

Current and Future Kaon Experiments

Taku Yamanaka
Osaka University

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CKM2014@Vienna, Austria

C K M



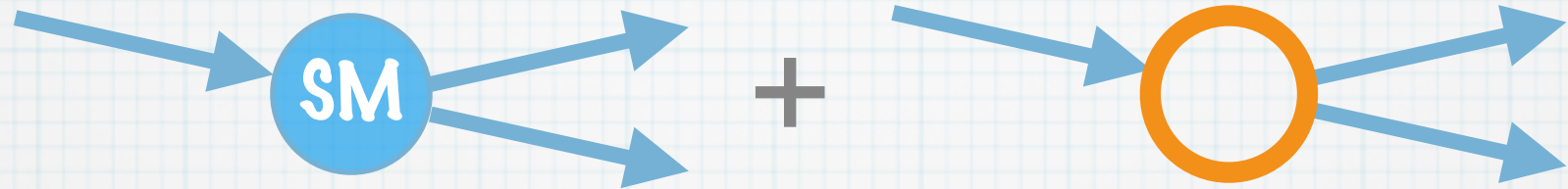
Kaon's Past Contributions

- * Cabibbo angle
- * CP violation
- * $\varepsilon'/\varepsilon \neq 0 \rightarrow$ Killed Superweak, together with B factory results,



To search for New Physics

- * Look for deviation from Standard Model



- * Standard Model process should be
 - * suppressed
 - * well-known

Probes:

$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$

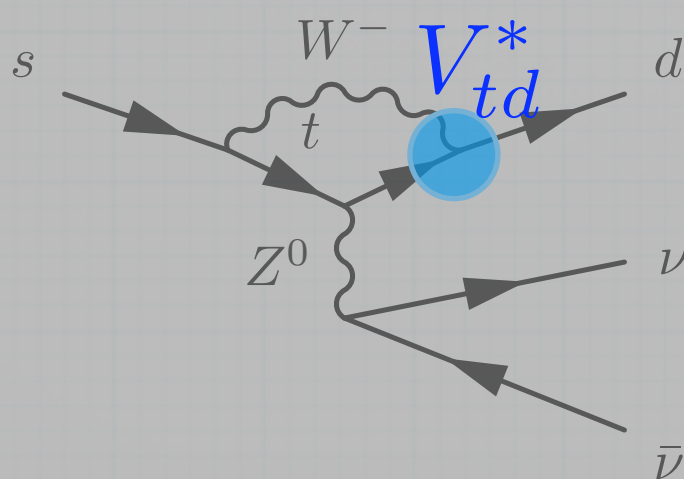
$$K^+ \rightarrow \pi^+ \nu \bar{\nu}$$

$$A(K^+ \rightarrow \pi^+ \nu \bar{\nu}) \propto V_{td}$$

$$A(K_L \rightarrow \pi^0 \nu \bar{\nu}) \propto V_{td} - V_{td}^*$$

$$\propto \text{Im}(V_{td})$$

Standard Model



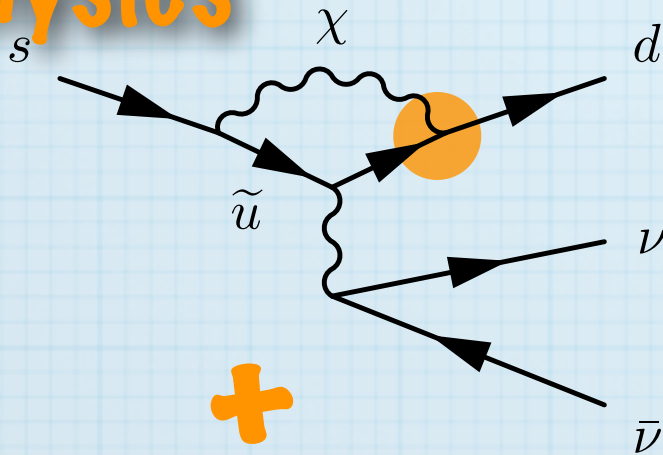
- * SM background is
- * small ($\text{BR}(K_L) \sim 3\text{E-}11$)
- * well known ($K_L \sim 2\%$ theo. error)

Probes:

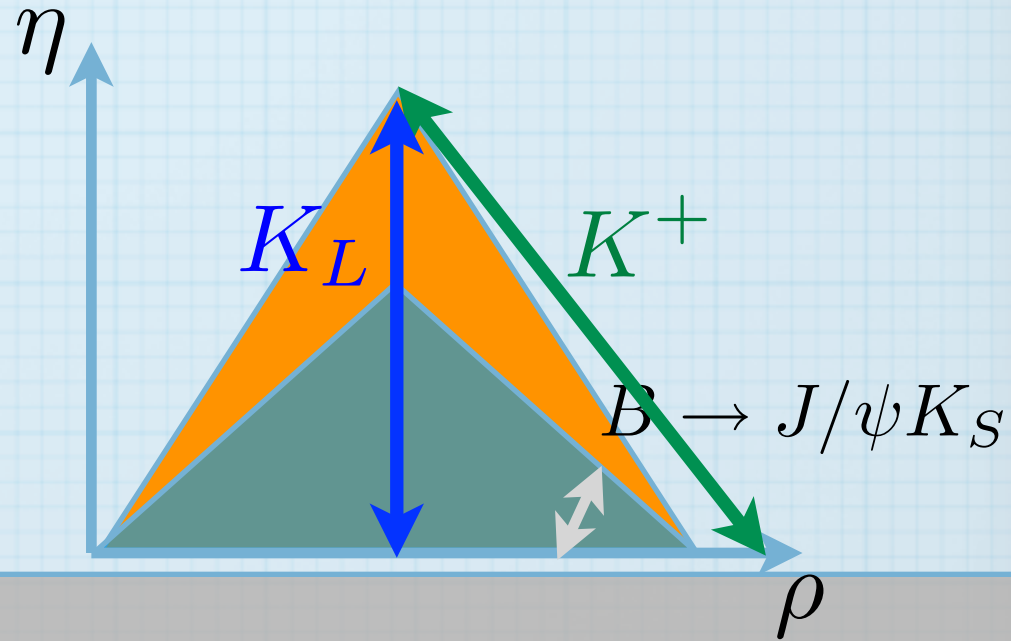
$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$

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

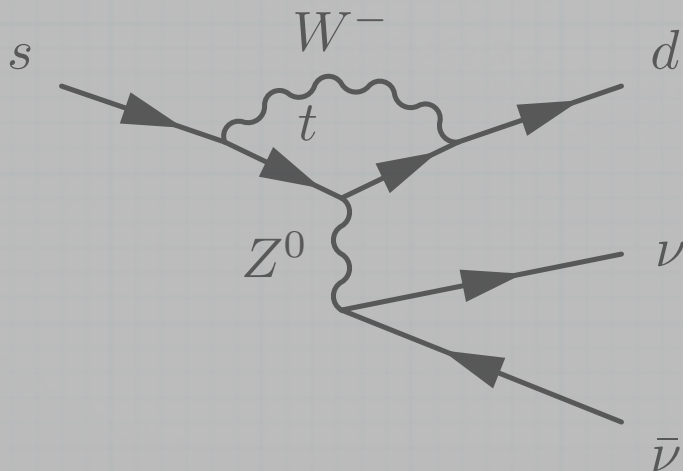
New Physics



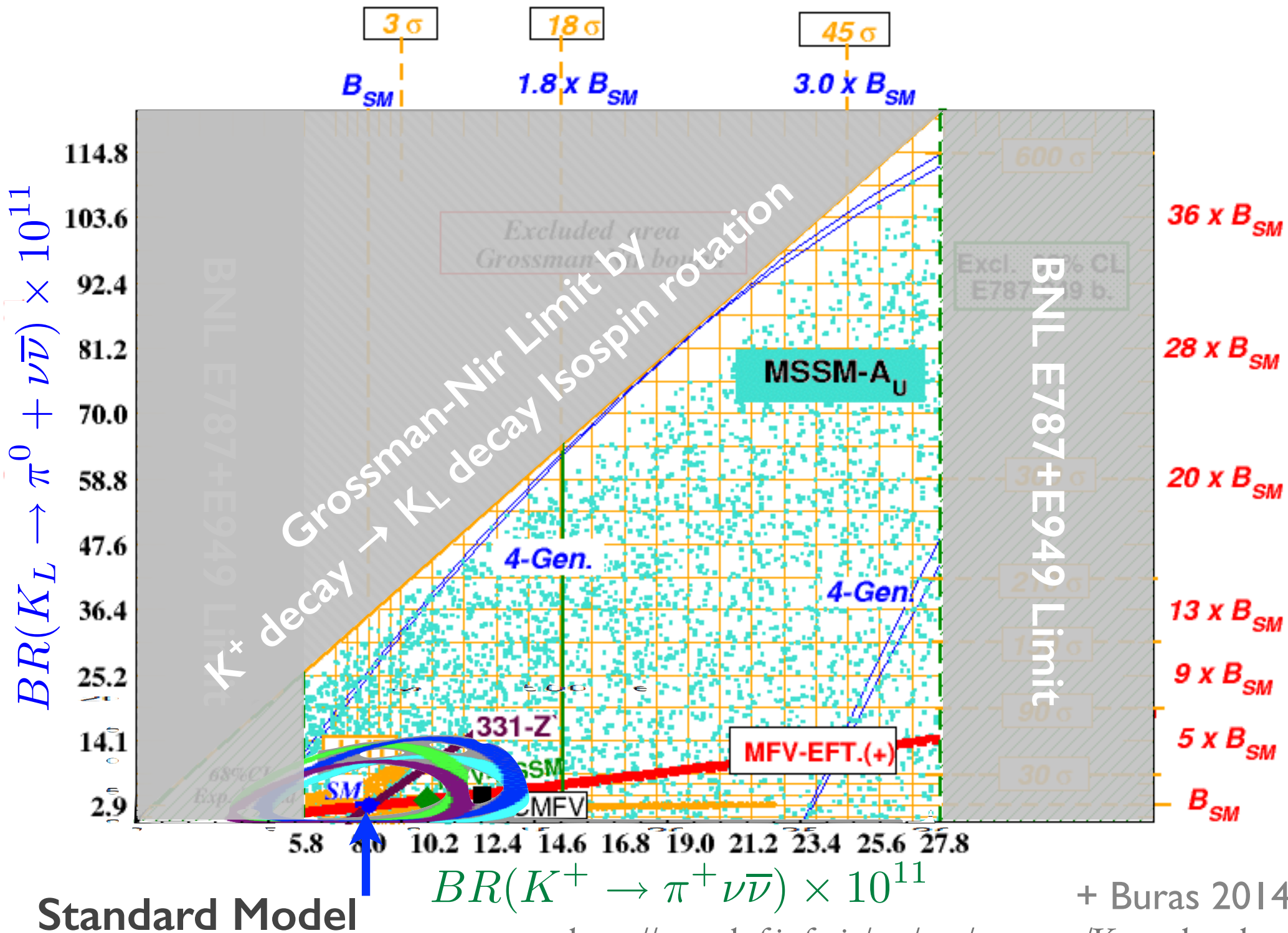
+



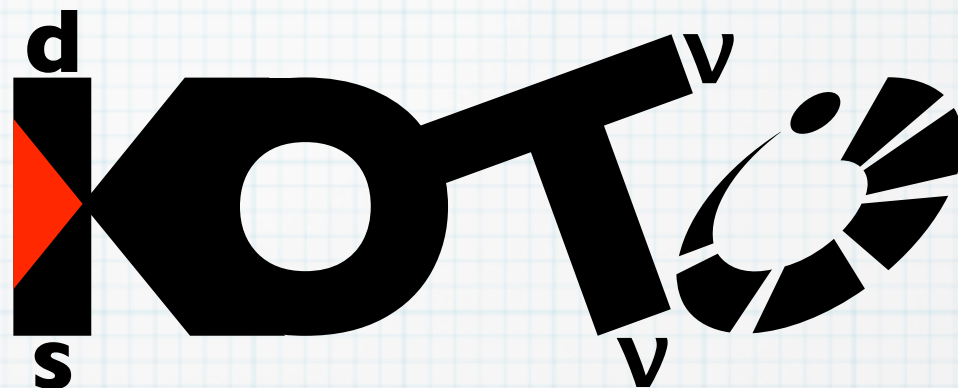
Standard Model



- * SM background is
- * small ($\text{BR}(K_L) \sim 3\text{E-}11$)
- * well known ($K_L \sim 2\%$ theo. error)



