P14: $K_L \to \pi^0 \nu \nu$ Experiment at J-Parc

Taku Yamanaka
Osaka Univ.

...for the collaboration

* Arizona State Univ.
* Chicago Univ.
* JINR
* KEK
* Kyoto Univ.
* National Defense Academy
* National Taiwan Univ.
* Osaka Univ.
* Pusan National Univ.
* Saga Univ.
* Tbilisi State Univ.
* TRIUMF
* Yamagata Univ.

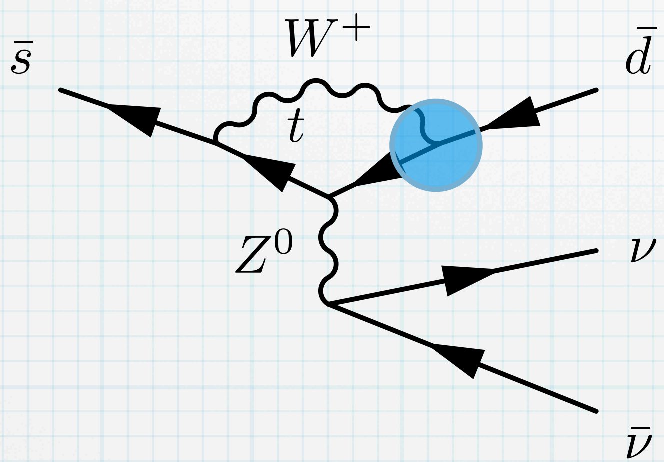
J-Parc in the LHC era

* Energy frontier: LHC, LC, ...
  * direct search for new physics, such as SUSY
* INTENSITY FRONTIER: J-Parc
  * understand the FLAVOR PHYSICS of the new particles
  * search beyond the energy frontier
* Why the matter dominant universe?

The probe: $K_L \to \pi^0 \nu\nu$

* $A(K_L \to \pi^0 \nu\nu) \propto A(K^0 \to \pi^0 \nu\nu) - A(\bar{K}^0 \to \pi^0 \nu\nu)$

=



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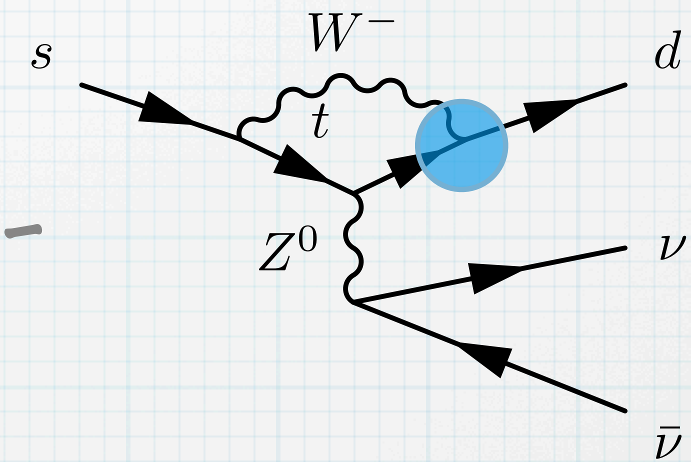
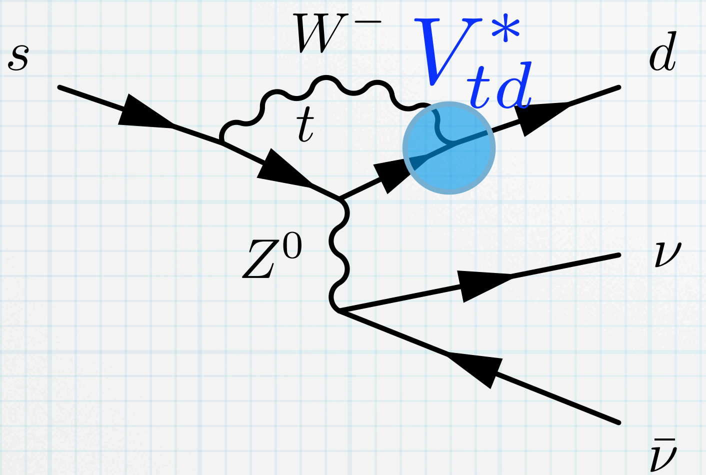


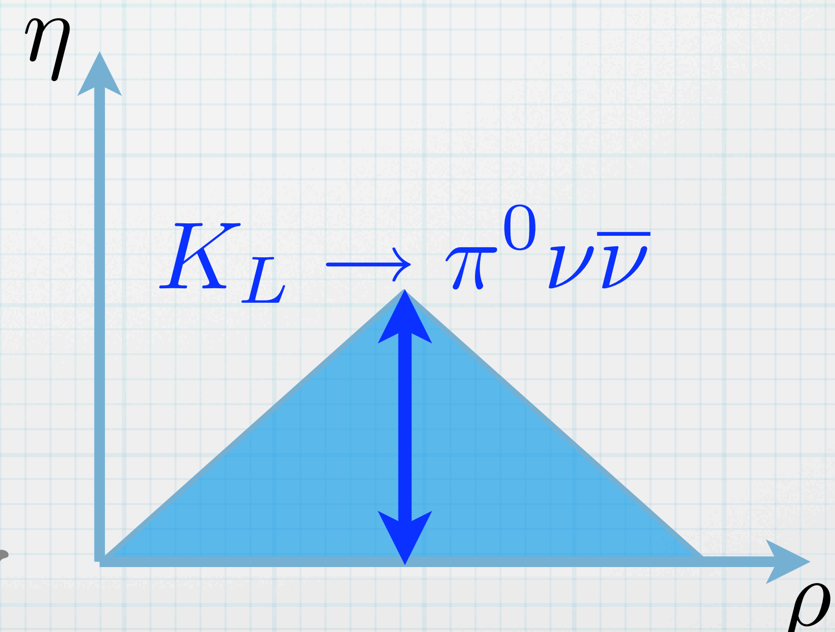
$\propto V_{td} - V_{td}^* = 2\,\mathrm{Im}(V_{td})$

