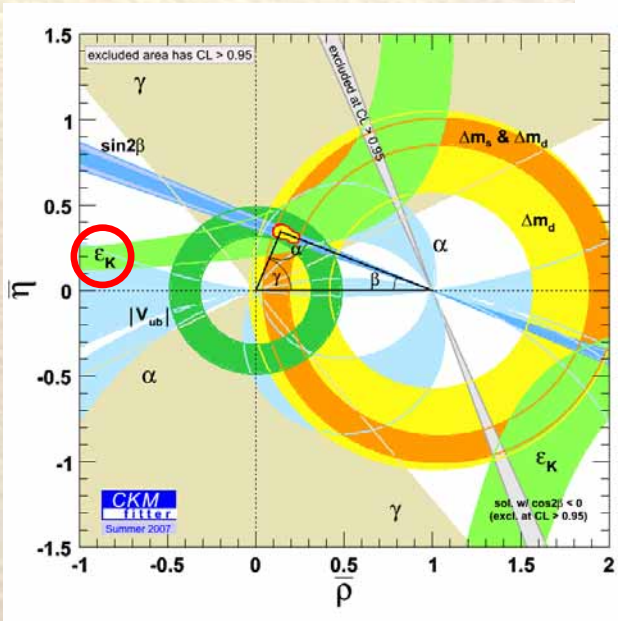
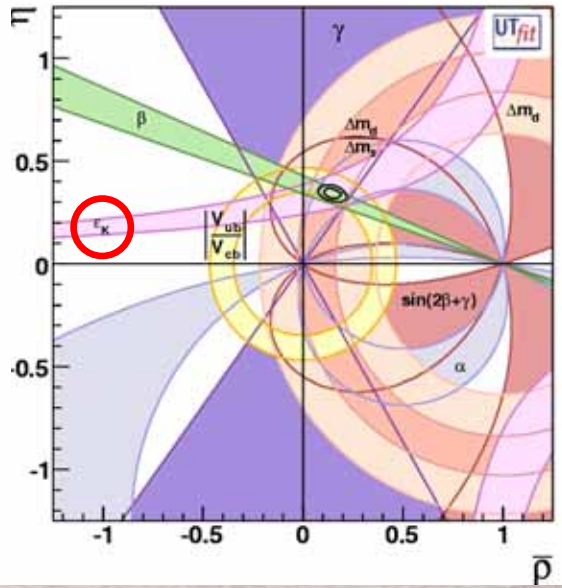
Reach of Future Kaon Efforts

Tadashi Nomura
(Kyoto U)

The Standard Model

- KAON inspired SM ideas in history
  - CPV in K decay ➔ KM theory, 3 generations
- And now..





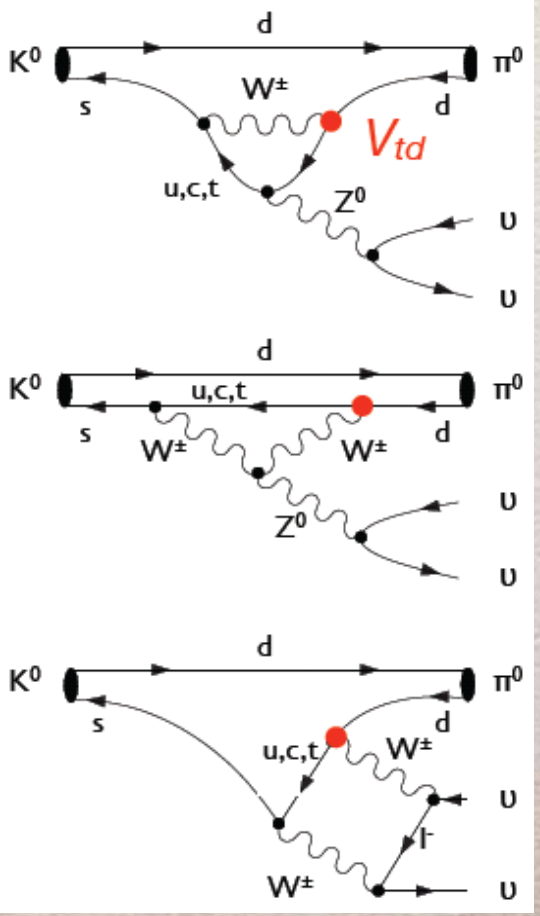
Role of Kaon efforts in future

- Explore physics beyond SM
  - Find discrepancy from SM
- Explore the flavor structure beyond SM
  - Find feature depending on flavors

COMMON TO
Flavor physics in next generation

Golden Modes : K→πνν

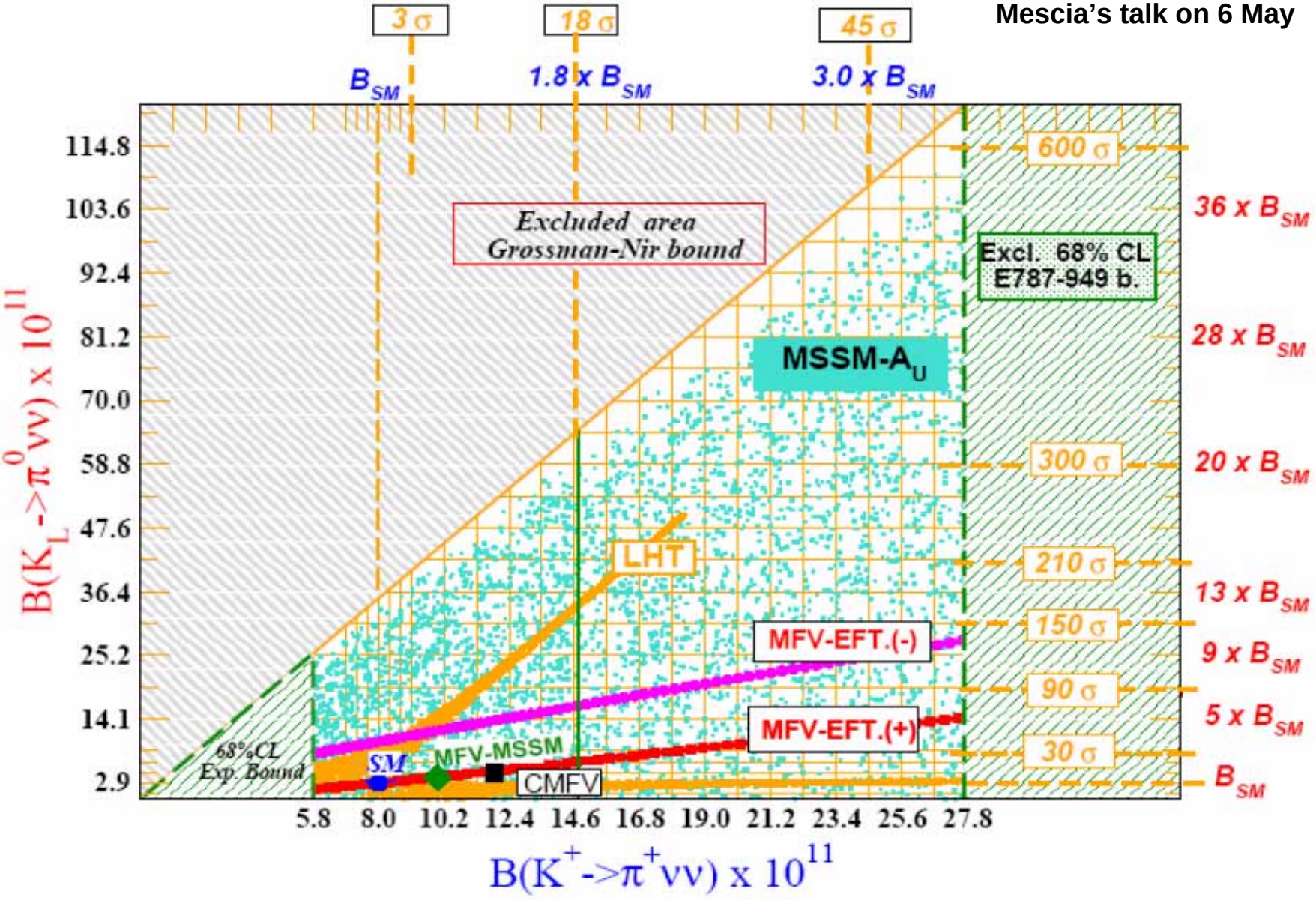
- Rare decays, O(10^{-11})
- Process via loop diagrams
  - "Top"-loop dominant in terms of SM
  - New particles can contribute in the loop
  - New flavor-violation can occur in the loop



Golden Modes : $K \rightarrow \pi\nu\nu$

- Extremely small theoretical uncertainty
  - <2% for neutral mode : $K_L \rightarrow \pi^0\nu\nu$
  - <5% for charged mode : $K^+ \rightarrow \pi^+\nu\nu$
- Many room to be contributed from BSM and not yet to be constrained