$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$



Material - Life Science
Facility

Hadron Experimental
Facility

Accelerator-Driven
Transmutation
Experimental
Facility

500 m !

Neutrino Facility

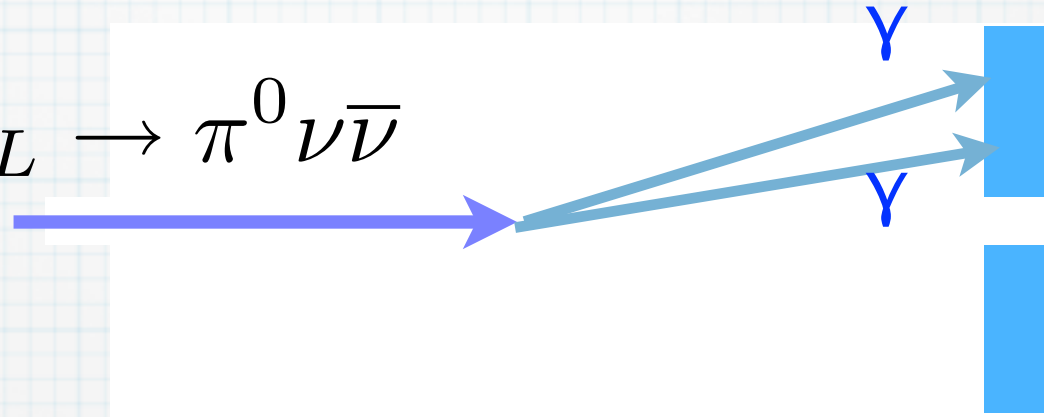
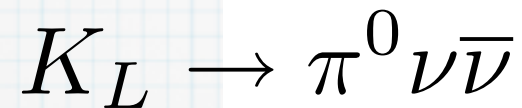
Linac
(350m)

3GeV Synchrotron
(25Hz, 1MW)

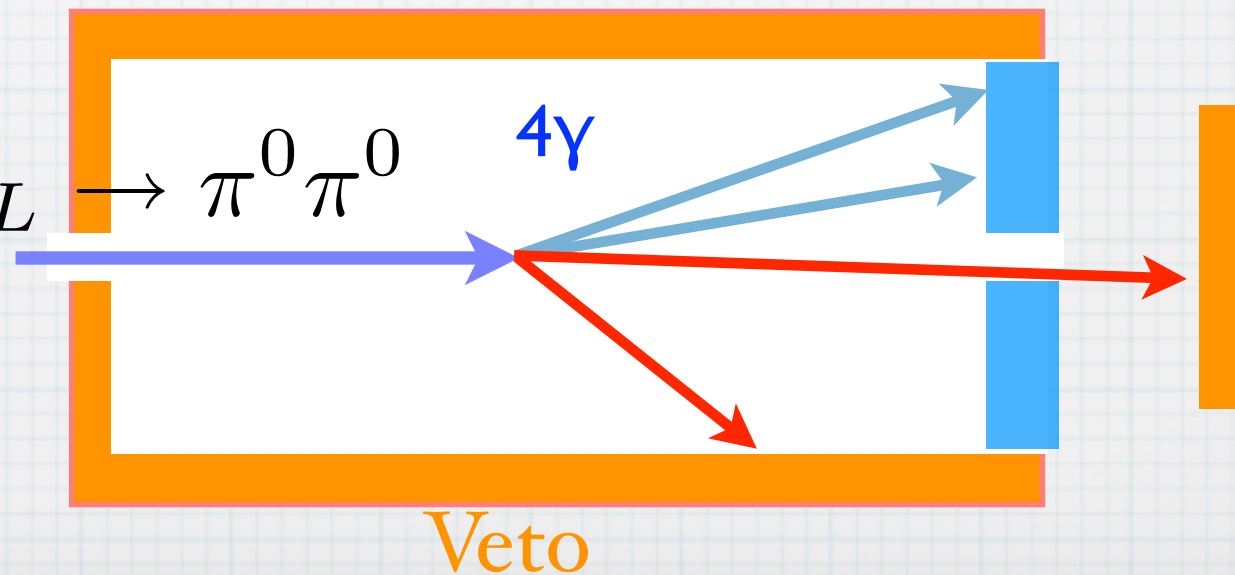
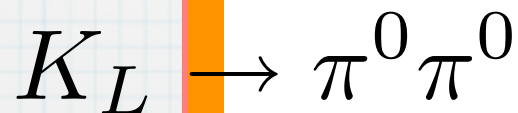
50GeV Synchrotron
(0.75MW)

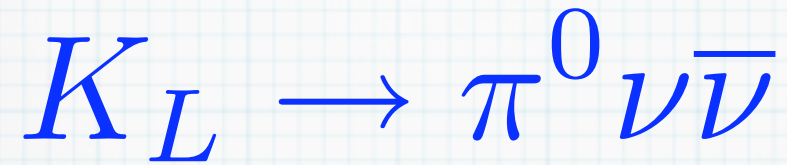
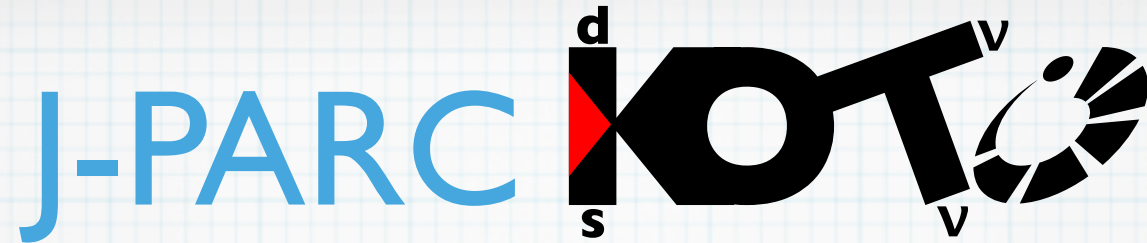
Signal and Background

* Signal:

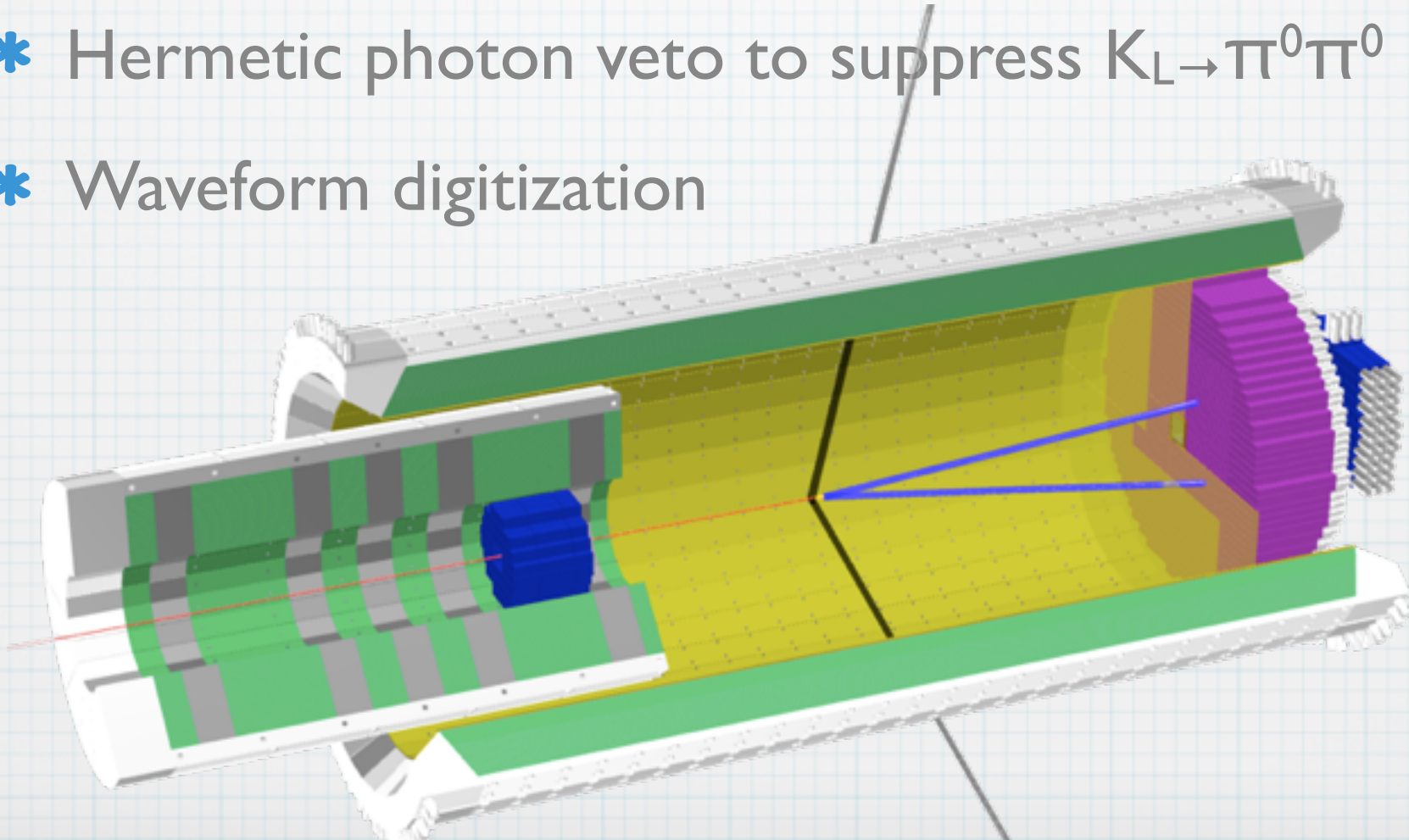


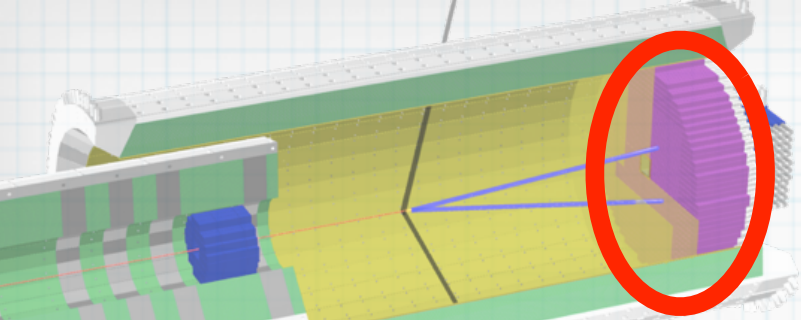
* Background





- * CsI calorimeter from KTeV
- * Hermetic photon veto to suppress $K_L \rightarrow \pi^0 \pi^0$
- * Waveform digitization