$\propto$ CP violation

$K_L \to \pi^0 \nu\nu$ in Standard Model

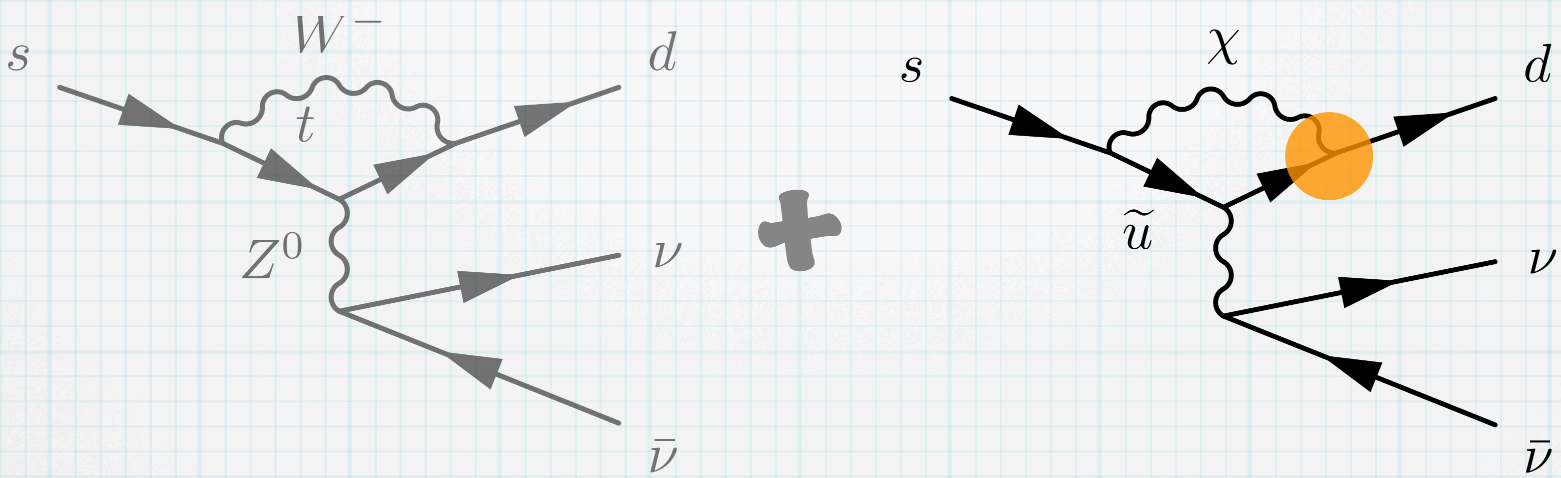


$$A(K_L \to \pi^0 \nu\overline{\nu}) \propto V_{td} - V_{td}^*$$

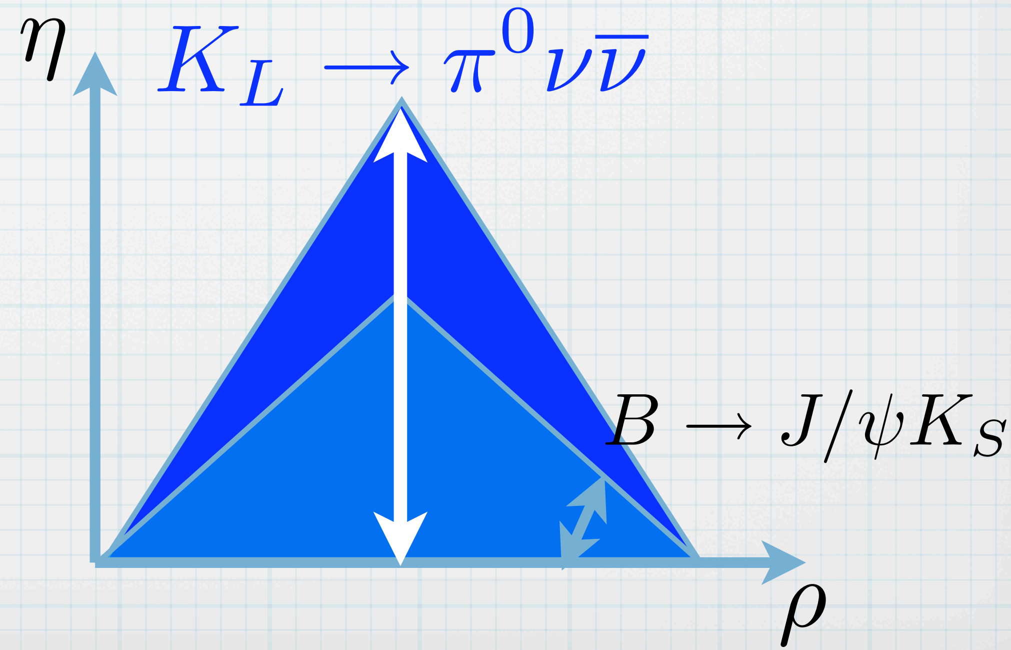


- BR = $(2.8 \pm 0.4) \times 10^{-11}$ (w/currently known CKM parameters)
- 1 - 2% theoretical error

New Physics adds extra amplitude



- Still the same 1-2% theoretical error!
- Compare with B results

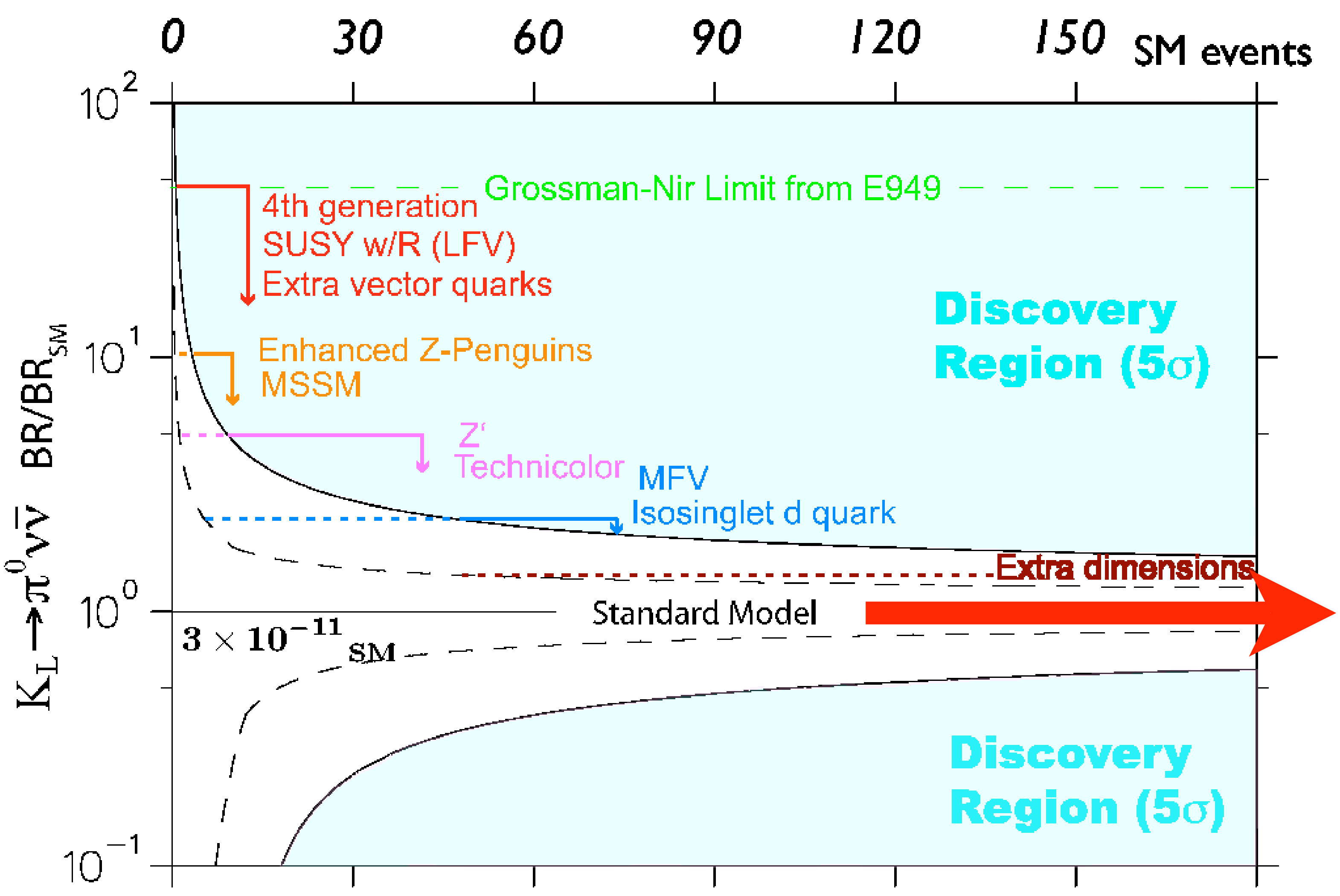


Our ultimate goal at J-Parc

* Measure the $BR(K_L \to \pi^0 \nu\nu)$ to several % by collecting >100 signal events