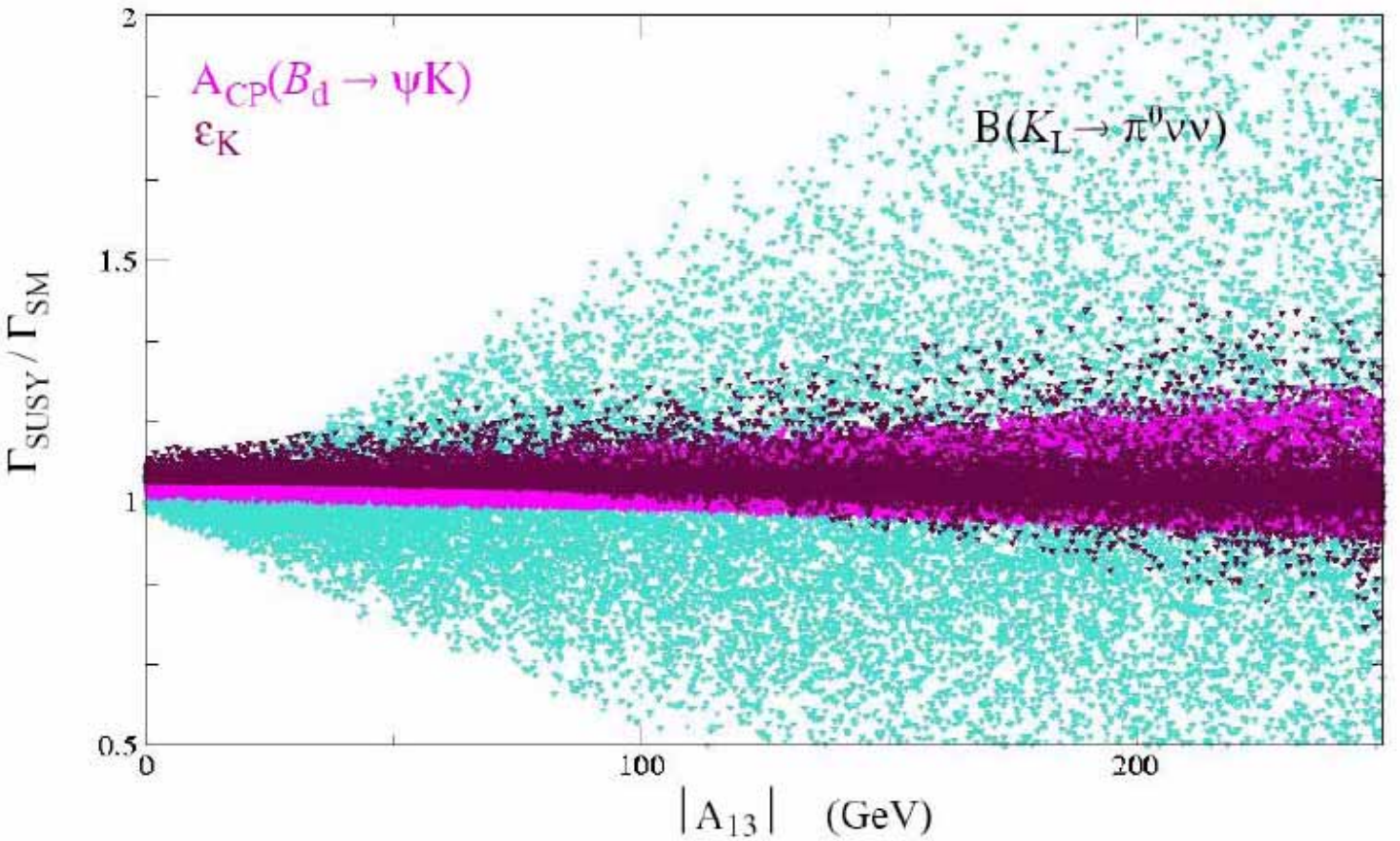
Mescia's talk on 6 May



Mescia's talk on 6 May

MSSM + non-MFV

CPV observables at comparison:
large room left due to the A^U terms



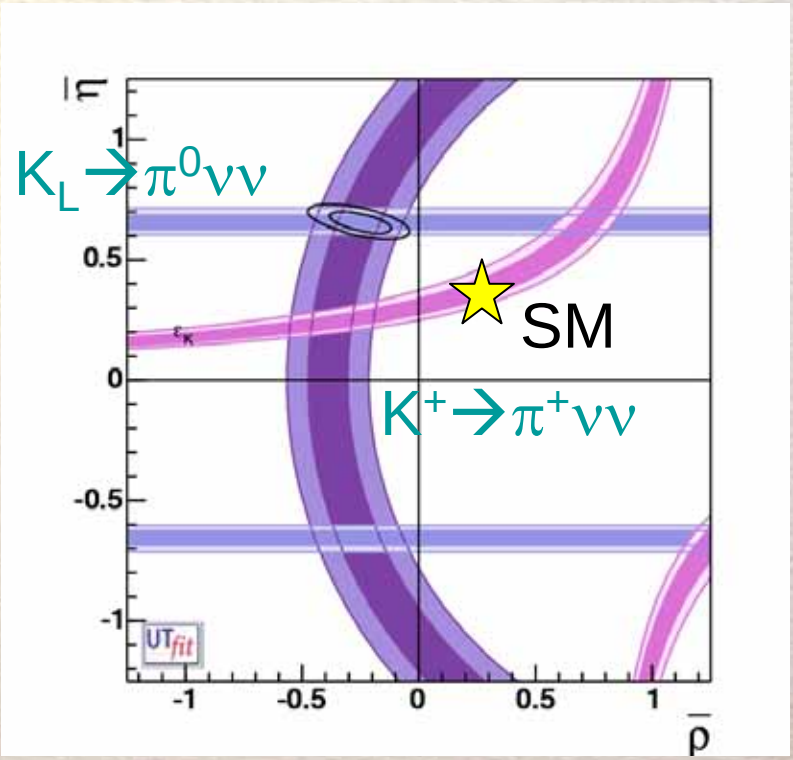
small impact on ε_K & sinβ, complementarity to LHCb/SuperB

Isidori,F.M,Paradisi,Trine,Smith (06)

Comparison with SM

➔ Once we achieve 10% measurements of K→πνν…

May find discrepancy



Current Achievements in Experiment

Current Situation - K^+

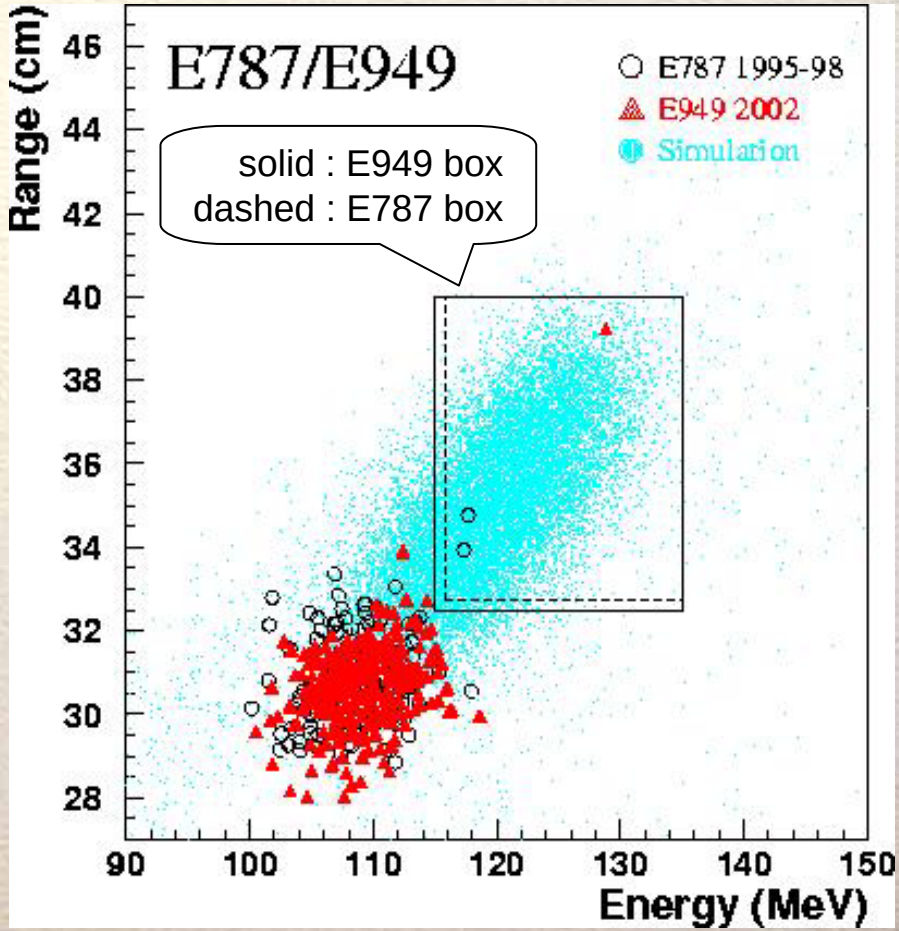
- BNL-E787/949
  - 3 candidates observed

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

$$BR = (1.5^{+1.3}_{-0.9}) \times 10^{-10}$$

$$\Updownarrow$$

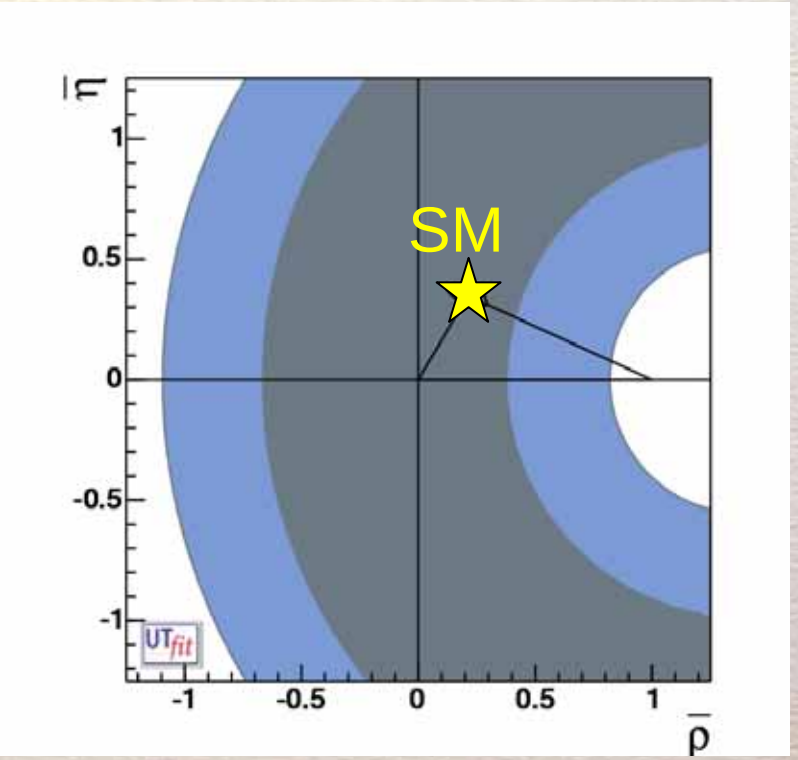
$$BR_{SM} = 8.2 \times 10^{-11}$$



Constraints in ρ-η plane (by now)

- By $K^+ \rightarrow \pi^+ \nu\nu$
  - Based on
    3 candidate events

➔ Clearly, we want to get more statistics.