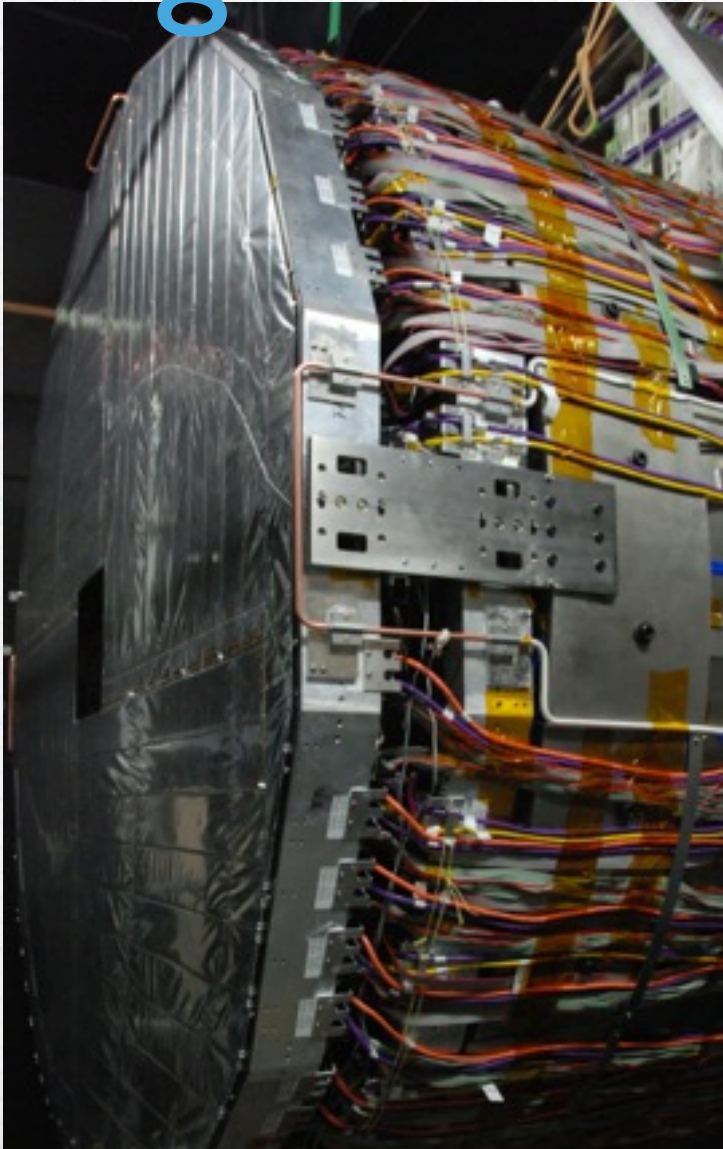




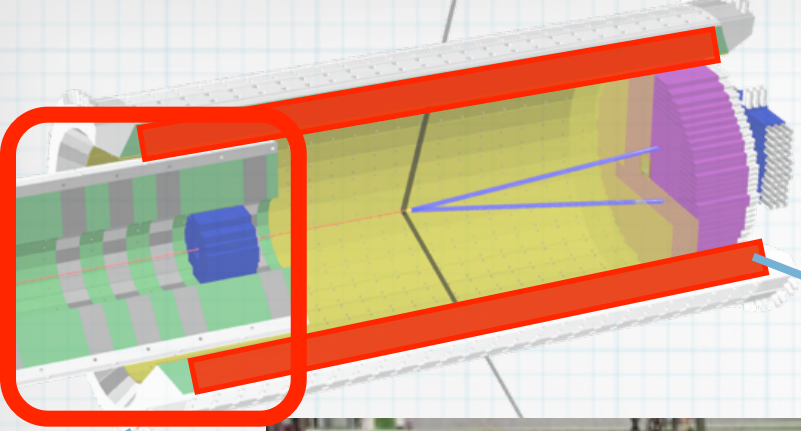
CsI Calorimeter

Charged Veto

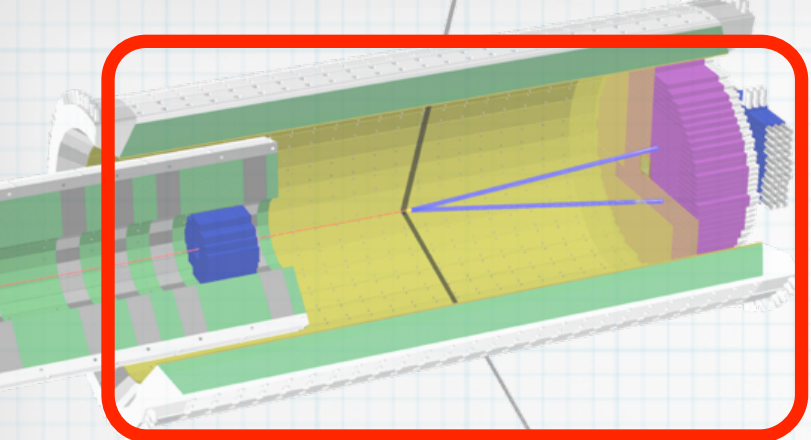
Brought FNAL KTeV CsI



Main Barrel¹³ Photon Veto



Main Barrel + CsI Calorimeter

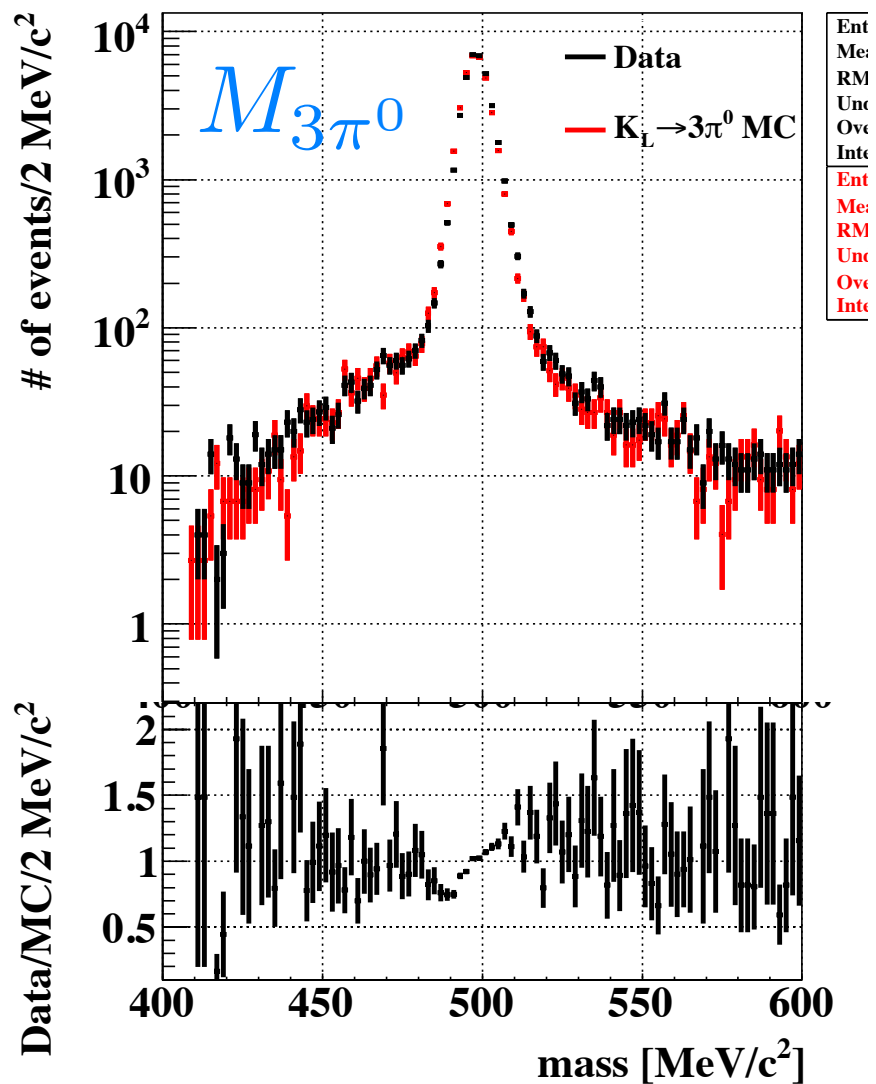
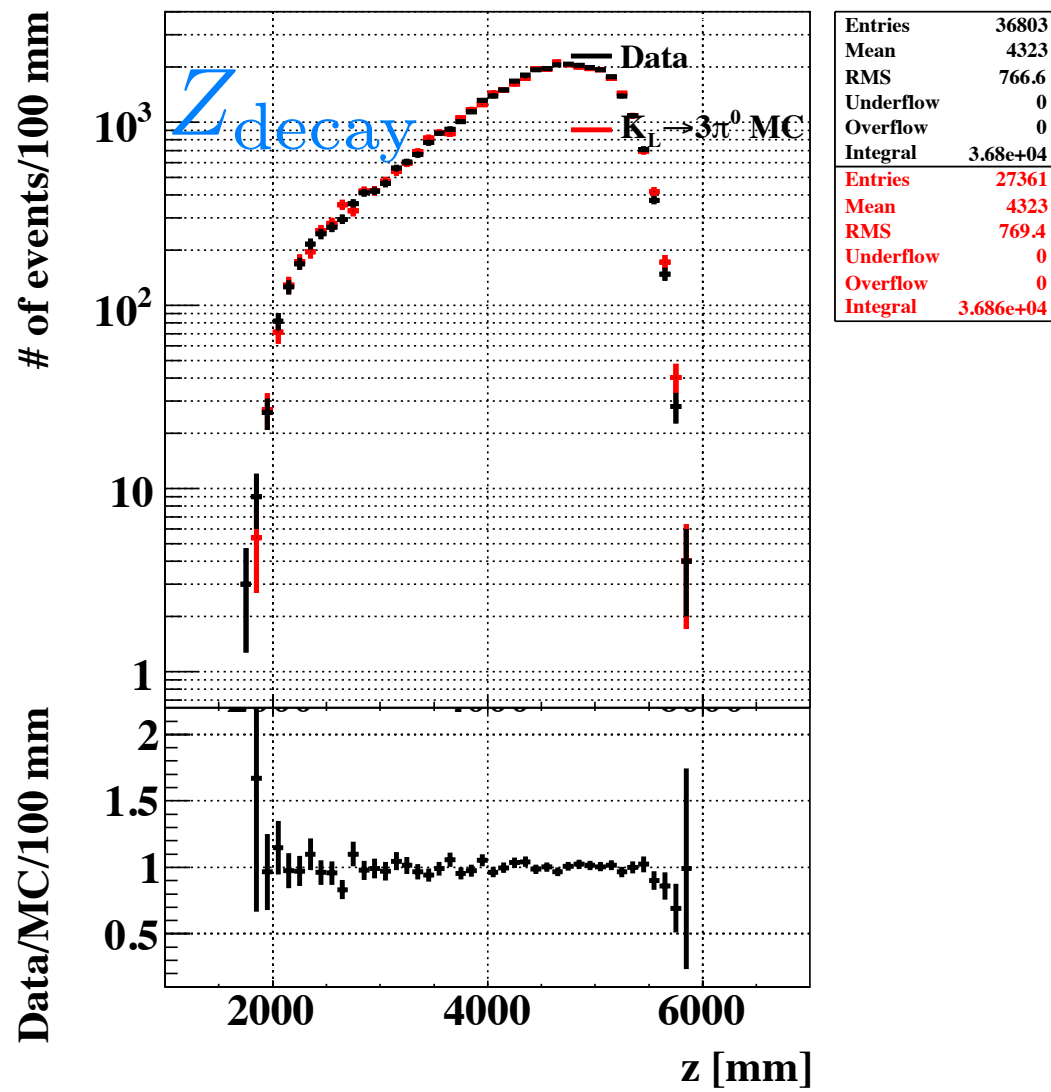


