Rare Decay Experiments

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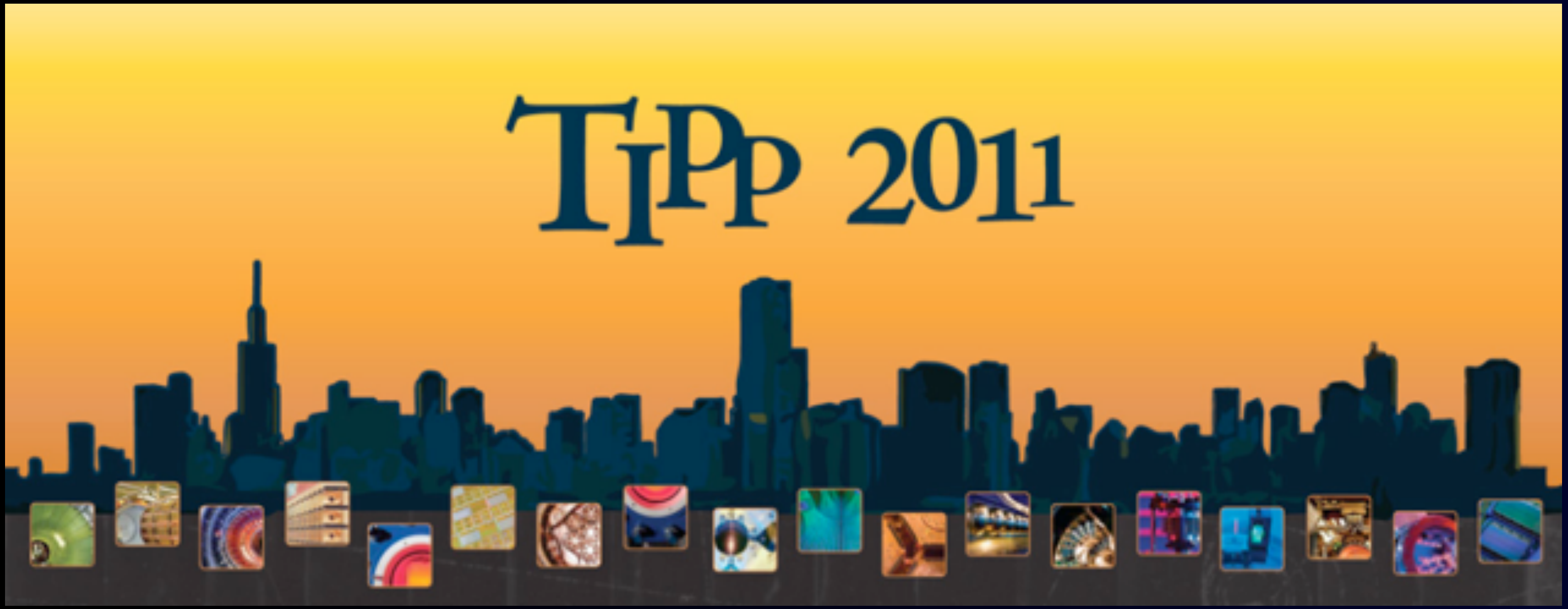
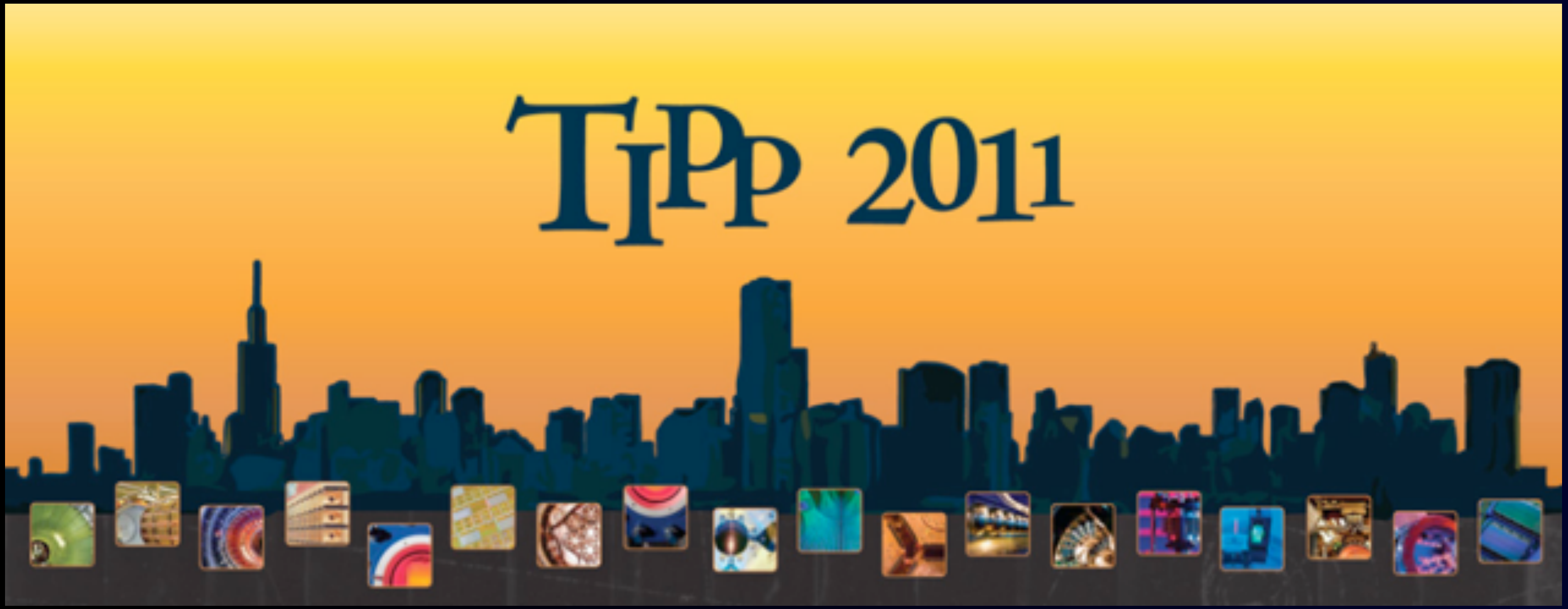


Outline

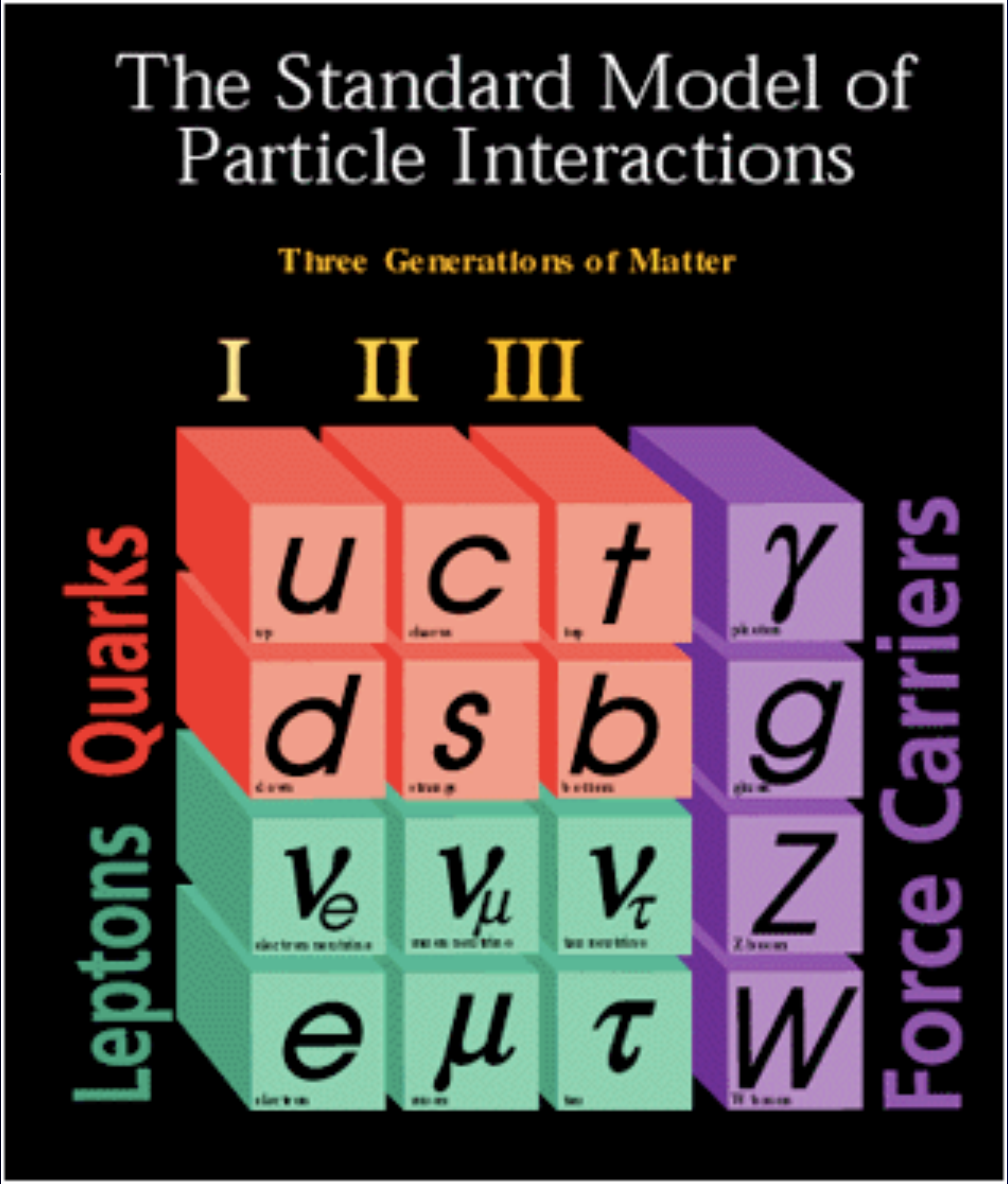
- Why Rare Decay Experiments ?
- Which Rare Decays ?
- Examples of the Rare Decay Experiments
- How to do Rare Decay Experiments ?
- Beam for Rare Decay Experiment
- Summary



Why Rare Decay Experiments ?

Standard Model

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



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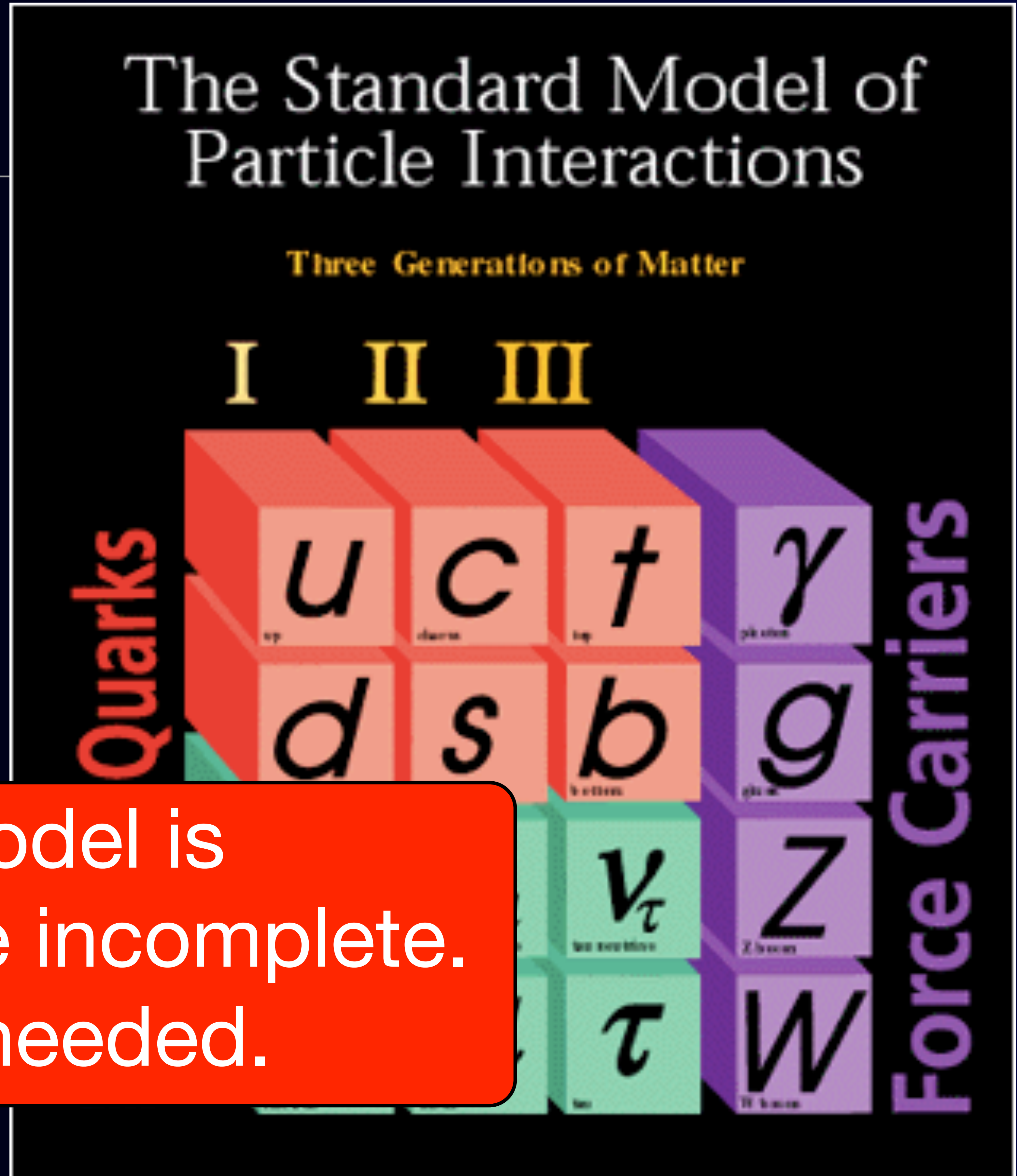
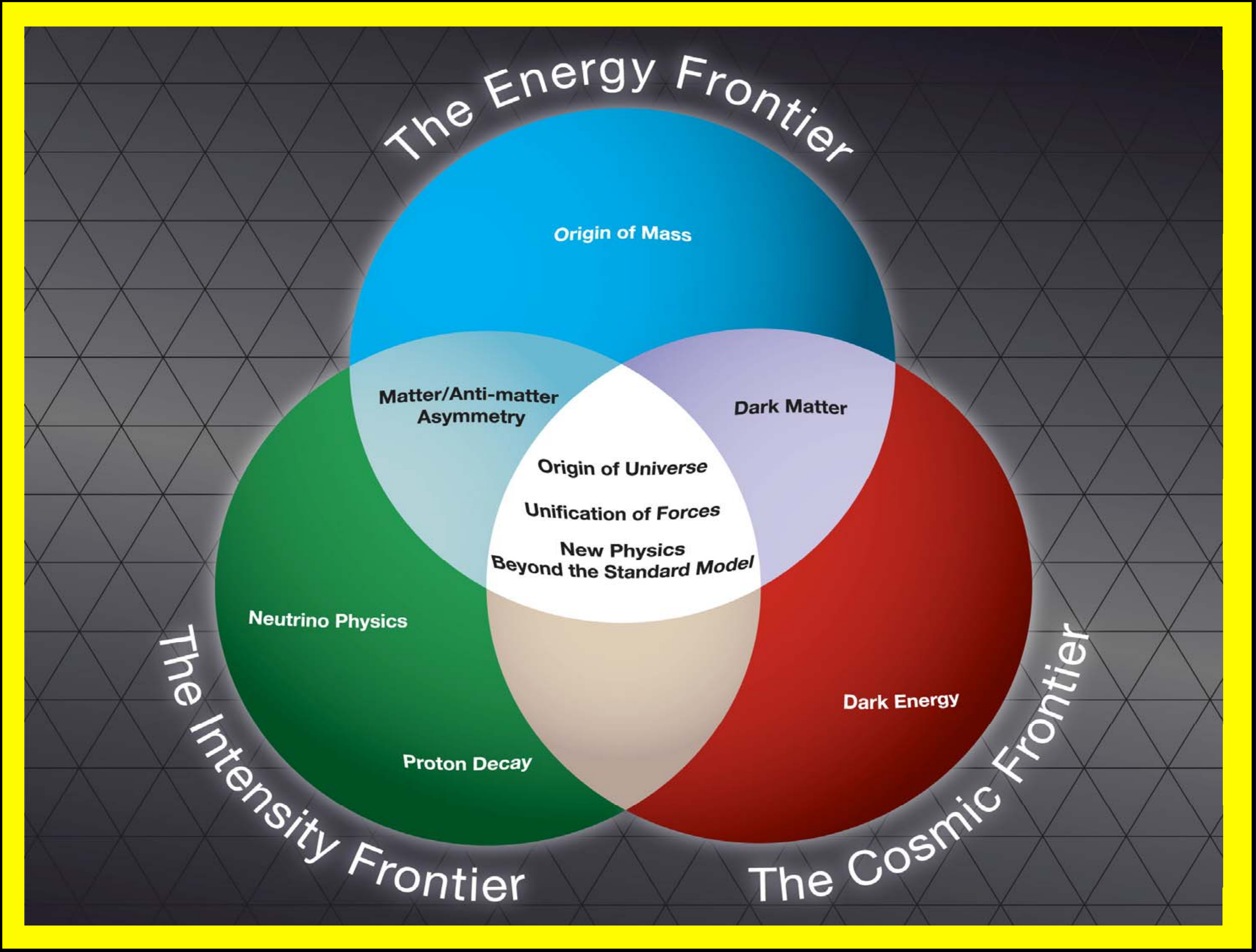


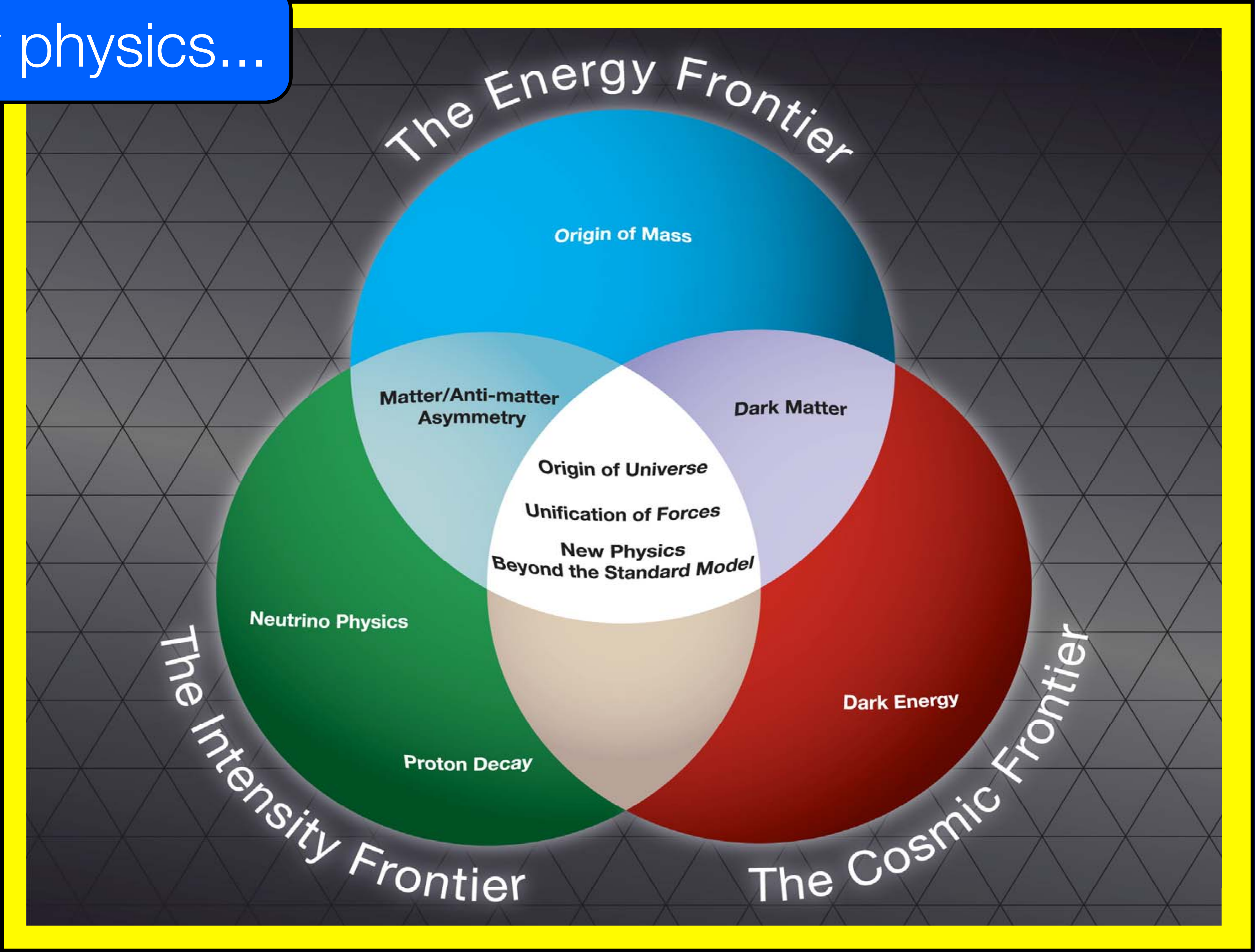
The Standard Model is considered to be incomplete. New Physics is needed.

Three Frontiers of Particle Physics



Three Frontiers of Particle Physics

To explore new physics...

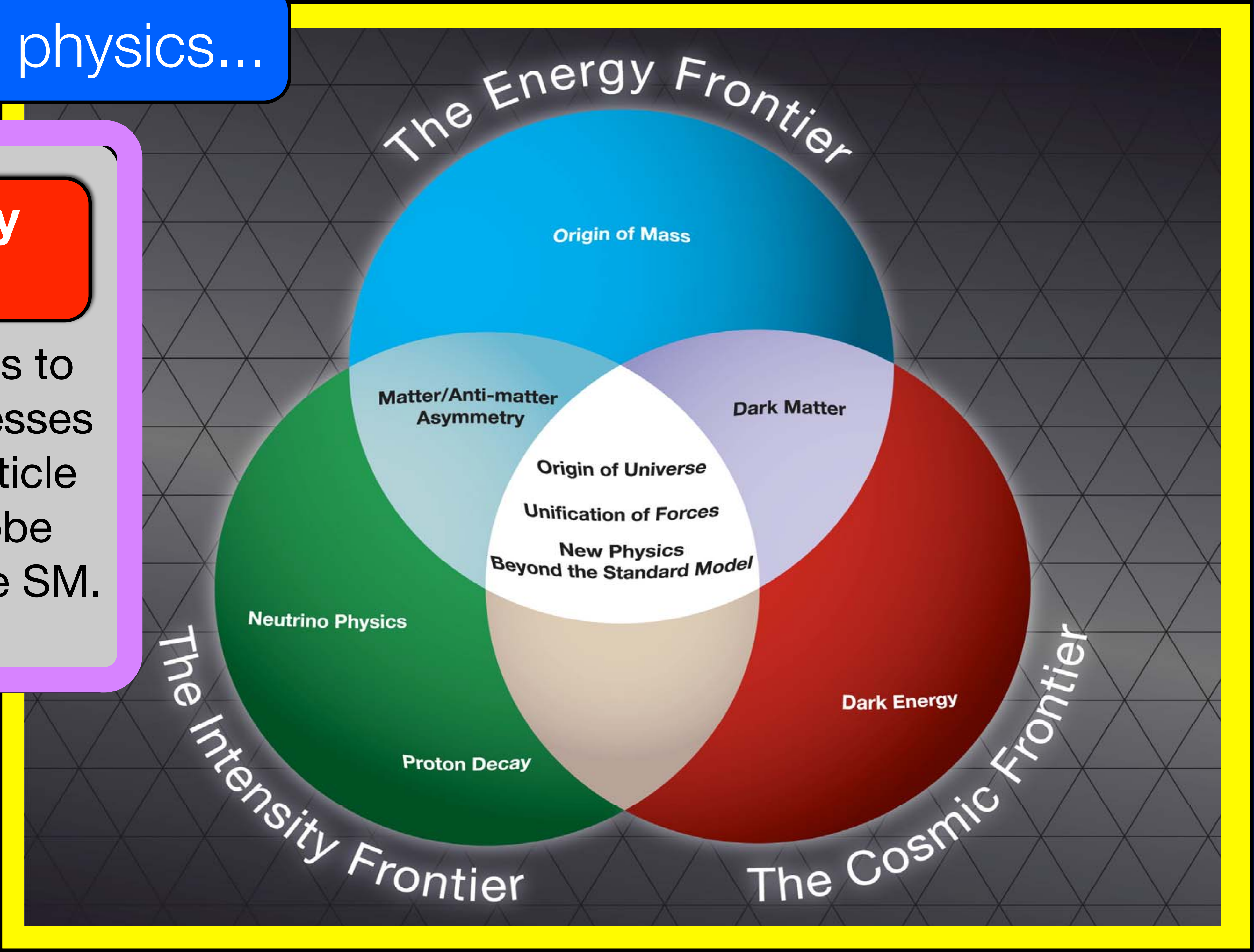


Three Frontiers of Particle Physics

To explore new physics...

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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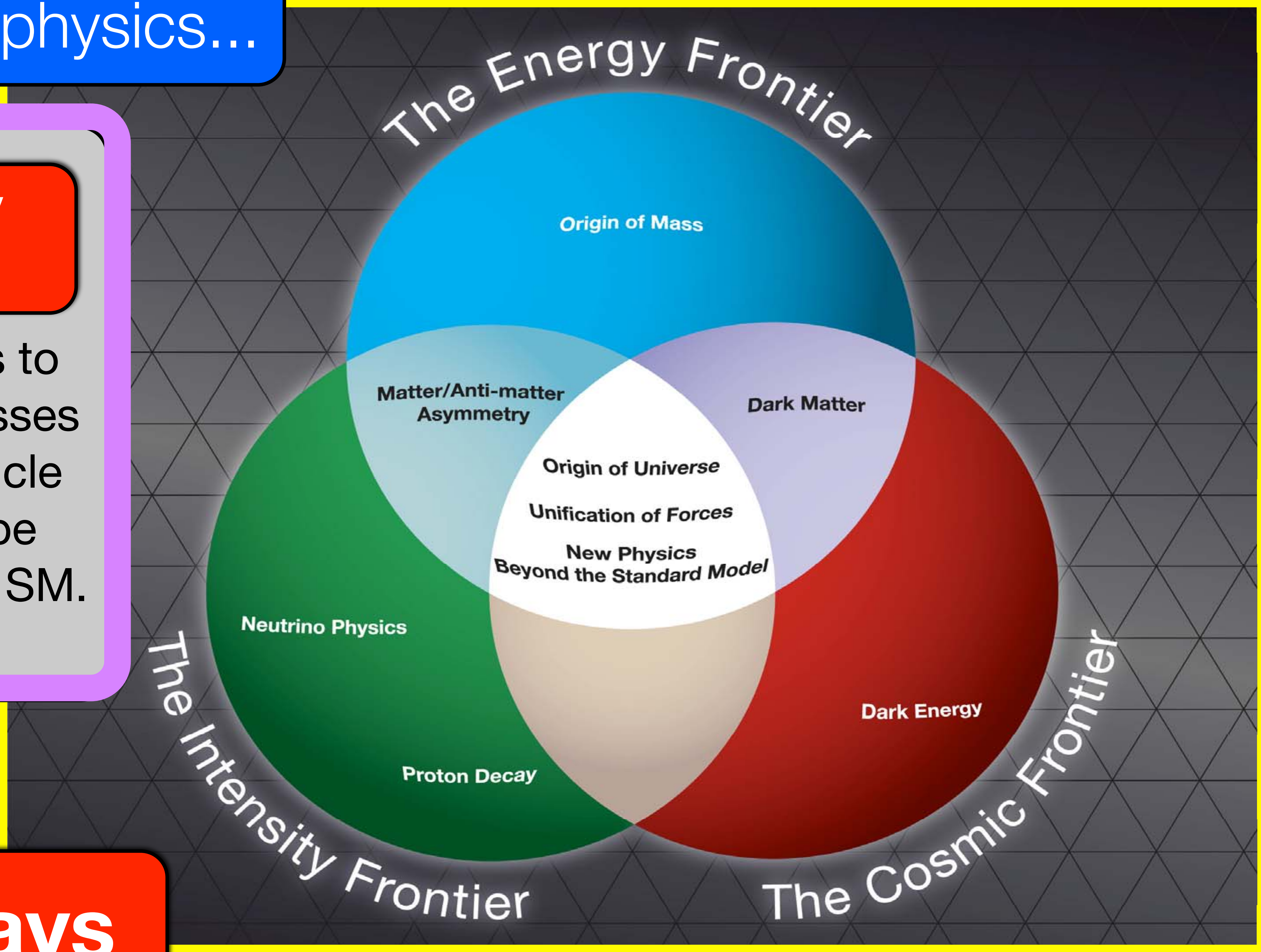
Rare Decays



Symmetry Breaking and Frontiers

Symmetry Breaking and Frontiers

Electroweak Symmetry Breaking

$$SU(2)_L \times U(1)_Y \rightarrow U(1)_{\mathrm{EM}}$$

~ O(100 GeV)

- The LHC will directly address this.