Current Situation - K_L

- KEK E391a
  - No events observed

$K_L \rightarrow \pi^0 \nu\nu$

$$BR < 6.7 \times 10^{-8}$$

⇕

$$BR_{SM} = 2.8 \times 10^{-11}$$

I realize we didn't announce our results at any conference…

➔ Let me present more for E391a

KEK-E391a : Introduction

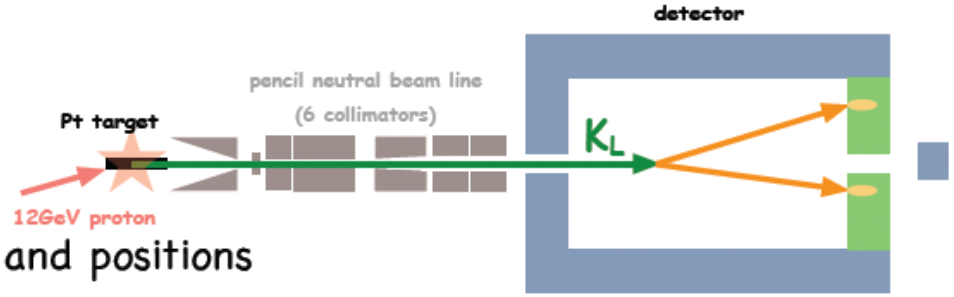
- Dedicated to $K_L \rightarrow \pi^0 \nu\nu$
  - With 12GeV KEK-PS,
    intensity of 2×10^{12} protons per pulse
  - 3 run periods in 2004-05
    - one not-clean run (Run1)
    - two clean runs (Run2 and 3)
  - Run2 result was announced last December

    arXiv:0712.4164 (will appear in PRL soon)

KEK E391a : Strategy

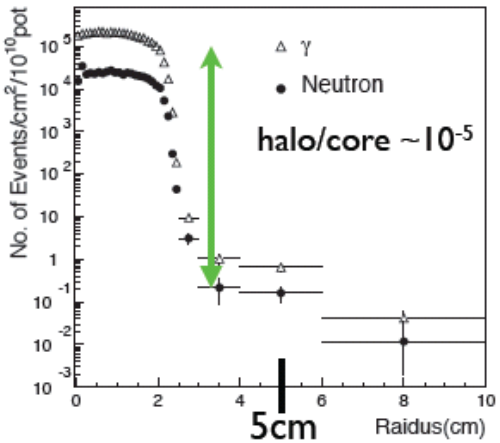
Signal = 2γ + nothing

1. require 2 photons
   - Hermetic veto system

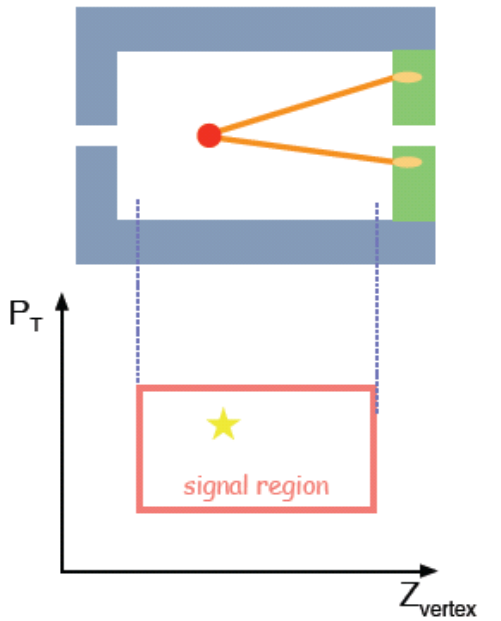


2. measure the photon energies and positions

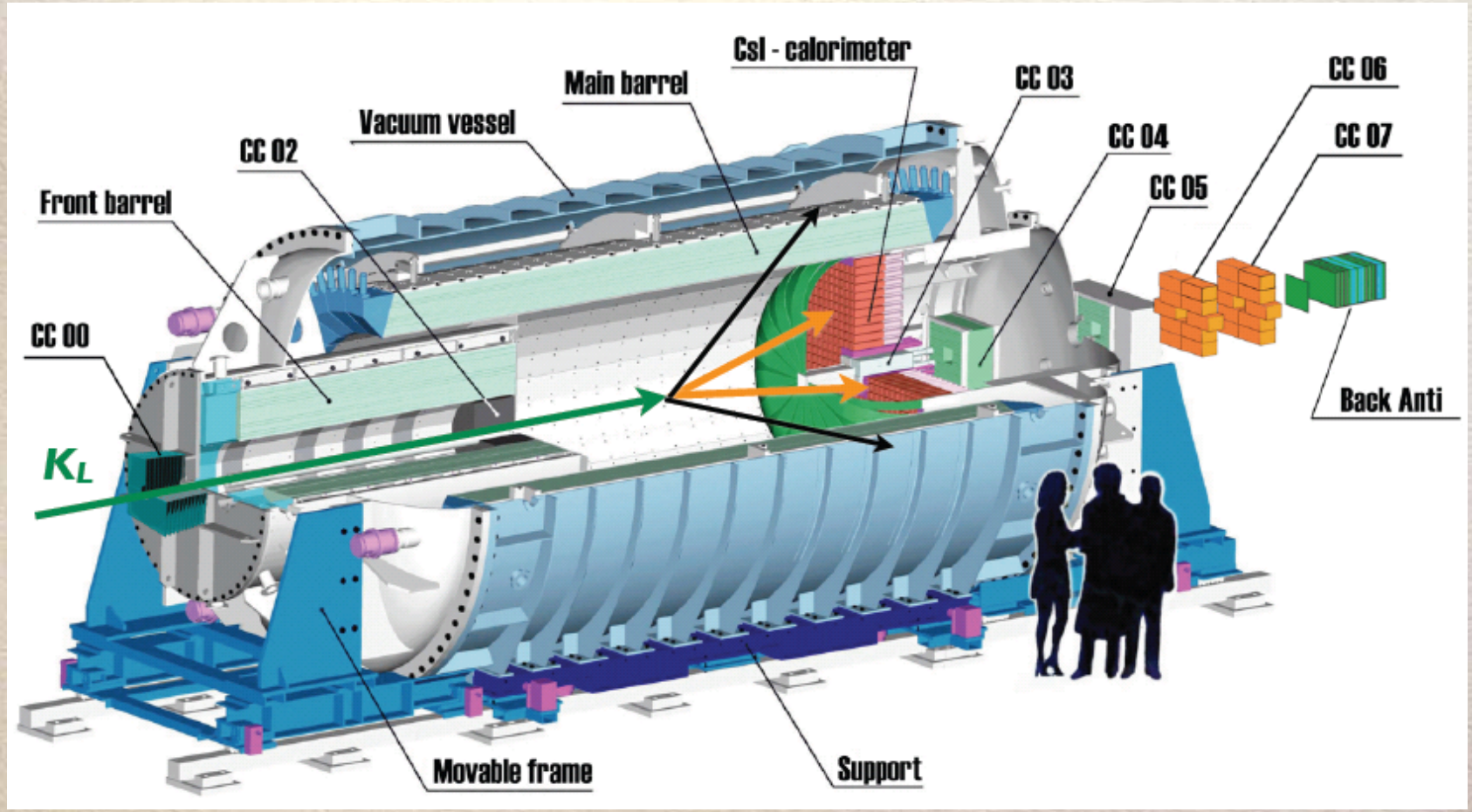
3. reconstruct the decay vertex
   on the beamline assuming $M_{2\gamma} = M_{\pi 0}$

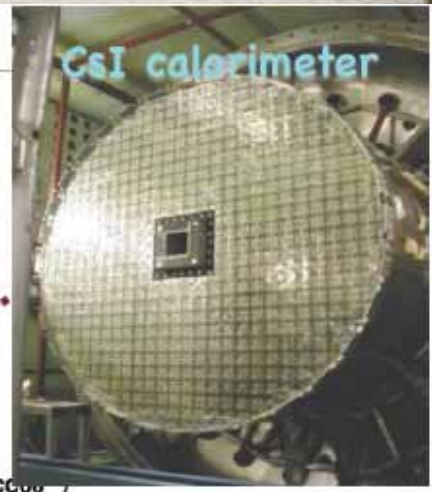


4. require missing P_T and the vertex in the fiducial region
   - "Pencil" beam line
     to improve P_T resolution
     - 8cm diameter @ 16m
       from the target