First Physics Run

- * Started on May 18, 2013
- * After 100 hours, data taking was terminated due to a radiation accident

Good Detector Understanding

$$K_L \rightarrow 3\pi^0$$

Rec. K_L massRec. K_L z vertex

$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$

at KOTO

by Koji Shiomi

12:15 on Thursday

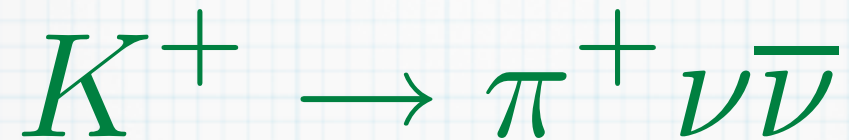
WG3, E1 9 lecture hall

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

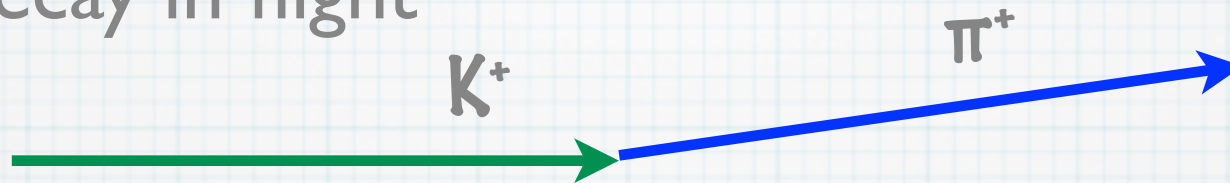
CERN



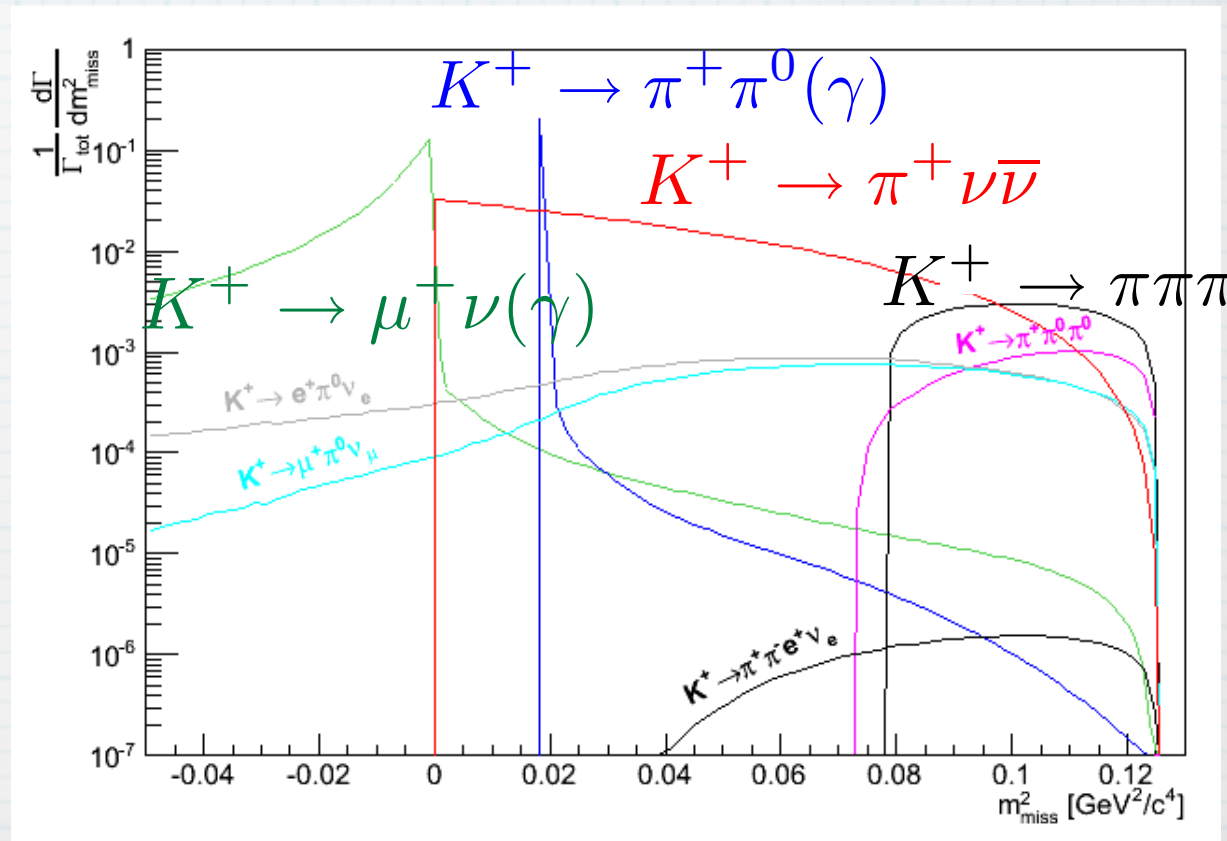
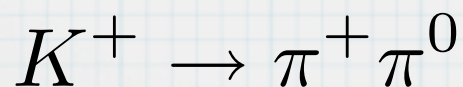
CERN NA62