Energy Frontier

Symmetry Breaking and Frontiers

Electroweak Symmetry Breaking

$$SU(2)_L \times U(1)_Y \rightarrow U(1)_{\rm EM}$$

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Energy Frontier

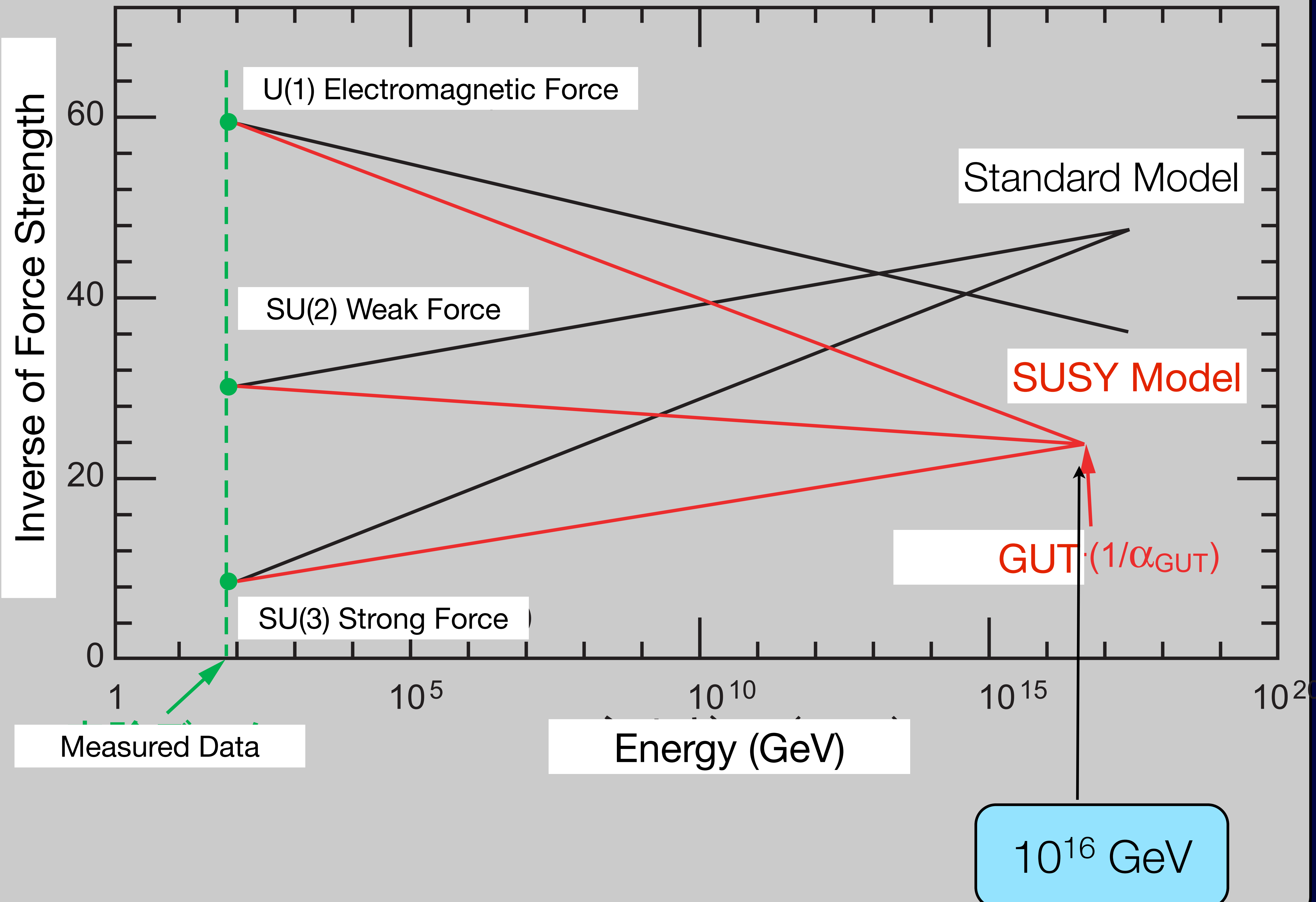
Flavor Symmetry Breaking

- Which interaction distinguishes generations.

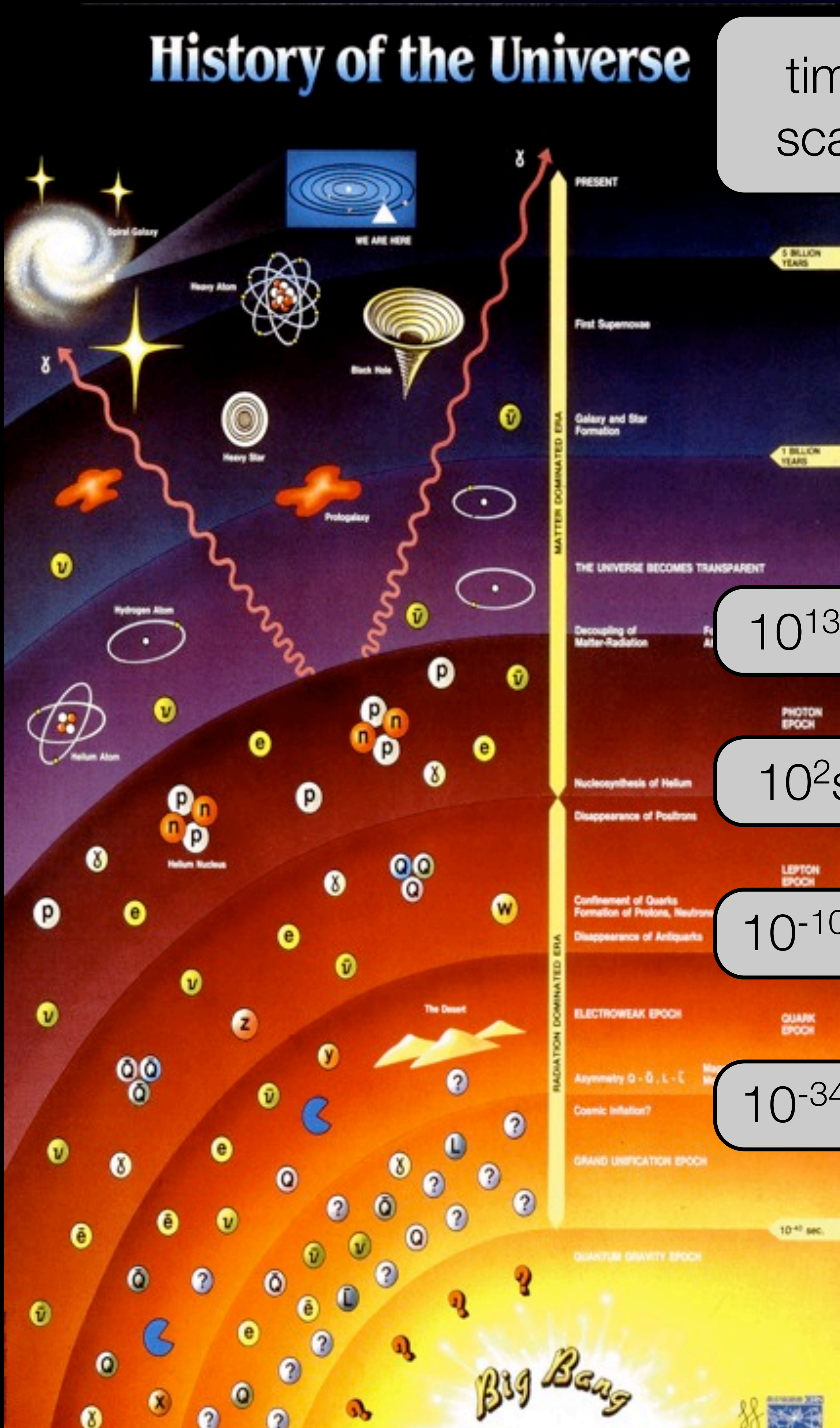
~ Higher energy scale (GUT?)

- Flavor physics in quark and lepton sectors.

Intensity Frontier



U(1) Electromagnetic Force
SU(2) Weak Force
SU(3) Strong Force
Standard Model
SUSY Model
GUT $(1/\alpha_{GUT})$
Inverse of Force Strength
60
40
20
0
1
10^5
10^{10}
10^{15}
10^{20}
Measured Data
Energy (GeV)
10^{16} GeV



time scale	energy scale
10^{13}sec	10^{-9}GeV
10^{2}sec	10^{-3}GeV
10^{-10}sec	10^{3}GeV
10^{-34}sec	10^{16}GeV
	10^{19}GeV

Electroweak Epoch

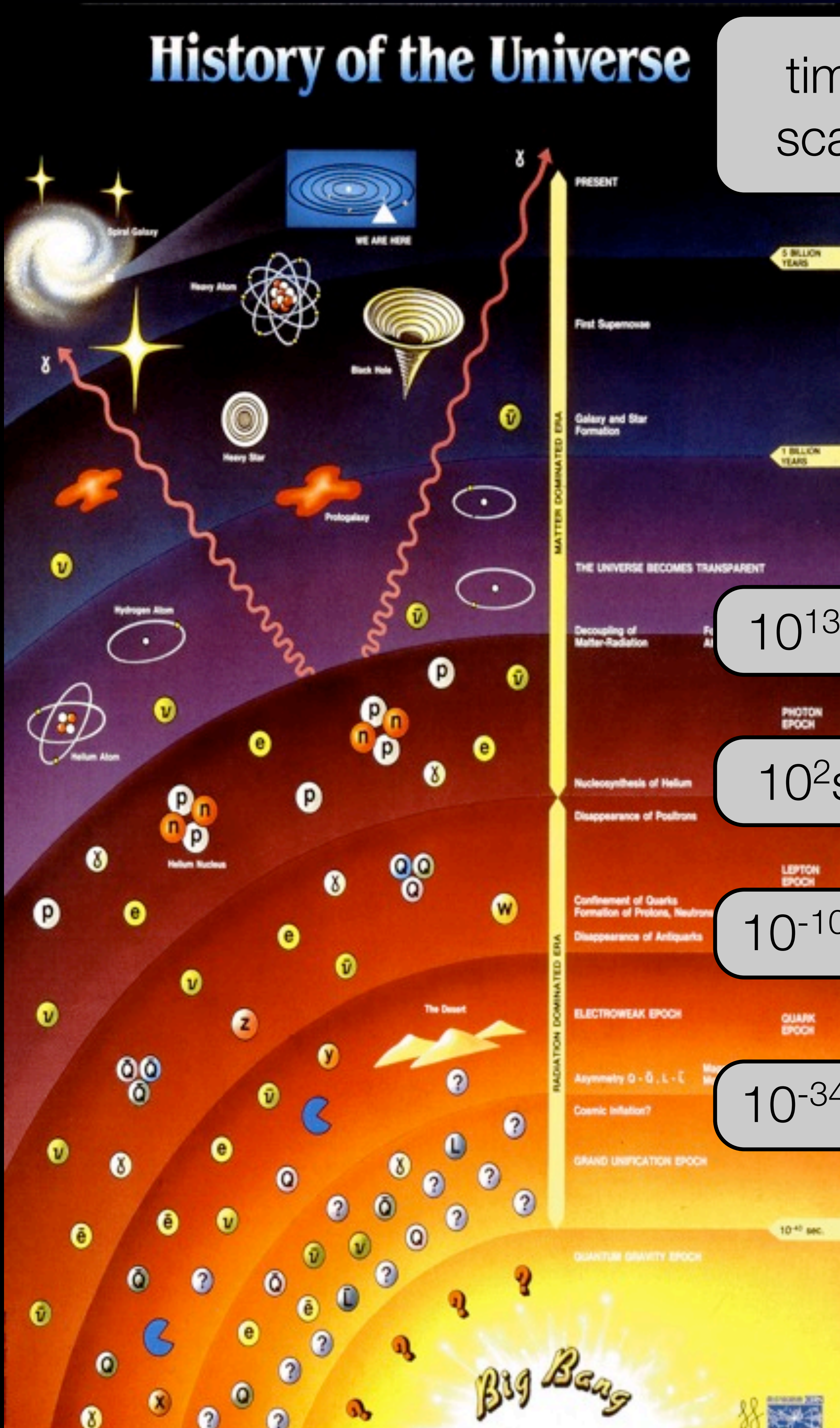
- Higgs particles
- Supersymmetry

Unification Epoch

- Grand unification of fundamental forces
- Origin of Neutrino mass (RH neutrino)
- Leptogenesis (baryogenesis)

Quantum Gravity Epoch

- Superstrings



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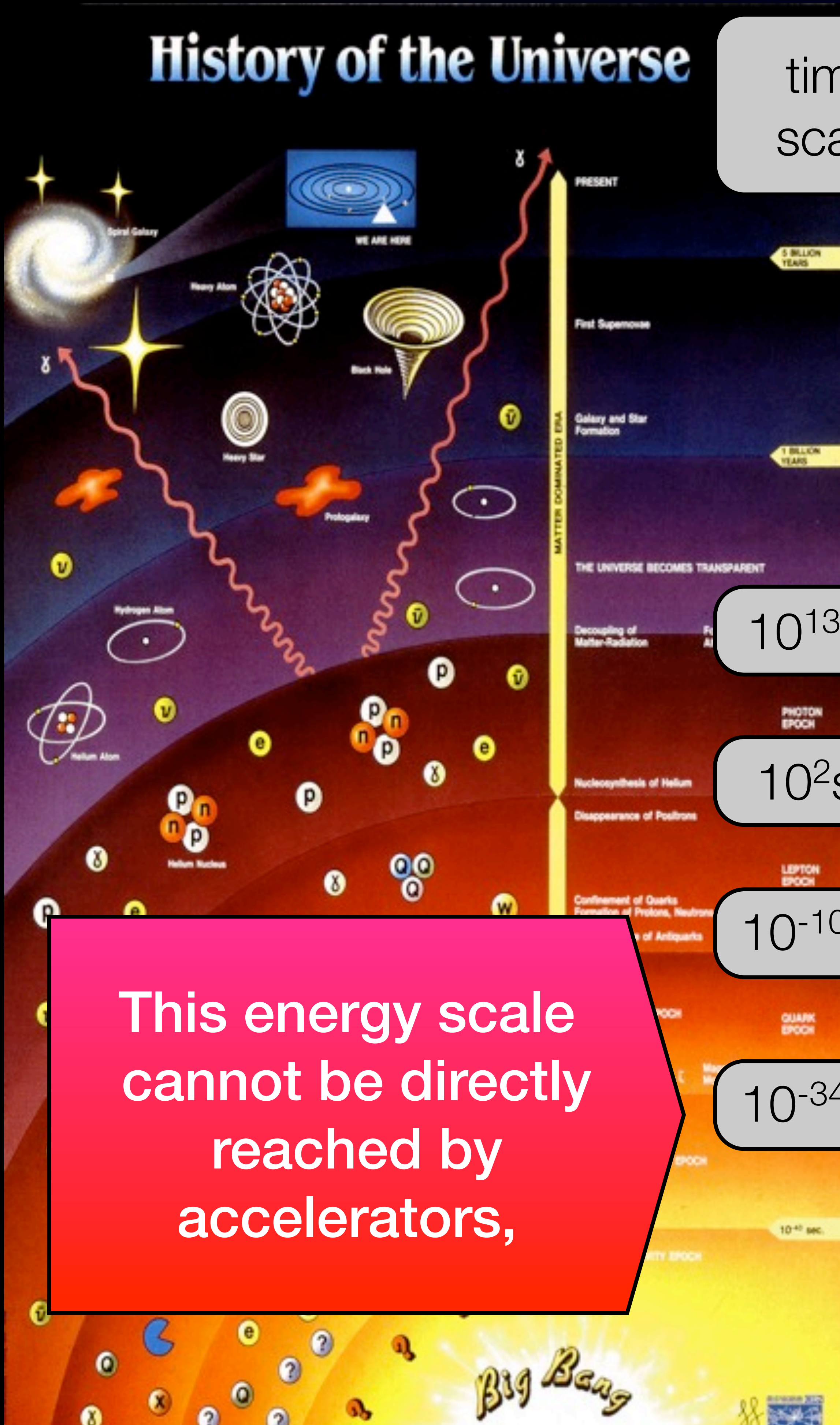

This energy scale cannot be directly reached by accelerators,

time scale	energy scale
10^{13}sec	10^{-9}GeV
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Electroweak Epoch (10^{3}GeV)
- Higgs particles
- Supersymmetry

Unification Epoch (10^{16}GeV)
- Grand unification of fundamental forces
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Quantum Gravity Epoch (10^{19}GeV)
- Superstrings

The Intensity Frontier is.....

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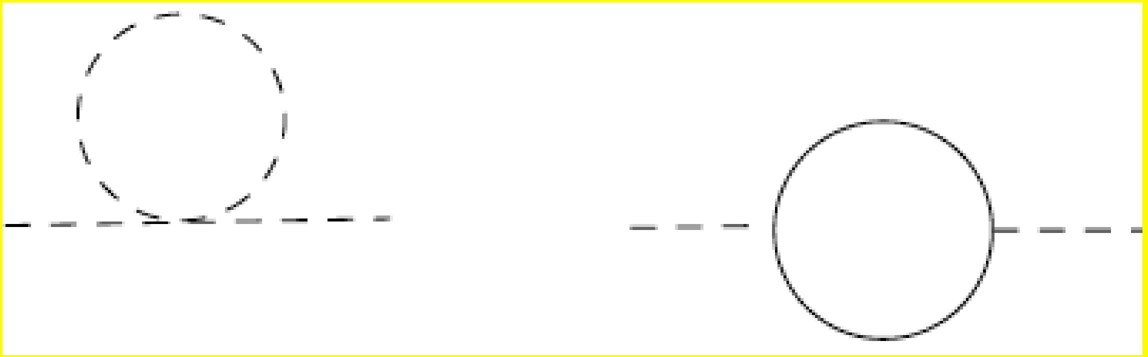
The energy scale reached by the intensity frontier could be very high through quantum radiative corrections (renormalization group equation = RGE).

Quantum Corrections



Effects are small.

$$\Delta E \sim \frac{\hbar}{2\Delta t}$$

Uncertainty principle

The Intensity Frontier is.....

The energy scale reached by the intensity frontier could be very high through quantum radiative corrections (renormalization group equation = RGE).

Quantum Corrections

Effects are small.

Rare Decays

$$\Delta E \sim \frac{\hbar}{2\Delta t}$$

Uncertainty principle

Sensitivity to High Energy-scale Physics
Exercise (1) :

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Take an example of rare decay of μ→eγ (Br<10^{-11})

$$\mathcal{L}_{\mathrm{LFV}} = y\frac{e m_\mu}{\Lambda^2}\bar{\mu}_R \sigma^{\mu\nu} e_L F_{\mu\nu} + \mathrm{h.c.} + \cdots$$

$$\mathrm{BR}(\mu \to e\gamma) = y^2 \frac{3(4\pi)^3\alpha}{G_F^2 \Lambda^4}$$

Λ :new physics scale

Sensitivity to High Energy-scale Physics
Exercise (1) :

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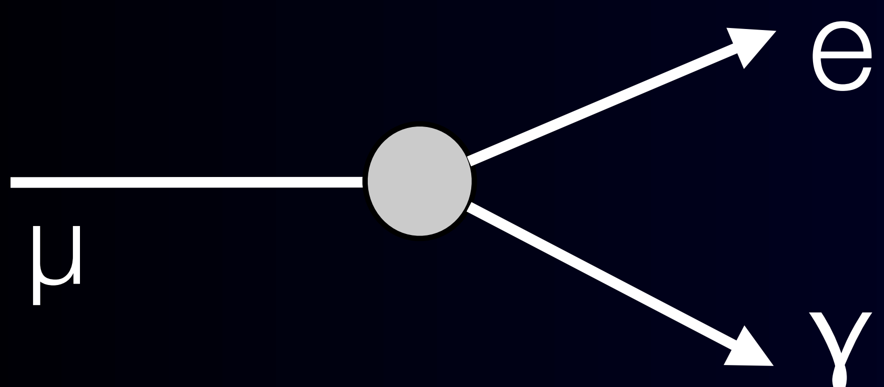
Λ :new physics scale

- For tree diagrams,

$$\mathrm{BR}(\mu \to e\gamma) = 1 \times 10^{-11} \times \left(\frac{400\mathrm{TeV}}{\Lambda}\right)^4 \left(\frac{y}{1}\right)^2$$

> sensitive to energy scale higher than 400 TeV



Sensitivity to High Energy-scale Physics
Exercise (2) :

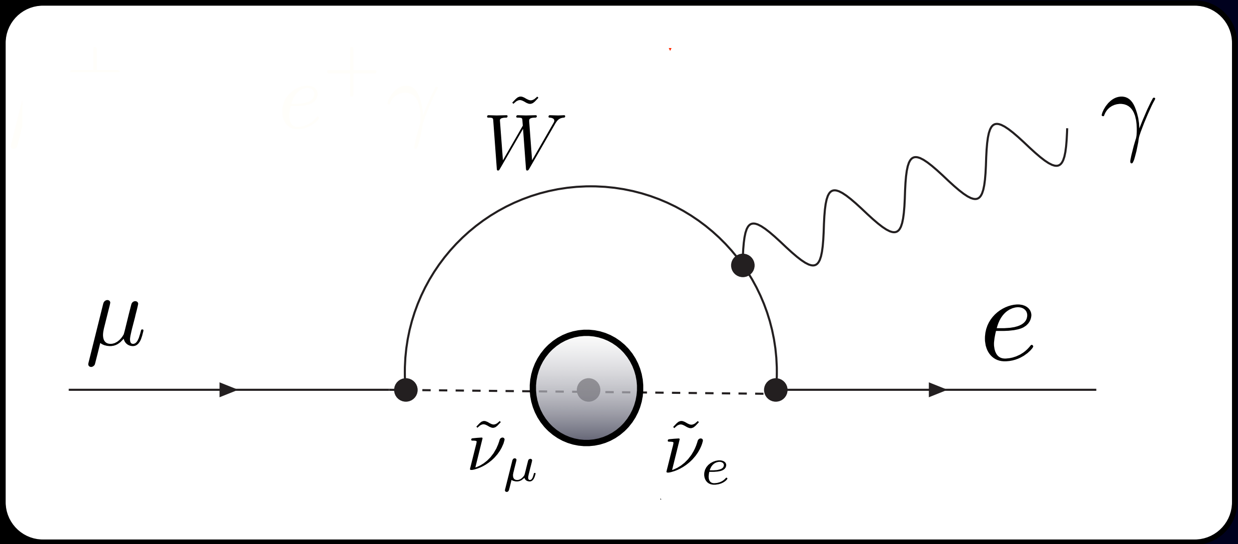
Sensitivity to High Energy-scale Physics Exercise (2) :

- For loop diagrams,

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

$$y = \frac{g^2}{16\pi^2}\theta_{\mu e}$$

> sensitive to TeV energy scale with reasonable mixing



Sensitivity to High Energy-scale Physics
Exercise (2) :

- For loop diagrams,

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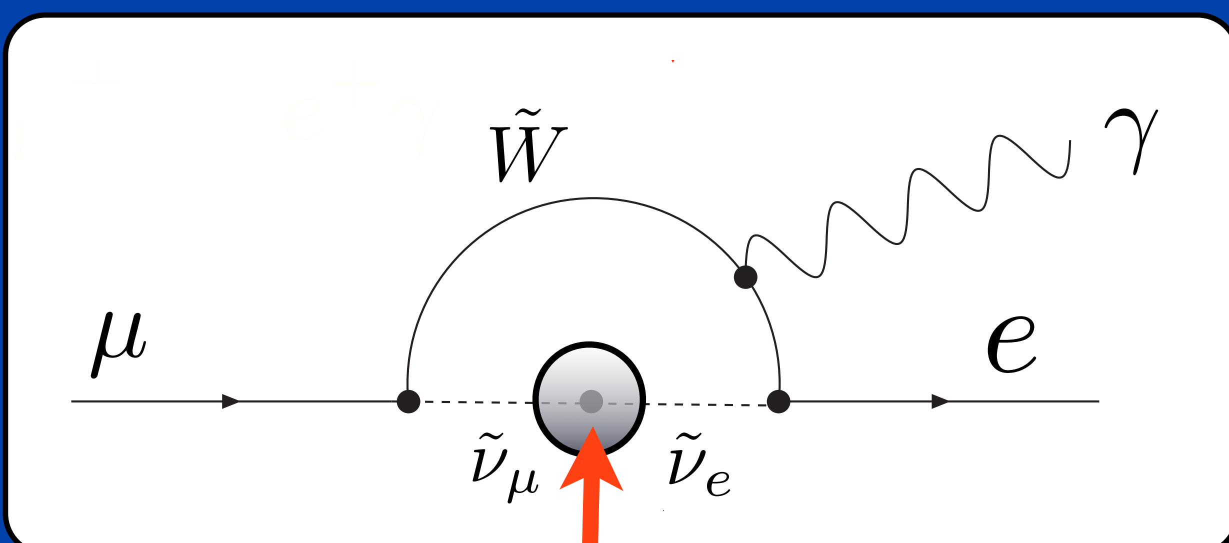

example diagram for SUSY (~TeV)

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

$$(m^2_{\tilde{L}})_{21} \sim \frac{3m_0^2 + A_0^2}{8\pi^2} h_\tau^2 U_{31} U_{32} \frac{M_{GUT}}{M_{R_s}}$$ SUSY neutrino seesaw model

Which Rare Decays ?

Guideline for Choosing Processes.....

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Contributions from new physics must be small.