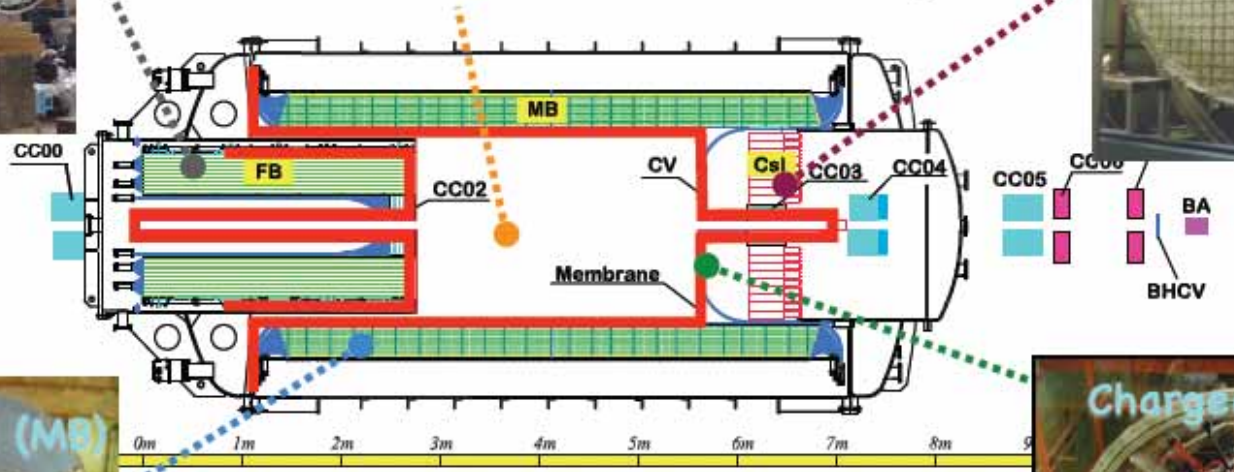


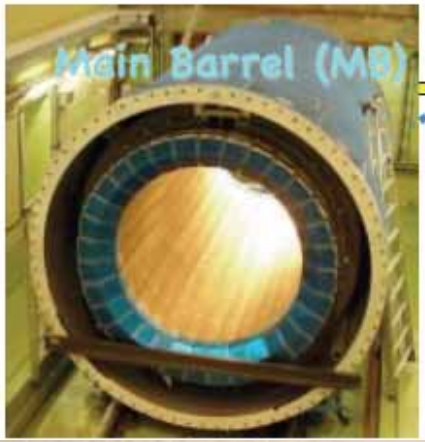
KEK E391a : Detector





- Decay region
  - High vacuum: 10^{-5} Pa
    - to suppress the background from interactions w/ residual gas



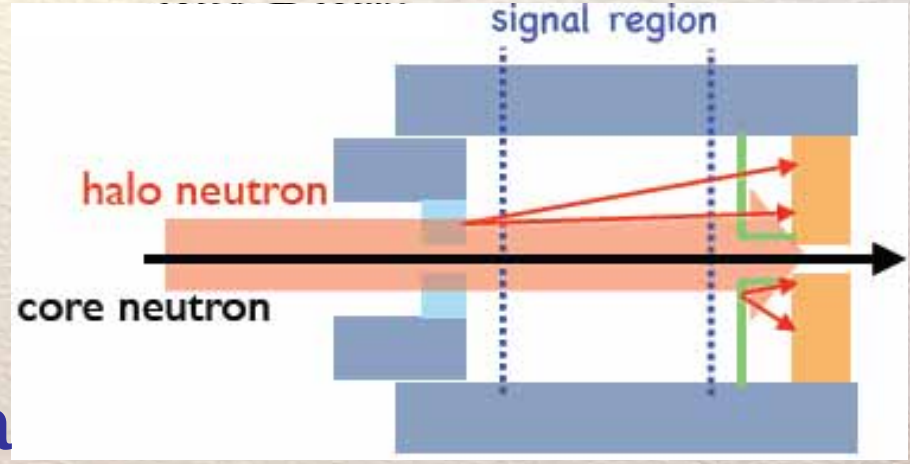


- Detector components
  - Set in the vacuum: 0.1 Pa
    - separating the decay region from the detector region with "membrane": 0.2mmt film

KEK E391a : Fight against BG

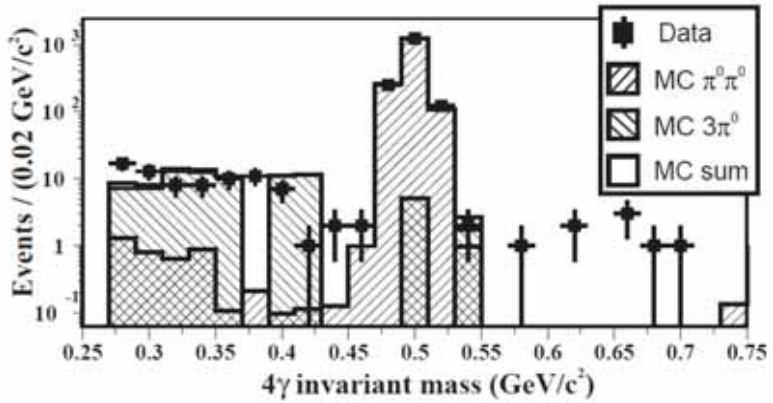
- Kaon BG
  - $K_L \rightarrow 2\pi^0$, with 2γ escaping detection
- Halo neutron BG
  - Interact with detectors placed near the beam
  - Produce π^0, η

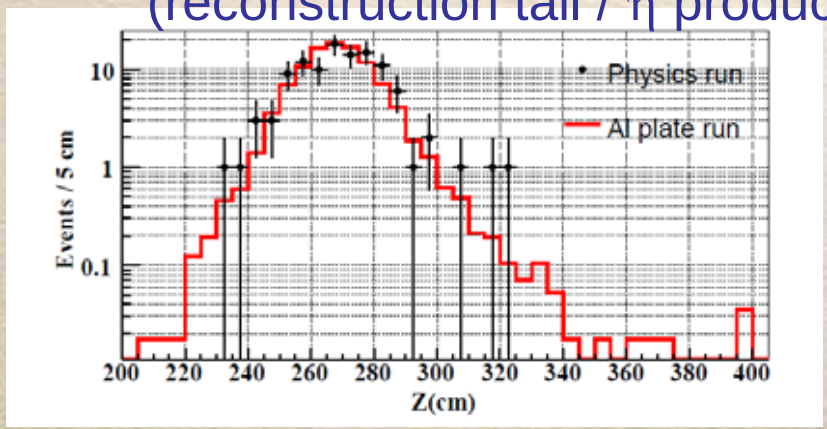
Dominant in E391a

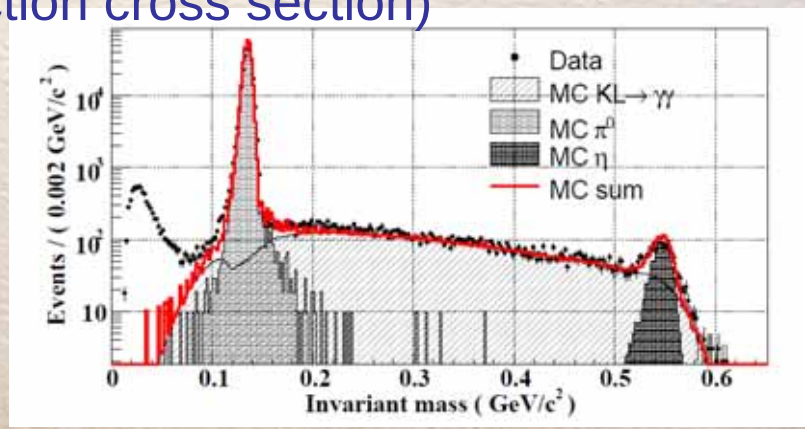


KEK E391a : Control BG

- Kaon BG
  Verify photon veto using 4γ data
  (“$2\pi^0$” and “$3\pi^0$+2γ missing”)
- Halo neutron BG
  Verify neutron interaction
  using special run data
  (reconstruction tail / η production cross section)







KEK E391a : Sensitivity

- BG well controlled

Background source	Estimated number of BG
$K_L^0 \to \pi^0\pi^0$	0.11 ± 0.09
CC02	0.16 ± 0.05
CV	0.08 ± 0.04
CV-η	0.06 ± 0.02
total	0.41 ± 0.11

} Neutron-induced

- N(K_L decays) = 5.1x10^9, ACC=0.67%

  ➔ S.E.S = 2.9 x 10^{-8}

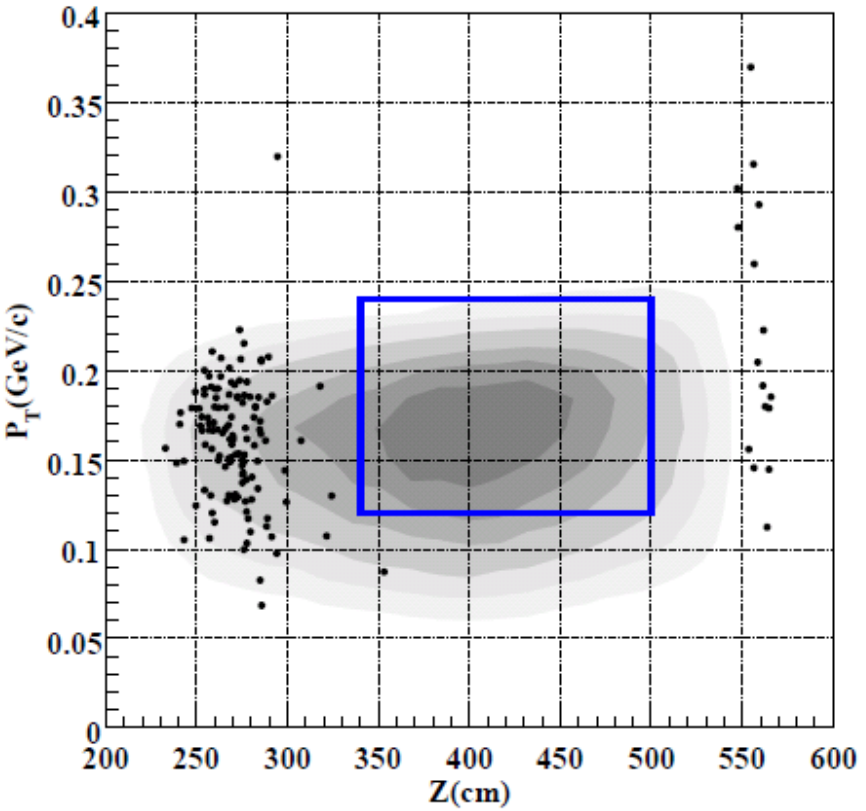
KEK E391a : Result

- Open the box
  and
  no event inside

➔ Set upper limit

$$BR < 6.7 \times 10^{-8}$$

E391a has another dataset
with similar statistics
and it is now on analysis.