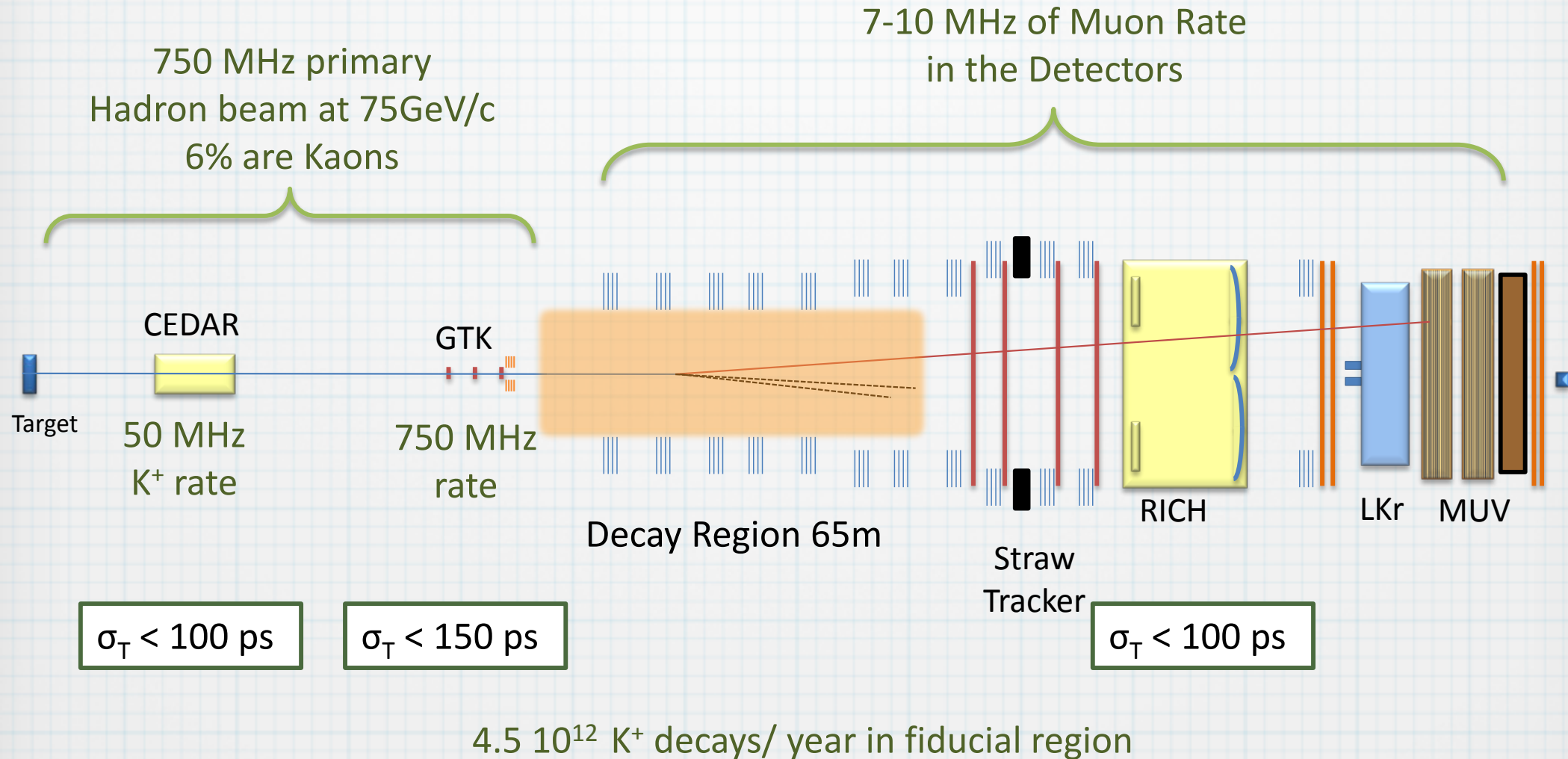
- * Decay in flight



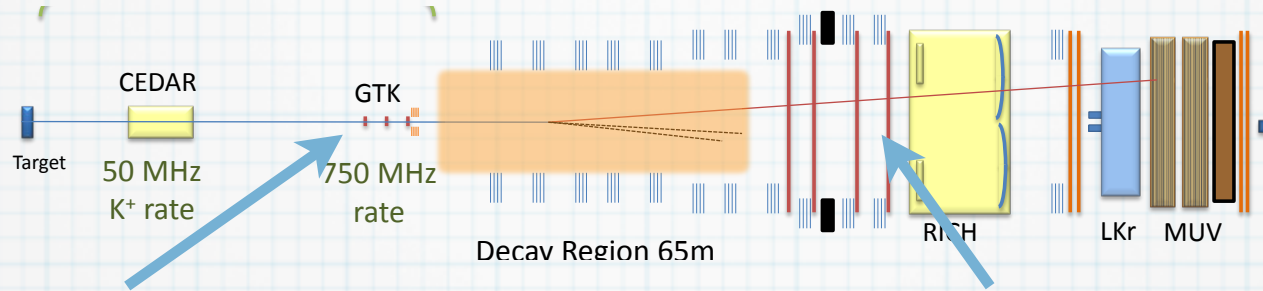
- * Missing mass
- * Good tracking
- * Particle ID
- * Photon Veto to suppress



CERN NA62



CERN NA62 trackers

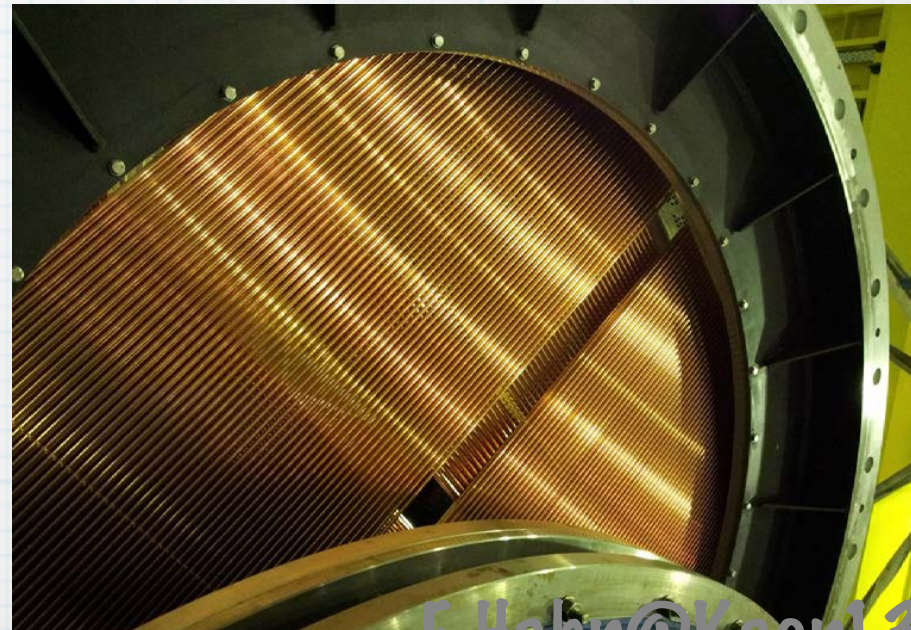
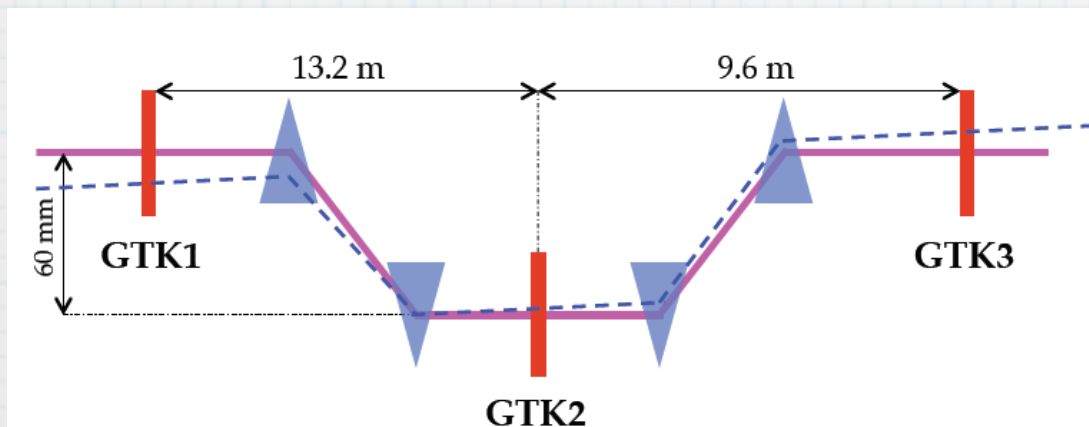


* For K⁺

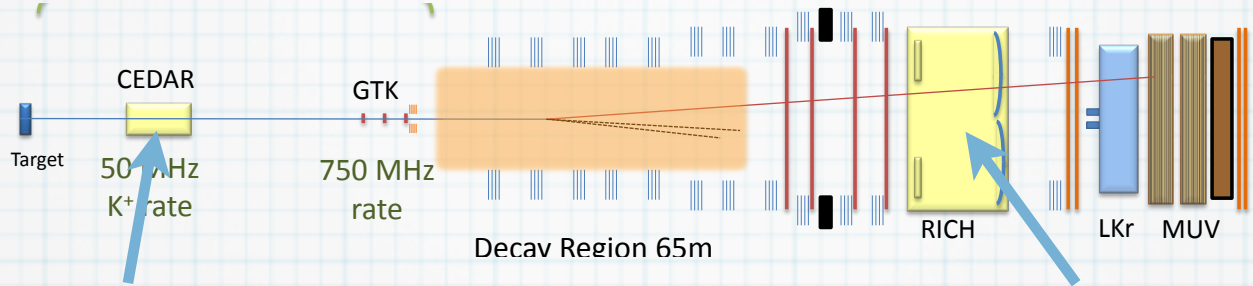
- * 300μm pixels
- * $\Delta\theta \sim 0.016\text{mrad}$
- * $\Delta t \sim 200\text{ps}$

* For π^+

- * straw tracker
- * $\Delta x \sim 140\mu\text{m}$

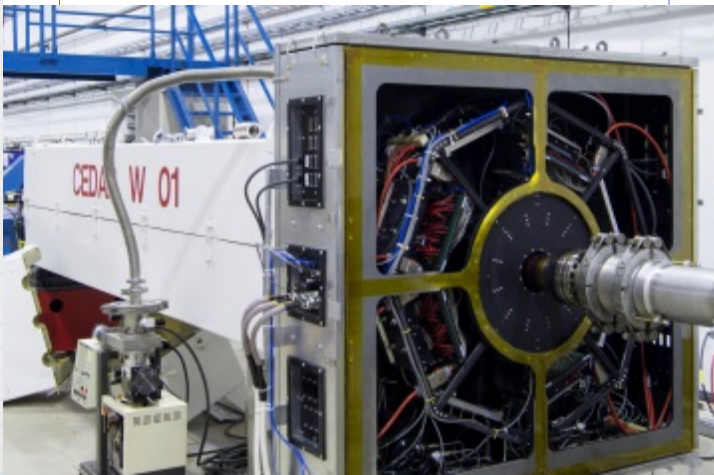
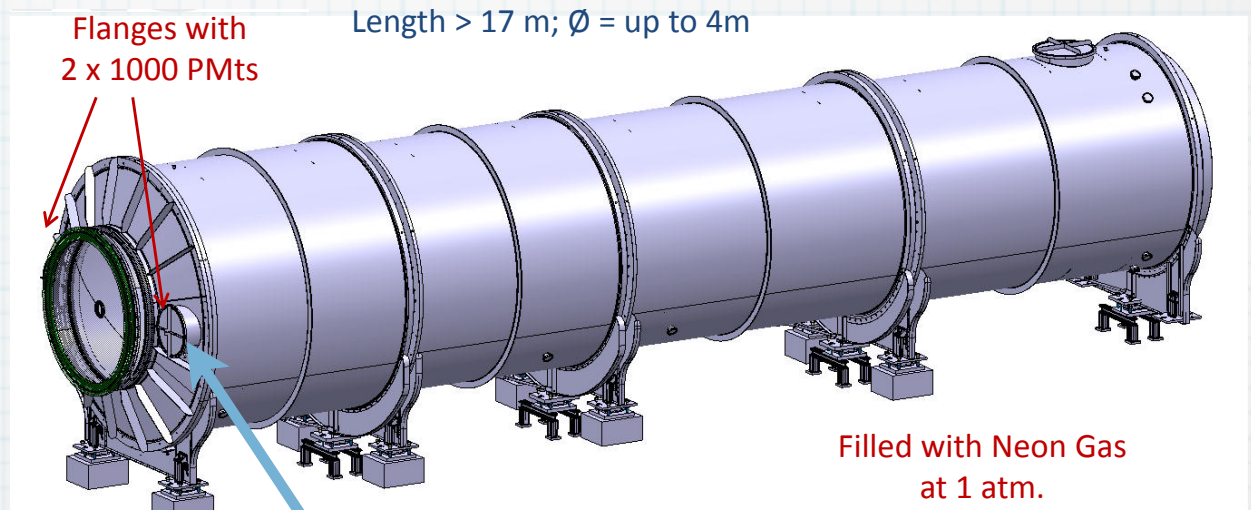
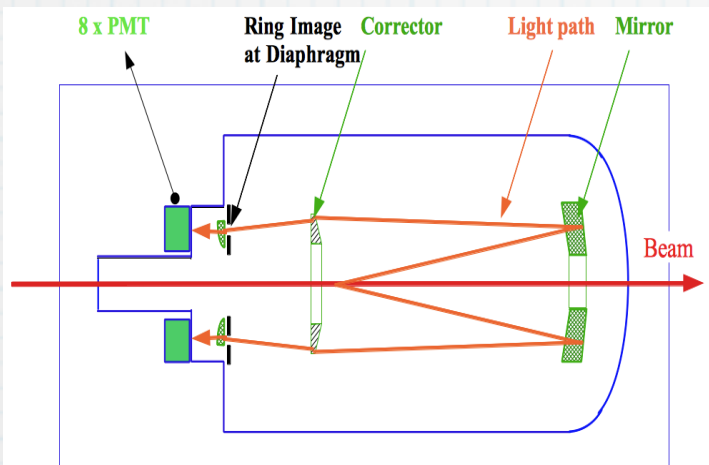