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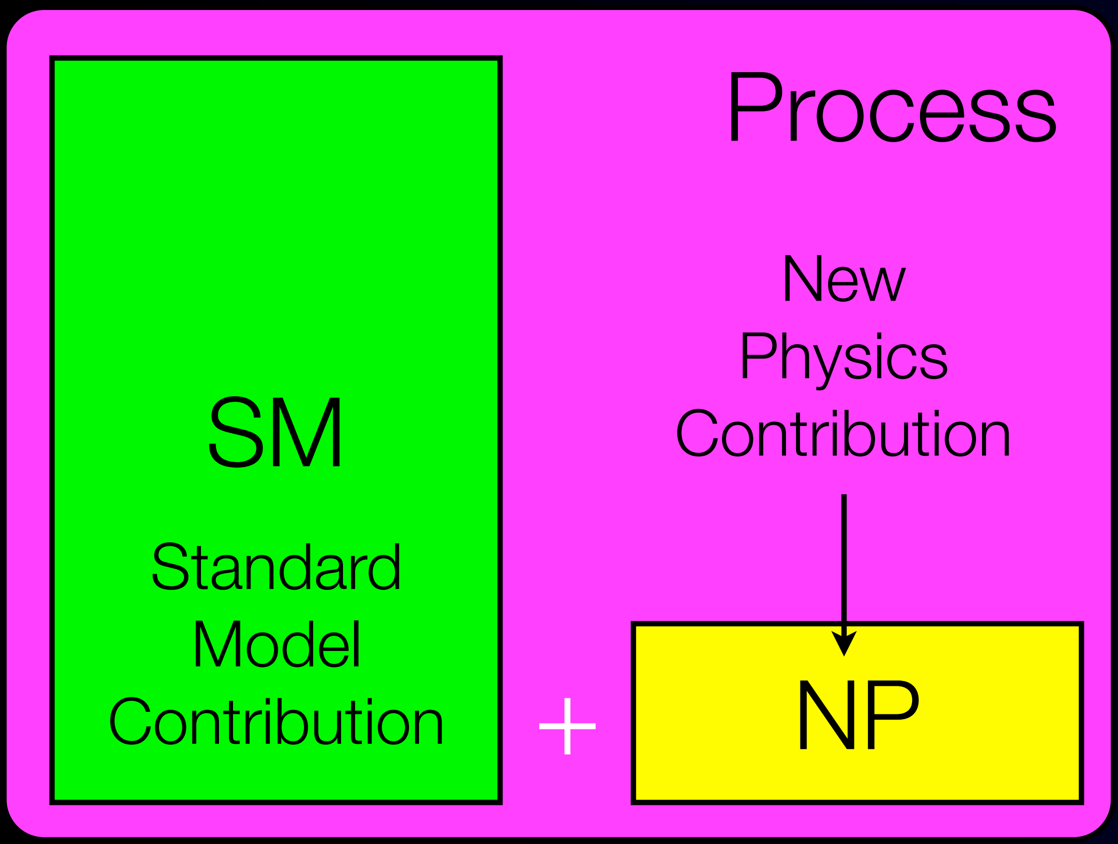
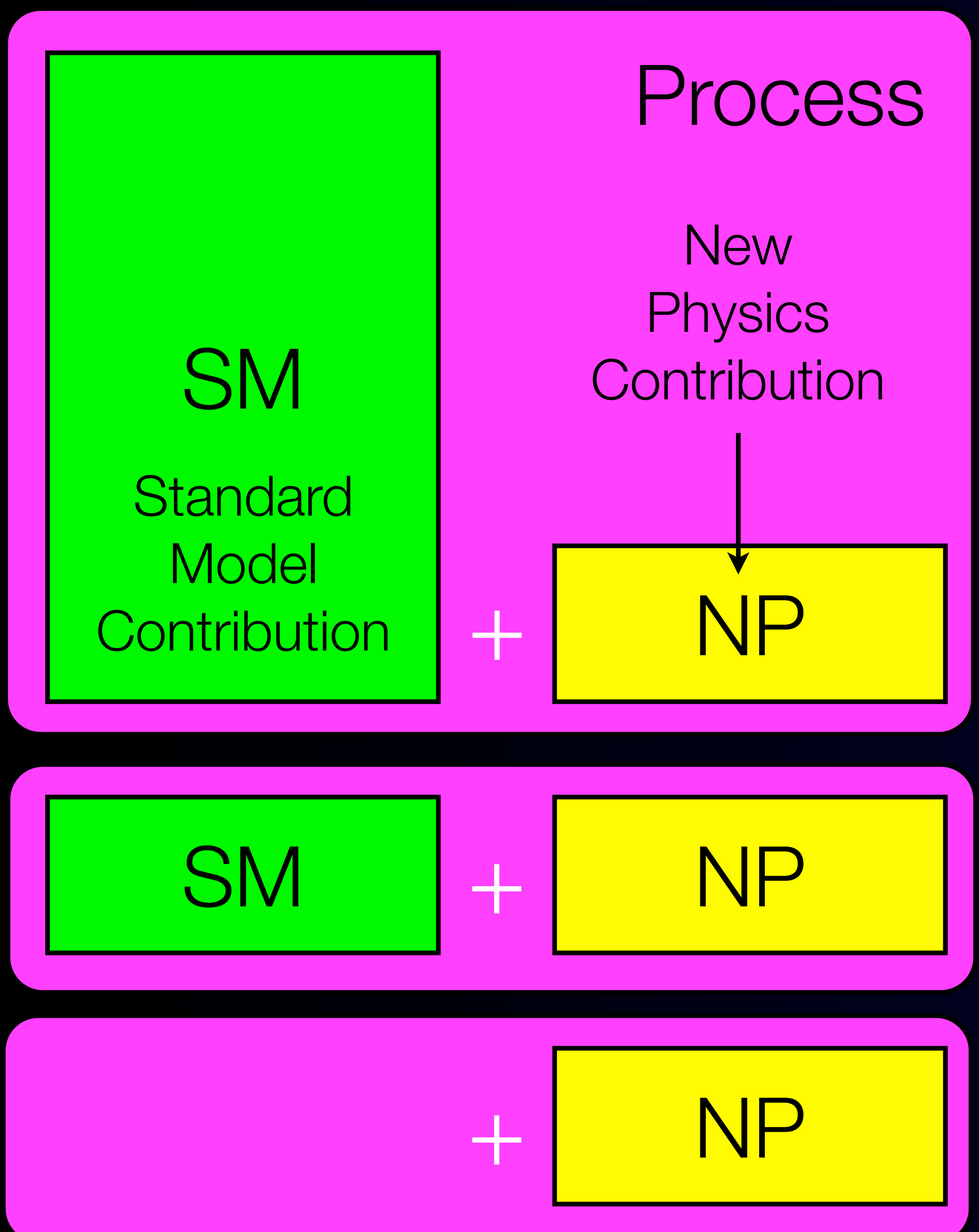


SM contribution is dominant.

Guideline for Choosing Processes.....

Contributions from new physics must be small.



SM contribution is dominant.

SM contribution is highly suppressed.

SM contribution is forbidden.

Flavor Changing Neutral Current (FCNC)

a process that is highly suppressed or forbidden in the SM.

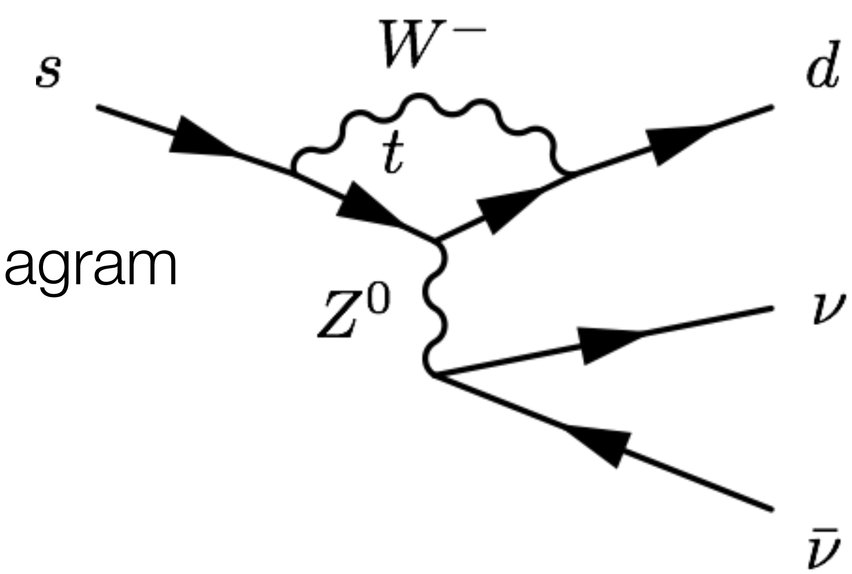
FCNC in Quark Sector

$$B \to X_s \gamma$$

$$K^+ \to \pi^+ \nu \overline{\nu}$$

$$K_L \to \pi^0 \nu \overline{\nu}$$ CPV

penguin diagram



$B_{SM}(K^+ \to \pi^+ \nu \overline{\nu}) = (8.2 \pm 0.8) \text{ x } 10^{-11}$

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

The SM contributions are highly suppressed and are known within the uncertainty of a few %.

Flavor Changing Neutral Current (FCNC)

ia process that is highly suppressed or forbidden in the SM.

FCNC in Lepton Sector

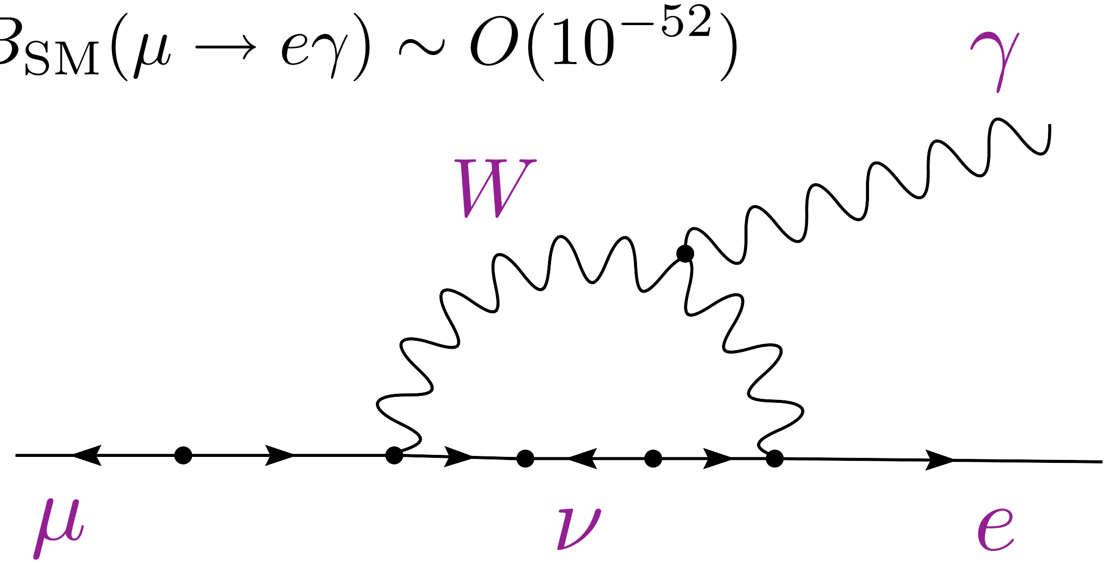
$$\mu \to e\gamma$$

$$\mu^- N \to e^- N$$

$$\mu^+ \to e^+ e^+ e^-$$

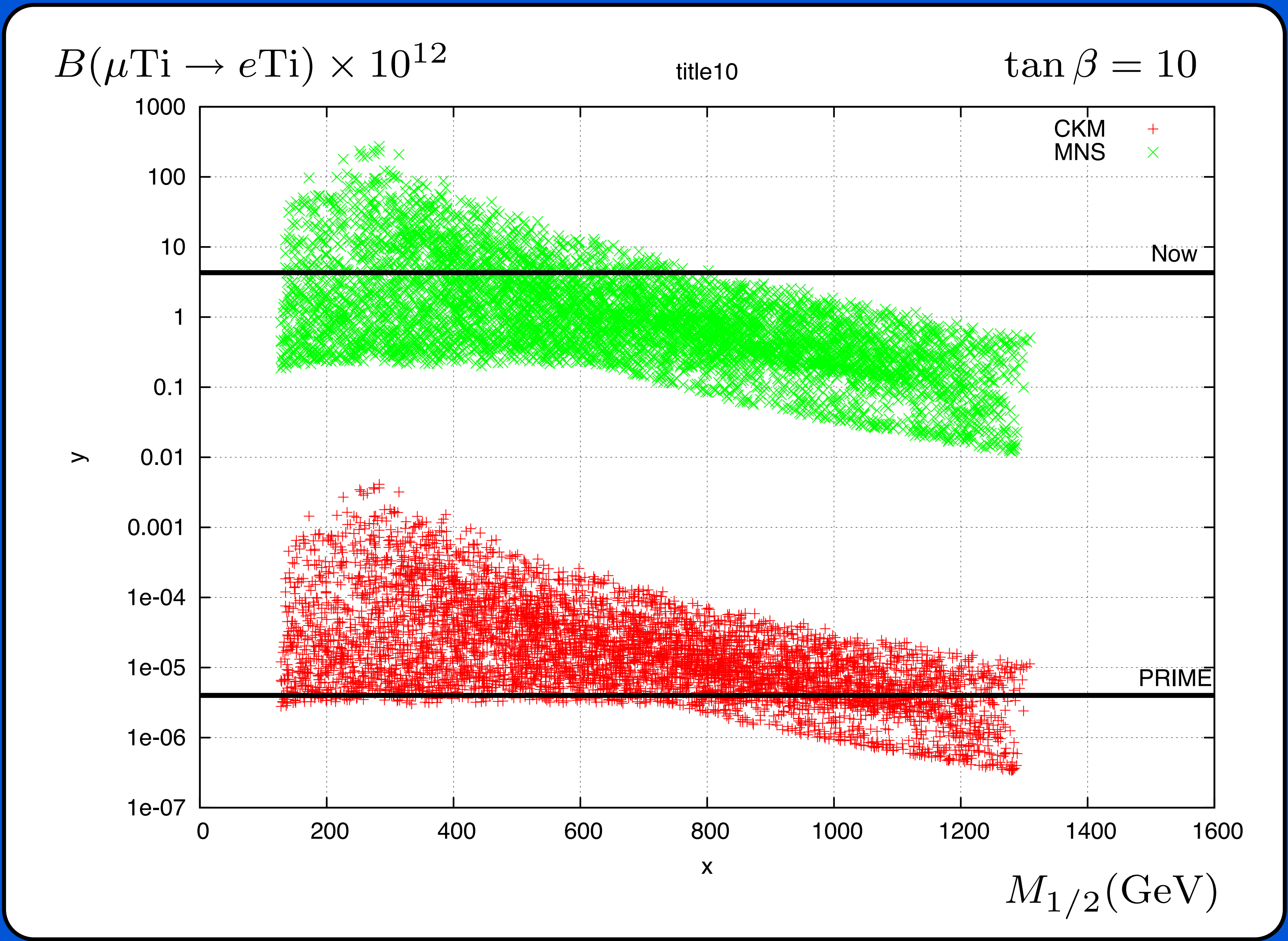
charged lepton flavor violation (cLFV)

$$B_{\rm SM}(\mu \to e\gamma) \sim O(10^{-52})$$



The SM contributions are forbidden for cLFV.

Example : SUSY Prediction for μ-e conversion (charged lepton flavor violation)



Calibbi, Faccia, Masiero, Vempati, hep-ph/0605139

experimental bound
BR~10^{-12}

10^6

experiment projection
BR~10^{-18}

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

W. Altmannshofer, A.J. Buras, S. Gori, P. Paradisi, D.M. Straub, . **Nucl.Phys.B830:17-94 ,2010**.

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

Table 8: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY and non-SUSY models ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

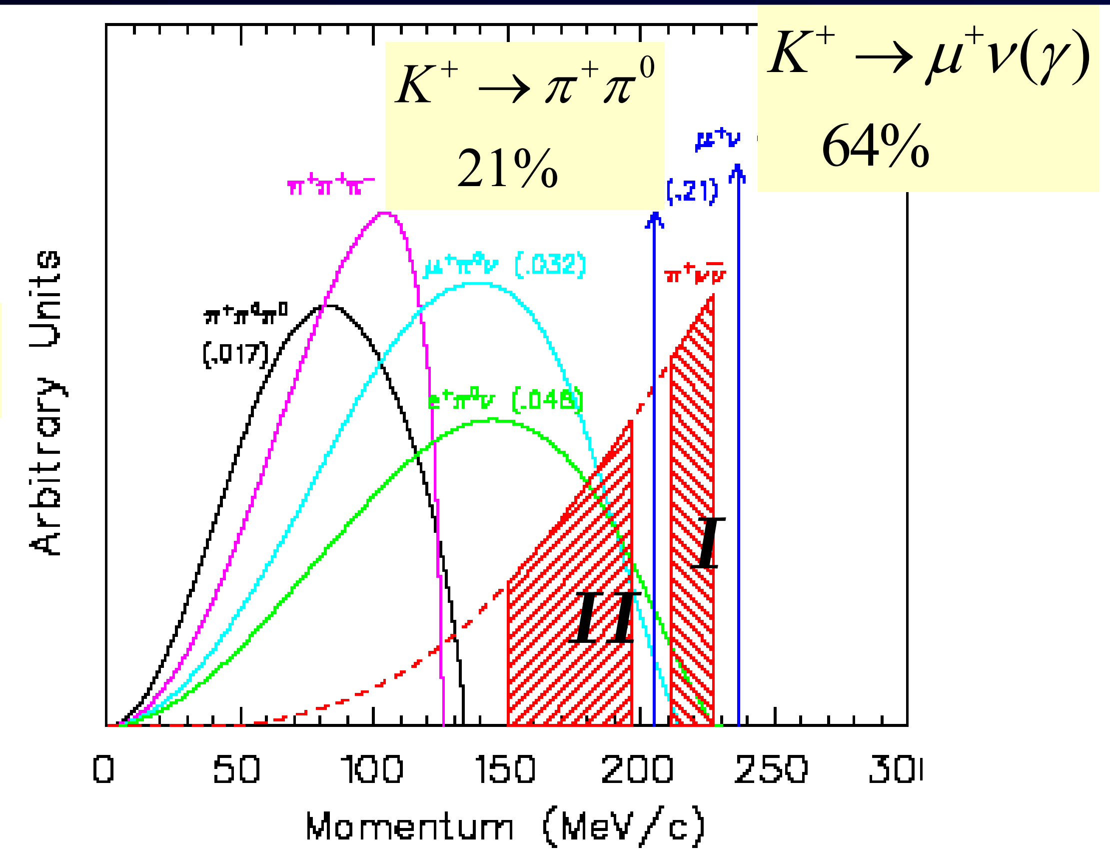
Examples of
Rare Decay Experiments

$K^+ \to \pi^+\nu\nu$:
E787/E949 at BNL (1988 - 2008)

Special Features of Measuring $K^+ \to \pi^+\nu\bar{\nu}$

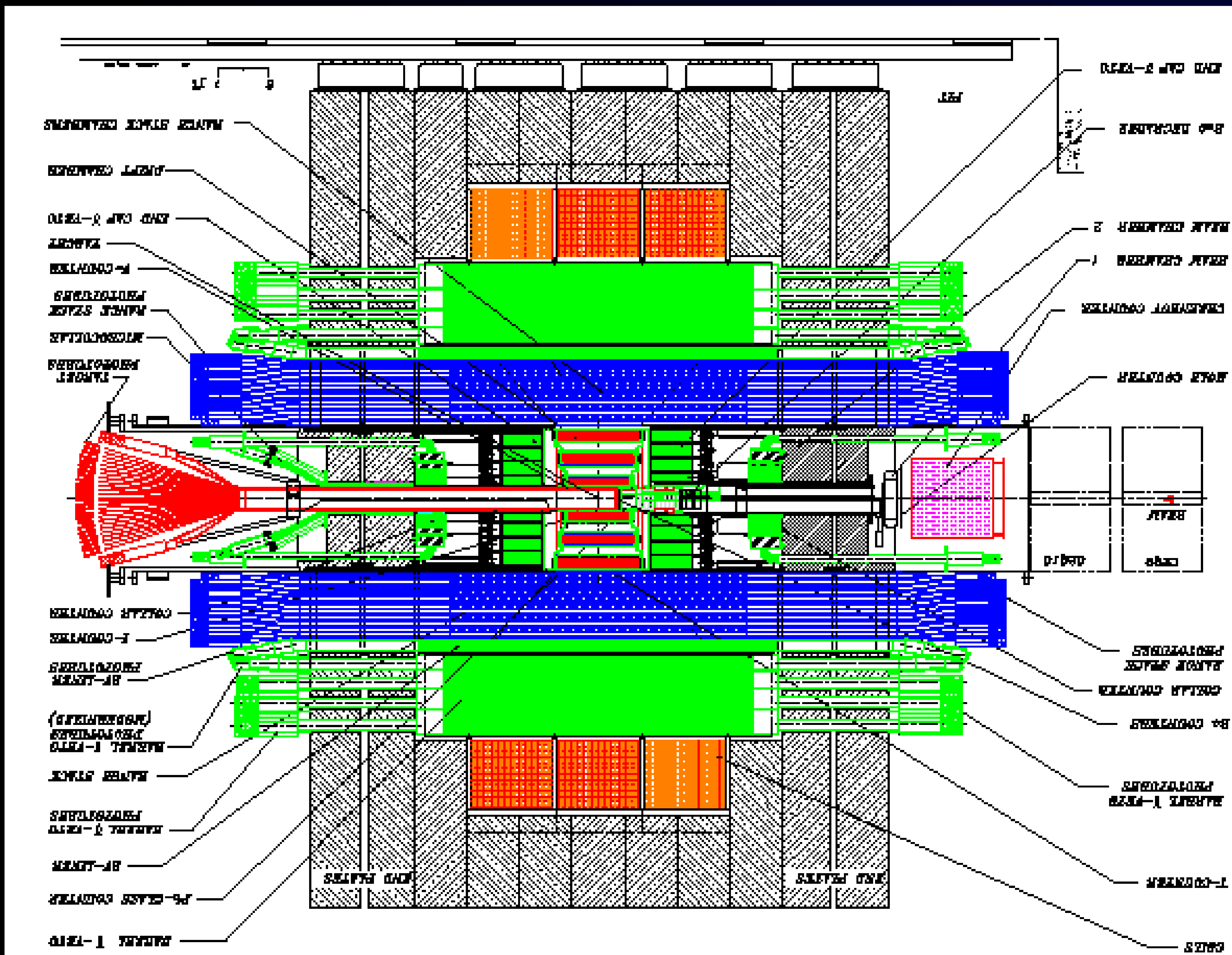
$B_{SM}(K^+ \to \pi^+\nu\bar{\nu}) = (8.5 \pm 0.7) \times 10^{-11}$

Experimentally weak signature with background processes exceeding signal by $>10^{10}$



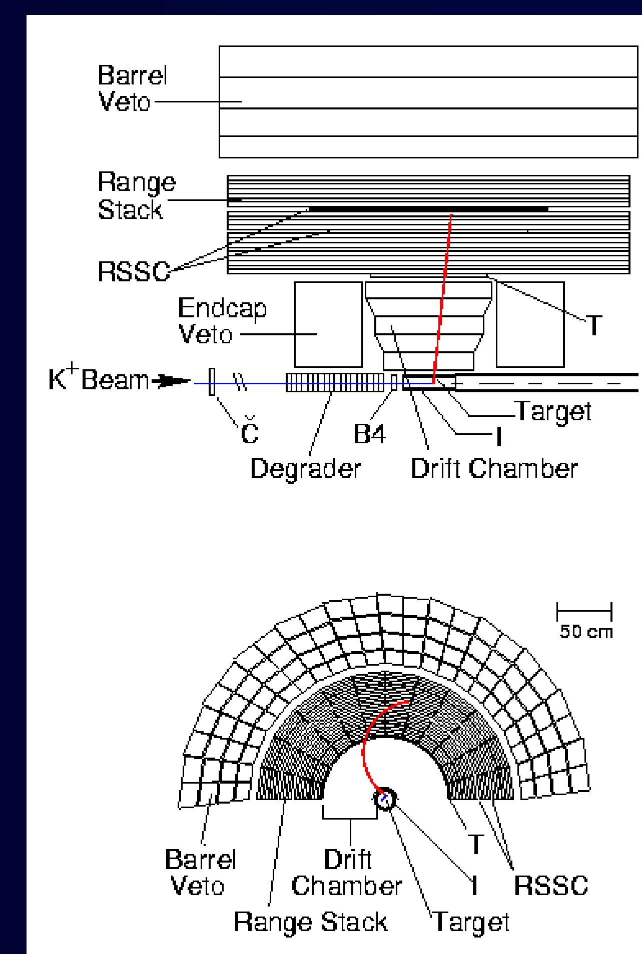
- Determine everything possible about the K^+ and π^+
  - * π^+/μ^+ particle ID better than 10^6 ($\pi^+ \to \mu^+ \to e^+$)
- Eliminate events with extra charged particles or ***photons***
  - * π^0 inefficiency $< 10^{-6}$
- Suppress backgrounds well below the expected signal (S/N~10)
  - * Predict backgrounds *from data*: dual independent cuts
  - * Use "Blind analysis" techniques
  - * Test predictions with outside-the-signal-region measurements
- Evaluate candidate events with S/N function

$K^+ \to \pi^+ \nu\nu$:
E787/E949 at BNL (1988 - 2008)