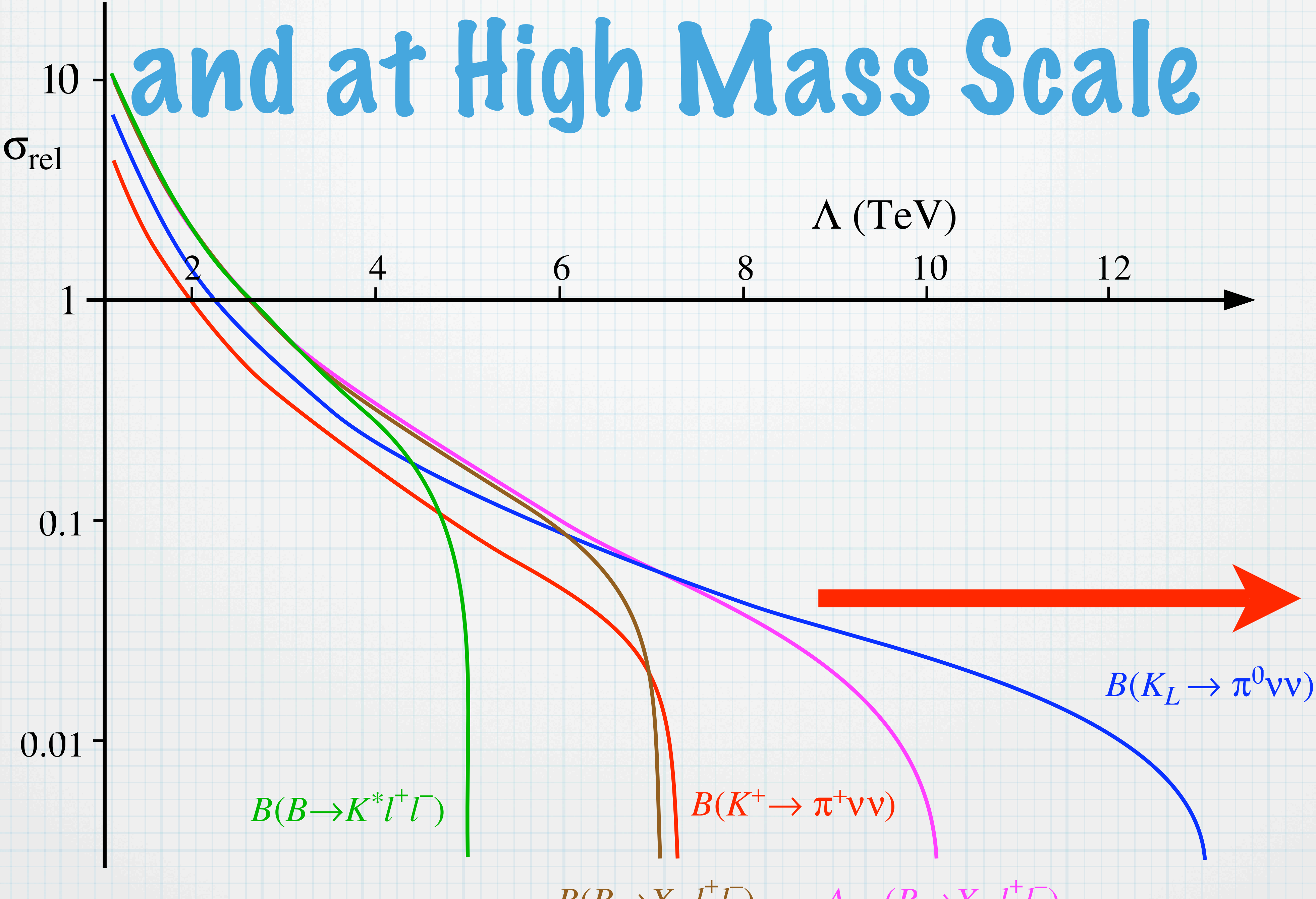
to ...

probe New Physics



based on Bryman-Buras-Isidori-Littenberg, hep-ph/0505171

and at High Mass Scale



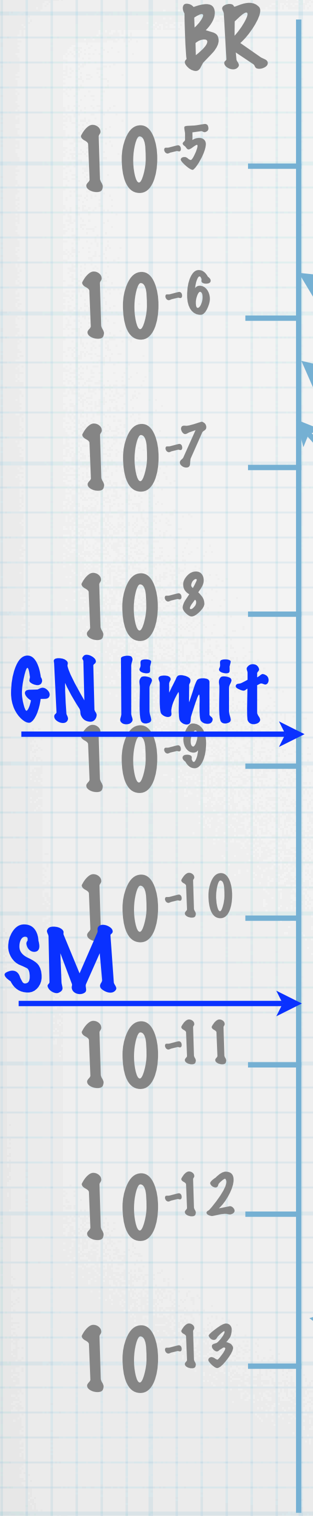
D'Ambrosio, Giudice, Isidori, Strumia, Nucl. Phys. B645, 155 (2002)

Issues

- BR(SM) = 3×10^{-11}
- Need high K_L yield
- $K_L \to \pi^0 \pi^0$ background with 2 missing photons
- Neutron interactions and rates