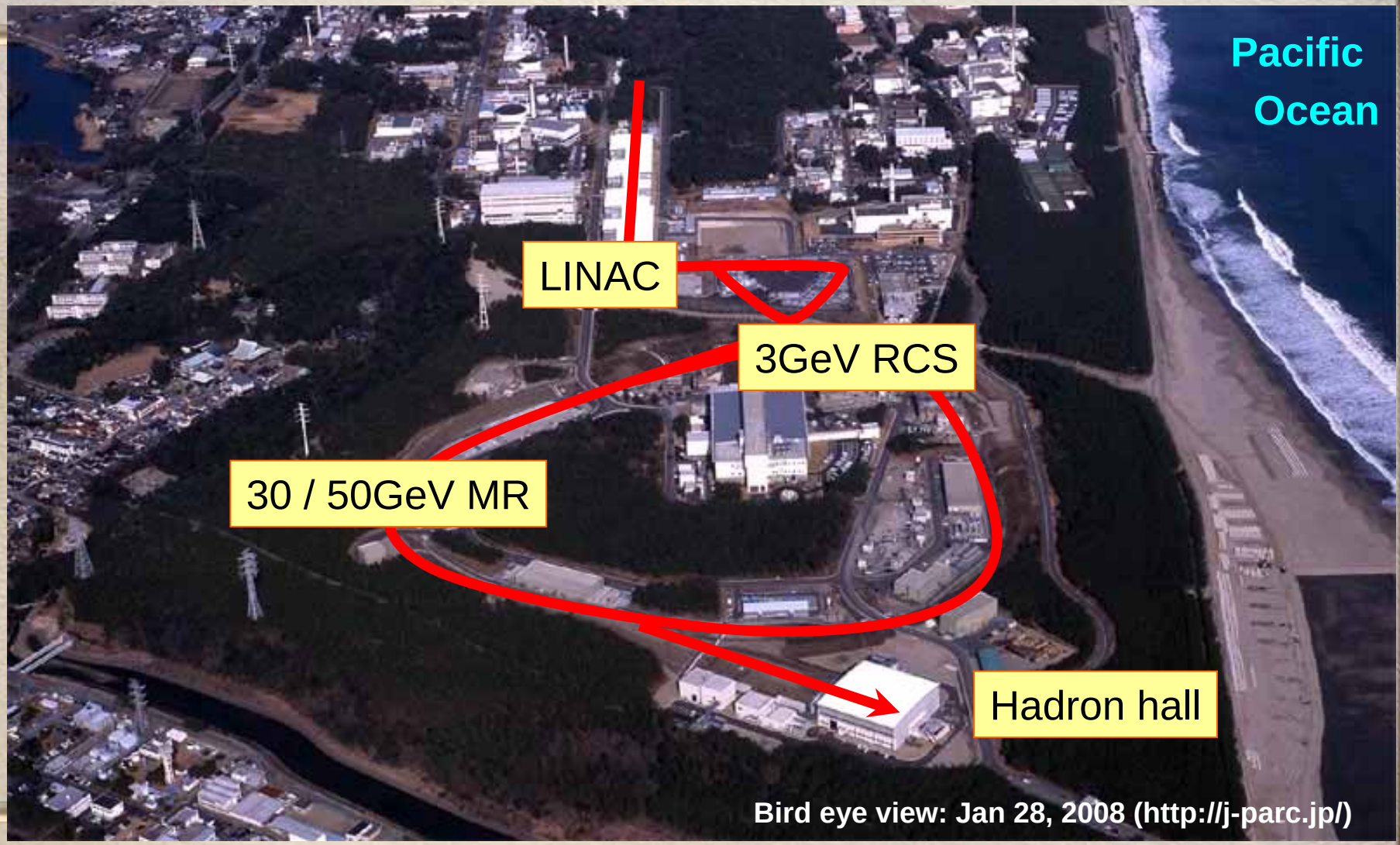
Kaon on the menu in Japan

J-PARC is coming

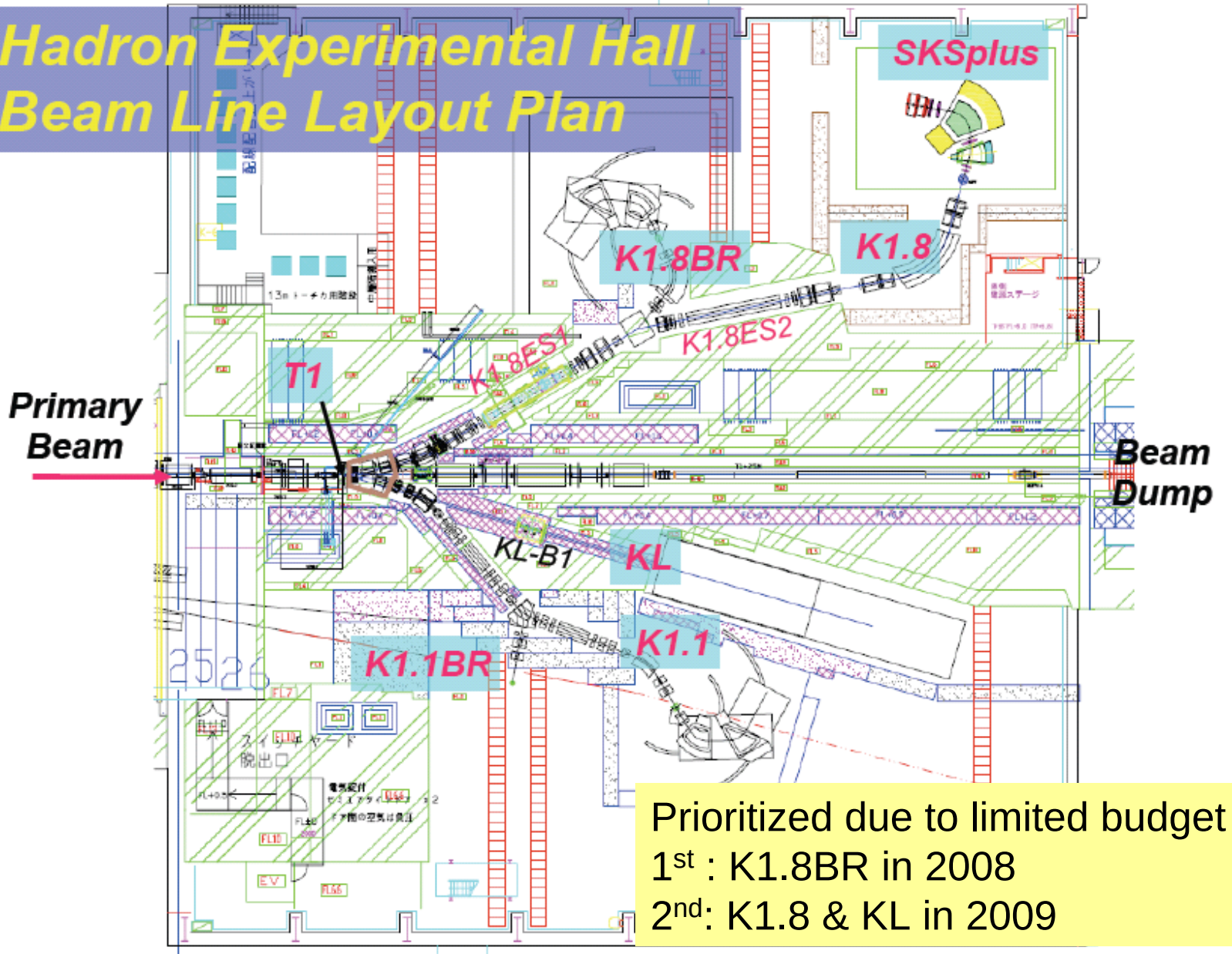
- High intensity proton synchrotron being constructed in Japan

= J-PARC [Japan Proton Accelerator Research Complex]