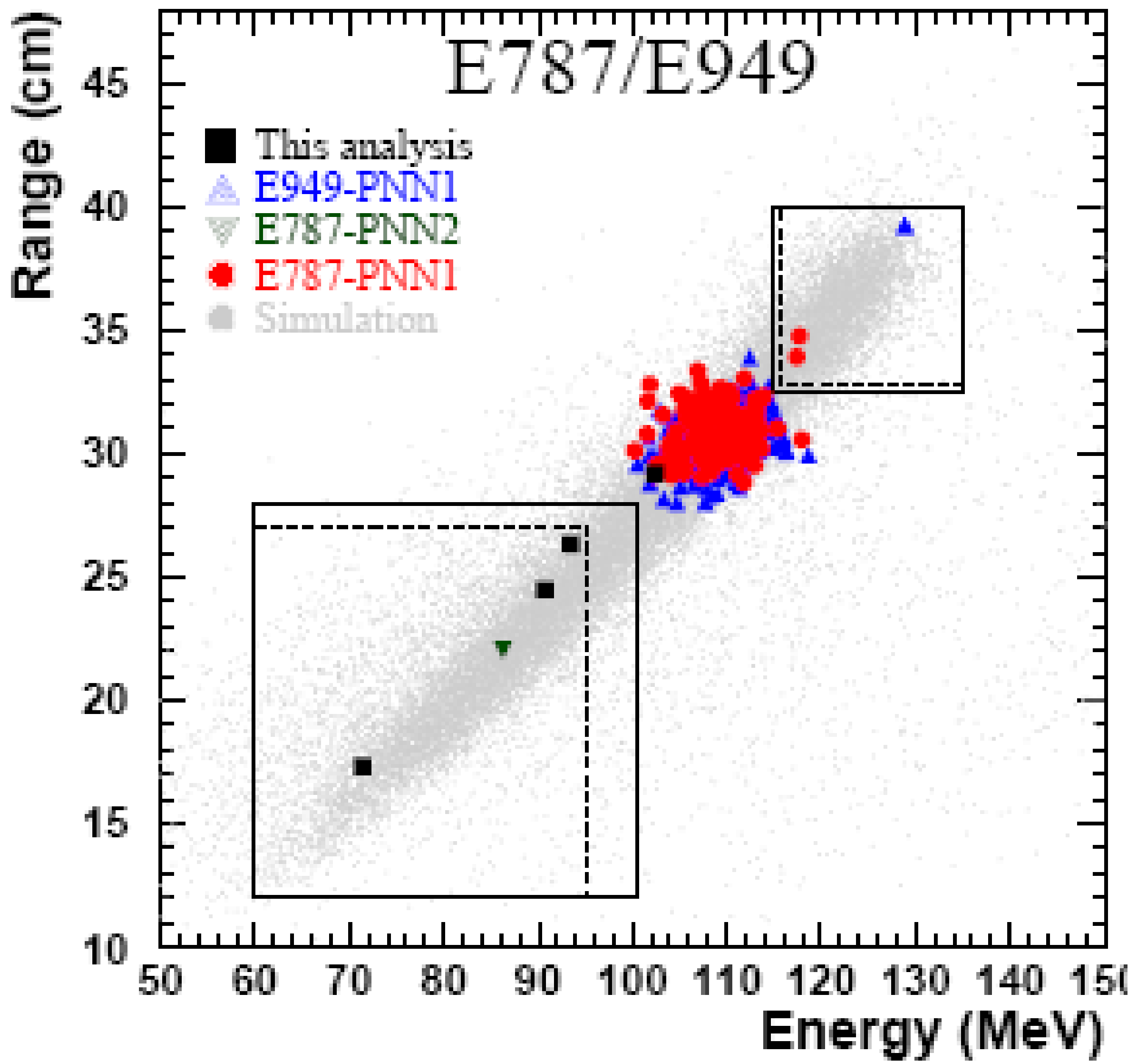


Measurement of

$K^+ \to \pi^+ \nu\bar{\nu}$



$K^+ \to \pi^+ \nu\nu$:
Observation of $K^+ \to \pi^+ \nu\nu$ Events



E787/E949: 7 events observed

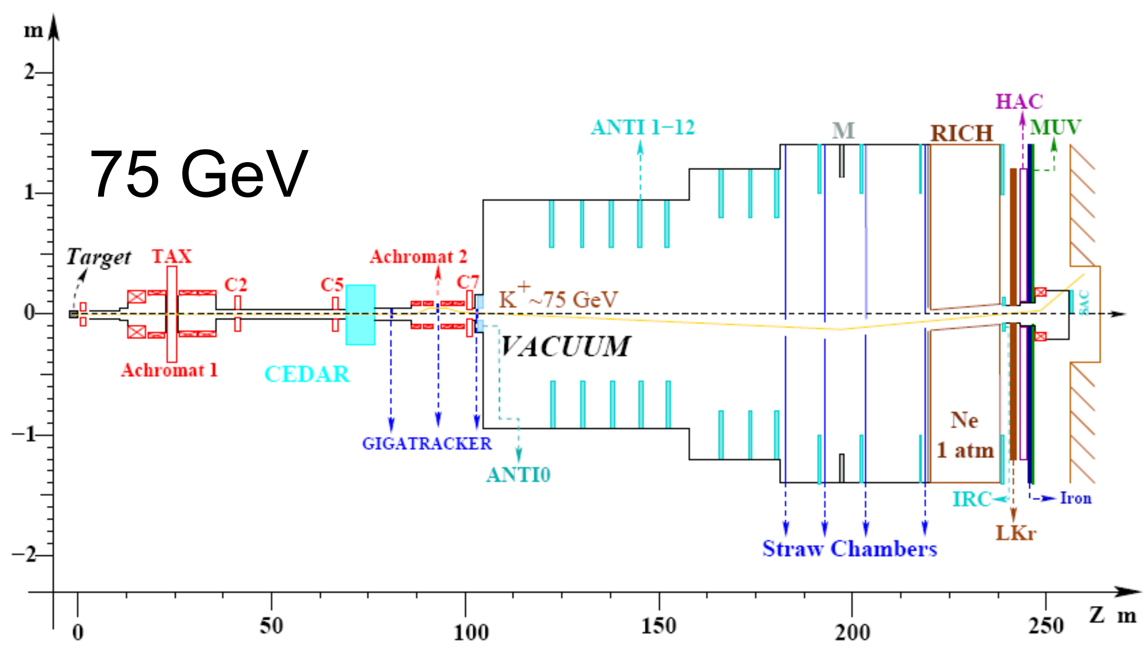
$$B(K^+ \to \pi^+ \nu\bar{\nu}) = 1.73^{+1.15}_{-1.05} x10^{-10}$$

Standard Model:

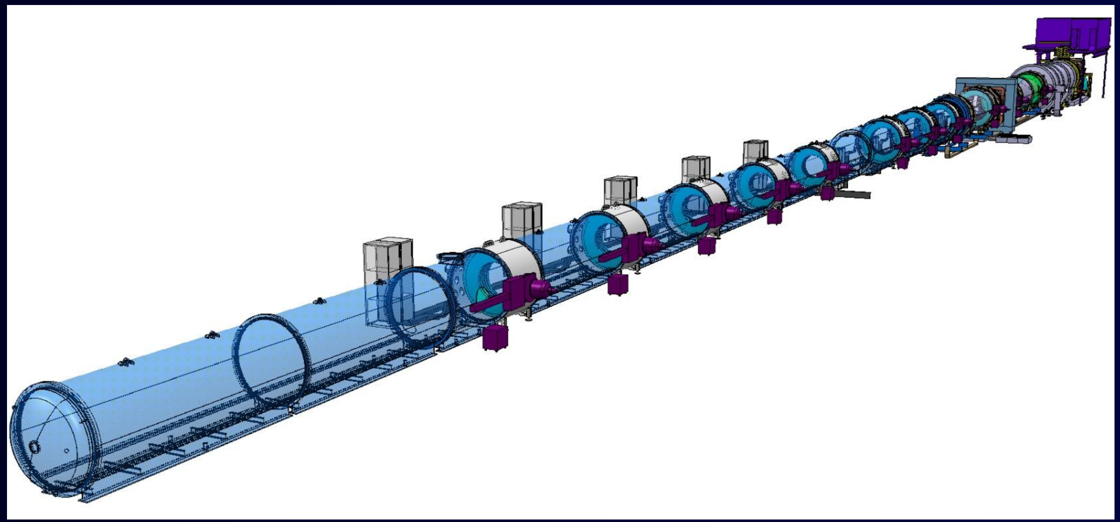
$$B(K^+ \to \pi^+ \nu\bar{\nu}) = (0.85 \pm 0.07) x10^{-10}$$

$K^+ \to \pi^+ \nu\nu$:
NA62 at CERN SPS

CERN NA-62 first generation decay-in-flight experiment.



- Builds on NA-31/NA-48
- Un-separated GHz beam
- Aim: 40-50 events/yr at SM
- Under construction; start >2013



- cherenkov
- Si trackers
- straw chambers
- RICH detector
- liquid Kr calorimeter
- muon veto

- 2007-2008 data

$$\Gamma(K_{e2})/\Gamma(K_{\mu 2})$$

$K^+ \to \pi^+ \nu\nu$: NA62 at CERN SPS talks at TIPP2011

[59] The Large Angle Photon Veto System for the NA62 Experiment at CERN : PALLADINO, Vito
[369] The TDCpix readout ASIC: a 75 ps resolution timing front-end for the Gigatracker of the NA62 experiment : Dr. AGLIERI RINELLA, Gianluca
[9] THE NA62 RICH DETECTOR : PEPE, Monica
[55] Results from the NA62 Gigatracker prototype: a low-mass and sub-ns time resolution silicon pixel detector : Dr. FIORINI, Massimiliano
[108] GPUs for fast triggering in NA62 experiment : LAMANNA, Gianluca MARCO, Sozzi
[135] NA62 spectrometer: a low mass straw tracker : SERGI, Antonino
[389] The CHarged ANTIcounter for the NA62 experiment at CERN : Dr. SARACINO, Giulio

$K_L \rightarrow \pi^o \nu\nu$:
K0TO (E16) at J-PARC

K0TO: use improved KEK E391a ($<2.6 \times 10^{-8}$) detector

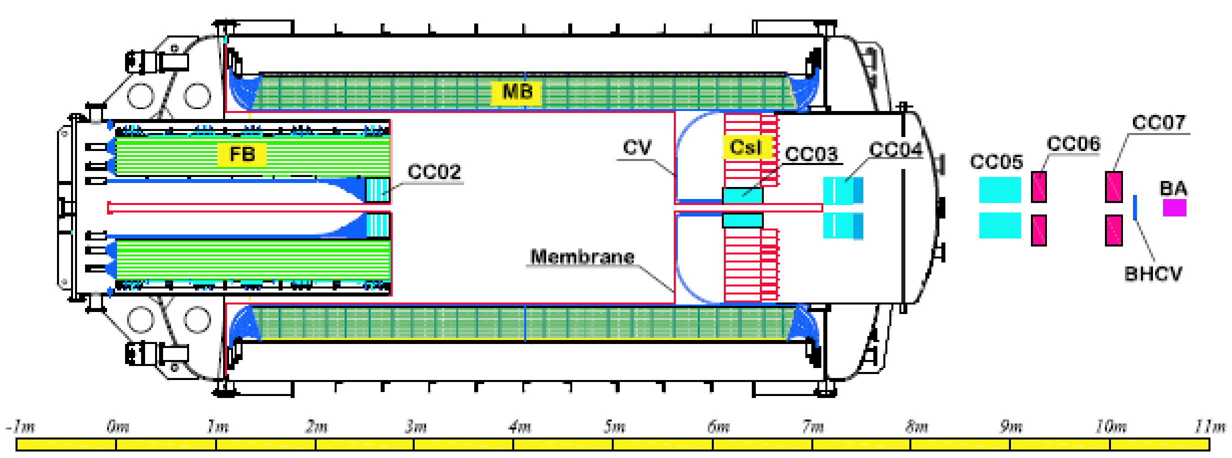
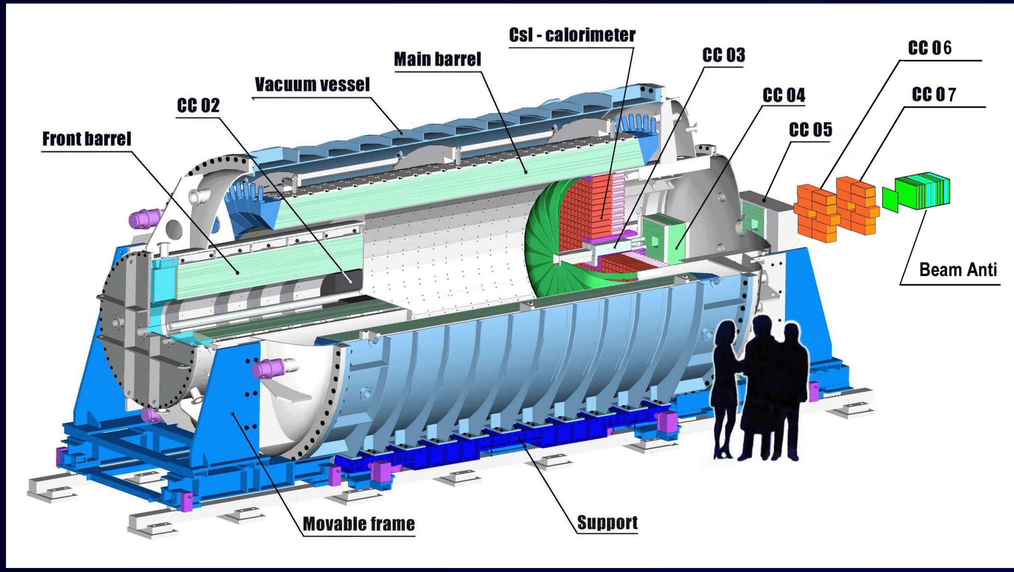


FIG. 1: Cross section of the E391a detector. K_L^0's enter from the left side.

- Improved J-PARC Beam line
- (Eventually) higher power
- Aim: 2.8 events (S/B~1) at SM
- Under construction; start >2011



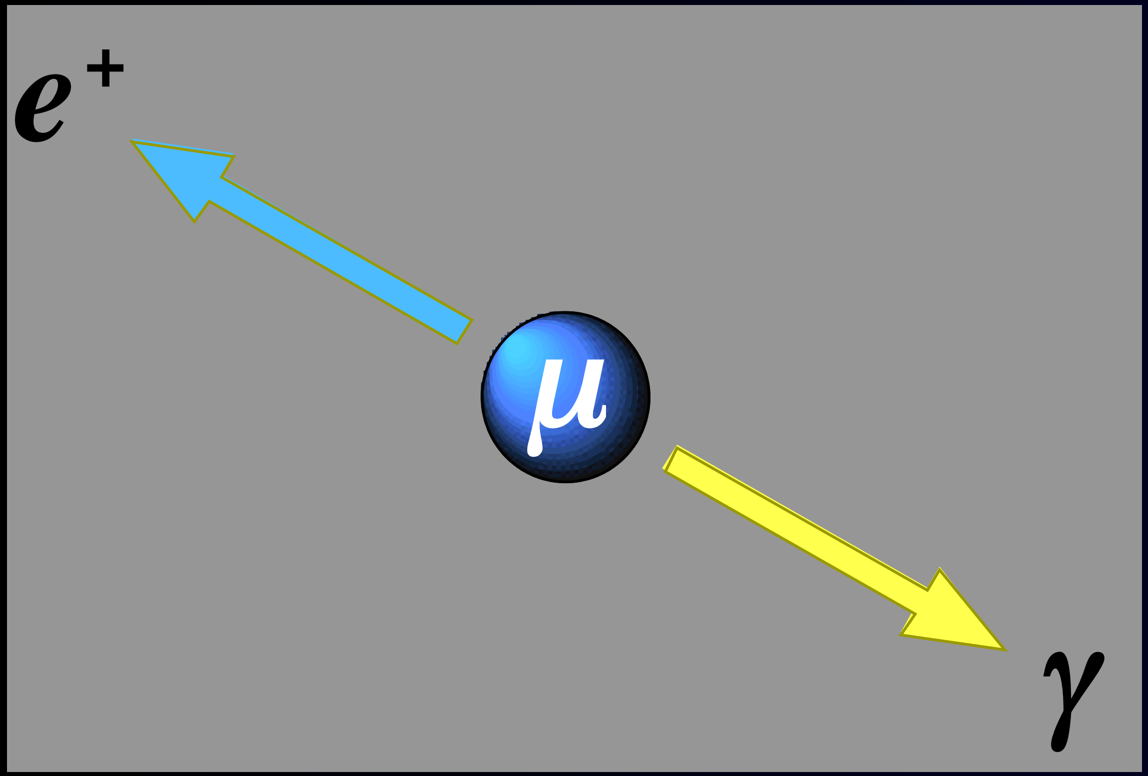
- CsI carolimeter
- photon veto

$K_L \to \pi^o \nu\nu$:
K0TO (E16) at J-PARC talks at TIPP 2011

[132] The Data Acquisition System for the K0TO Detector TECCHIO, Monica

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

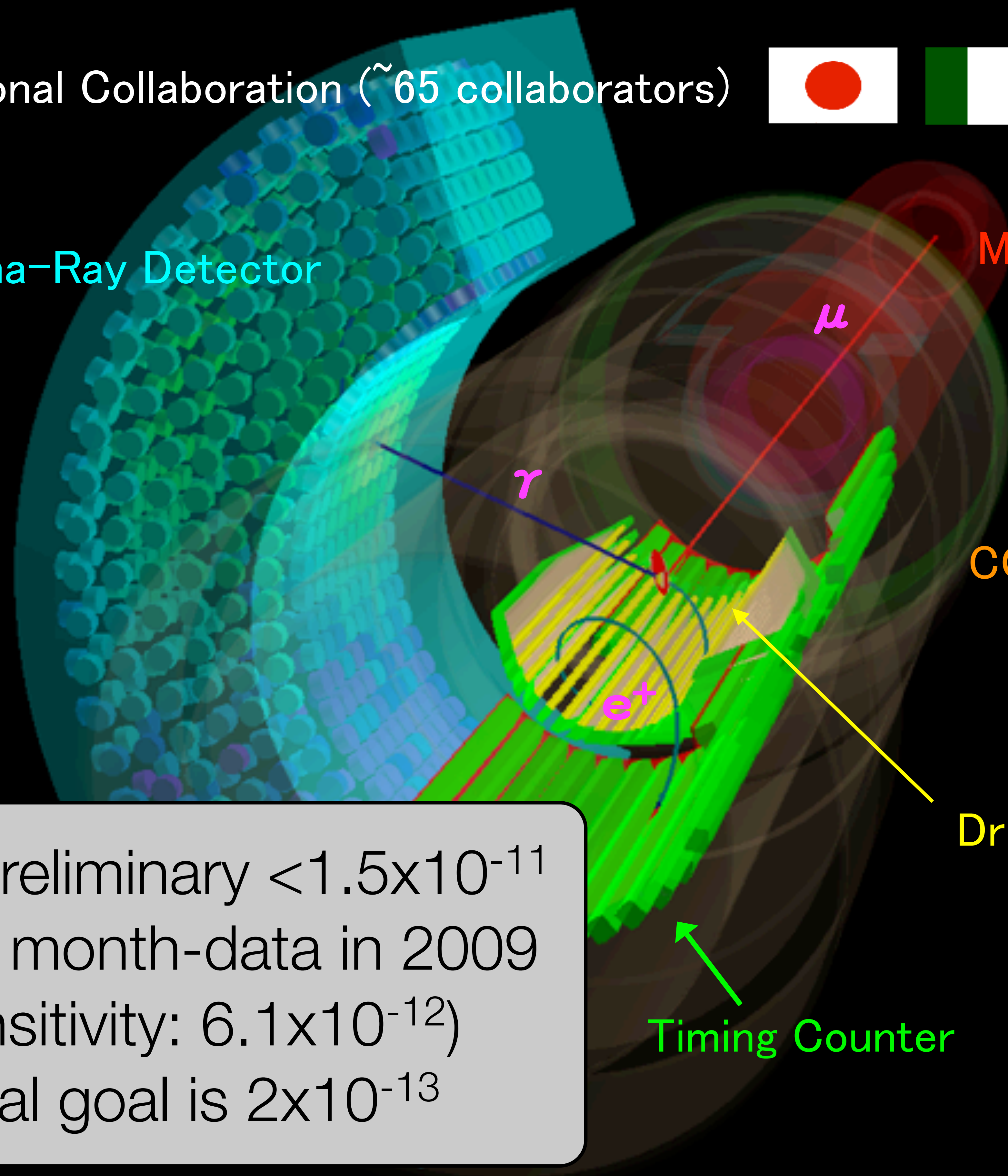
- Event Signature
  - $E_e = m_\mu/2$, $E_\gamma = m_\mu/2$ (=52.8 MeV)
  - angle $\theta_{\mu e}$=180 degrees (back-to-back)
  - time coincidence



- 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.

The MEG Experiment

International Collaboration (~65 collaborators)



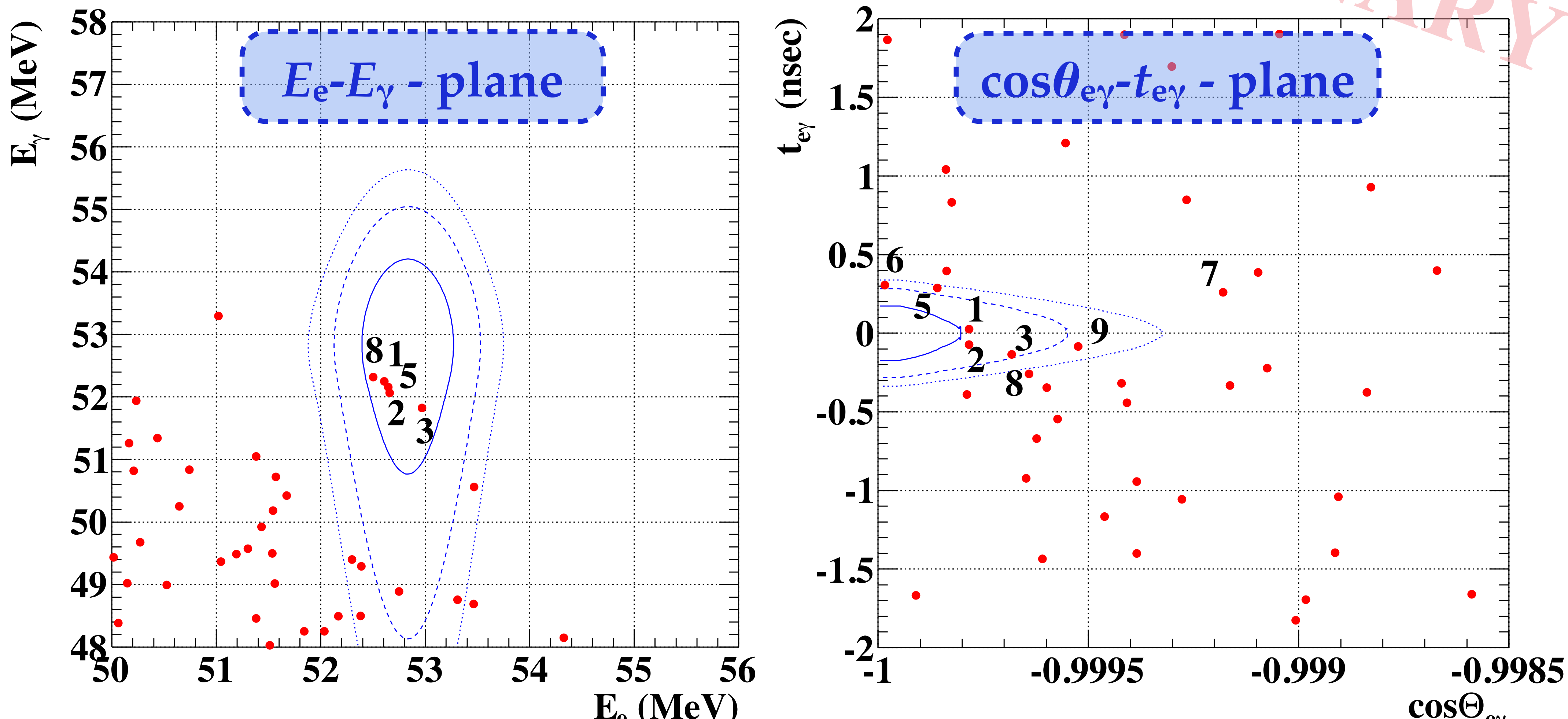
2010 preliminary <1.5×10^{-11}
from 2 month-data in 2009
(sensitivity: 6.1×10^{-12})
Final goal is 2×10^{-13}

Smoking from MEG 2010 Results (preliminary)

Event Distribution

PRELIMINARY

We opened the blind box on 06/July/2010



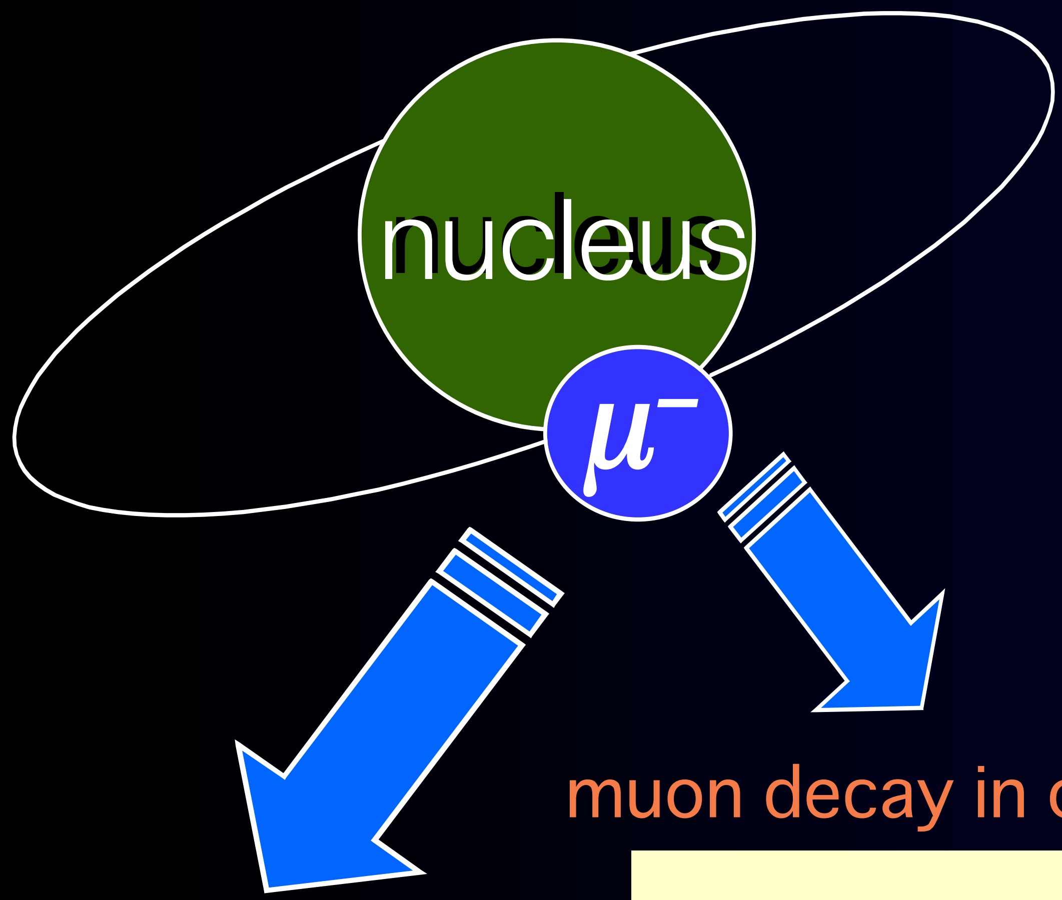
- Contours of the PDFs (**1σ, 1.64σ** & **2σ**) are shown
- Same events in two plots are numbered correspondingly, by decreasing ranking in terms of relative signal likelihood ($S(R+B)$)

$\mu \rightarrow e\gamma$:
MEG at PSI talks at TIPP 2011

[287] Liquid xenon gamma-ray calorimeter for the MEG experiment : Dr. IWAMOTO, Toshiyuki

Muon to Electron Conversion

1s state in a muonic atom



muon decay in orbit

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

nuclear muon capture

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

μ-e conversion

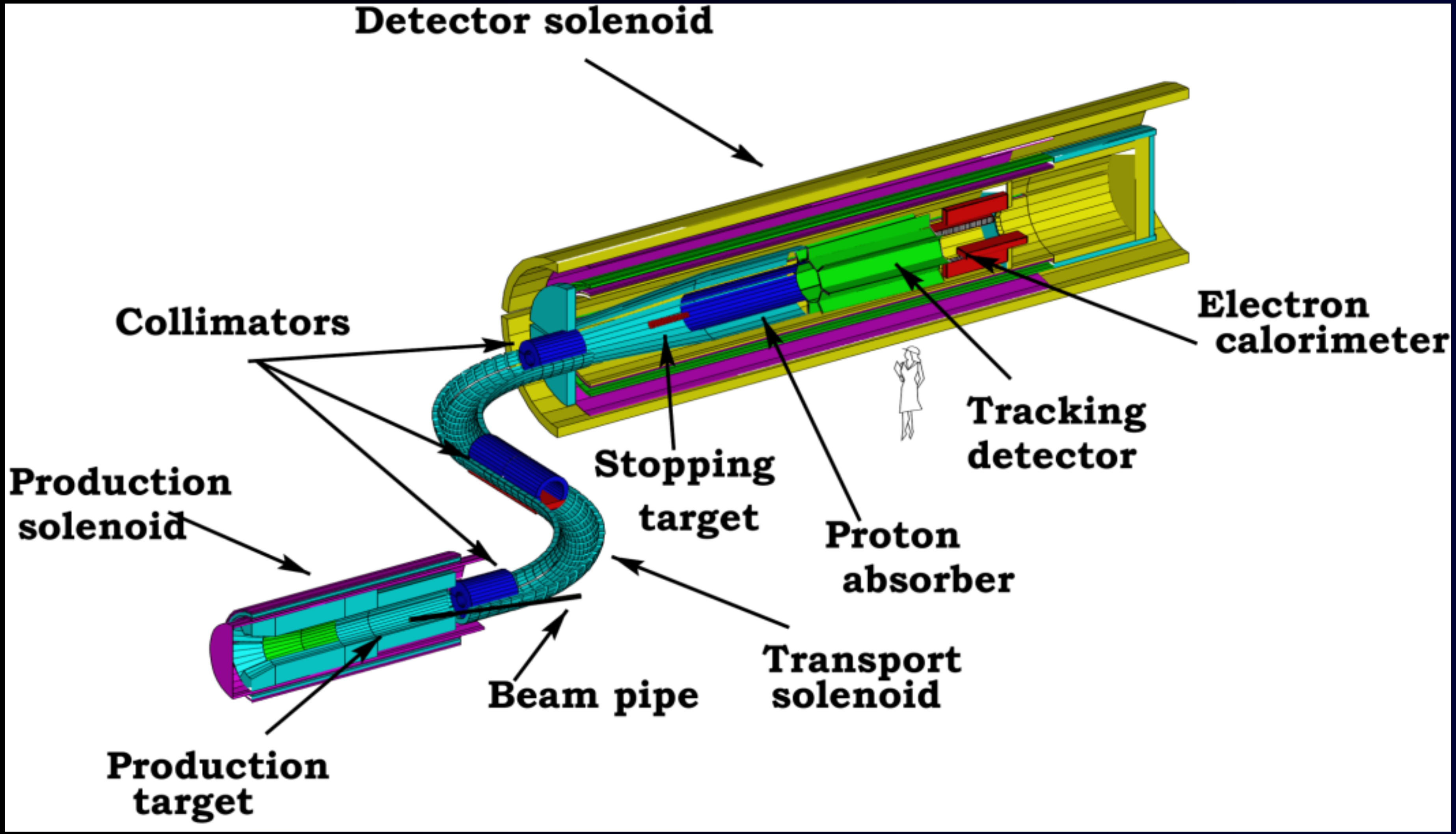
$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

lepton flavors changes by one unit.