CERN NA62 PID

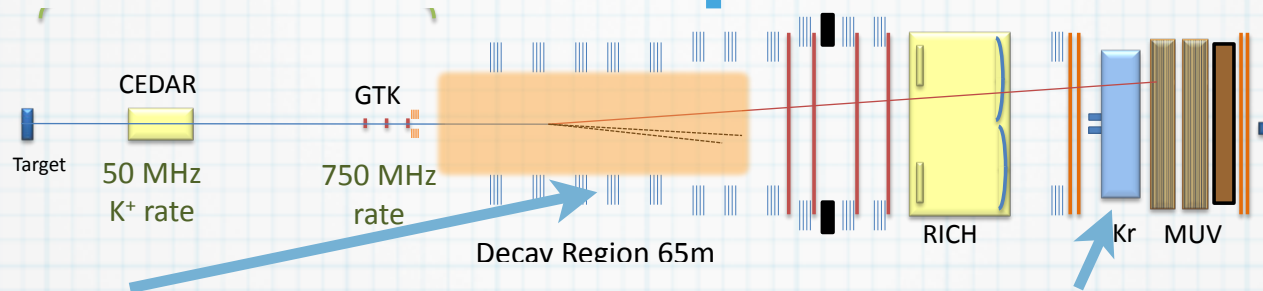


* For K^+

* For π^+



CERN NA62 photon veto

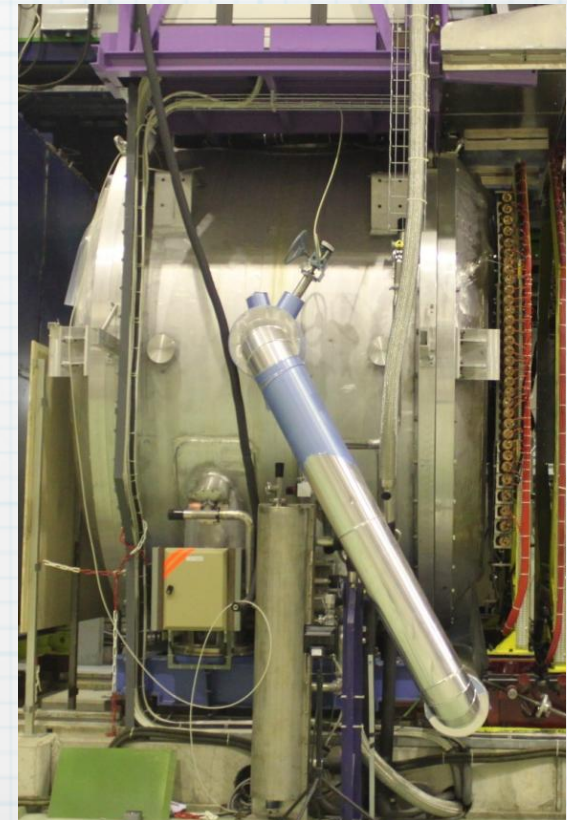


* large angle photons

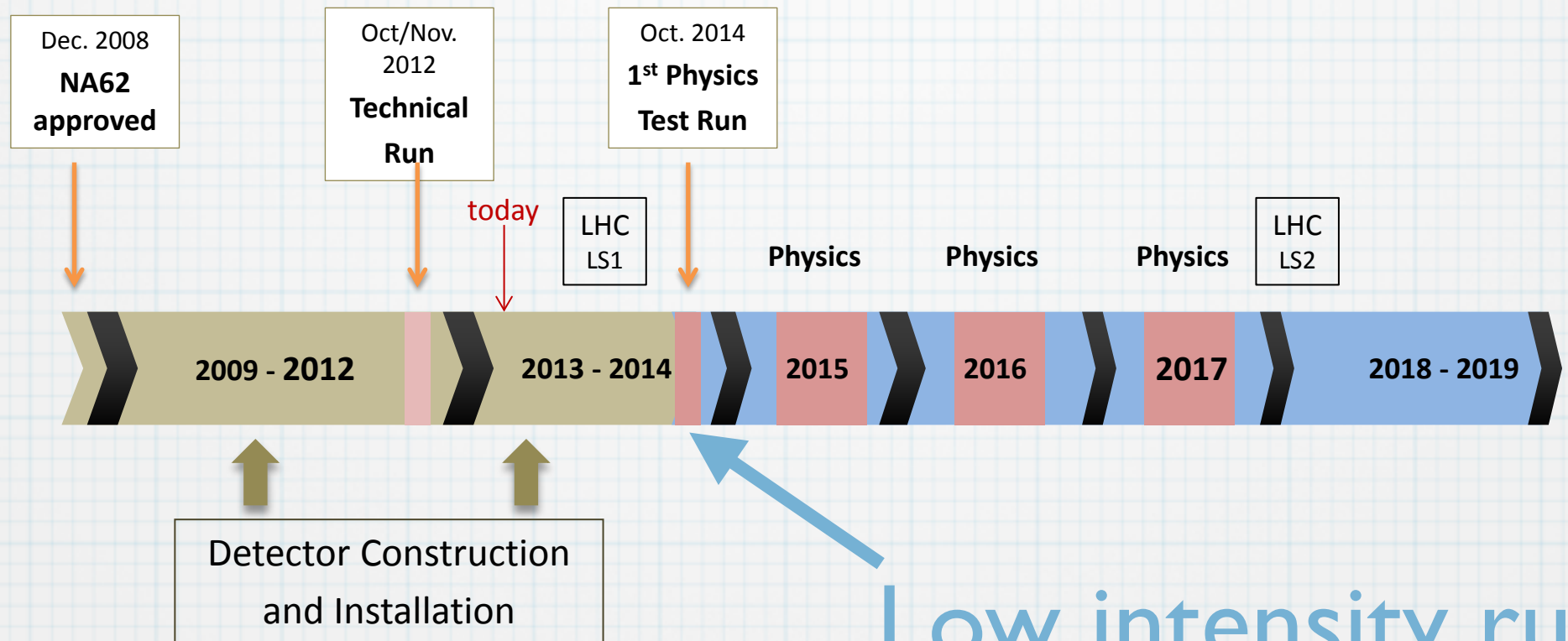
* leadglass from OPAL

* small angle photons

* NA48 LKr cal.