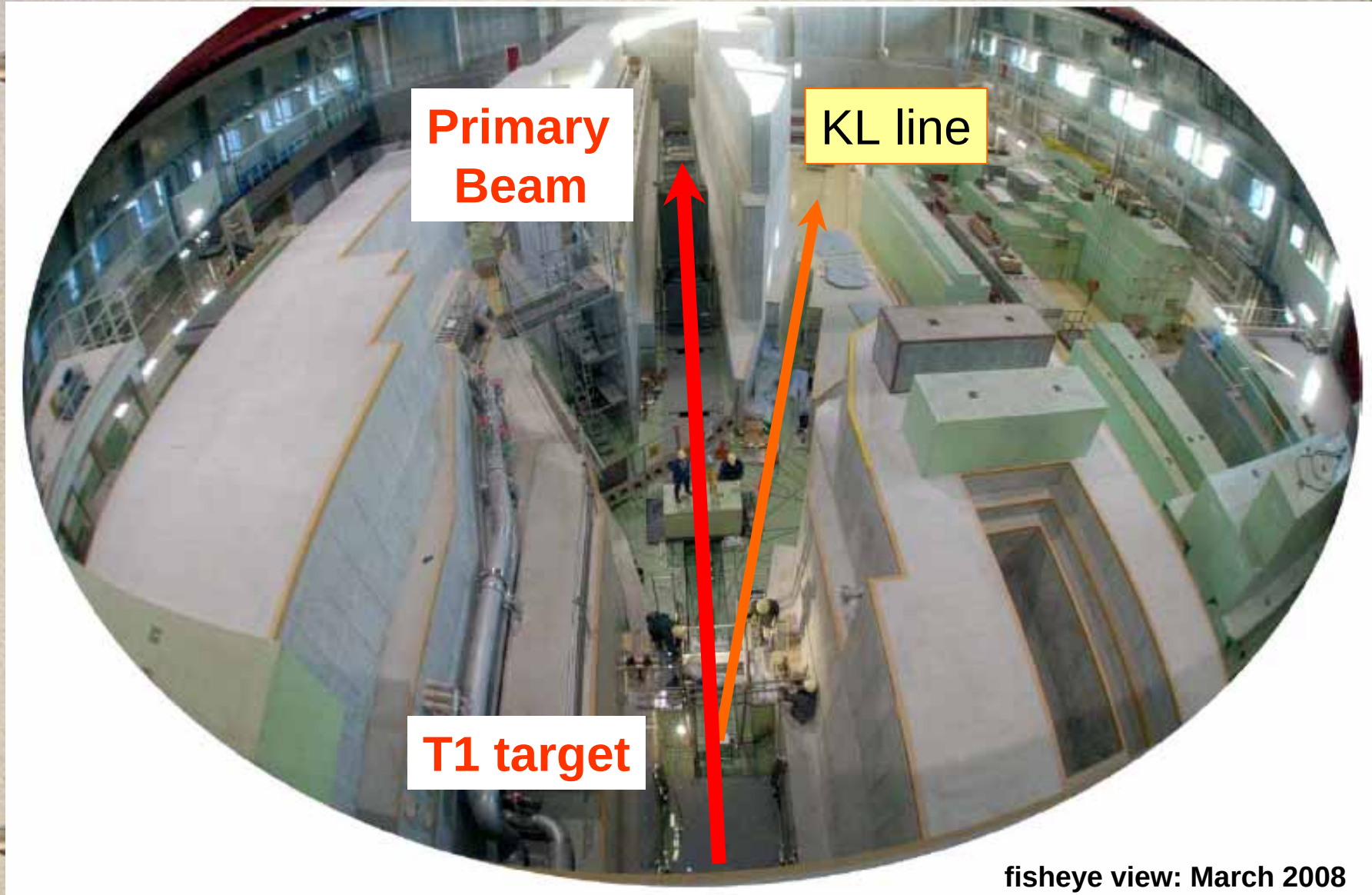
  - High power (0.75MW in phase 1), ~x100 of KEK-PS
  - 30 GeV Main Ring
  - Start MR commissioning in 2008 (this month!!)


Pacific Ocean
LINAC
3GeV RCS
30 / 50GeV MR
Hadron hall
Bird eye view: Jan 28, 2008 (http://j-parc.jp/)

Hadron Experimental Hall
Beam Line Layout Plan



Prioritized due to limited budget
1st : K1.8BR in 2008
2nd: K1.8 & KL in 2009



fisheye view: March 2008

$K_L \rightarrow \pi^0 \nu\nu$ at J-PARC : E14

Step 1

- Start with “modified E391a detector”
- Aim to touch the SM sensitivity
  - K_L yield ~ x40 of KEK-E391a
  - Run period ~ x10 of KEK-E391a
    - 30 days of Run2 → 3 snowmass years
  - Reduce acceptance loss ~ x3
    - Upgraded detectors

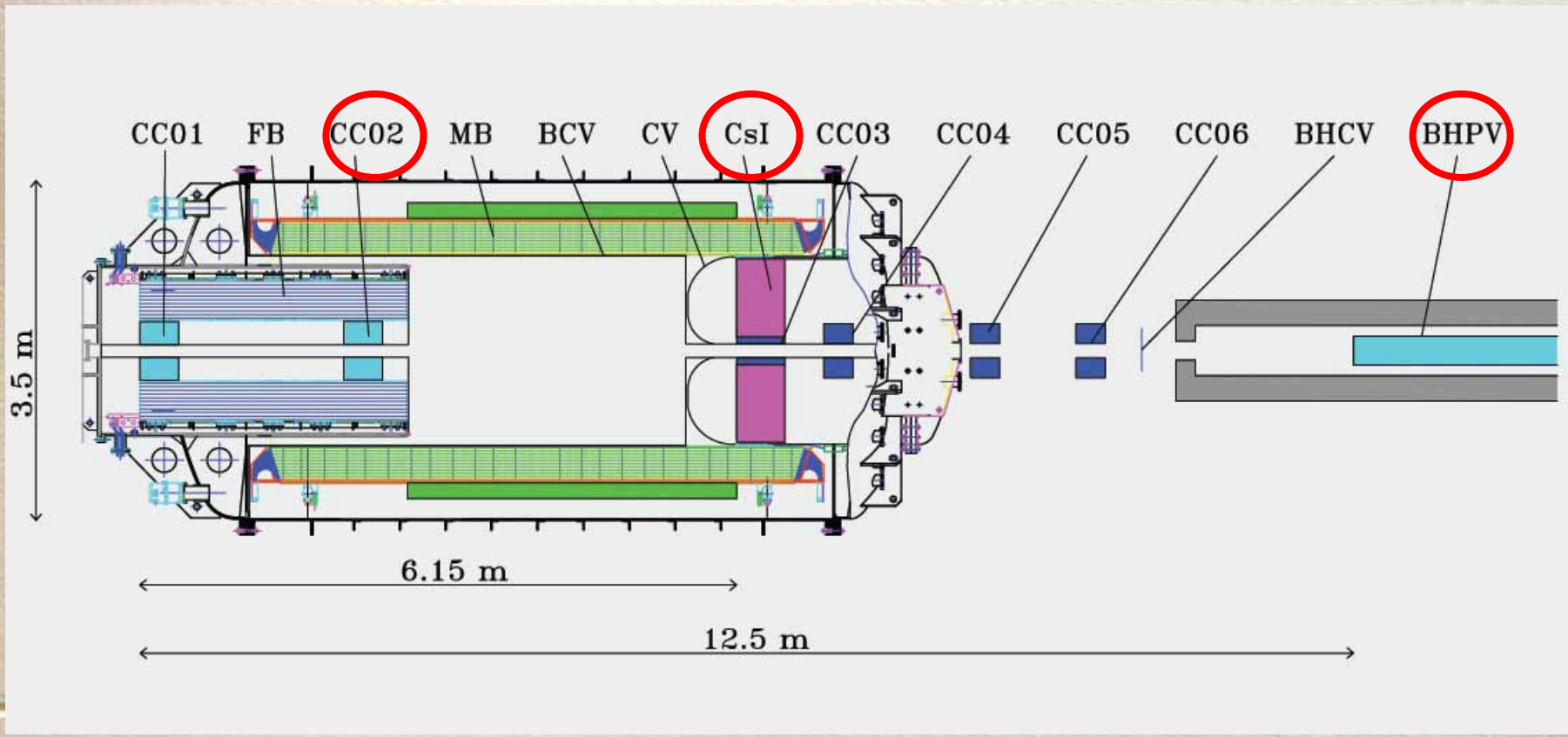
E14 Beam-line

- Common target to other experiments
- 16 degree production angle
- New beam-line configuration
  - Based on experience in E391a,
    newly designed and much improved

Note: These are not optimum
but compromise with boundary condition

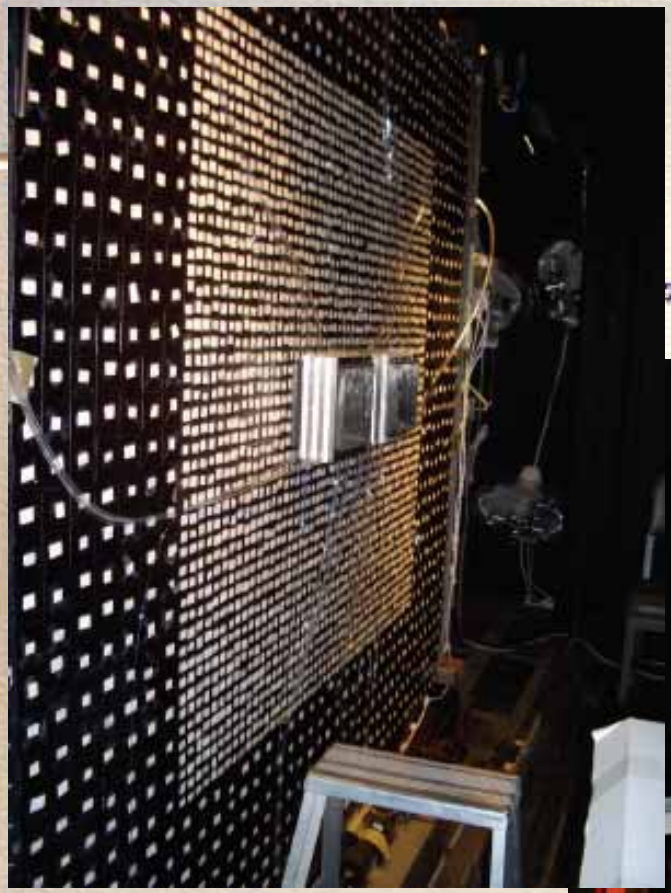
➔ There is a room to be improved in future step.