Signal is a single mono-energetic electron

$$m_\mu - B_\mu \sim 105 MeV$$

μ-e conversion : Mu2e at Fermilab



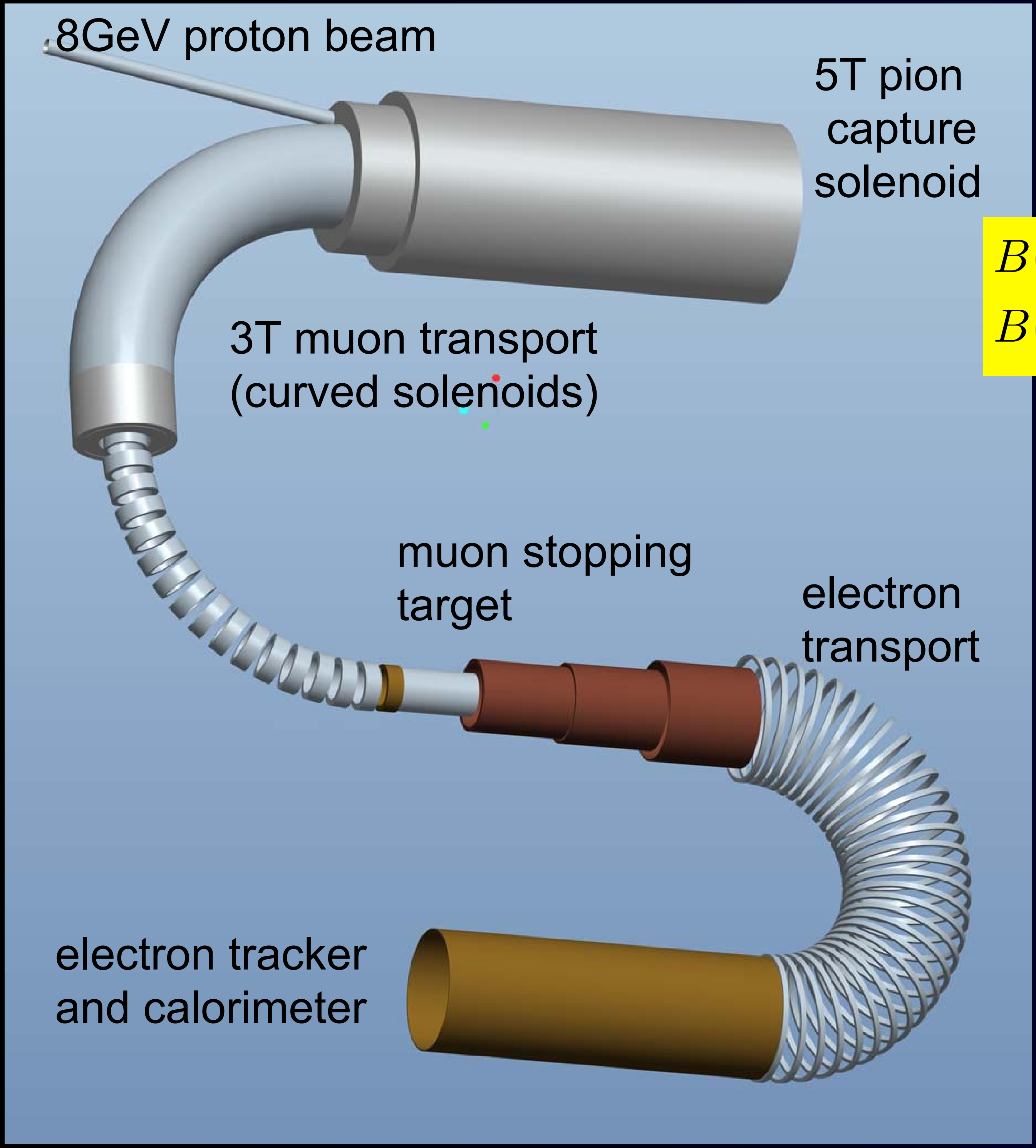
$$B(\mu^- + Al \to e^- + Al) = 2.6 \times 10^{-17}$$
$$B(\mu^- + Al \to e^- + Al) < 6 \times 10^{-17} \quad (90\% C.L.)$$

- Reincarnation of MECO at BNL.
- Antiproton buncher and accumulator rings are used to produce a pulsed proton beam.
- Approved in 2009, and CD0 in 2009.

μ-e Conversion : Mu2e at FNAL talks at TIPP 2011

[127] R Effort for Plastic Scintillator Based Cosmic Ray Veto System for the Mu2e : Dr. OKSUZIAN, Yuri

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.

How to Do Rare Decay Experiments?

Important Considerations in Experiment Design

Important Considerations in Experiment Design

1 Redundancy

Important Considerations in Experiment Design

1 Redundancy

2 Redundancy

Important Considerations in Experiment Design

1. Redundancy
2. Redundancy
3. Redundancy

Important Considerations in Experiment Design

1 Redundancy

2 Redundancy

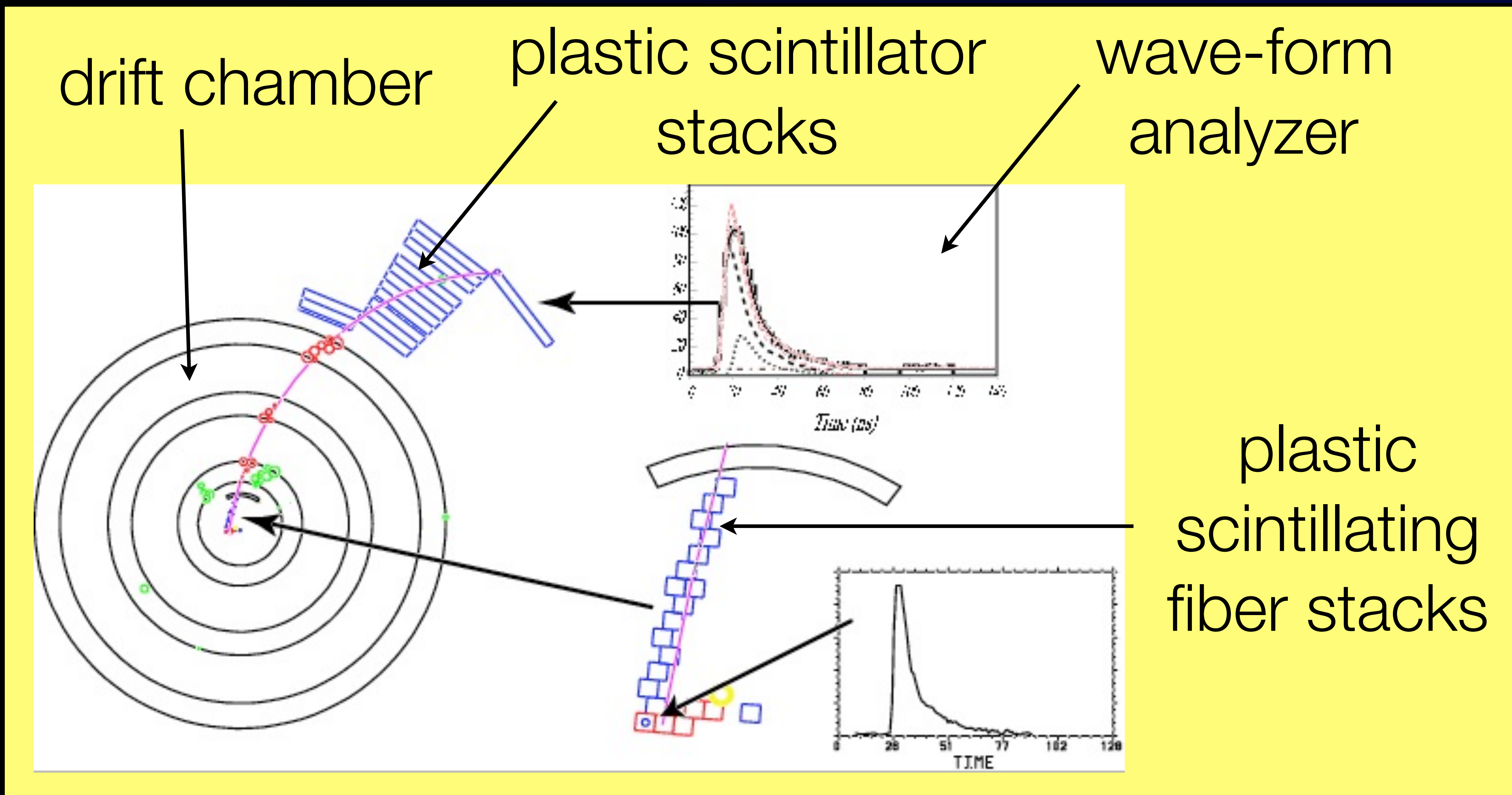
3 Redundancy

Redundancy only gives confidence to discriminate signals from backgrounds.

Ambiguous hits, accidental hits, dead channels, reconstruction of ghost tracks.

Example : E787/E949

measure momentum, energy, range of pions, and pion decay by wave-form digitizers

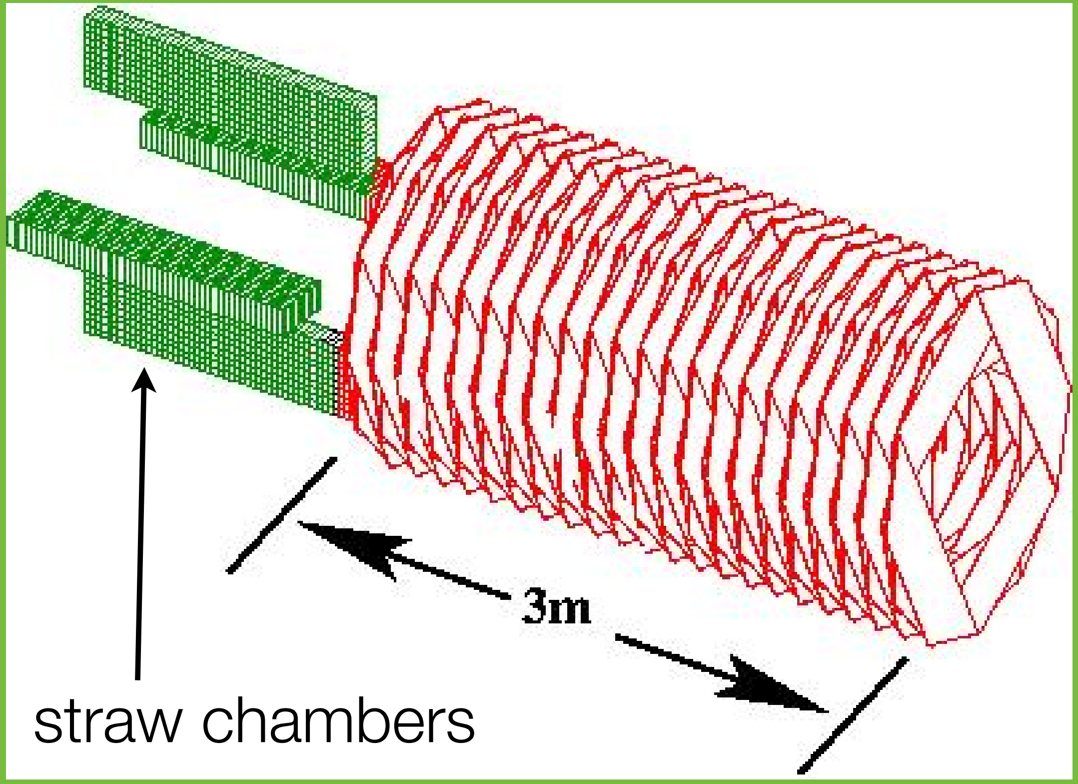


Considerations for Detectors (1)

To improve signal sensitivity, the number of parent particles (i.e. beam intensity) has to be increased.

1 High rate capability

example: rate for μ-e conversion experiments



With 10^{11}/s stops, the rate of straw chambers is about 6 MHz per wire at prompt, and 180 kHz per wire after 700 nsec (measurement window).

Considerations for Detectors (2)

2 Accidental Backgrounds

example. accidental backgrounds for $\mu \rightarrow e\gamma$

$$\text{Accidental Background} \propto \left(R_\mu\right)^2 \times \Delta E_e \times \left(\Delta E_\gamma\right)^2 \times \Delta t_{e\gamma} \times \left(\Delta\theta_{e\gamma}\right)^2$$

Place	Year	ΔE_e	ΔE_γ	$\Delta t_{e\gamma}$	$\Delta\theta_{e\gamma}$	Upper limit
TRIUMF	1977	10%	8.7%	6.7ns	–	$< 3.6 \times 10^{-9}$
SIN	1980	8.7%	9.3%	1.4ns	–	$< 1.0 \times 10^{-9}$
LANL	1982	8.8%	8%	1.9ns	37mrad	$< 1.7 \times 10^{-10}$
LANL	1988	8%	8%	1.8ns	87mrad	$< 4.9 \times 10^{-11}$
LANL	1999	1.2%	4.5%	1.6ns	15mrad	$< 1.2 \times 10^{-11}$
PSI (MEG)	2007	0.9%	5 %	0.1 ns	23mrad	$< 10^{-13}$

Improvements of detector resolutions are critical.

MEG Detector Resolutions

	2008	2009 (PRELIMINARY)
γ Energy σE_γ (%)	2.0 (depth>2cm)	2.1 (depth>2cm)
γ Timing σt_γ (ps)	80	>67
γ Position σx_γ (mm)	5/6	5/6
γ Efficiency ε_γ (%)	63	58
e^+ Mom. σp_e (%)	1.6	0.74
e^+ Timing σt_e (ps)	<125	<125
e^+ Angle $\sigma \theta_e$ (mrad)	10(ϕ)/18(θ)	7.4(ϕ)/11.2(θ)
e^+ Efficiency ε_e (%)	14	40
γ-e^+ Relative Timing	148	142
μ^+ decay vertex (mm)	3.2/4.5	2.3/2.8
Trigger Efficiency (%)	66	84
μ^+ Stopping Rate (Hz)	3×10^7	2.8×10^7
DAQ Time (days)	48	35
Sensitivity	1.3×10^{-11}	**coming soon**
BR Upper Limit	2.8×10^{-11}	**coming soon**

Because of accidental backgrounds, the full PSI beam of 10^8/s intensity cannot be taken yet.

To avoid accidental backgrounds at all,

try....

a single particle measurement,
such as μ-e conversion
($\mu^- N \to e^- N$)

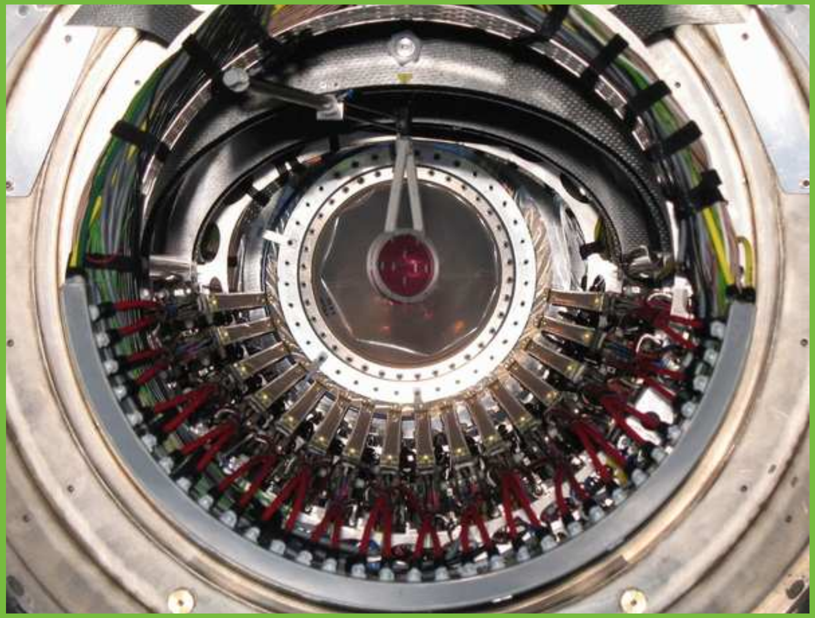
Considerations in Detectors (3)

3 Low energy detection

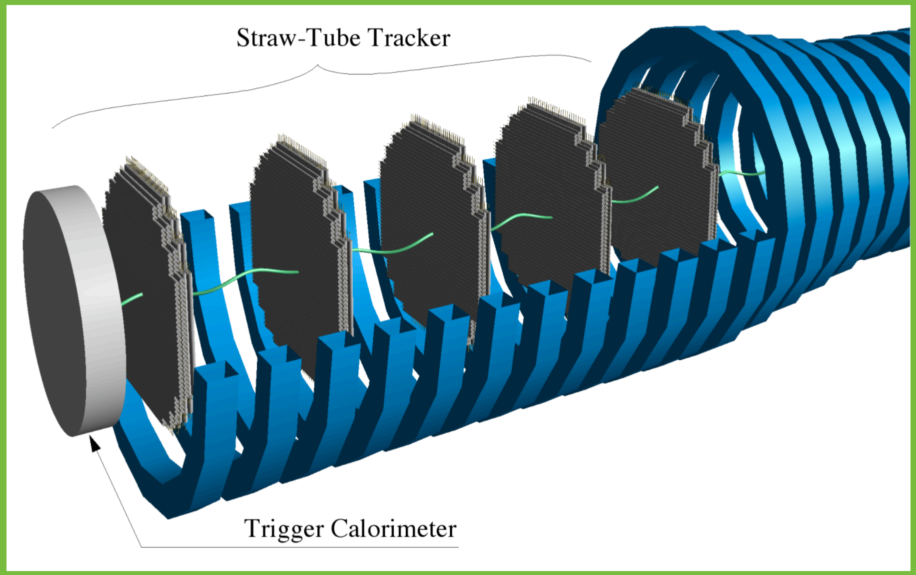
In rare decay experiments using muon and kaon decay at rest, decay products are all in low energy of O(10-100 MeV).

Trackers should be low-mass and be placed in vacuum.

thin chamber for MEG



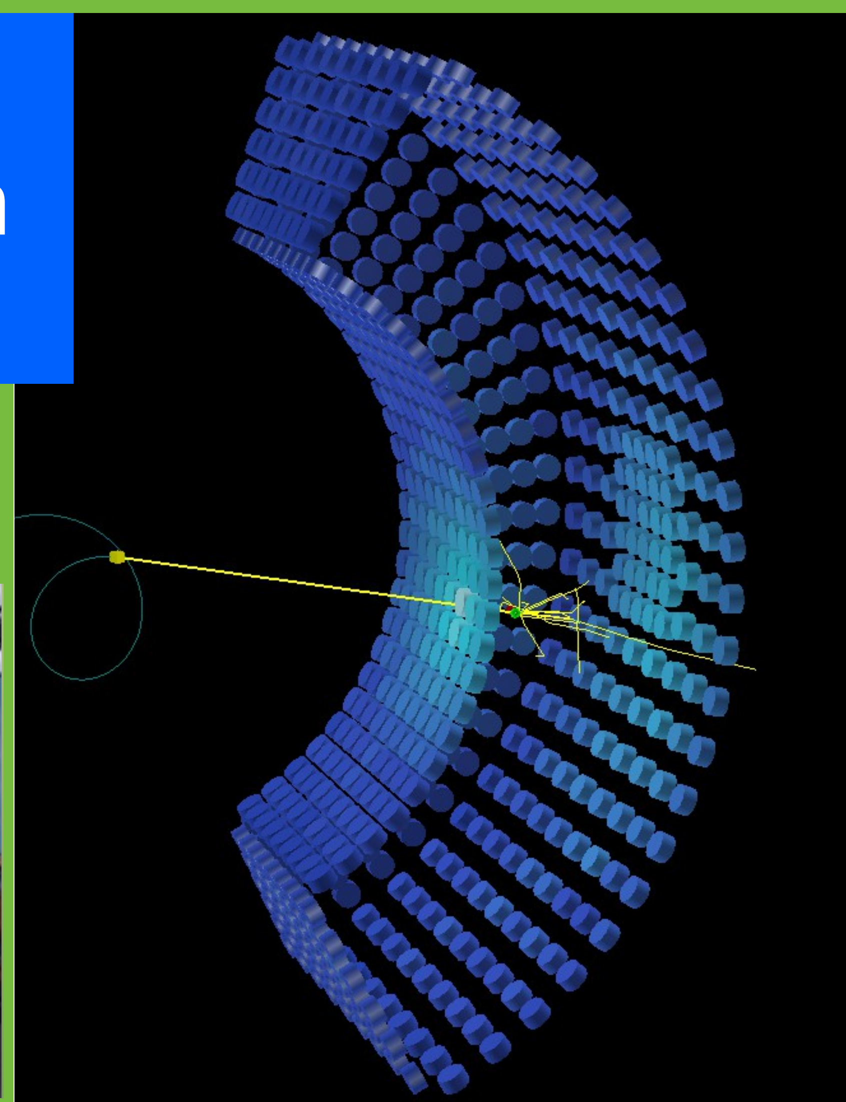
thin straw chambers in vacuum for COMET and Mu2e



Considerations in Detectors (3)

3 Low energy detection

Photon detector should have high light yields.



Liquid Xenon scintillation detector at MEG

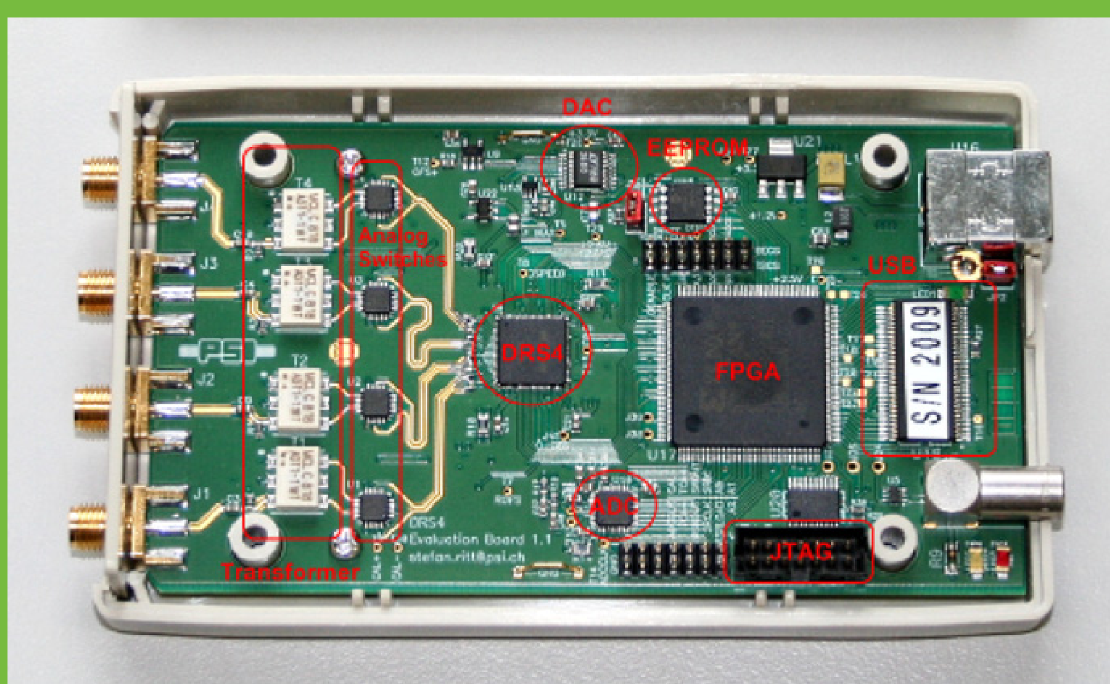
- 800 *litter* volume
- 846 PMT readout
- energy resolution
  - 2% at 52.8 MeV
- position resolution
  - 5-6mm at 52.8 MeV
- timing resolution
  - 70 ps at 52.8 MeV

Considerations in Detectors (3)

4 **Pile up rejection**

Wave form recording with high sampling rates is needed.

Example :
switched capacitor arrays (SCA) called DRS
(Domino Ring Sample) developed at PSI for MEG



DRS4
9 Giga-samples per second
depth 1024-8192
signal to noise : 11 bits

example : E787/E949 500 MHz
wave-form digitizers

Beams for
Rare Decay Experiments

Increase of Secondary Beam Intensity....

Increase of Secondary Beam Intensity....

1 Increase proton intensity

A number of secondaries is proportional to proton beam power.