Damn Hard

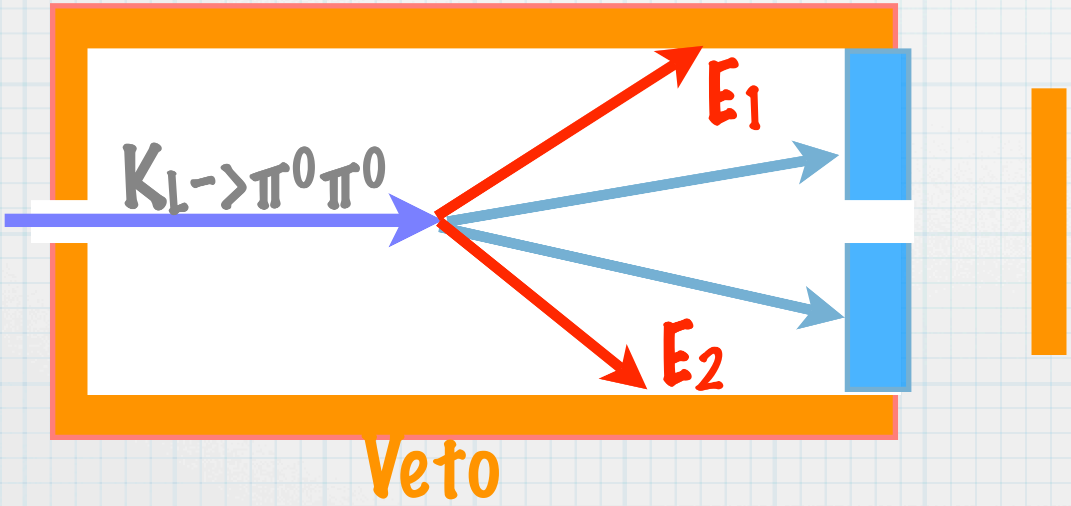
Step by Step

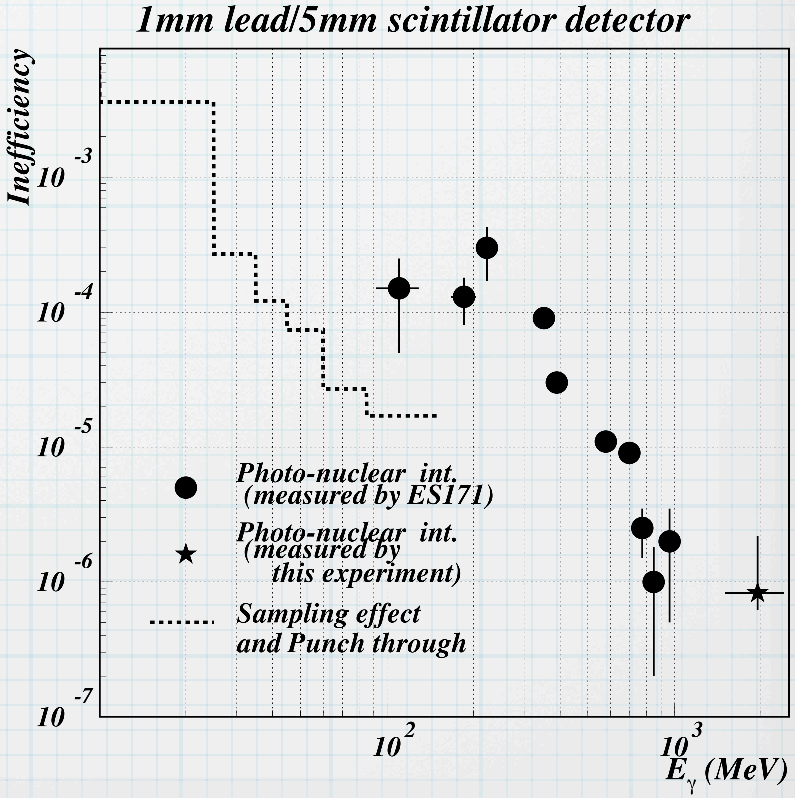


* KTeV/Nakaya
* KTeV/Hanagaki: $\pi^0 \to ee\gamma$
* KEK PS E391a 1week/Sakashita
* KEK PS E391a
* J-Parc Step 1: beyond GN limit, 1st observation
* J-Parc Step 2: >100 SM events

Basic Strategy Hermetic veto w/high detection effciency

* $\#K_L \to 2\pi^0$ bkg $\propto$ ineff(E_1)x ineff(E_2)