CERN NA62 Schedule and Sensitivity



* 45 SM events/year

* background < 10 events

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

at NA62

by Angela Romano

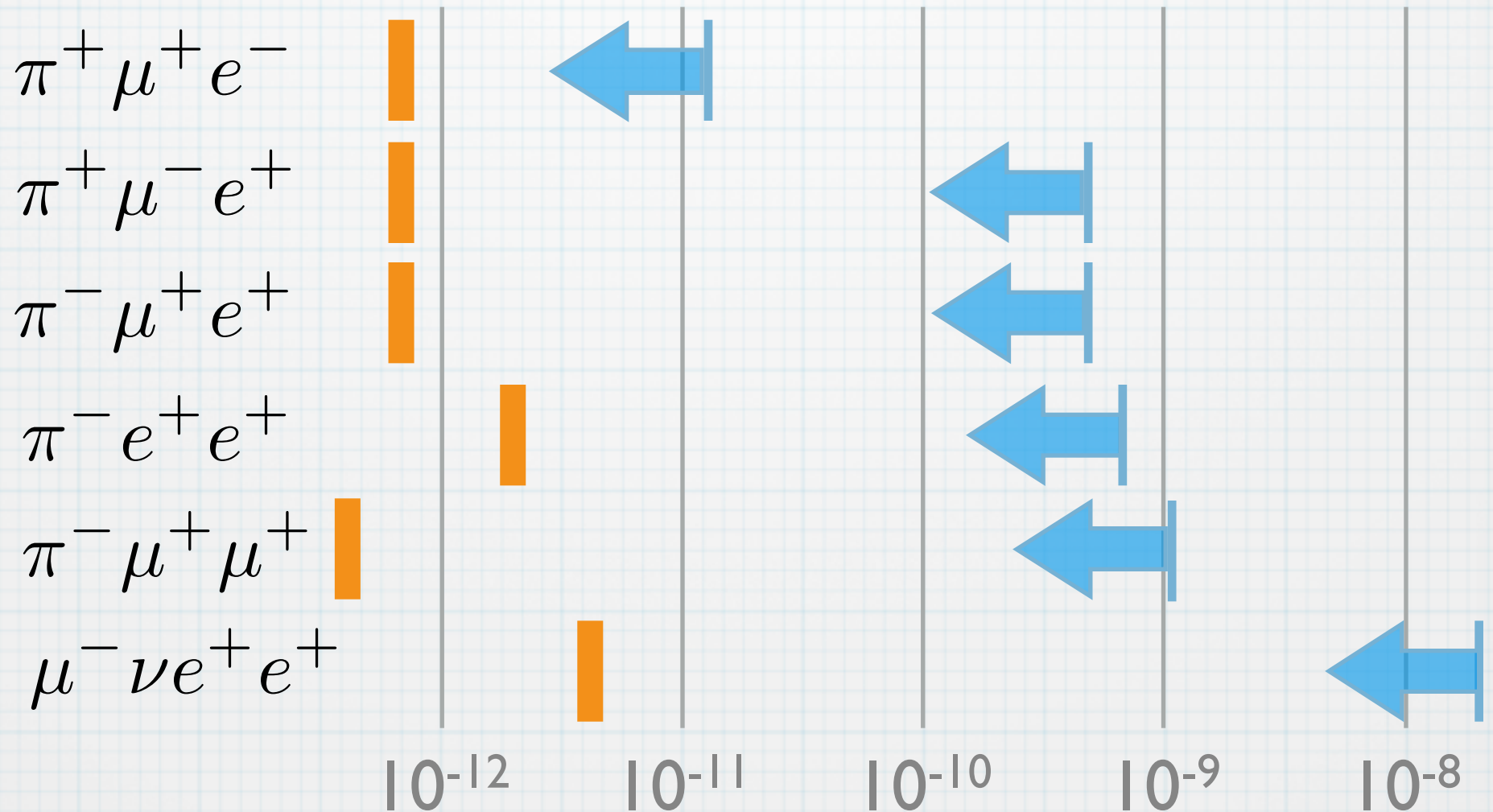
12:35 on Thursday

WG3 EI 9 lecture hall

NA62: Lepton number/flavor²⁶ violating K^+ decays

NA62 Sensitivity

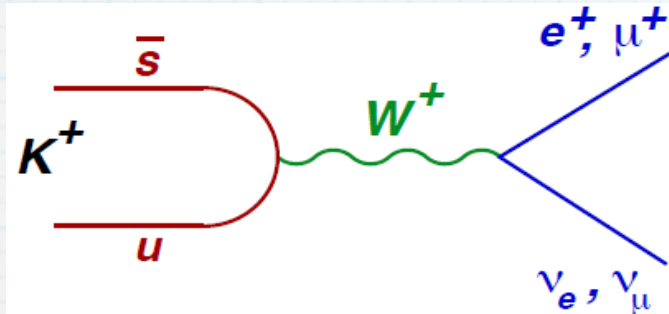
Present 90% CL limit



Numbers from Ryan Page@IPA2014

NA62: Lepton Universality

Standard Model

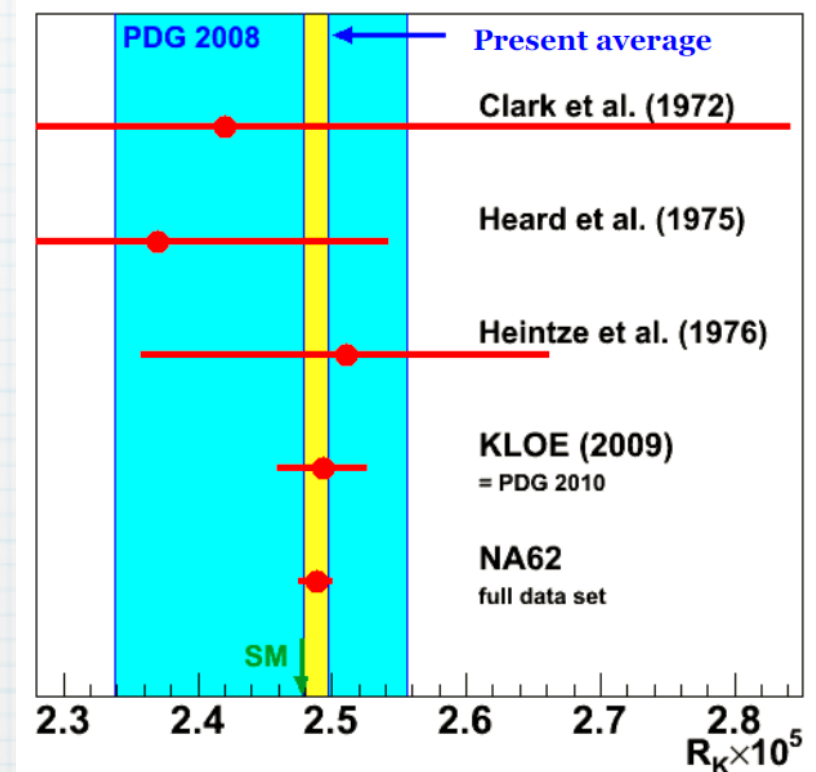
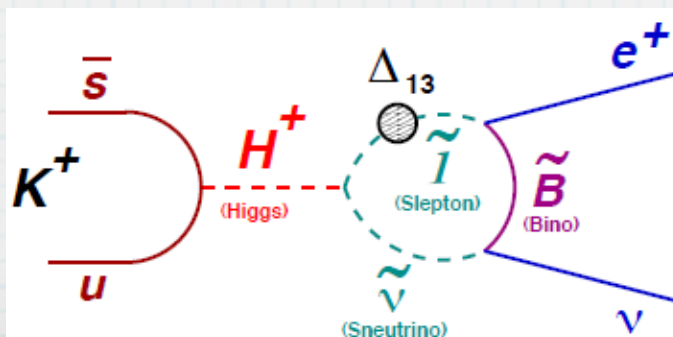
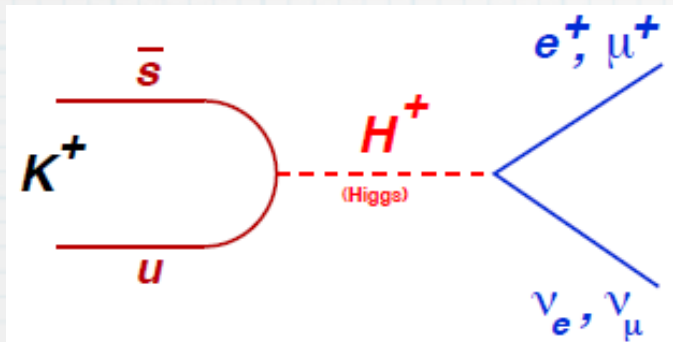


$$R_K = \frac{\Gamma(K^+ \rightarrow e^+ \nu)}{\Gamma(K^+ \rightarrow \mu^+ \nu)}$$

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

PLB 719, 326 (2013)

SM Extensions



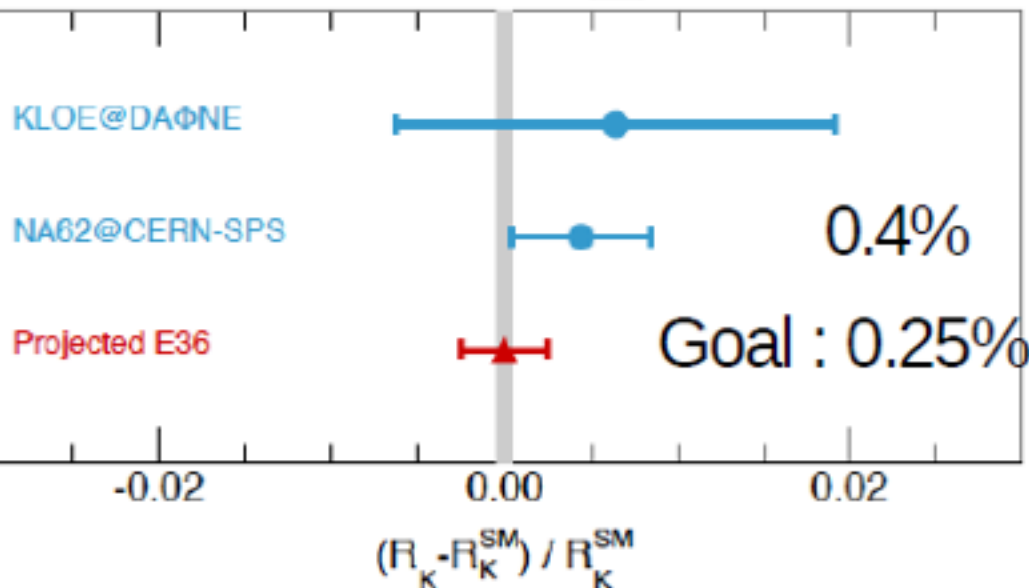
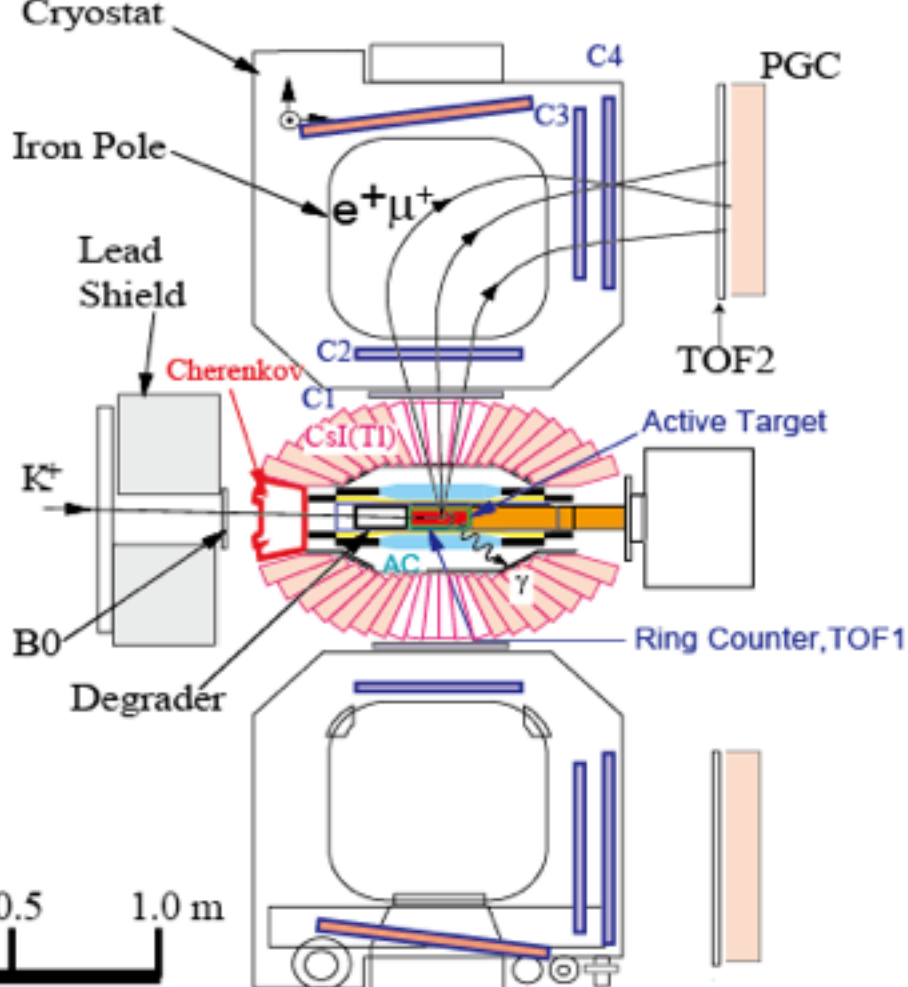
J-PARC TREK-E36

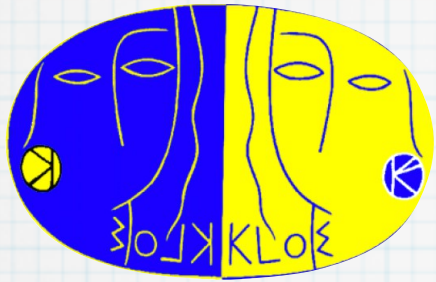
- * Lepton Universality

$$R_K = \frac{\Gamma(K^+ \rightarrow e^+ \nu)}{\Gamma(K^+ \rightarrow \mu^+ \nu)}$$