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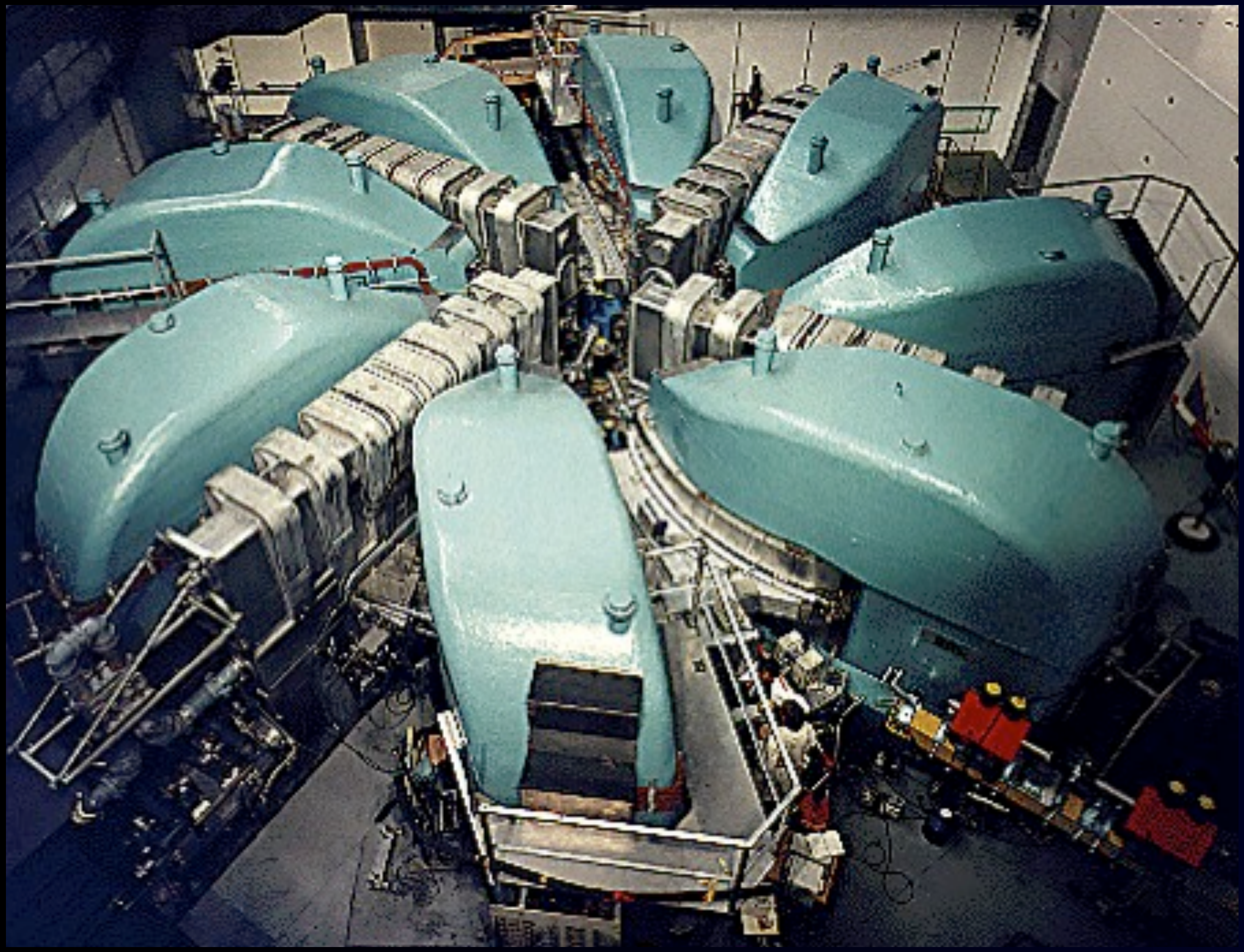
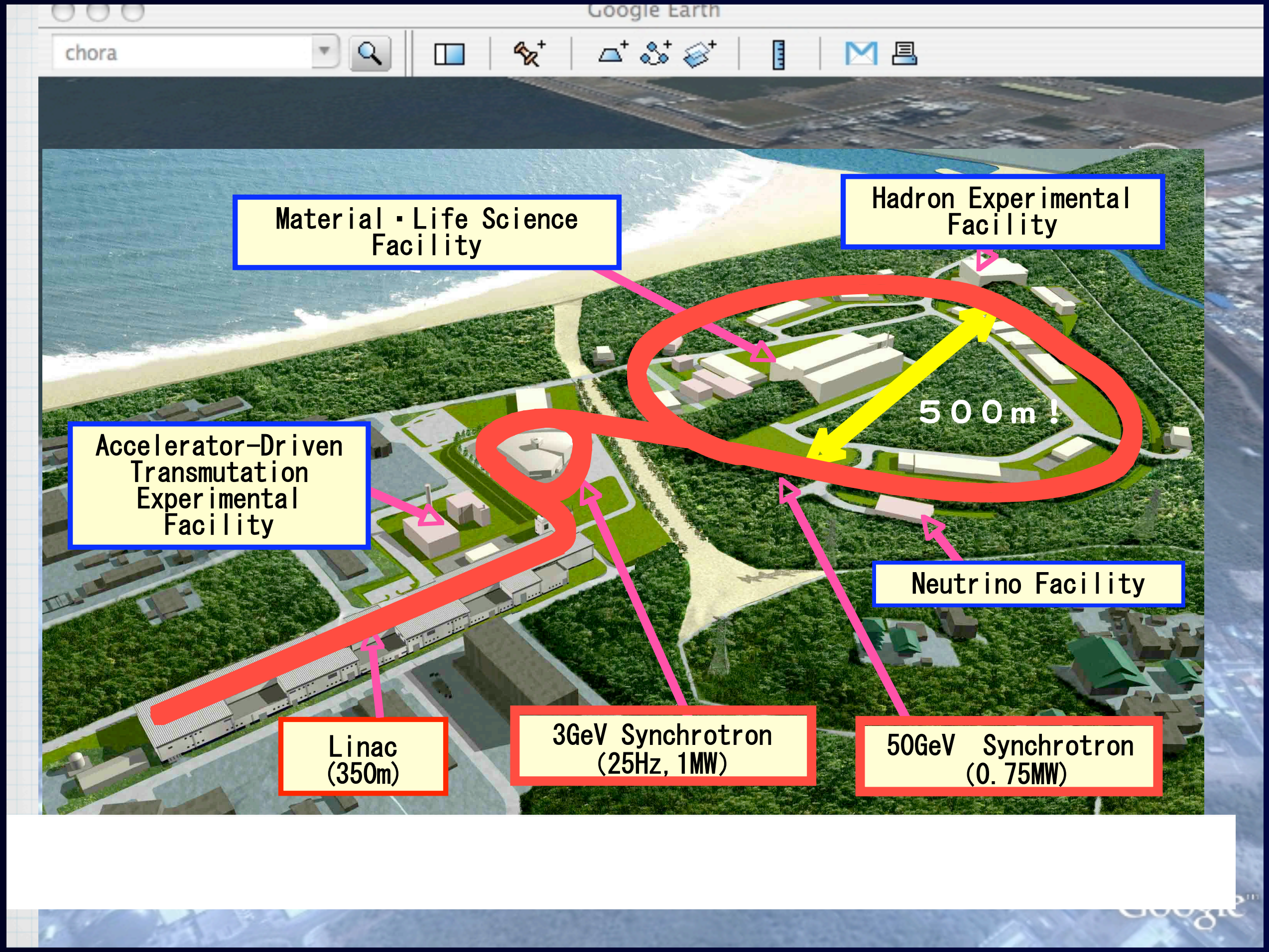
A number of secondaries is proportional to proton beam power.



PSI :
beam power ~ 1.2 MW



J-PARC :
goal beam power ~ 0.75 MW

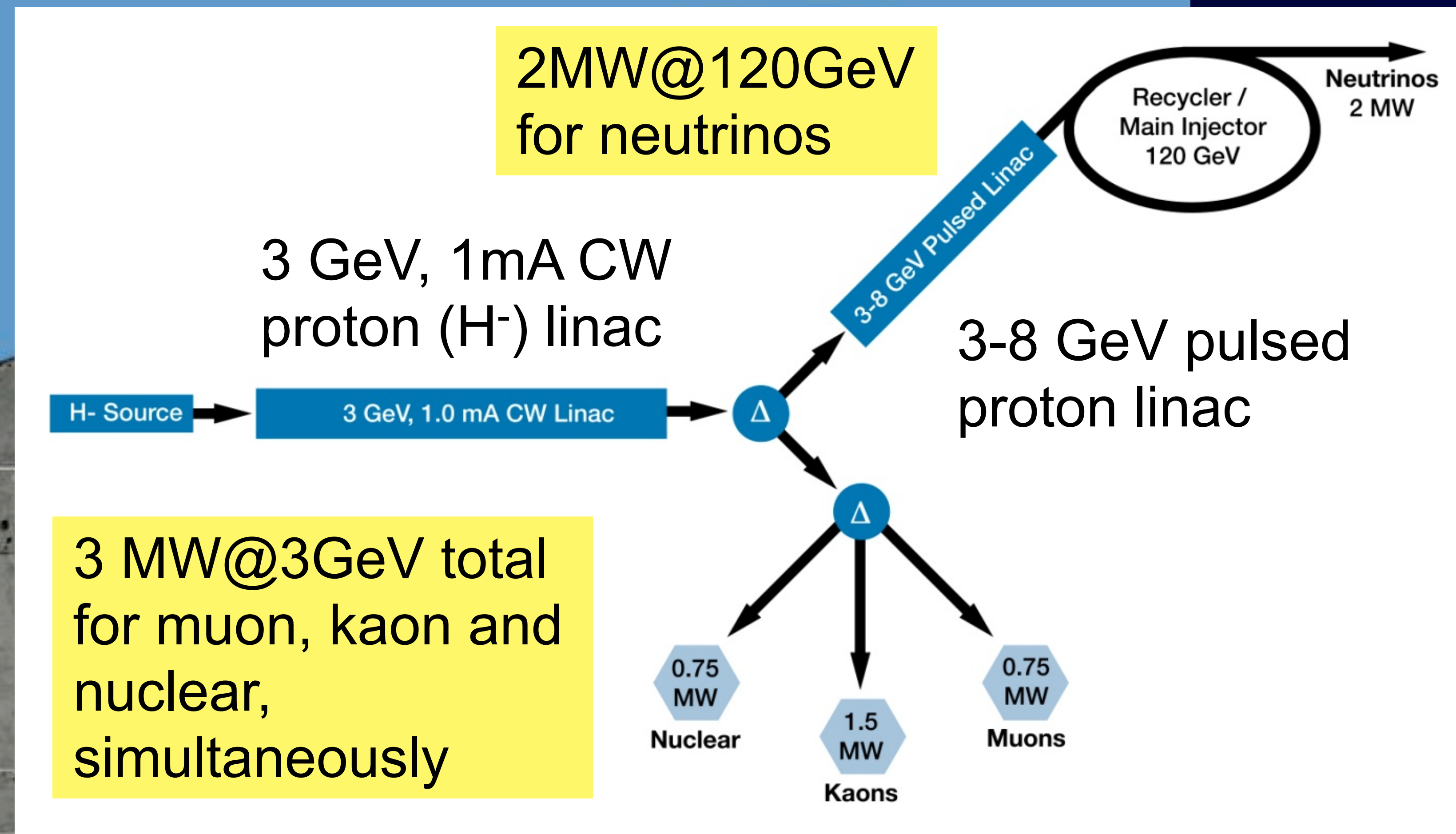
Project X at Fermilab

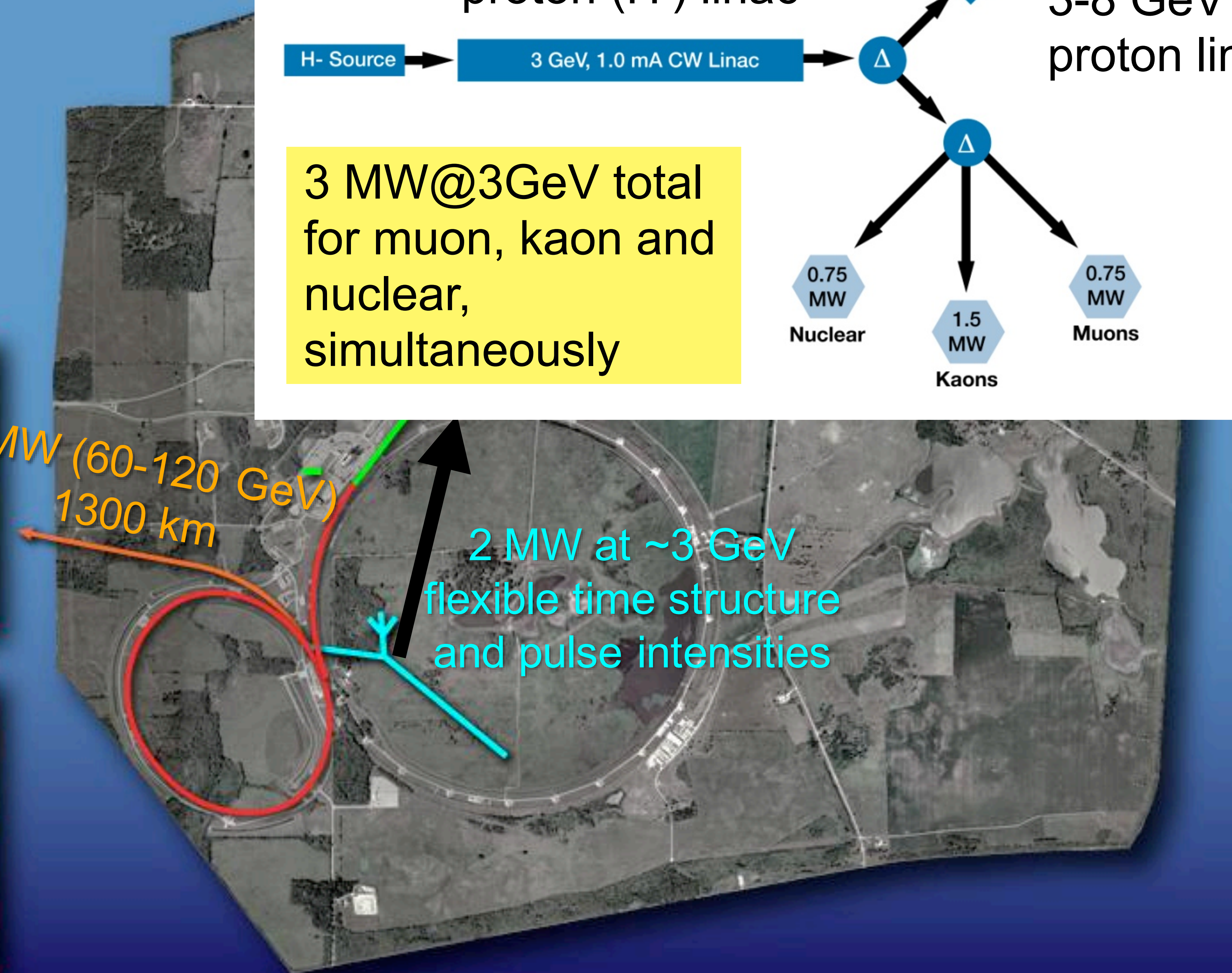
After Tevatron shutdown

Project X

Neutrino physics
Muon physics
Kaon physics
Nuclear physics

"simultaneouly"





Project X at Fermilab

After Tevatron shutdown

<u>Project X</u>

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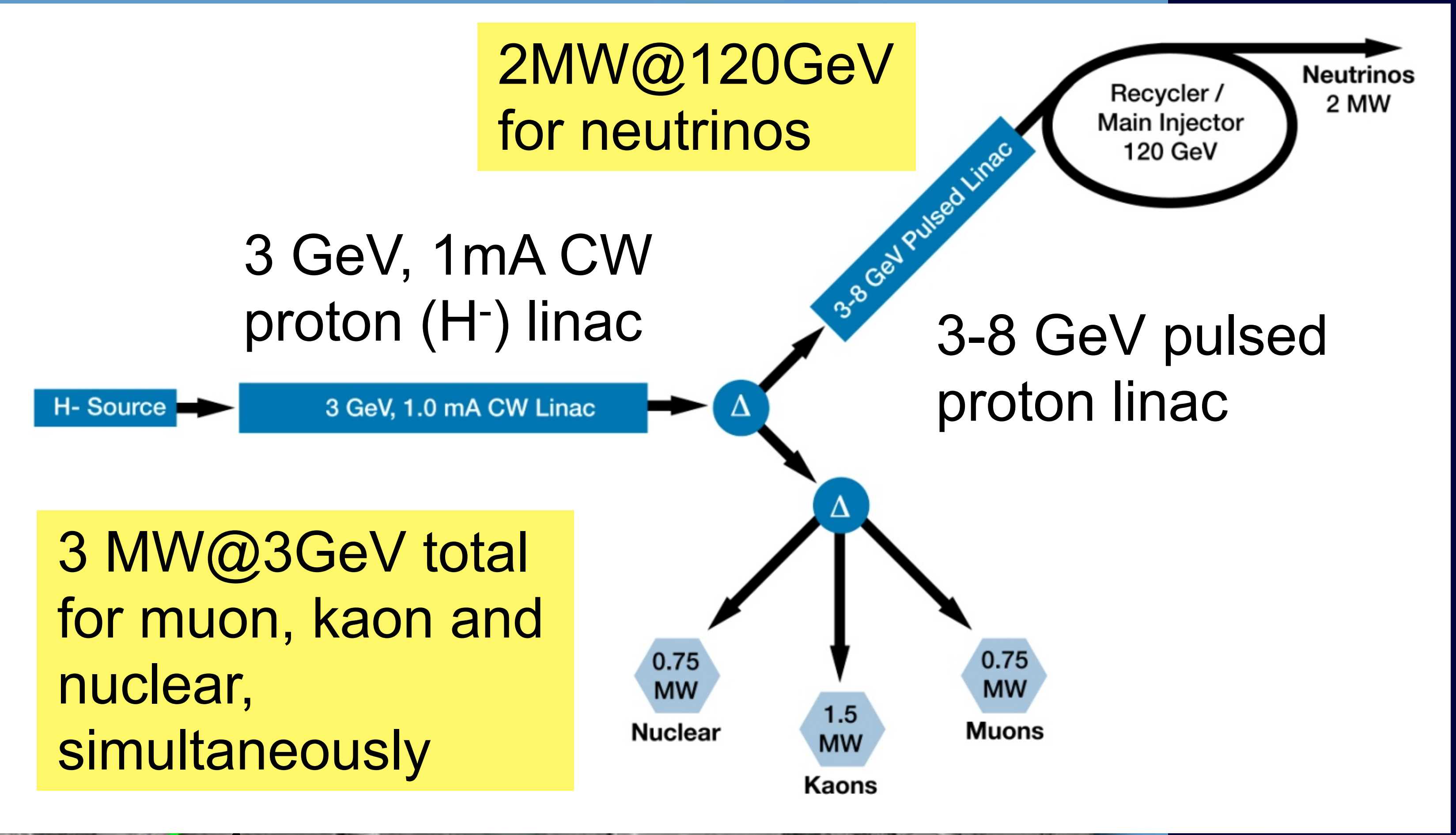
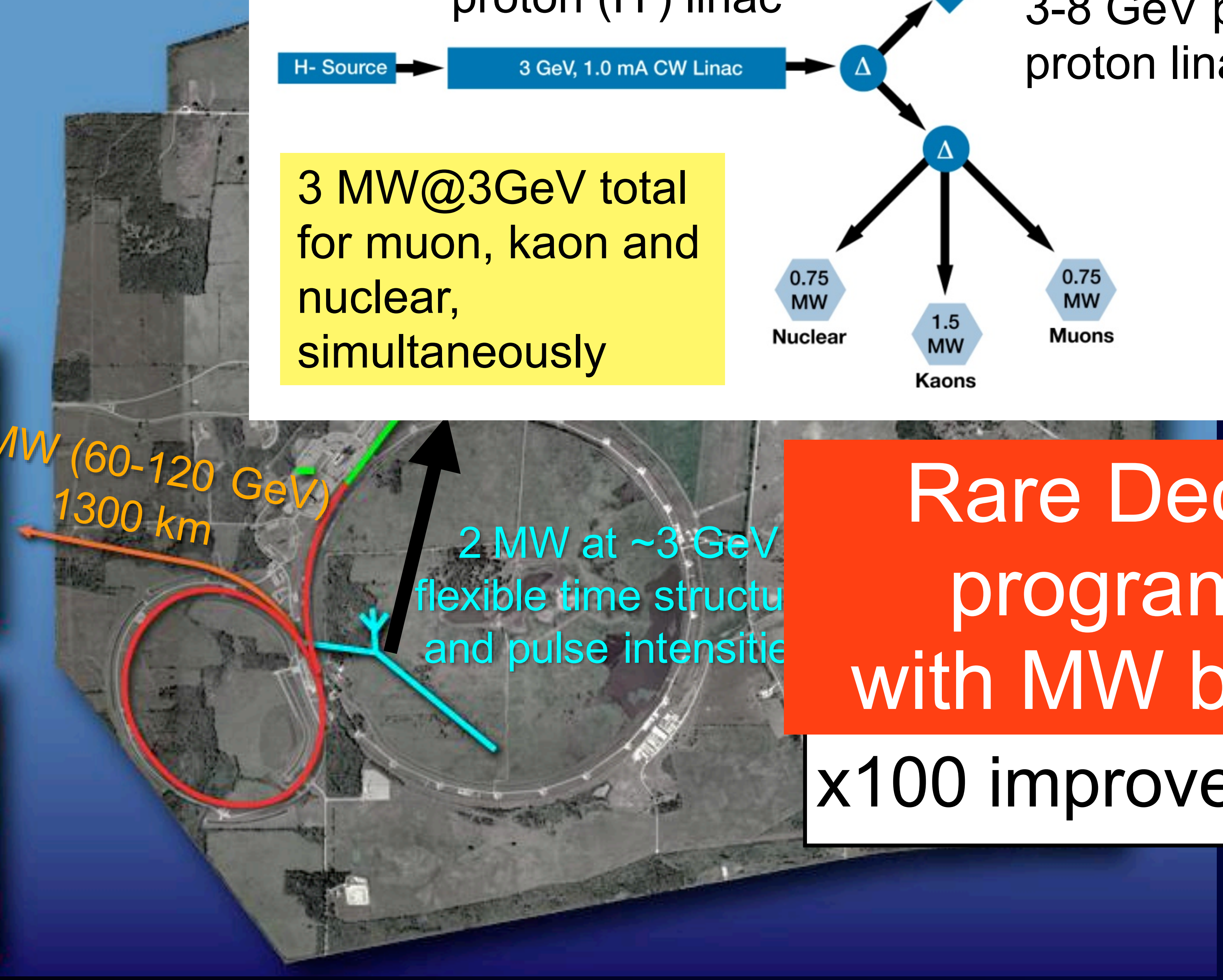
Muon physics
Kaon physics
Nuclear physics

"simultaneouly"





Rare Decay programs with MW beam

x100 improvements

Project X at Fermilab

After Tevatron shutdown

Project X

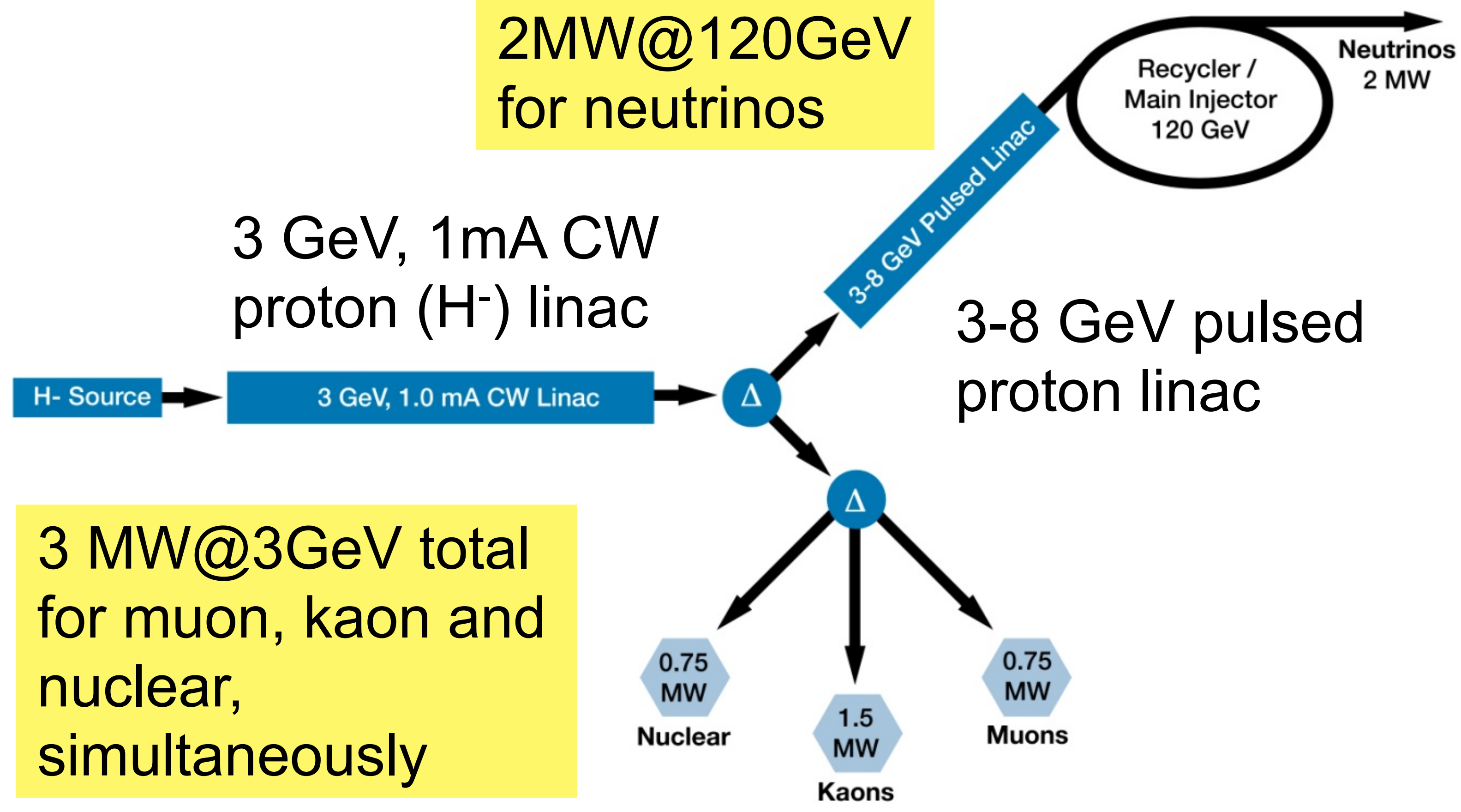
Neutrino physics
Muon physics
Kaon physics
Nuclear physics

“simultaneouly”

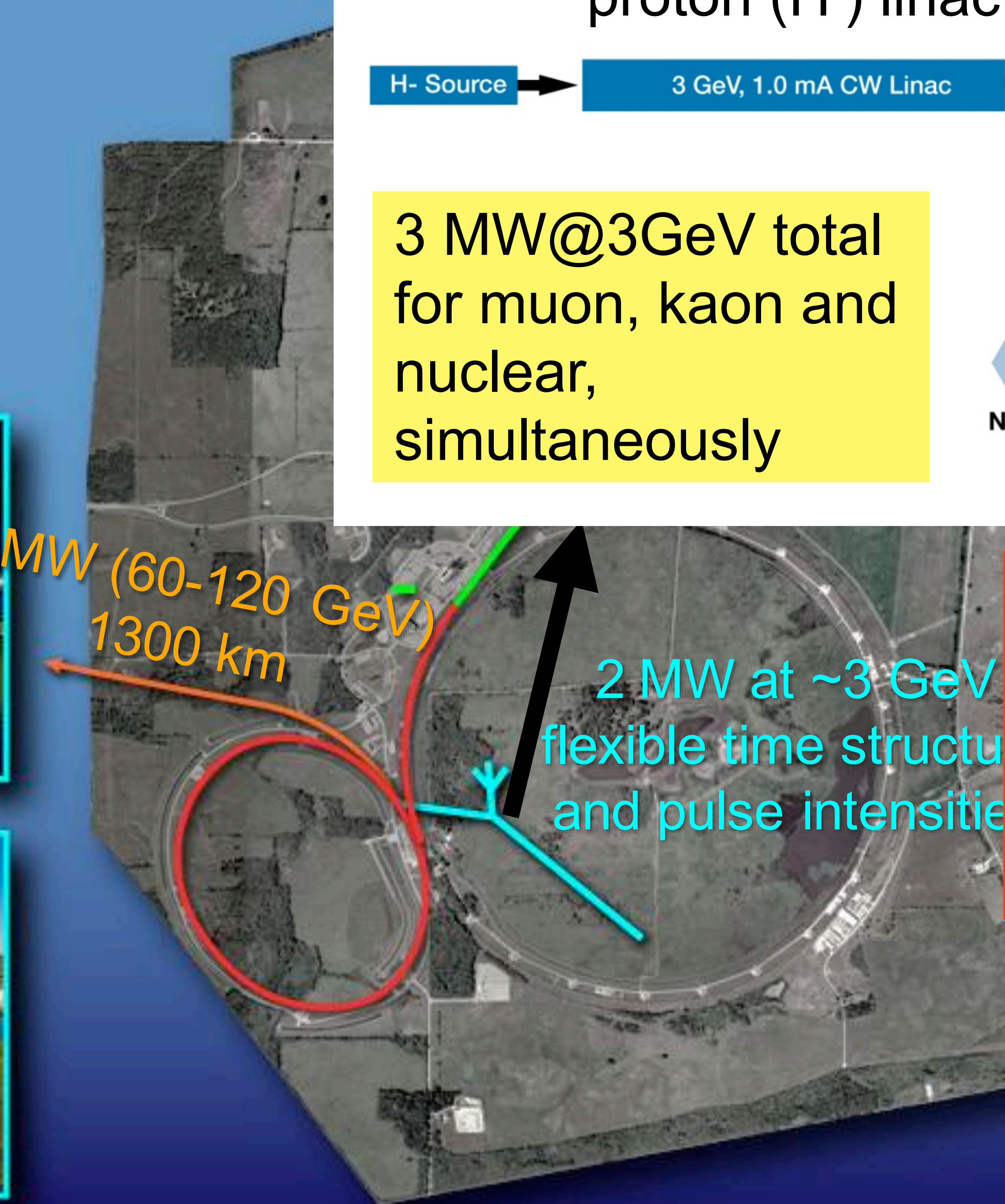
2MW@120GeV
for neutrinos

3 GeV, 1mA CW
proton (H^-) linac

3-8 GeV pulsed
proton linac



3 MW@3GeV total
for muon, kaon and
nuclear,
simultaneously



Rare Decay
programs
with MW beam

x100 improvements

aim to start in 2019

Increase of Secondary Beam Intensity.....