E14 Detector Upgrade



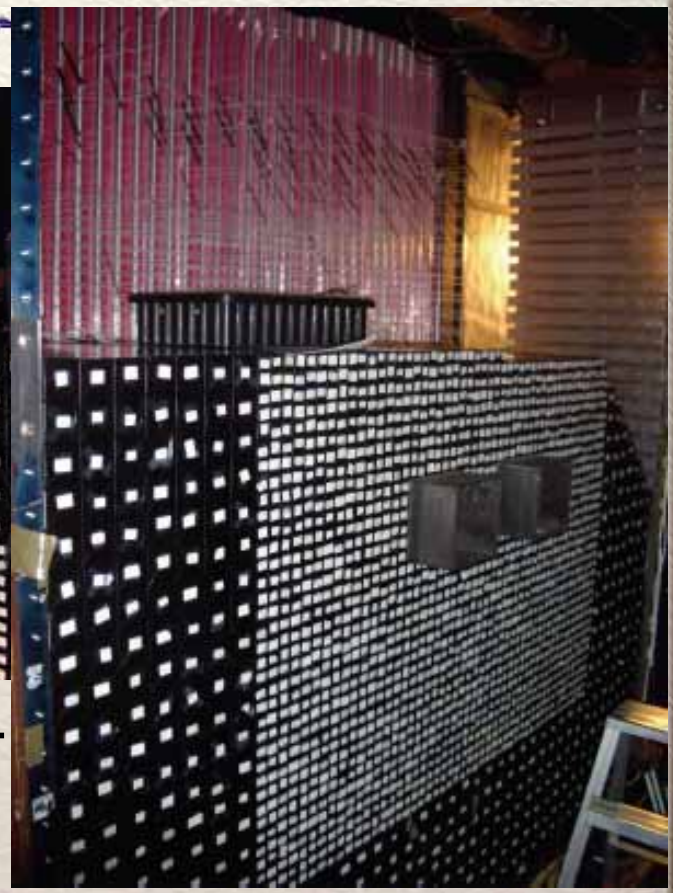
Pick up the calorimeter upgrade

- Wonderful KTeV CsI calorimeter is coming
  - Longer (30cm→50cm) and
    finer segmented (7cm-sq.→2.5cm-sq.)
  - →Better resolution (energy / position)
  - →Better shower shape analysis
- Newly developed readout
  - 125MHz FADC
  - Cockcroft-Walton base for PMT



KTeV calorimeter

Grad students work hard…



As of the end of April

Will finish transferring in this year

J-PARC E14 Sensitivity

- ~3 SM events
  in 3 snowmass years

- Signal-to-BG ratio ~ 1.5
  - Dominant BG : $K_L \rightarrow 2\pi^0$
  - Neutron BG well suppressed by
    - Softer beam
    - Optimize detectors near the beam

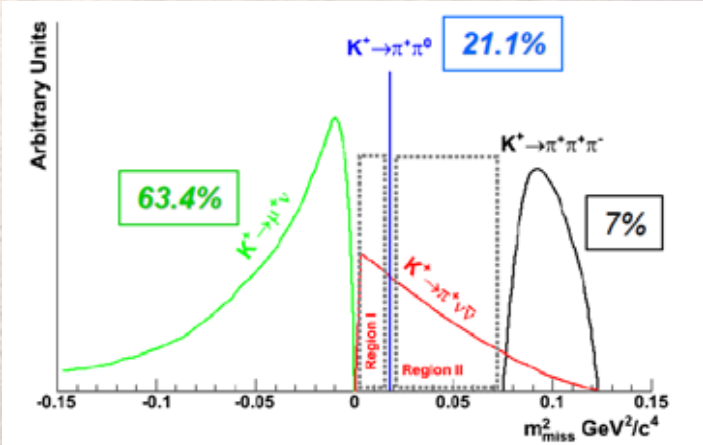
J-PARC E14 Timeline

- 2007 Stage 2 approval by PAC
- 2008 Preparing detector upgrade
- 2009 Construction of KL beam-line
- Beam-line survey
- 2010 Engineering run
- 2011 Physics run

Kaon on the menu at CERN

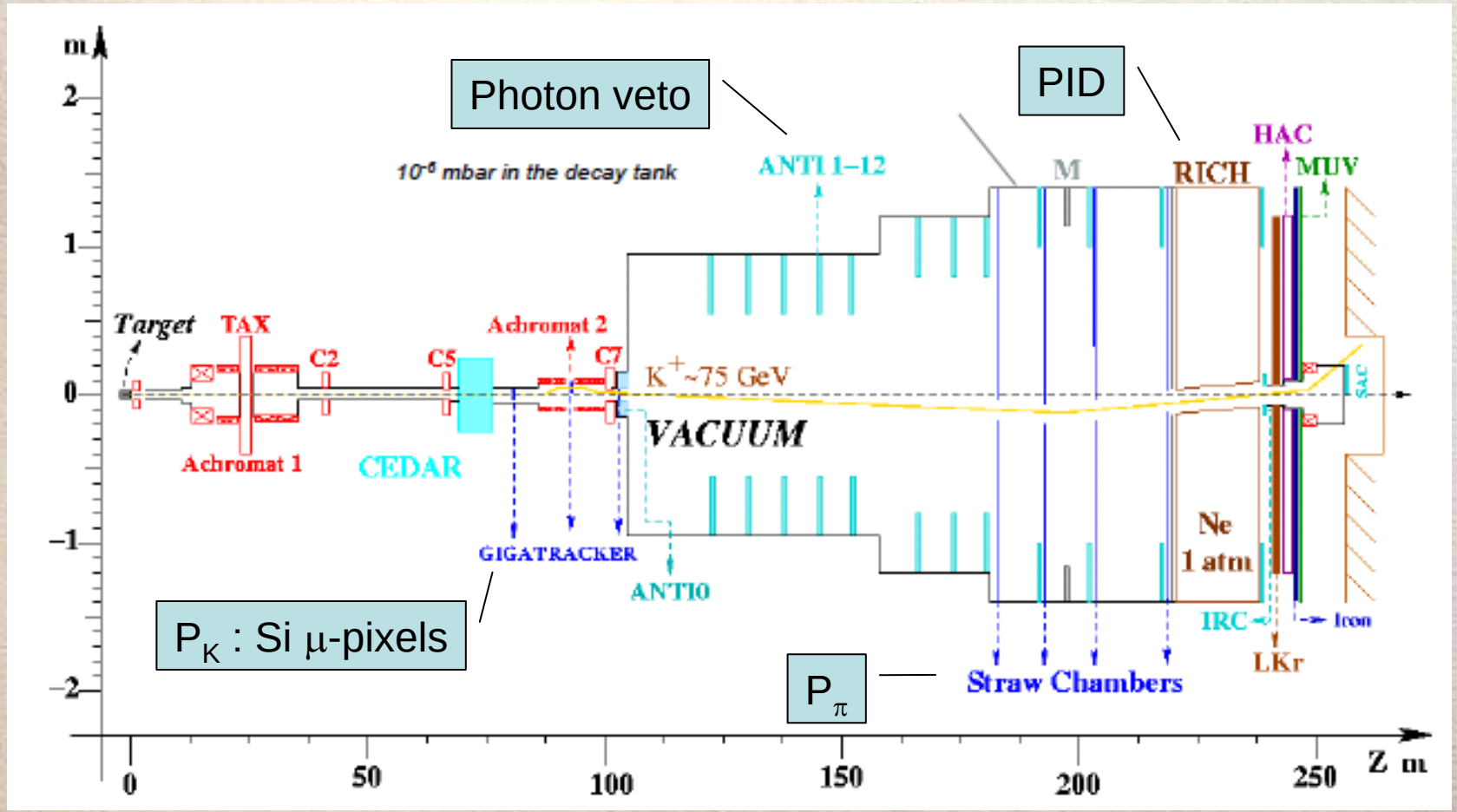
$K^+ \rightarrow \pi^+ \nu\nu$ at CERN-SPS : NA62

- K^+ decay in flight (cf. stopped K^+ in BNL-B787/949)
- Existing beam-line + modification
- Existing detector (NA48) + modification
- 80 events in 2 years
- S/N ~ 10
  - Key for BG rejection
    - Kinematical constraint
    - Veto
    - PID



$$m^2_{miss} \approx m^2_K\left(1-\frac{|P_\pi|}{|P_K|}\right)+m^2_\pi\left(1-\frac{|P_K|}{|P_\pi|}\right)-|P_K||P_\pi|\vartheta^2_{\pi K}$$