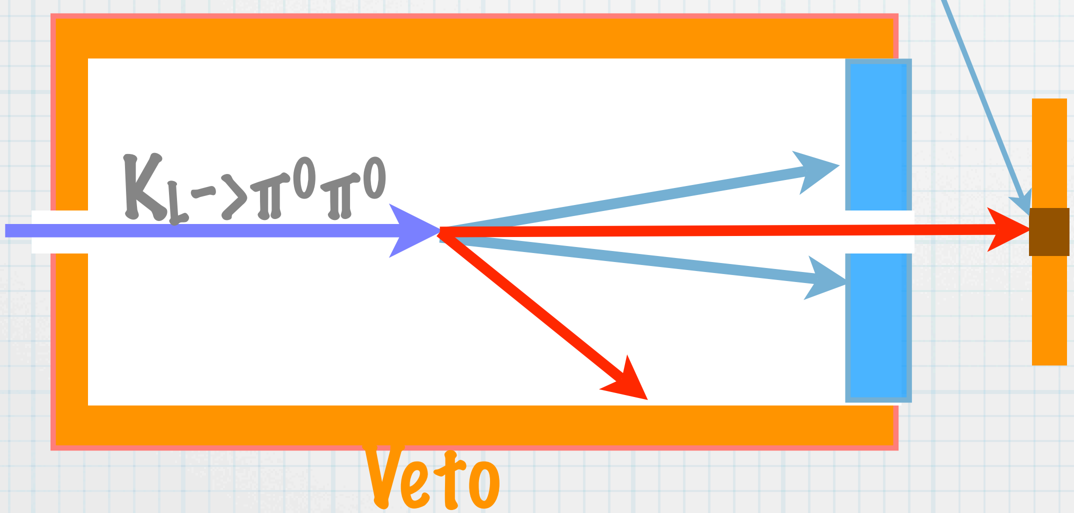


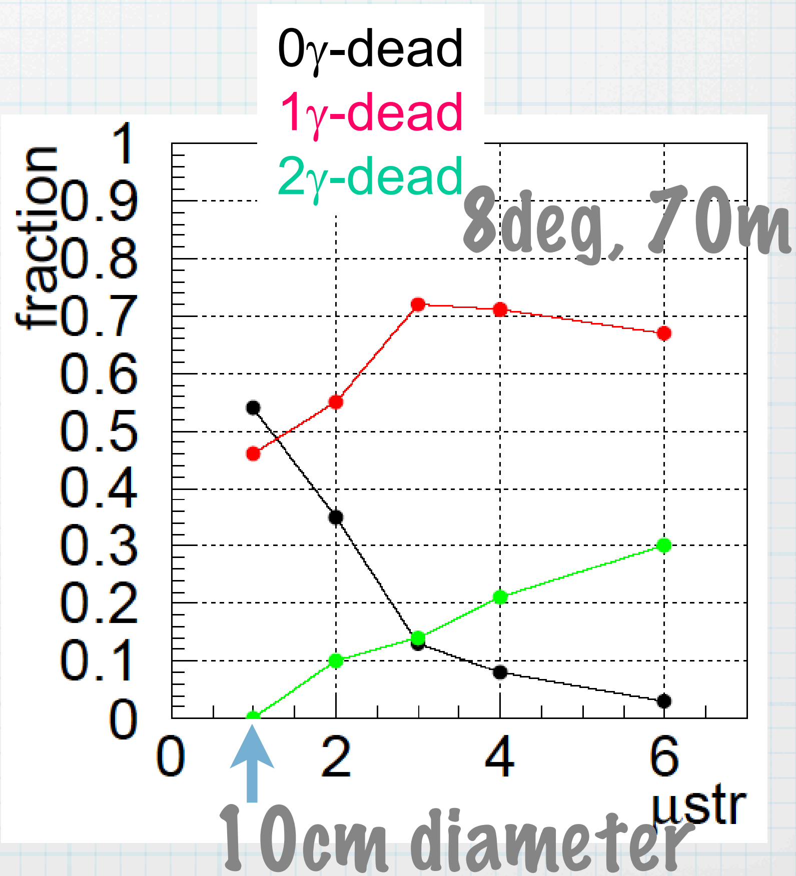


Basic Strategy
Small K_L Beam

* to suppress background photons escaping down the beam hole in the calorimeter

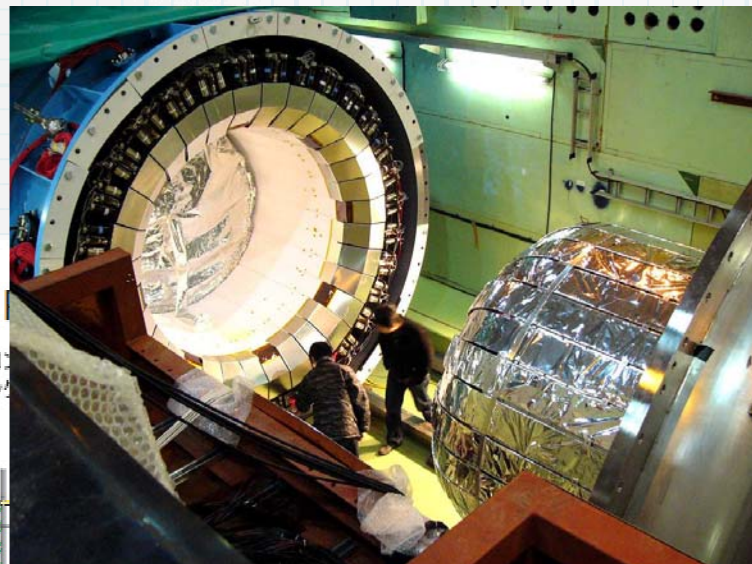
Low efficienciency due to high rate neutrons