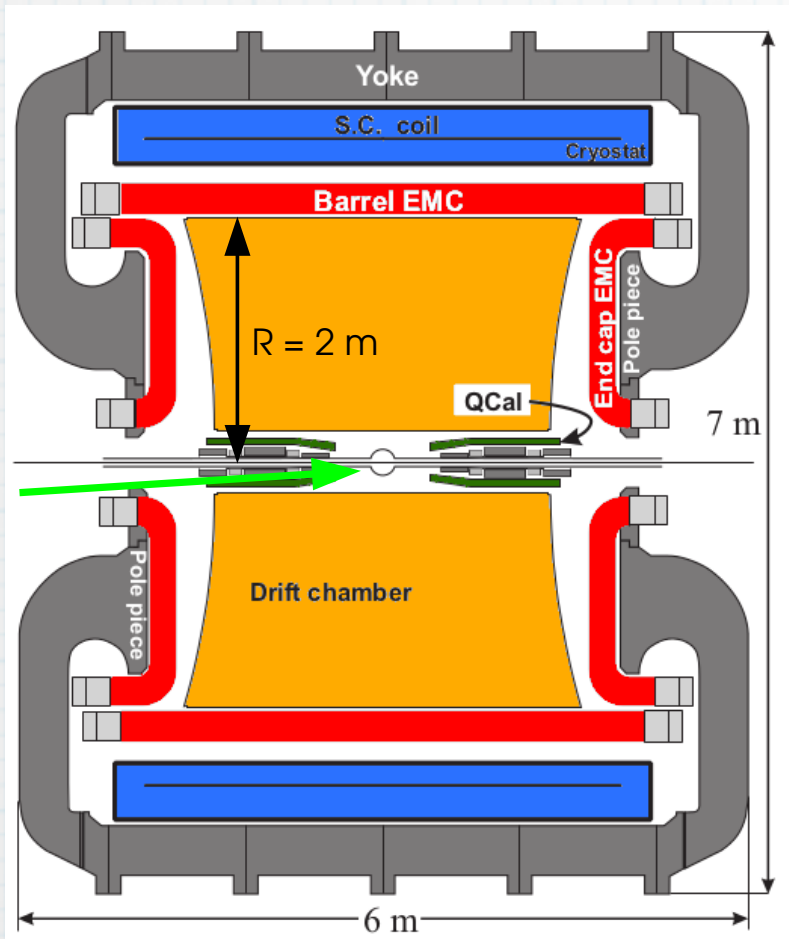
- * Run from spring 2015

- * Expect 0.20% stat error,
0.15% syst. error





KLOE, KLOE-2



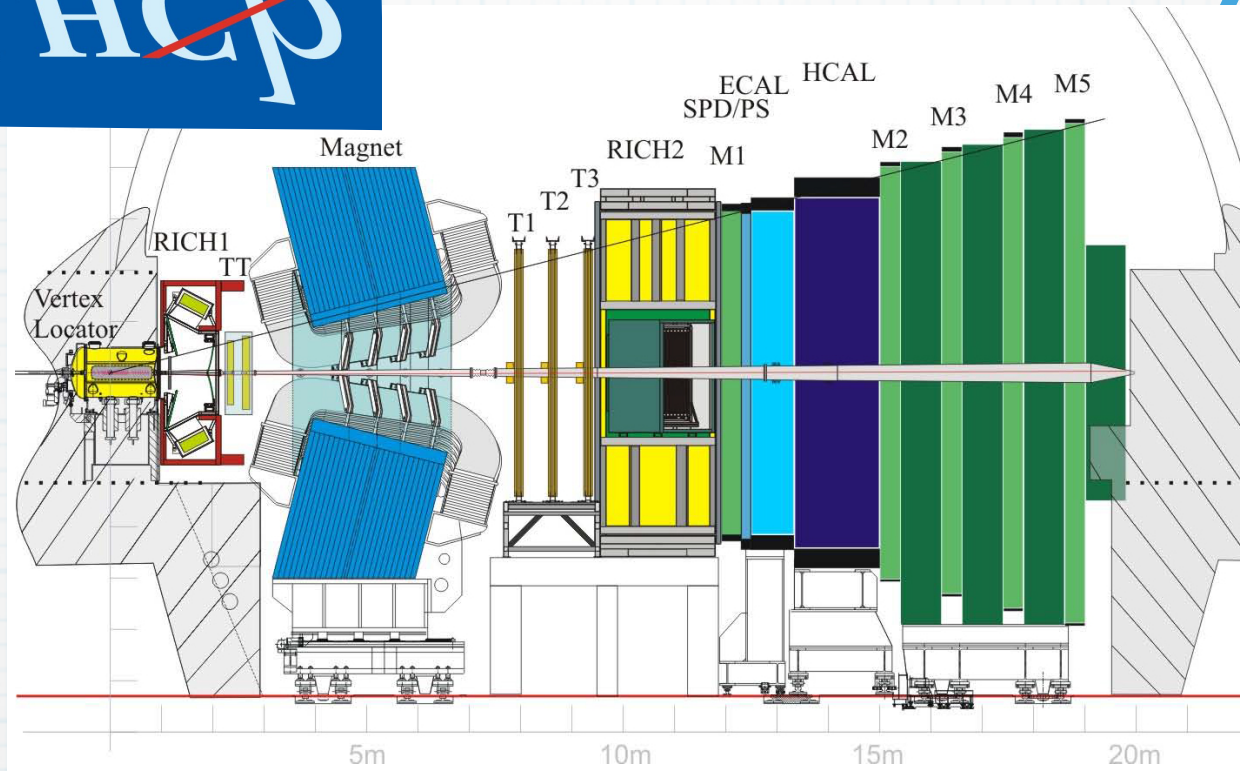
$$e^+e^- \rightarrow \phi \rightarrow K_S K_L$$

$$\rightarrow K^+ K^-$$

- * x3 Luminosity with crab-waist collision
- * Detector upgrades for higher acceptance and better vertex resolution
- * 5/fb in the next 2-3 years



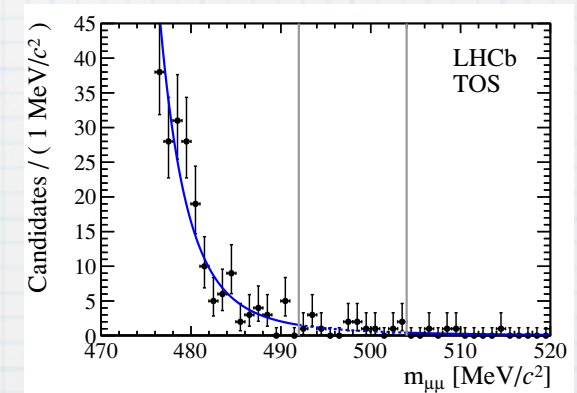
as K_s factory



* $B(K_s \rightarrow \mu\mu) < 9 \times 10^{-9}$ (90% CL)
 JHEP01(2013)090

* $\rightarrow O(10^{-10})$ w/ upgrade

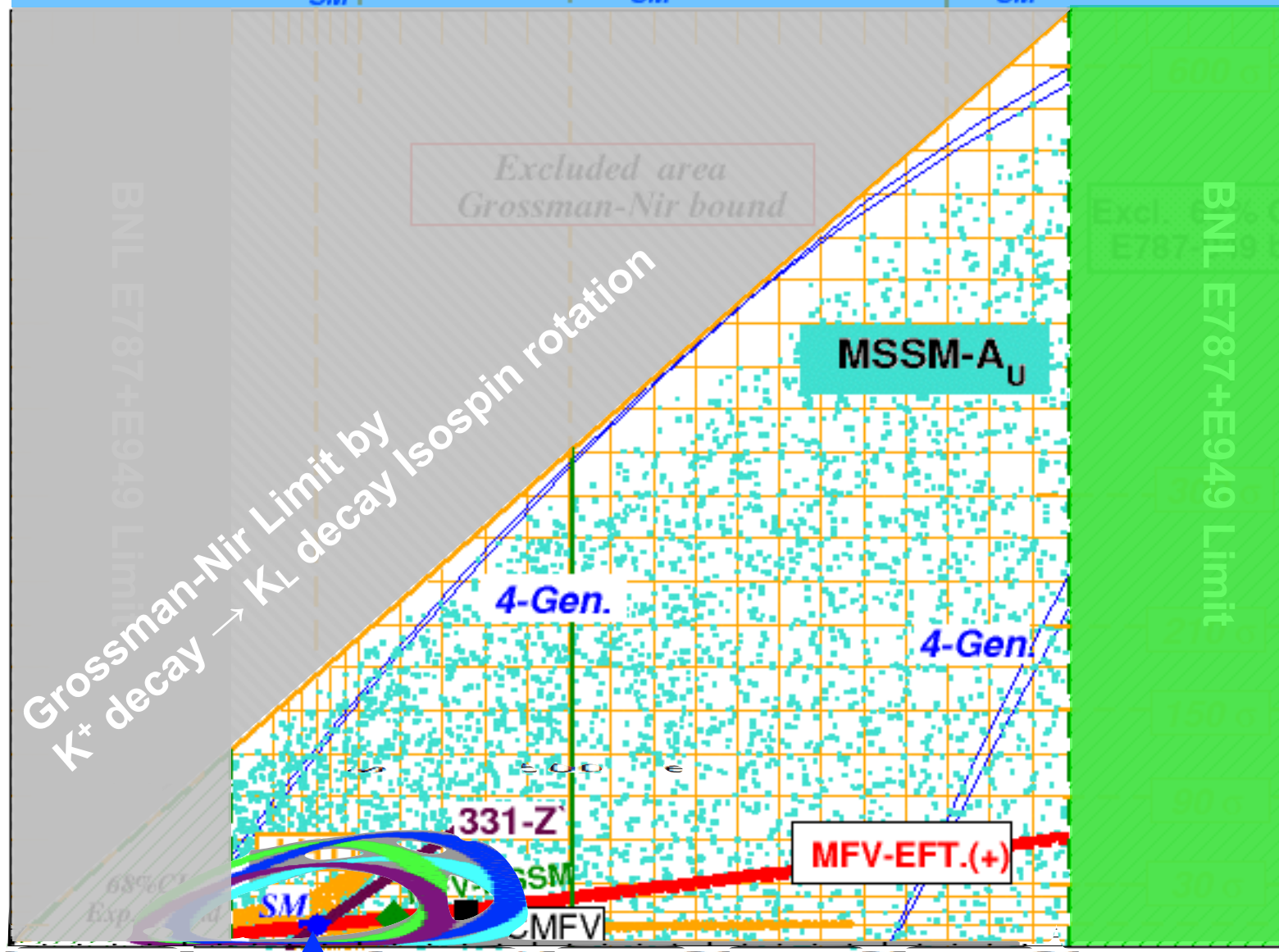
* Considering $K_s \rightarrow e e \mu \mu, e e e e, \pi^0 \mu \mu,$



Prospects of

$$K_L \rightarrow \pi^0 \nu \bar{\nu} \quad \& \quad K^+ \rightarrow \pi^+ \nu \bar{\nu}$$

$B(K_L \rightarrow \pi^0 \nu \bar{\nu}) \times 10^{11}$



3σ
 B_{SM}

$1.8 \times B_{SM}$

45σ
 $3.0 \times B_{SM}$

BNL E787+E949 Limit

BNL E787+E949 Limit

Grossman-Nir Limit by
 K^+ decay $\rightarrow K_L$ decay Isospin rotation

Excluded area
Grossman-Nir bound

MSSM- A_U

4-Gen.

4-Gen.

331-Z

MFV-EFT.(+)

SM

MFV

Standard Model

$B(K^+ \rightarrow \pi^+ \nu \bar{\nu}) \times 10^{11}$

+ Buras 2014

<http://www.lnf.infn.it/wg/vus/content/Krare.html>

Summary

- * Kaon experiments will explore physics beyond the standard model via
 - * $K \rightarrow \pi V V$ decay modes
 - * Lepton flavor violation, universality
 - * ...
towards the “zeptouniverse ($> 10^3$ TeV)” (Blanke)
- * Stay tuned!