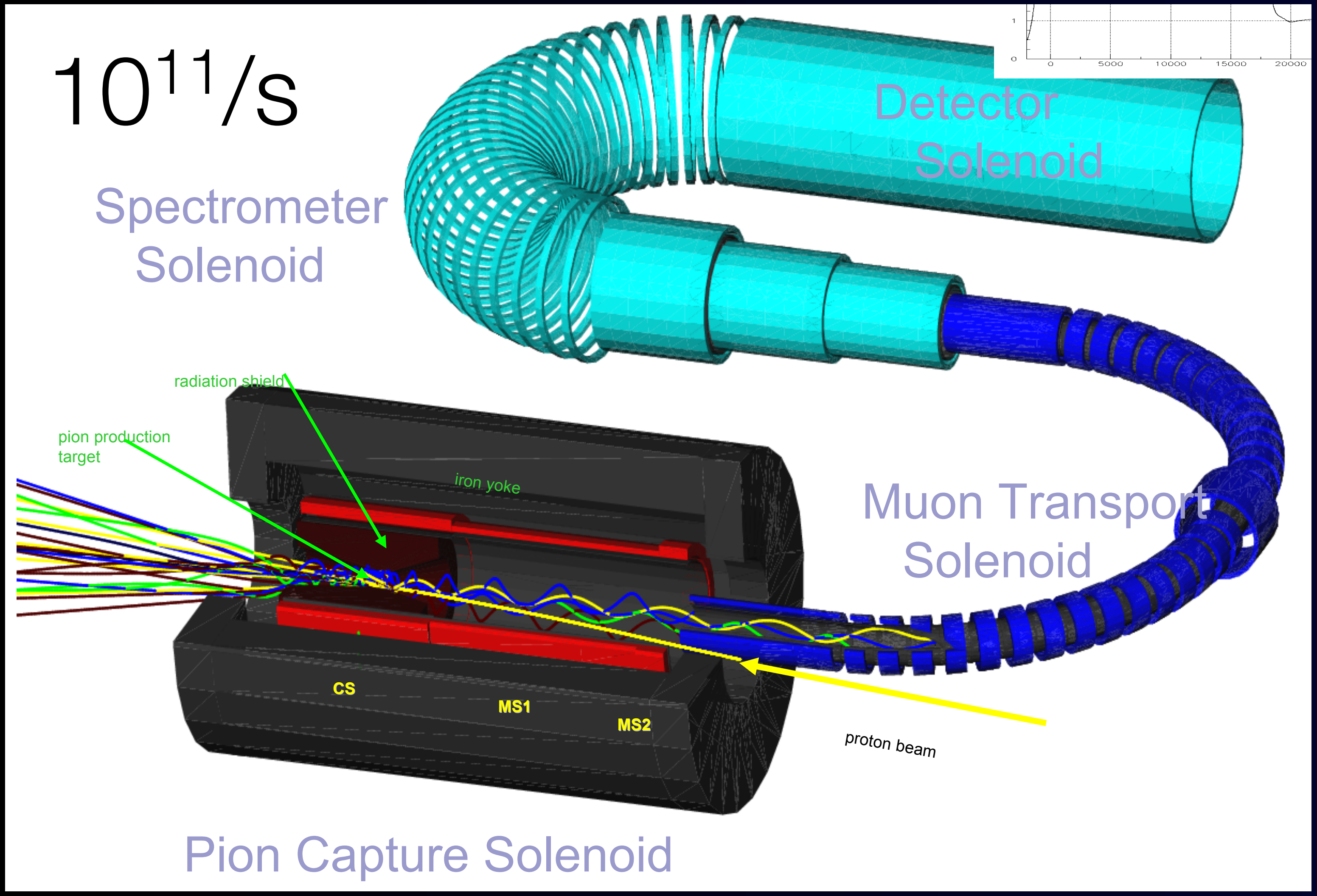
Increase of Secondary Beam Intensity.....

2 Increase collection efficiency of secondaries

Increase of Secondary Beam Intensity.....

2 Increase collection efficiency of secondaries

ex. a muon beam line for μ-e conversion experiments



The pion production target is surrounded by superconducting solenoid magnets of a high magnetic field.

For 50 kW beam power, 10^{11}/sec, (in contrast to 10^{8} /sec for 1.2 MW)

Increase of Secondary Beam Intensity.....

2 Increase collection efficiency of secondaries

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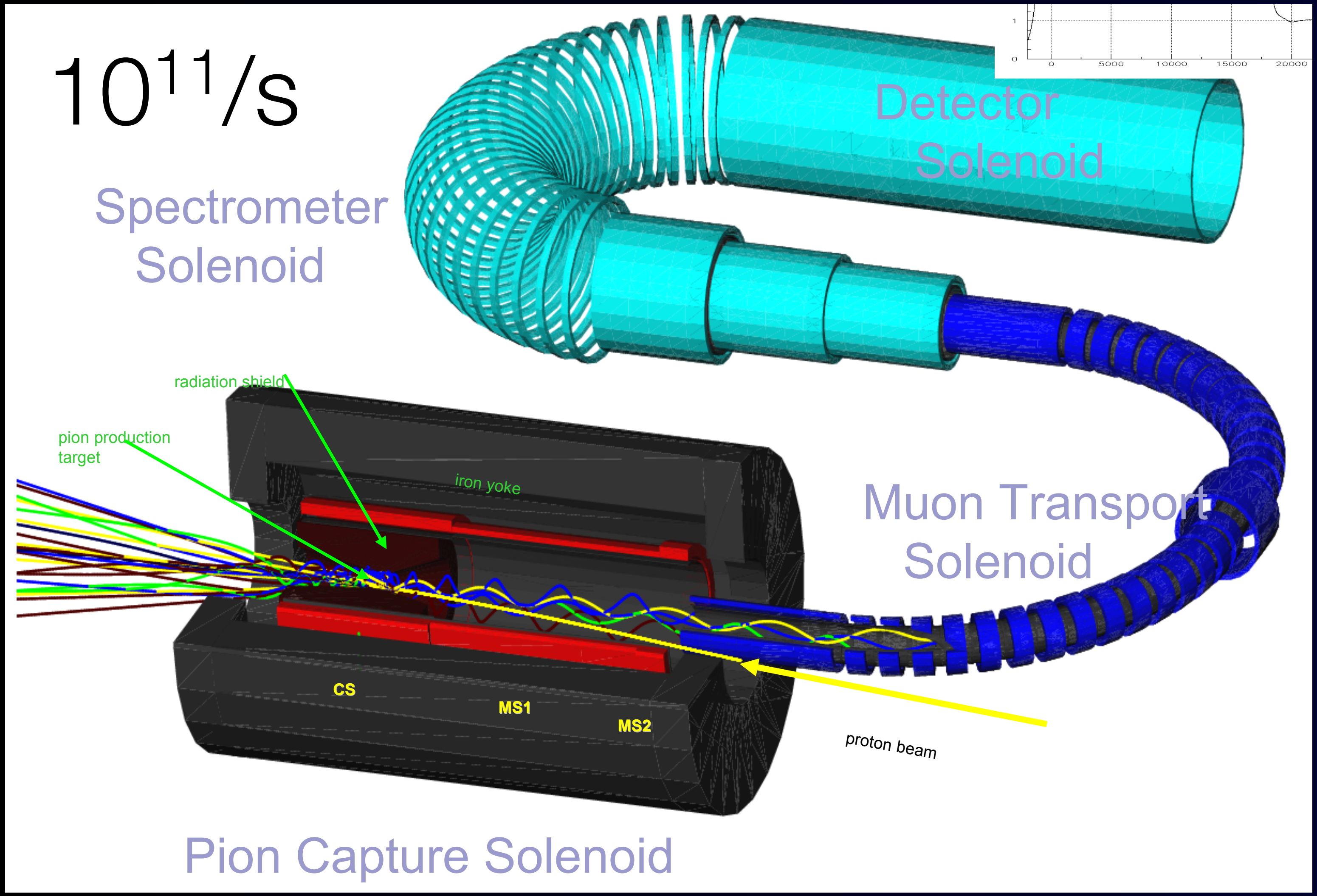
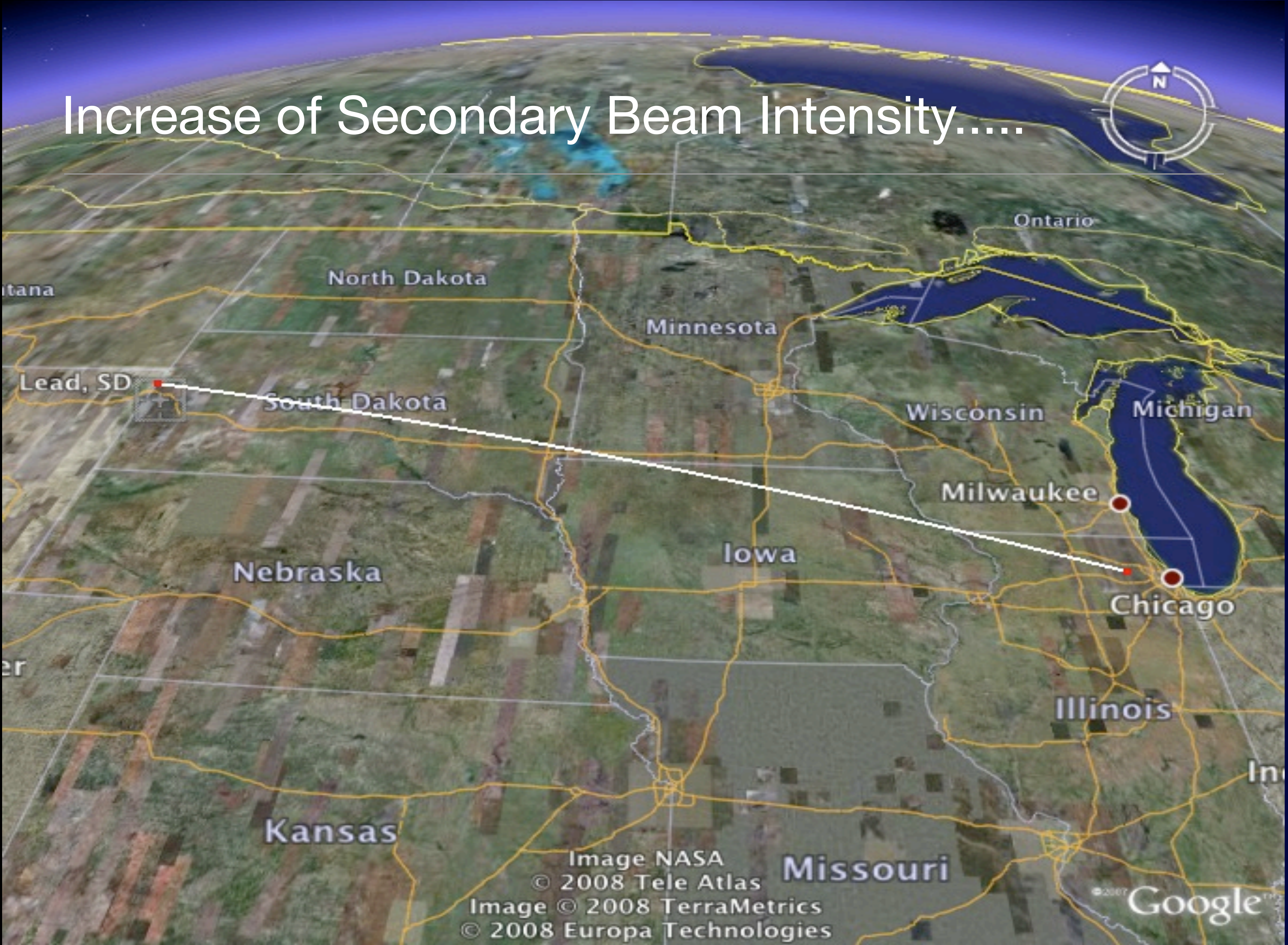


The pion production target is surrounded by superconducting solenoid magnets of a high magnetic field.

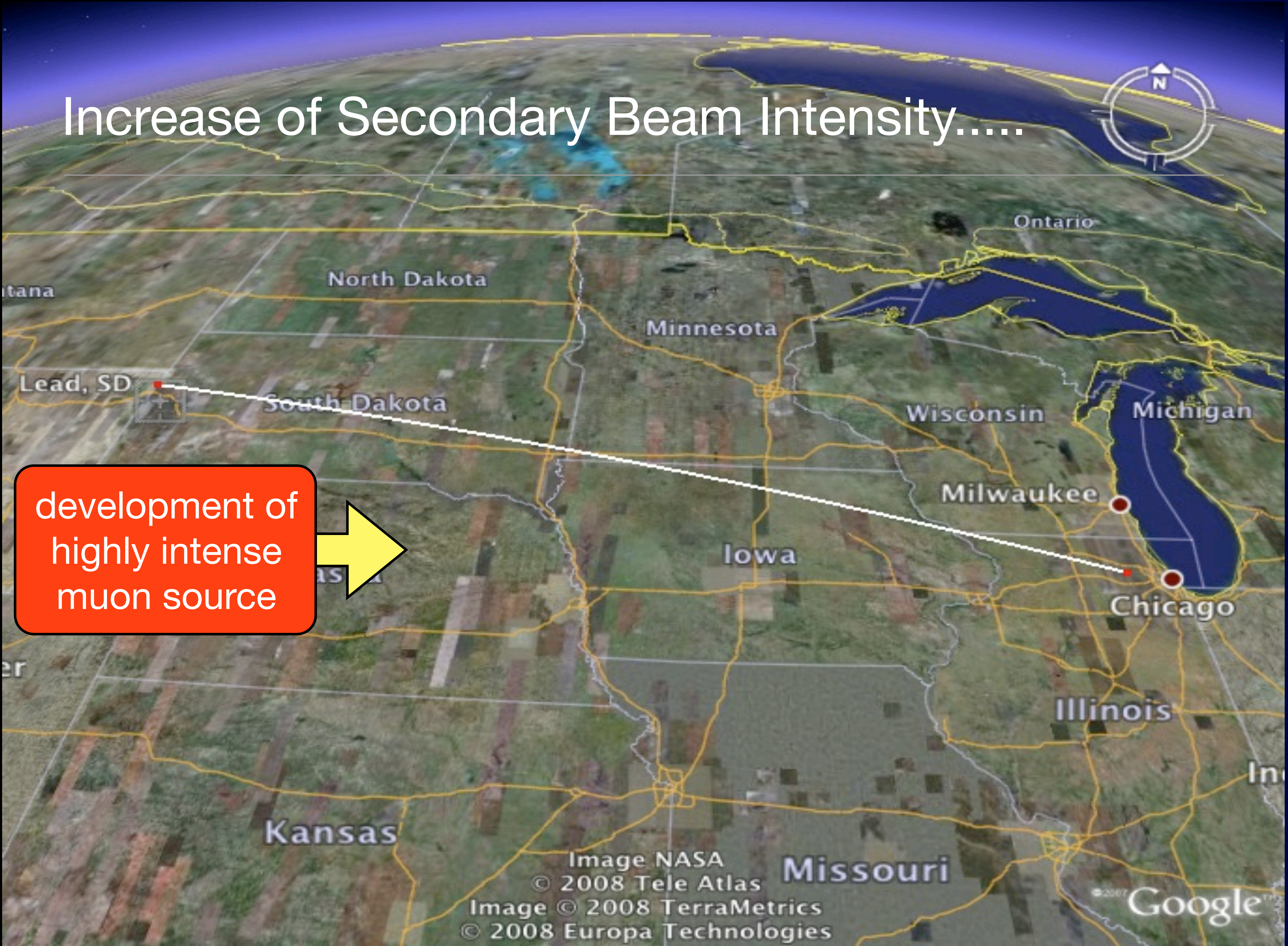
For 50 kW beam power, 10^{11}/sec, (in contrast to 10^{8} /sec for 1.2 MW)

improvement of muon yield of about10,000

Increase of Secondary Beam Intensity.....



Increase of Secondary Beam Intensity.....

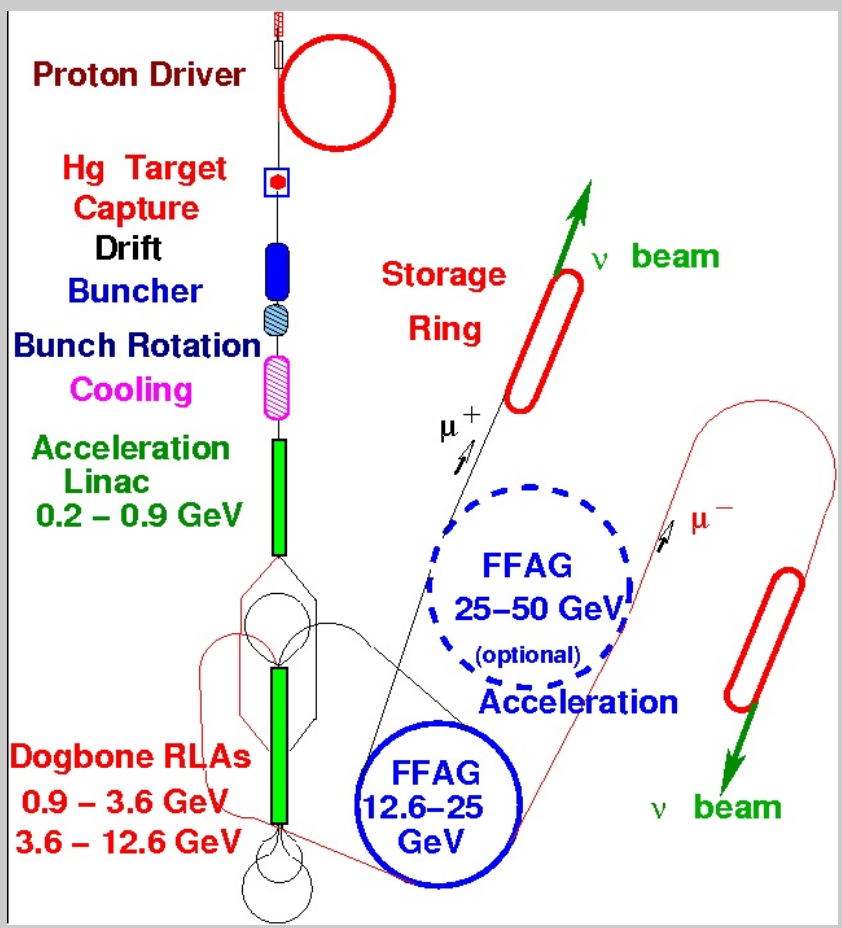


development of highly intense muon source

Increase of Secondary Beam Intensity.....

development of highly intense muon source

Neutrino Factory

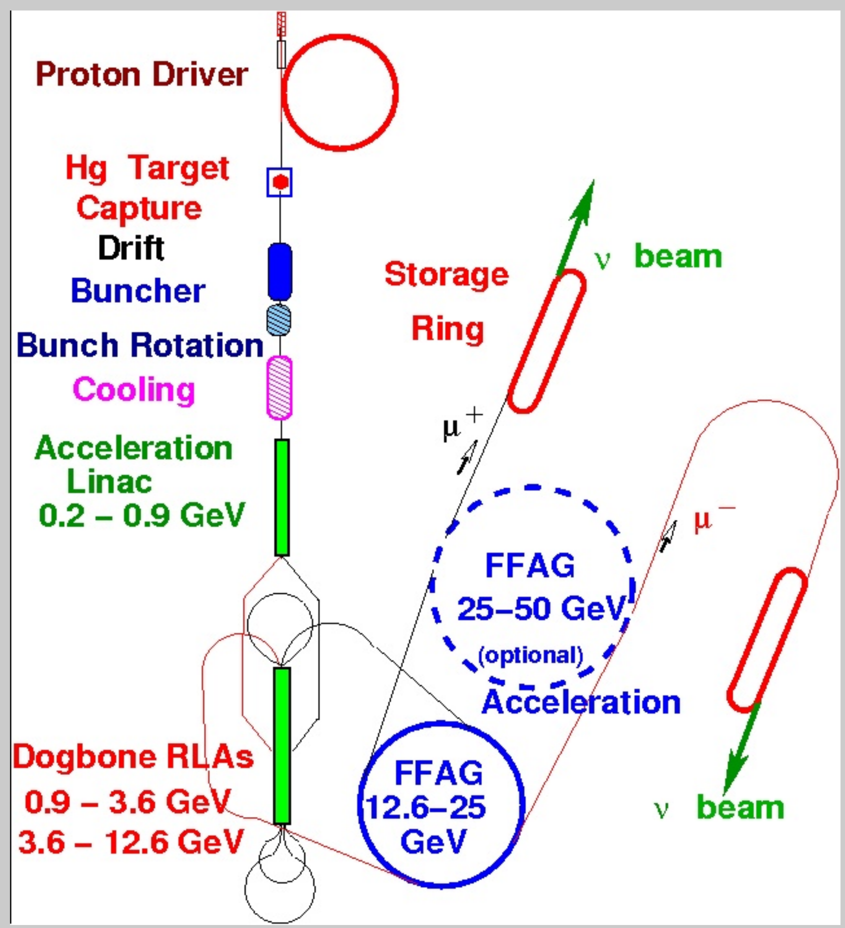


Ontario
North
Lead, SD
South Dak
Wisconsin
Michigan
Milwaukee
Chicago
Illinois
Kansas
issouri
© 2008 Europa Technologies
Google

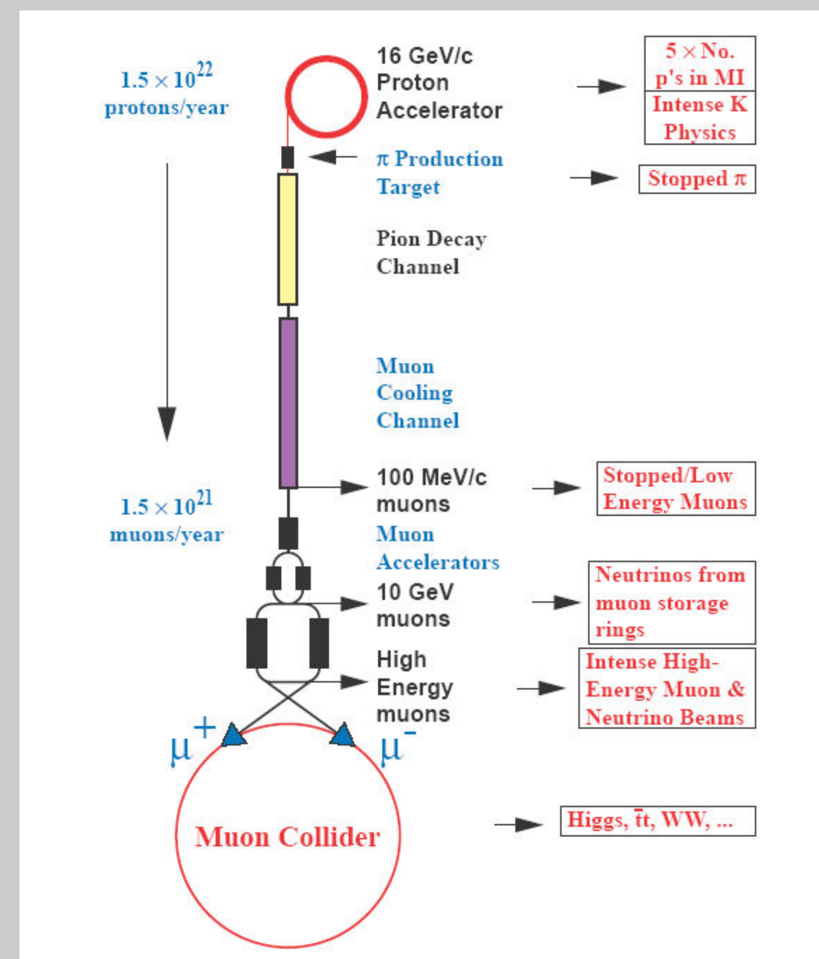
Increase of Secondary Beam Intensity.....

