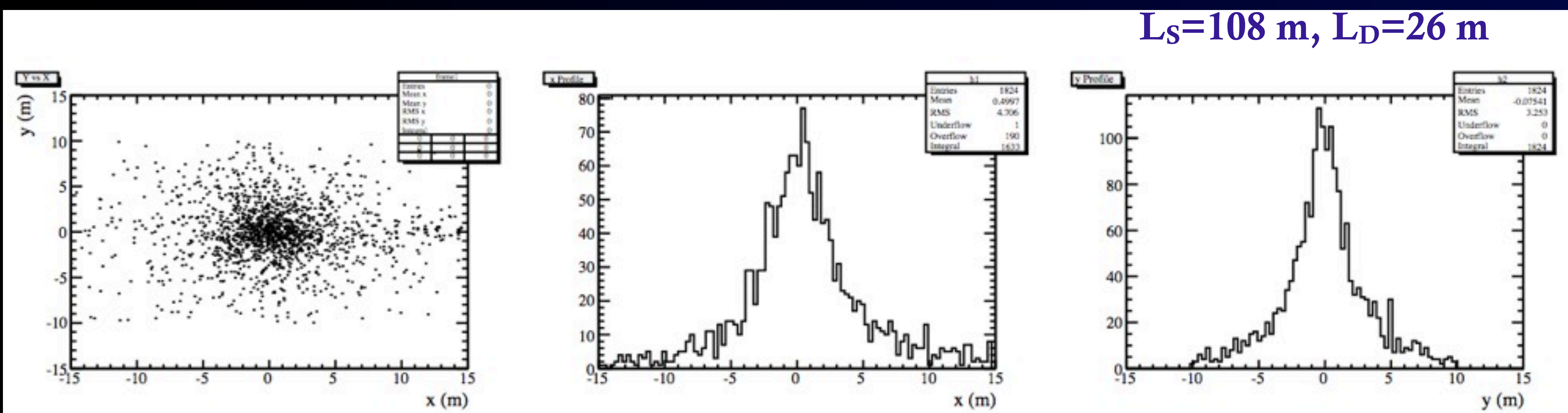
muon beam emittance in the storage ring



neutrino beam distribution



Summary

- CLFV would give the best opportunity to search for BSM. (So far, no BSM signals at the LHC.)
- μ-e conversion would be the best.
- Staged COMET will start in 2013.
- COMET Phase-I : $<10^{-(14-15)}$ (2016/17), and COMET Phase-II : $<10^{-16}$ (~2021),
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New collaborators to COMET are welcome.