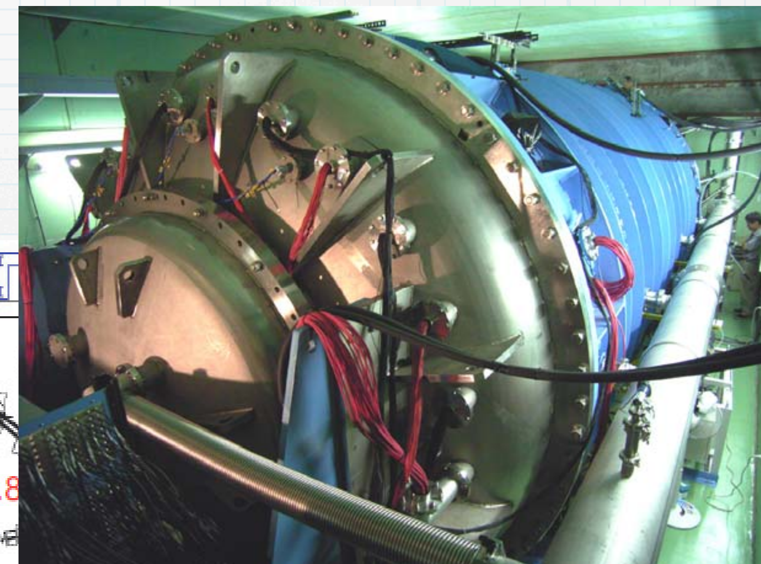


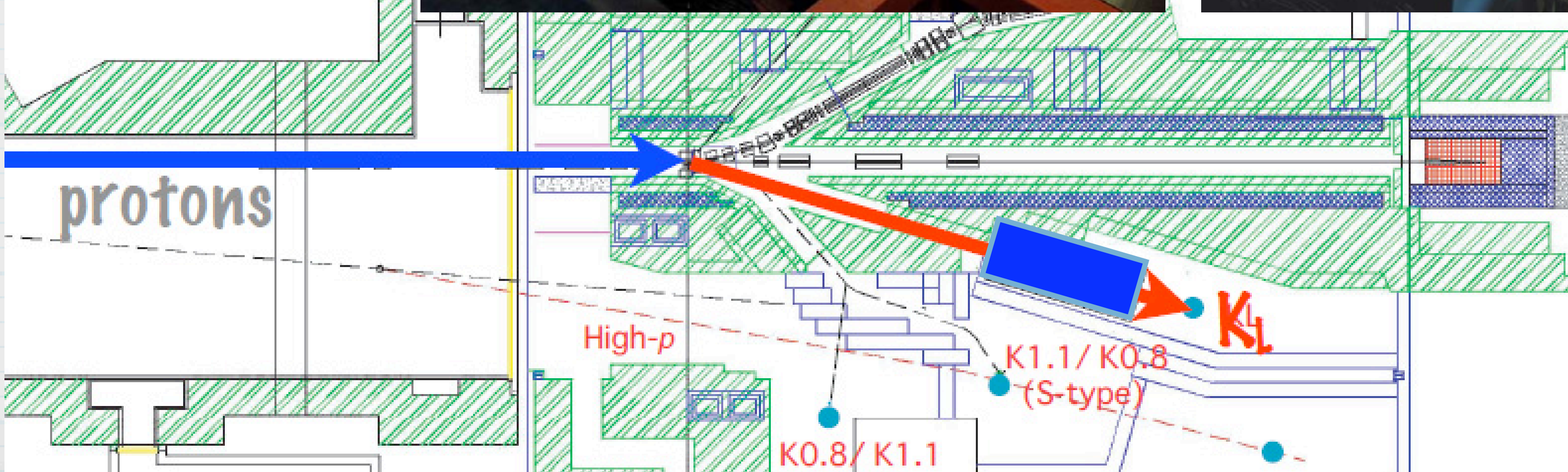


Step 1

* Modified E391a detector at K0 beamline

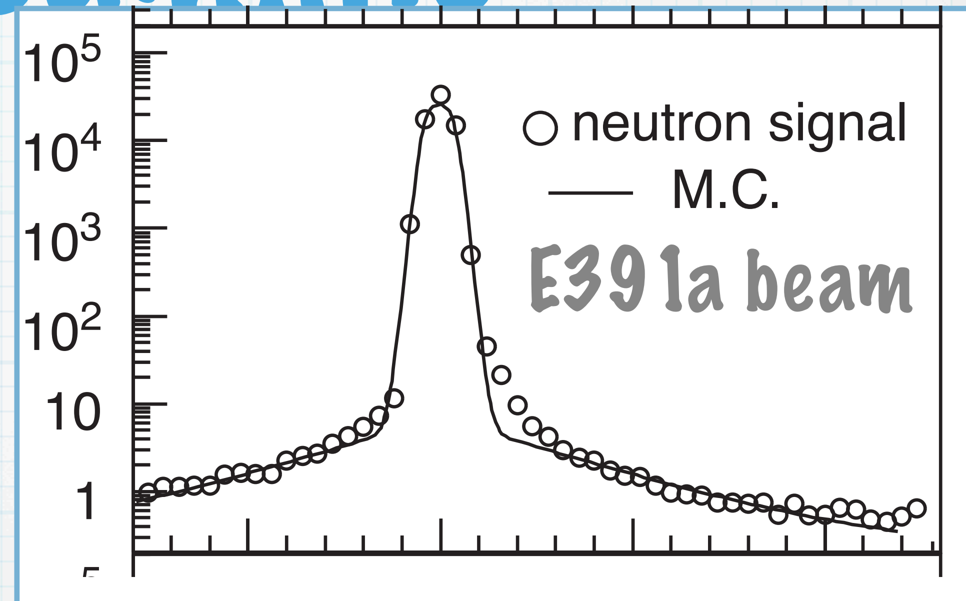


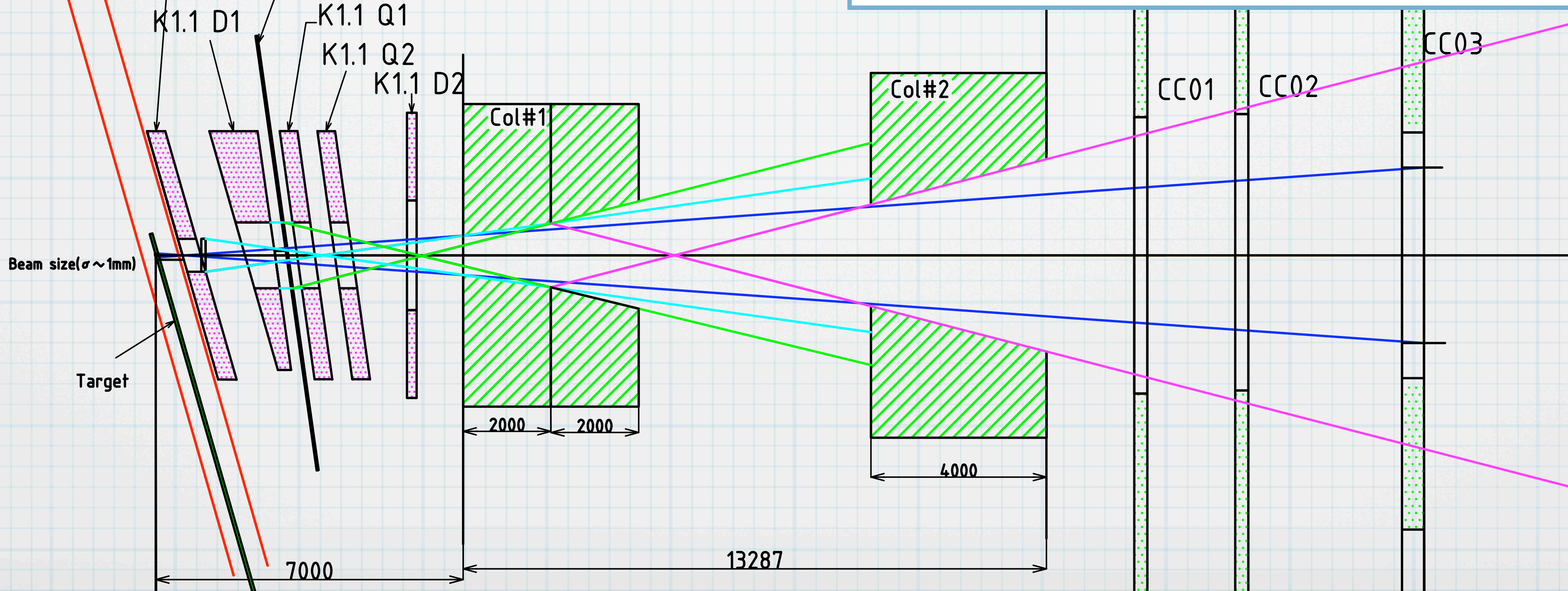




Step 1 beamline

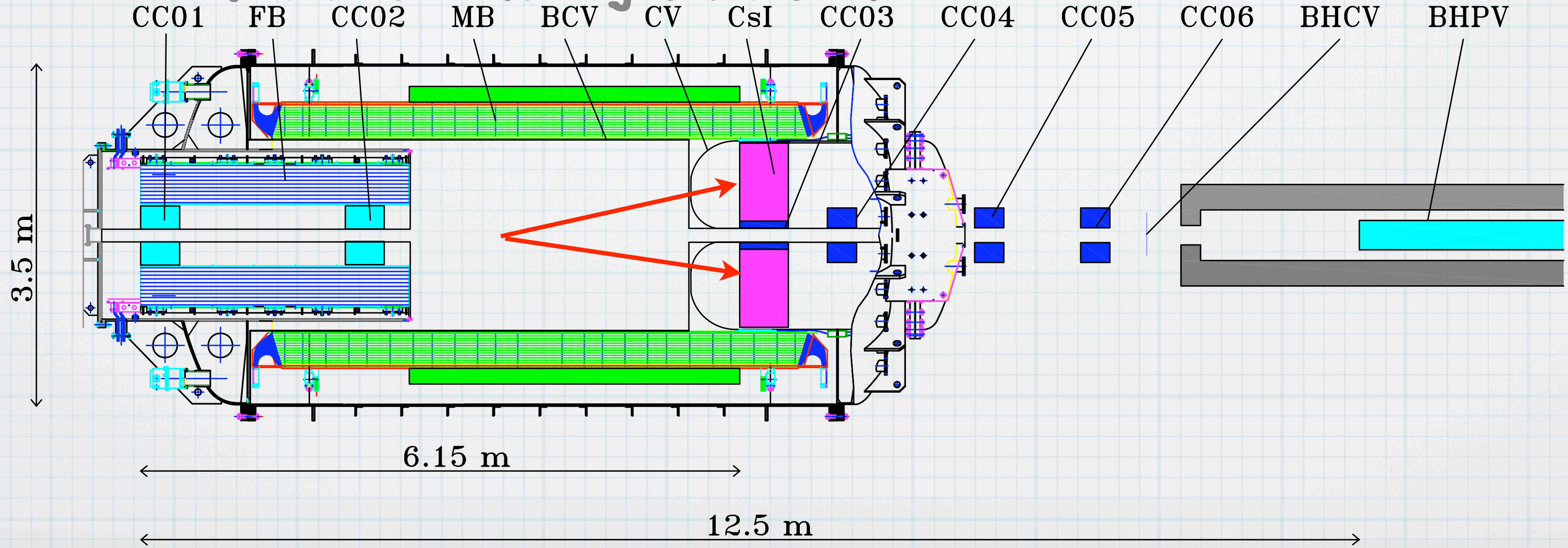
* halo neutrons/core < 10^{-5}