development of highly intense muon source

Neutrino Factory



Energy frontier Muon Collider - 2~4 TeV



“MuSIC Project”
at Osaka University

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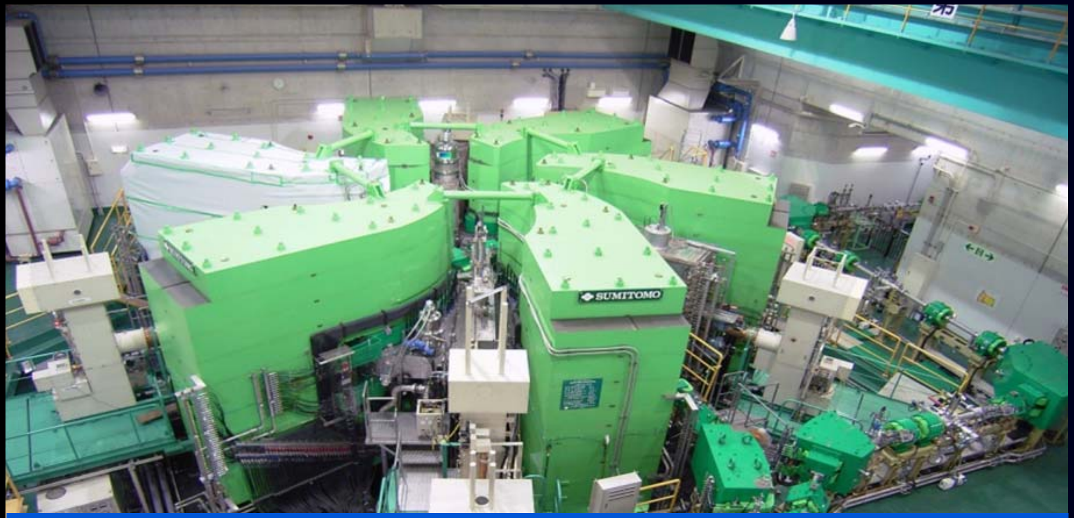
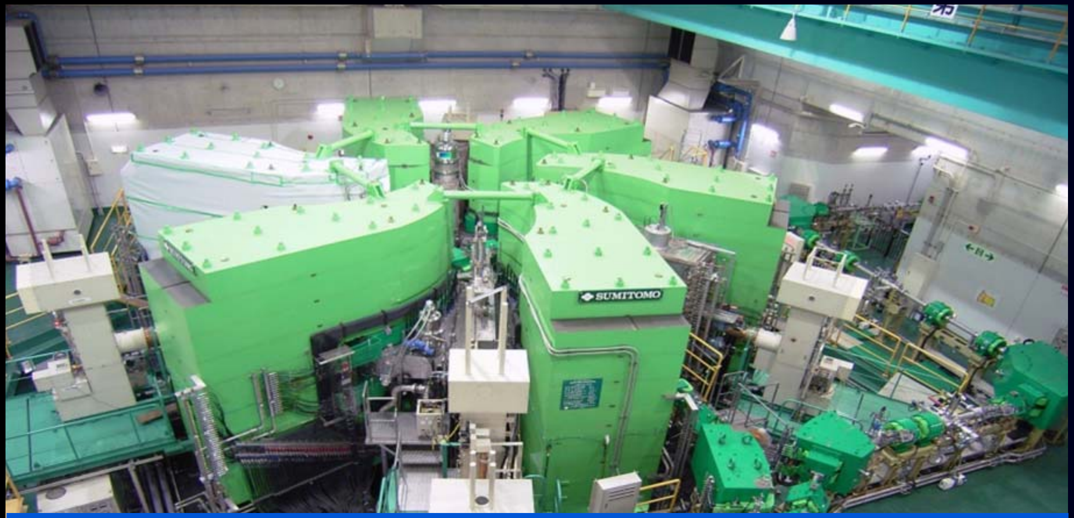


Cyclotron, Osaka University,
1μA, 400 MeV (400W)

“MuSIC Project” at Osaka University



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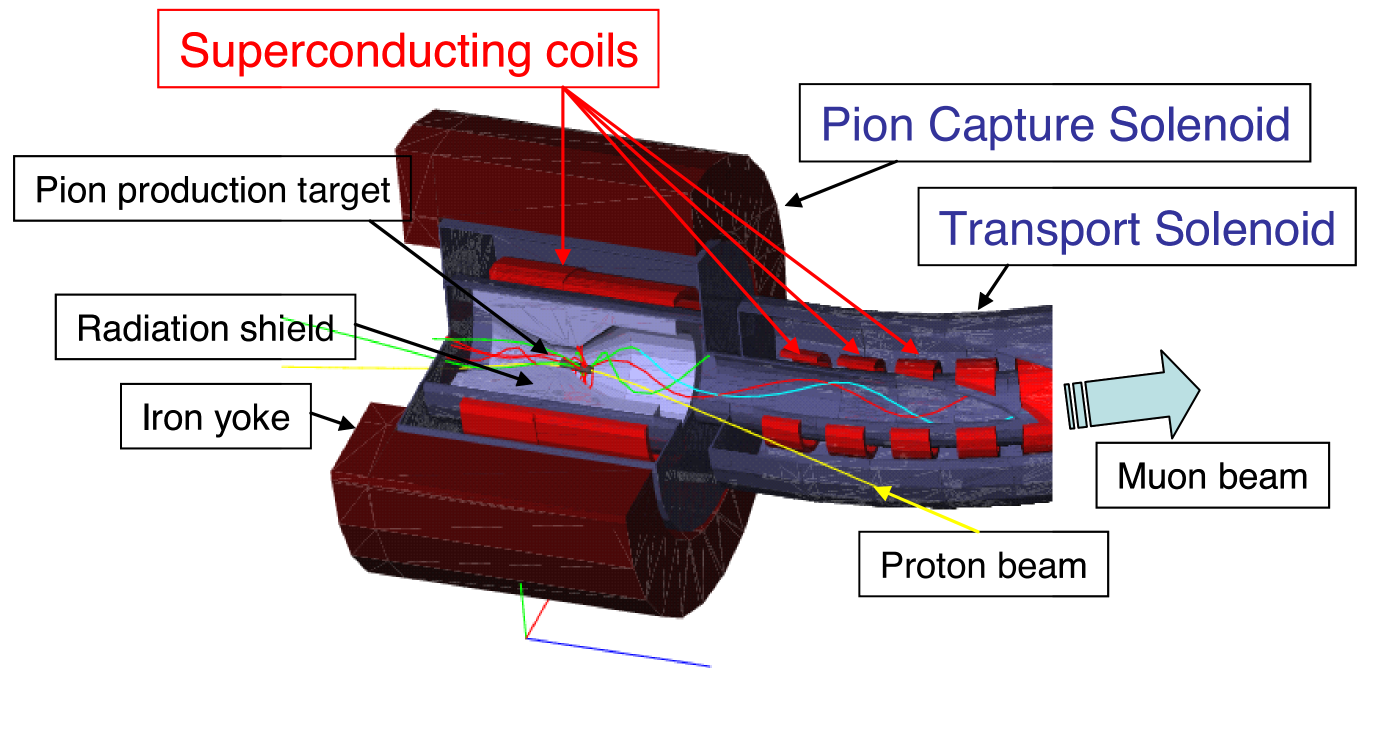

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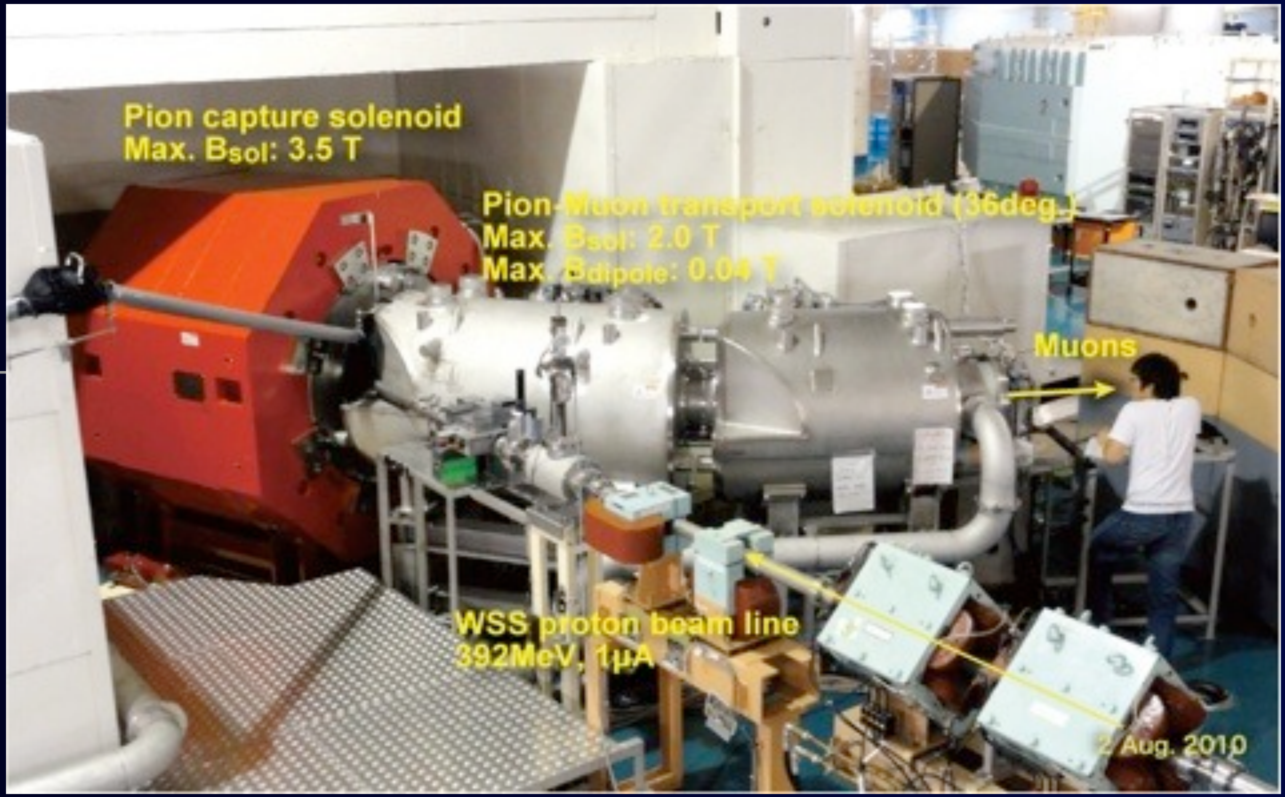

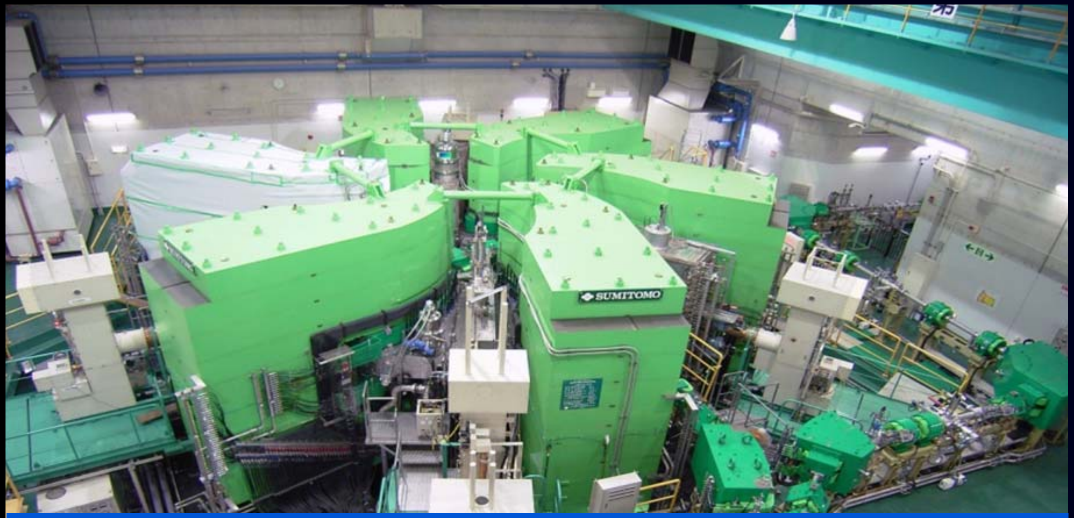

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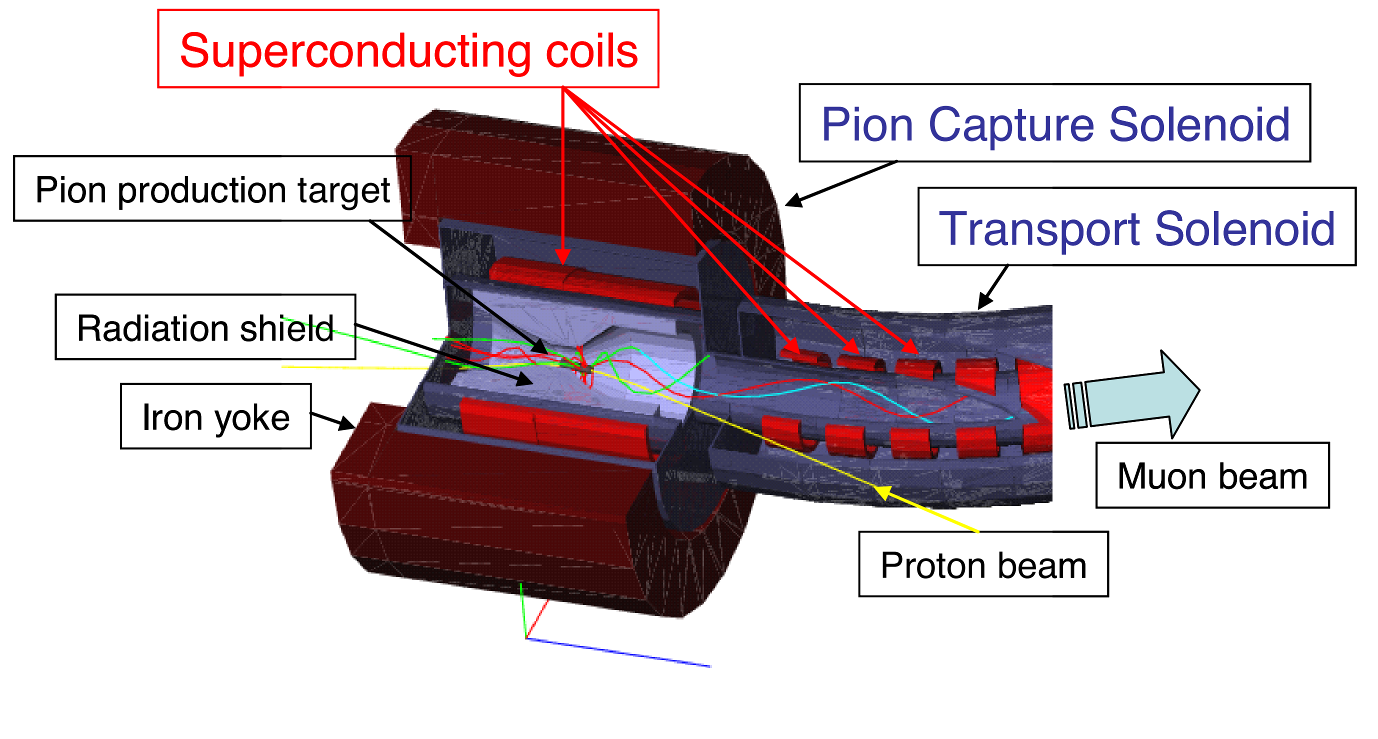
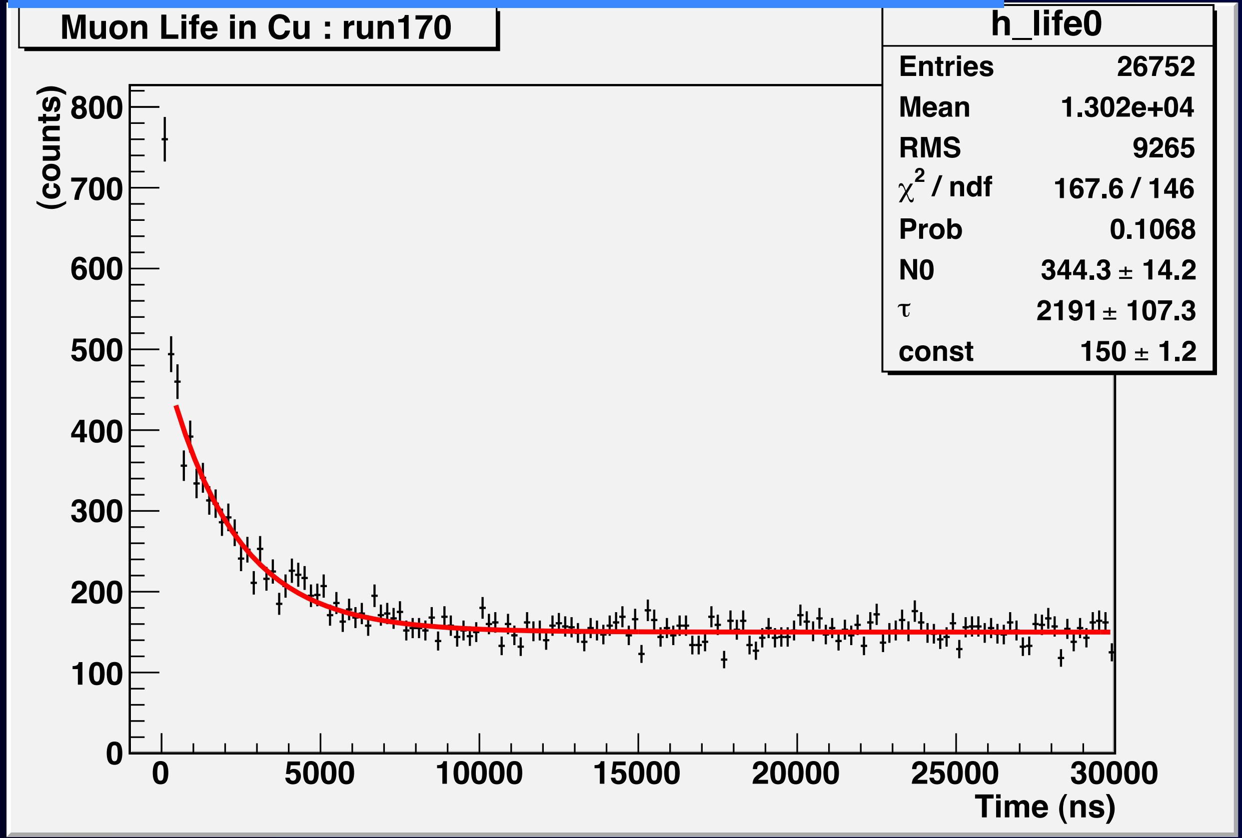
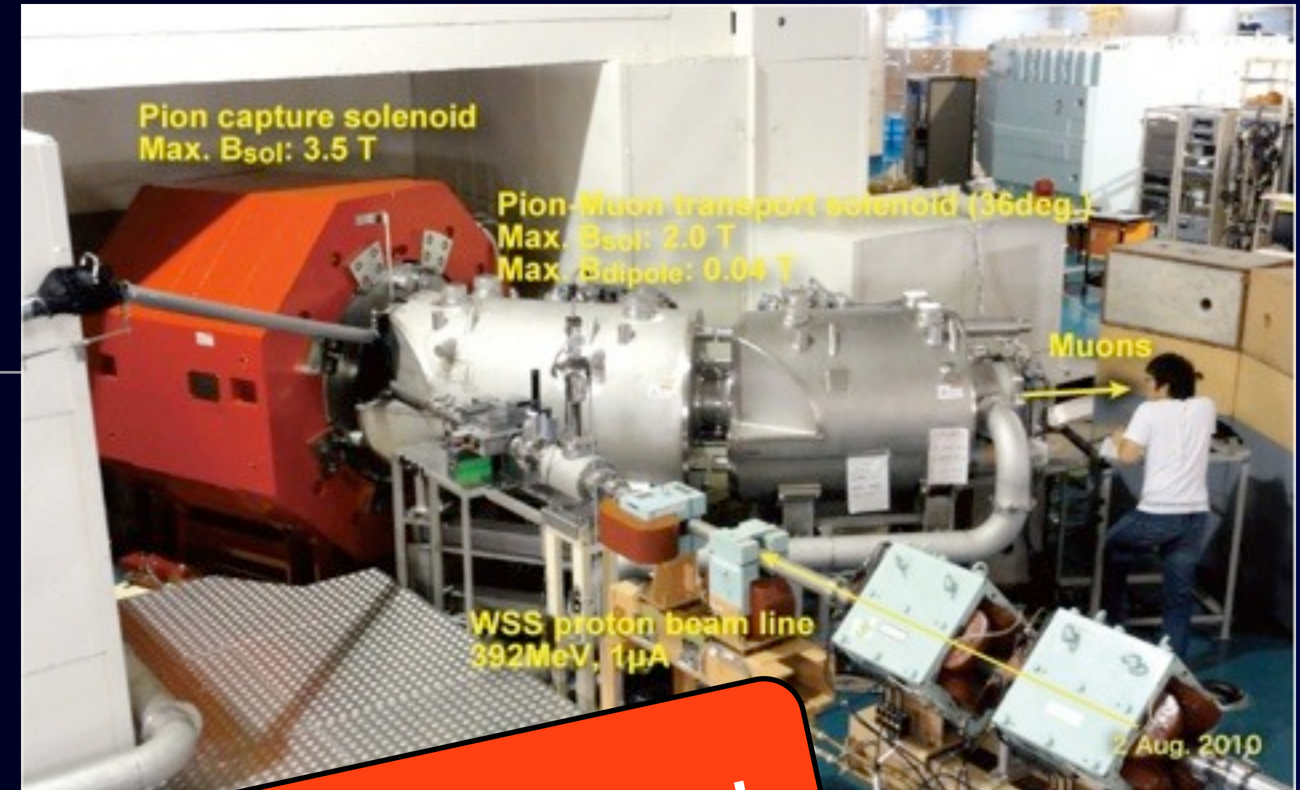


Beam test in February, 2011



about 10^9 /s for 400 W protons

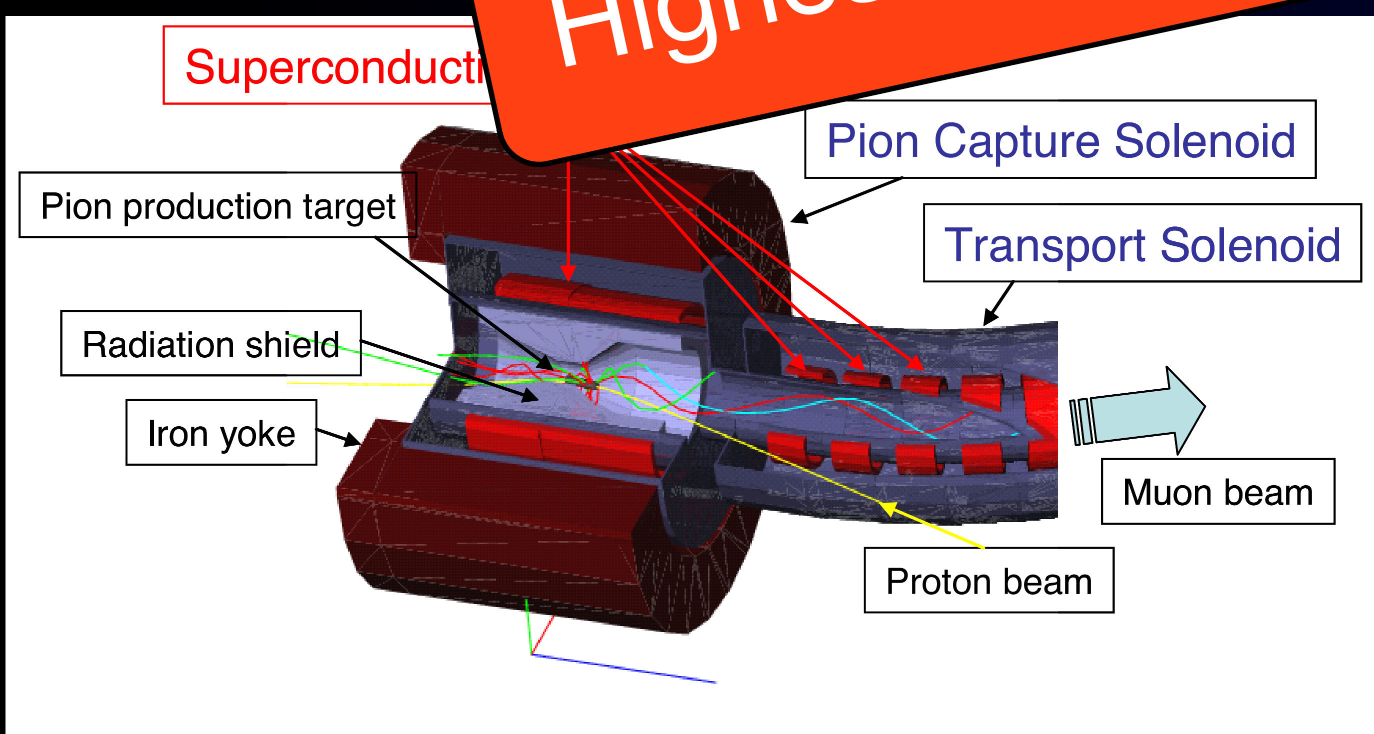
"MuSIC Project" at Osaka University

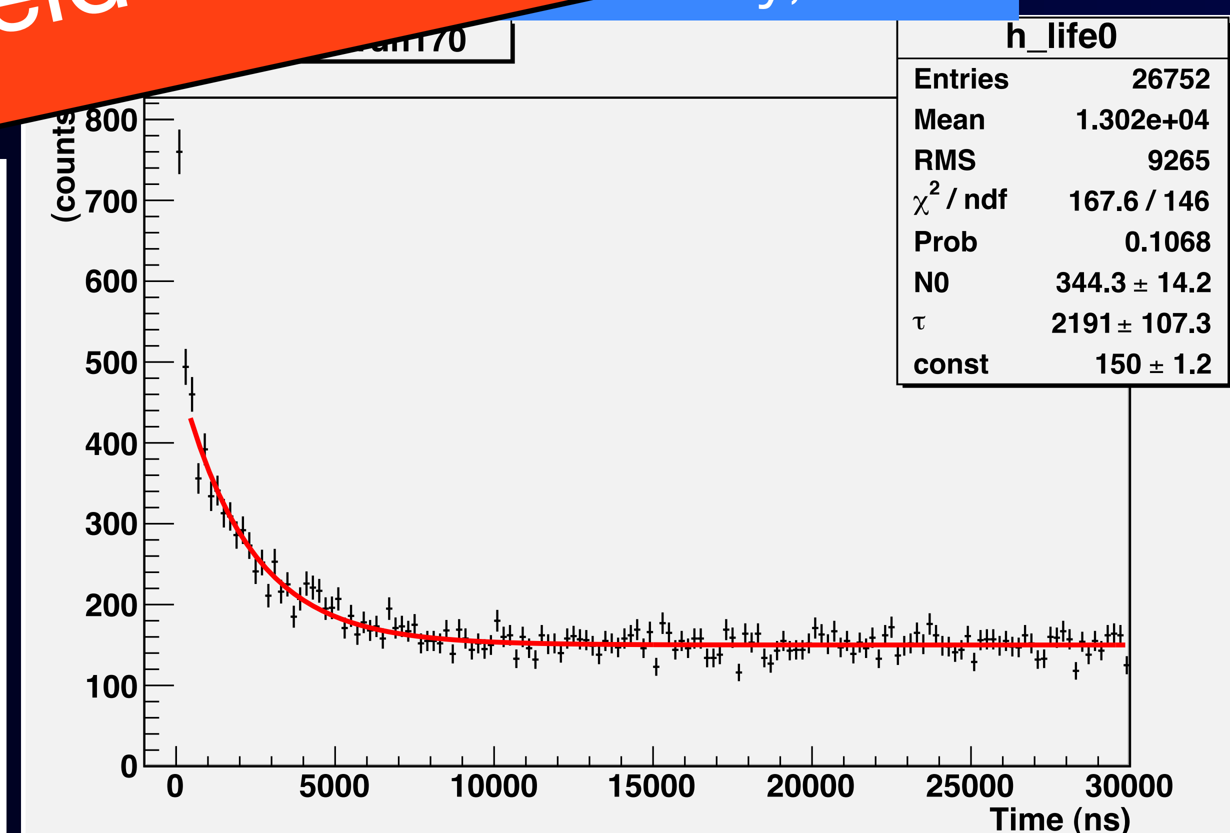


Cyclotron, Osaka U...
1μA, 4...

...uary, 2011

Highest Muon Yield in the World





about 10^9 /s for 400 W protons

Spin-off from MuSIC

A Eco Muon Source

Summary

Summary

- Rare decay experiments, as one of the intensity frontier, would be of compelling importance, in particular, their sensitivity to high energy-scale physics.
- Charged lepton flavor violation (cLFV) and quark FCNC would be the best choice for rare decay experiments.
- There are several rare decay experiments on-going and being prepared.
- Technology breakthrough on detectors as well as beams are being developed.
- We hope that these searches would make great discovery.