NA62 Key Detectors

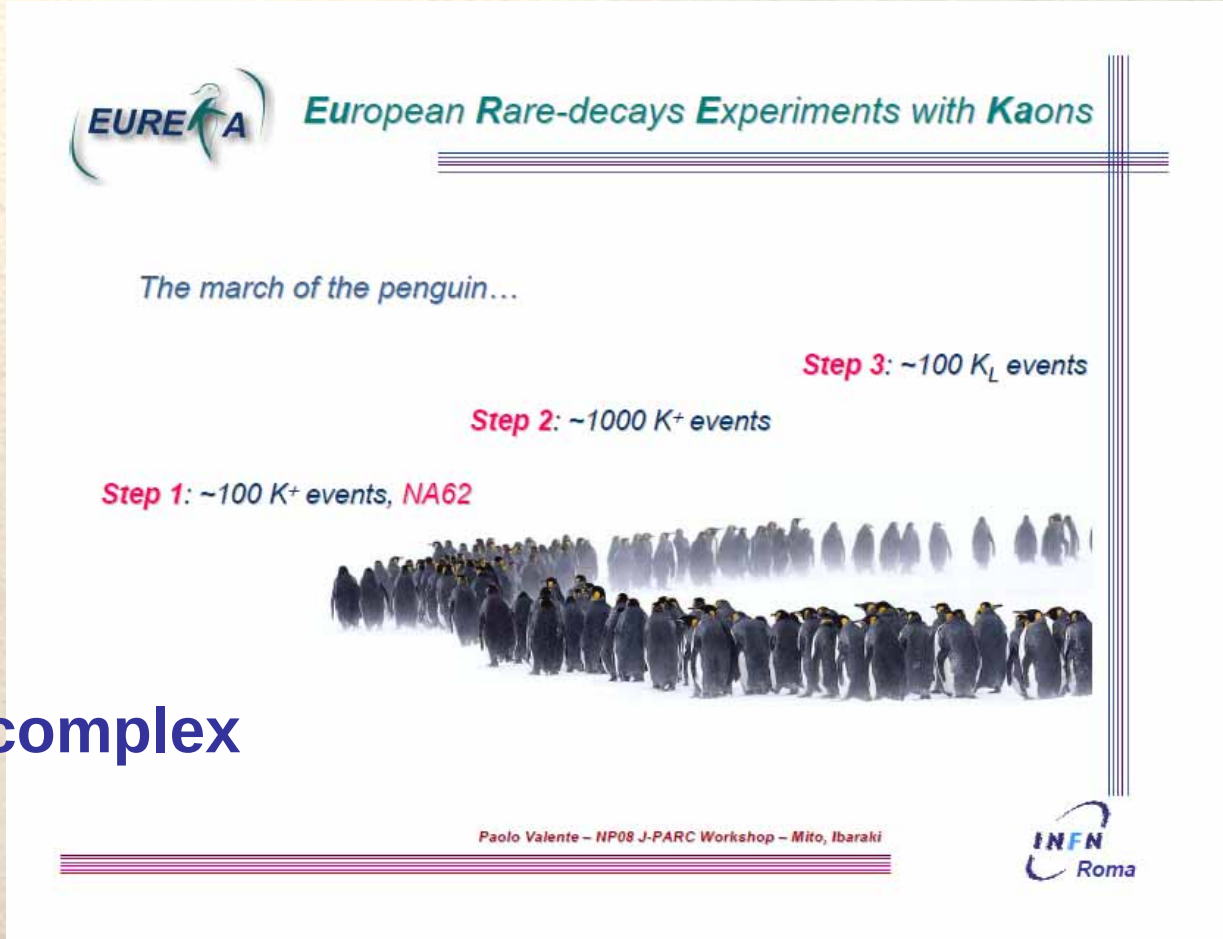


CERN NA62 Timeline

- 2008 TDR submission
- Full approval (Hope!)
- Detector R&D
- 2009- Design finalizing
- 2012- Data taking

And more at CERN…

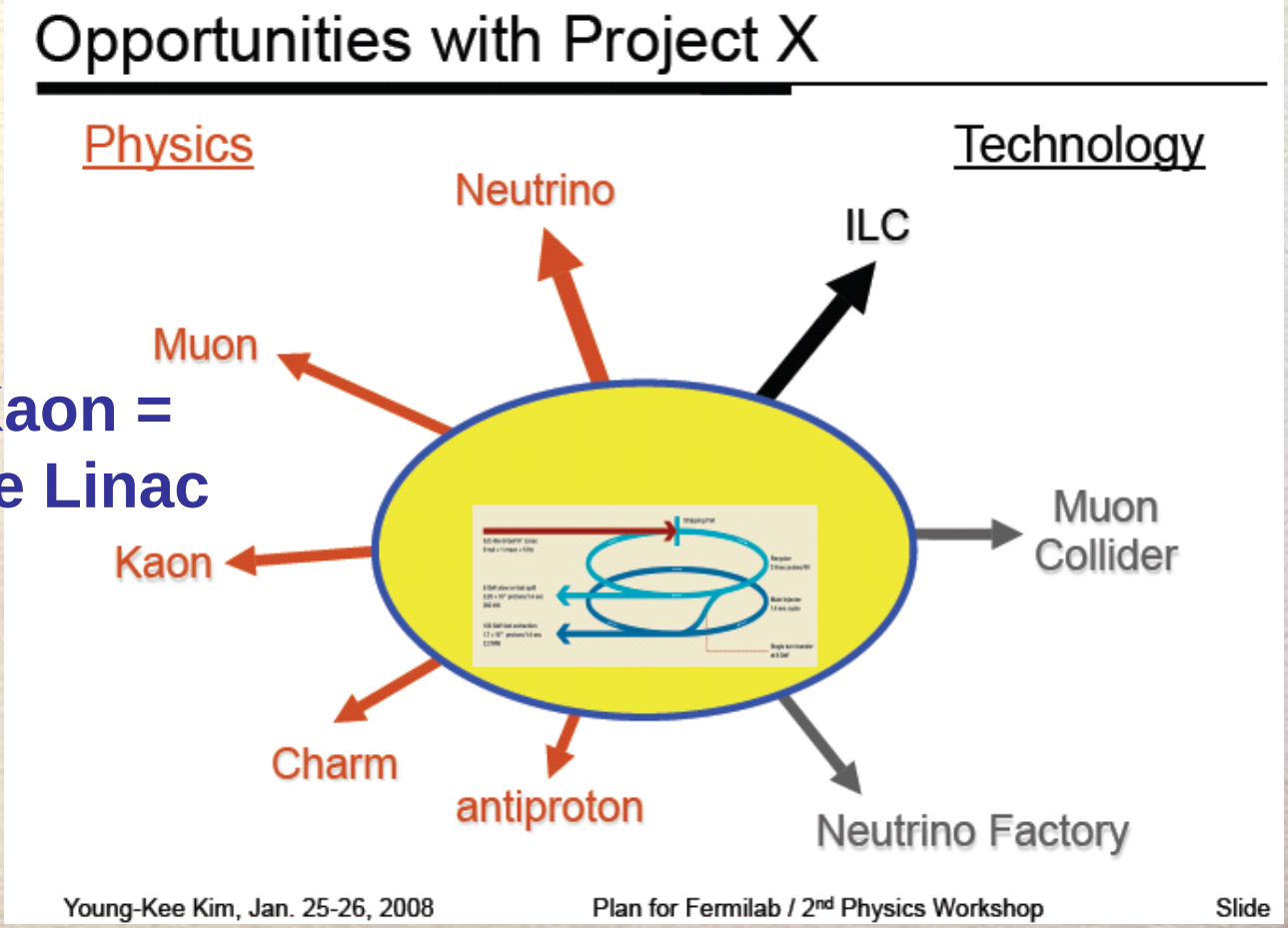
In upgrade of CERN proton complex



Kaon opportunity at FNAL

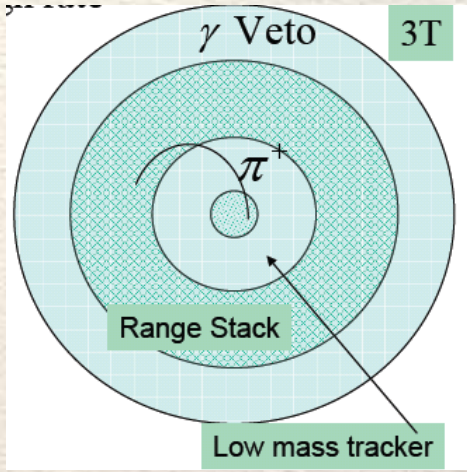
As a part of Project X

Project X for Kaon =
8GeV ILC-like Linac
+ Recycler

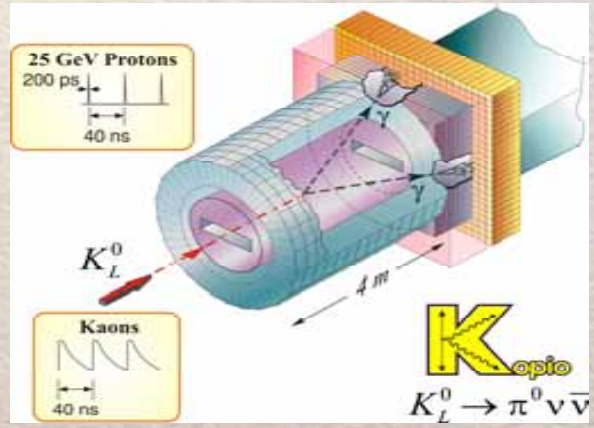


Ideas for $K \rightarrow \pi\nu\nu$

- $K^+ \rightarrow \pi^+\nu\nu$
  - Like BNL-E787/949
    - Stopped K^+
  - Compact and higher B field



- $K_L \rightarrow \pi^0\nu\nu$
  - KOPIO-like experiment
    - KL-TOF
    - Measure γ direction



Just a start of discussion, but…

Facility	Duty Factor	Clock hours	Beam hours	Projected # of $K \rightarrow \pi\nu\bar{\nu}$
CERN-SPS (450 GeV)	30%	1420	405	40 (charged)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	40 (charged)
Tevatron-Stretcher (120 GeV)	90%	5550	5000	200 (charged)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	250 (charged)
JPARC-I (30 GeV)	21%	2780	580	~1 (neutral)
BNL AGS (24 GeV)	50%	1200	600	20 (neutral)
JPARC-II (30 GeV)	21%	2780	580	30 (neutral)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	30 (neutral)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	300 (neutral)

B. Tschirhart @ FNAL-PAC, March 2008

Summary

- Kaon program still can play important roles in flavor physics
  - Explore beyond the SM
  - Explore flavor dynamics beyond the SM
- Experiments for golden mode $K \rightarrow \pi\nu\nu$ are planned and in preparation
  - Japan (E14), CERN (NA62), FNAL, …

Summary – cont'd

- $K_L \rightarrow \pi^0 \nu\nu$
  - Observation in 5 years : O(1) SM events
    - J-PARC E14
  - 10% measurement in 10 years : O(100) events
    - J-PARC Phase-2, FNAL Project-X, CERN Step-3
- $K^+ \rightarrow \pi^+ \nu\nu$
  - 10% measurement in 5 years : O(100) events
    - CERN NA62, FNAL Project-X

Final Message

KAON efforts proceed
step by step
toward BSM exploration
early next decade.

T hank you for your attention.