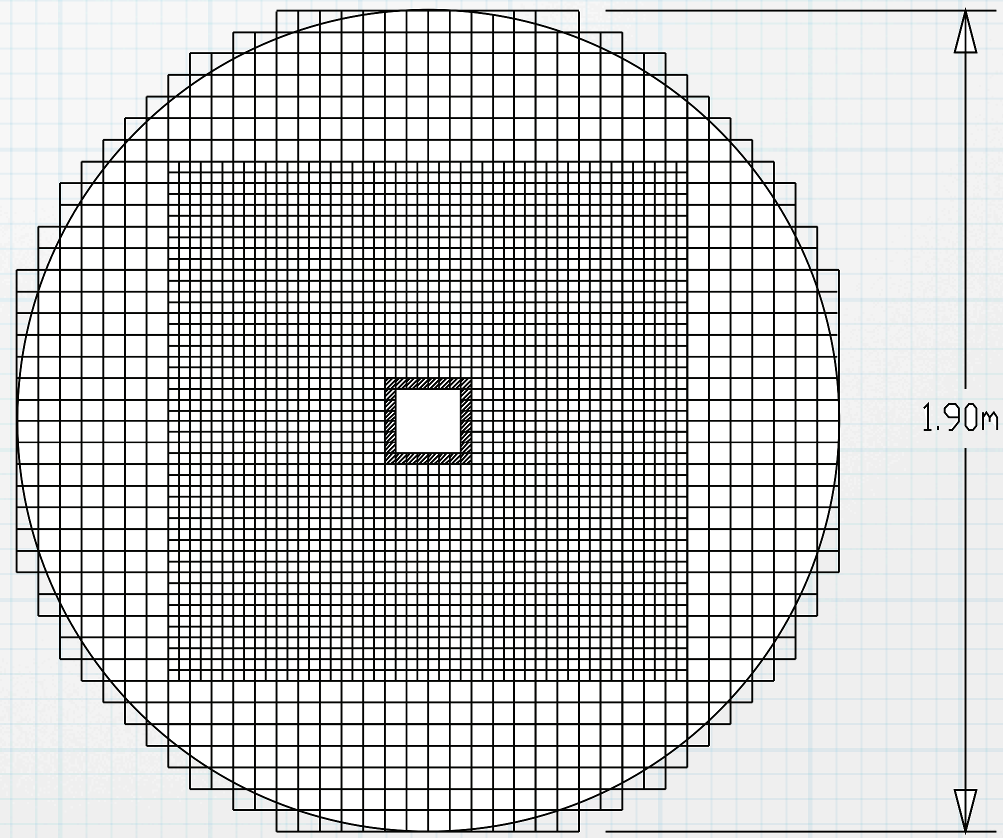
Step 1 Detector

* fine granularity calorimeter
* Hermetic veto system w/high detection efficiency
* Waveform digitization



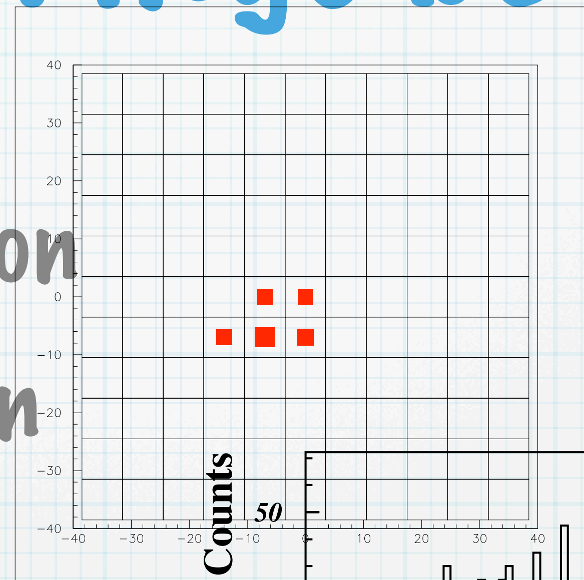
Calorimeter

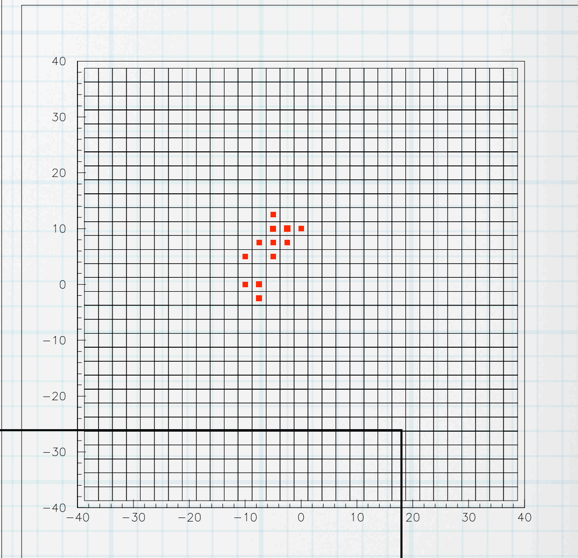
* 7cm x 7cm x 30cm CsI blocks for E391a
* 2.5cm x 2.5cm x 50cm CsI blocks from KTeV

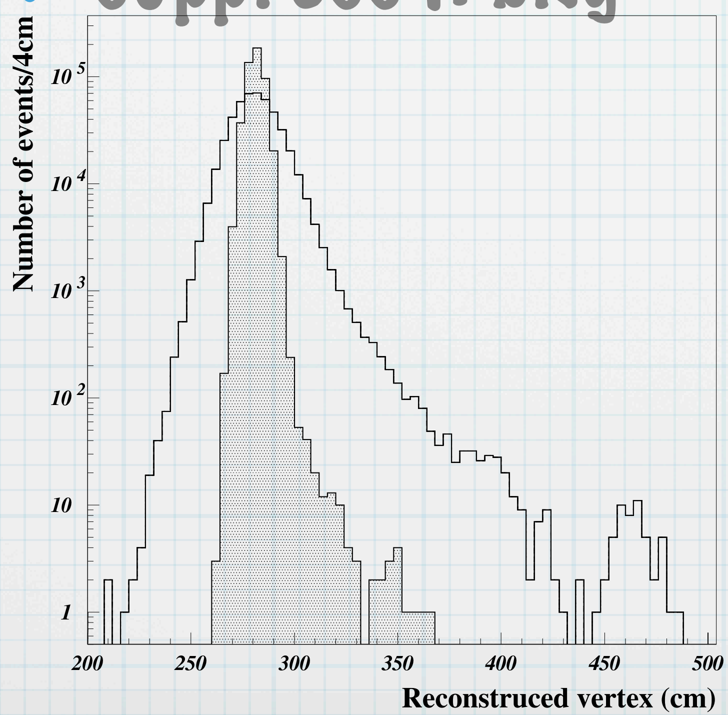


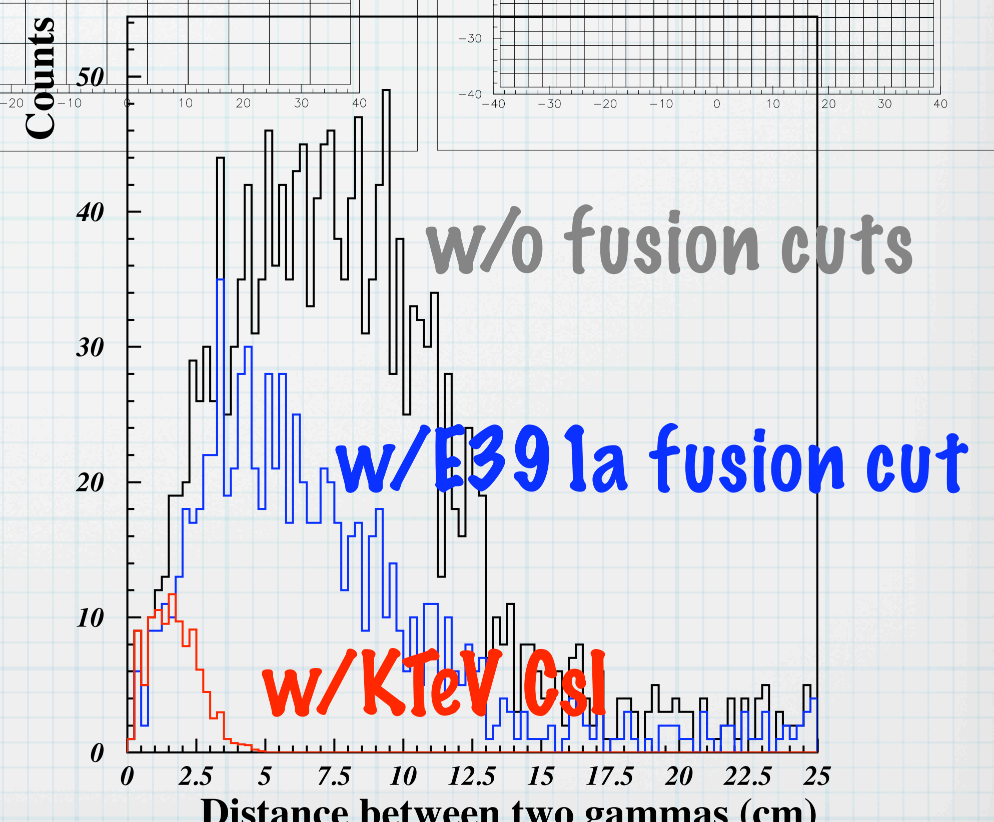
KTeV CsI brings better

* photon isolation
    * x8 bkg reduction
* energy resolution
    * suppress n bkg

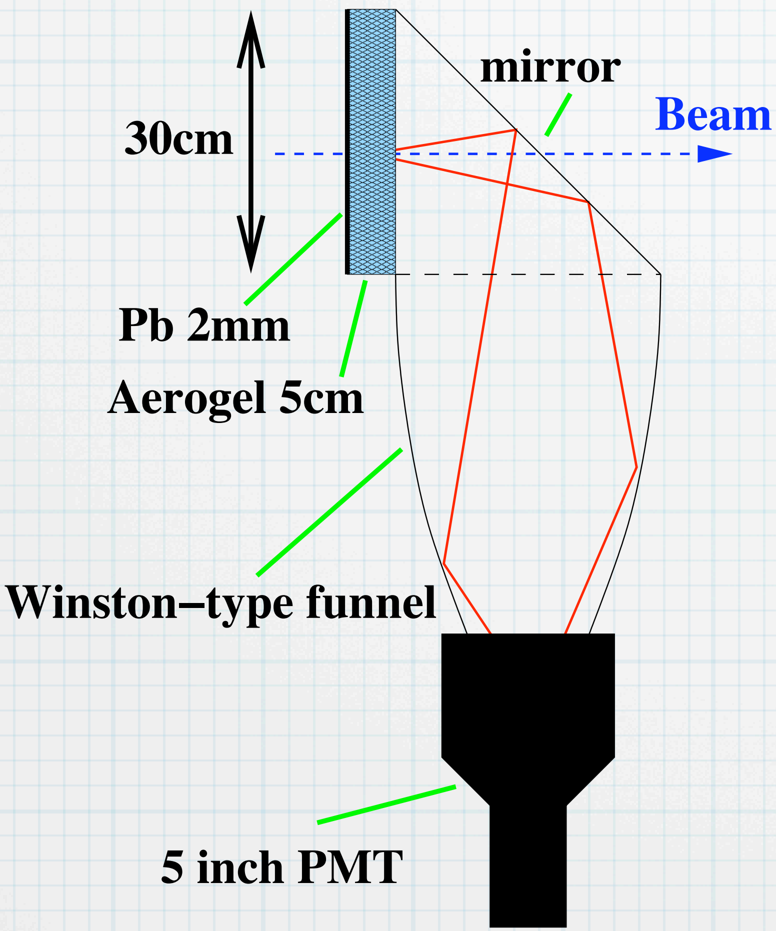


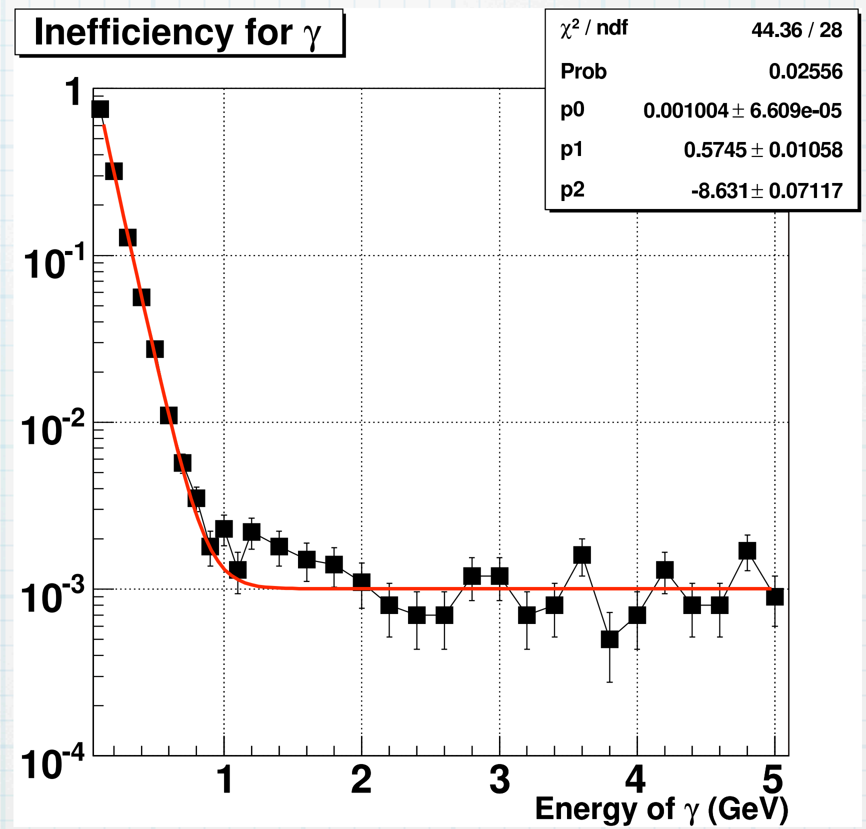


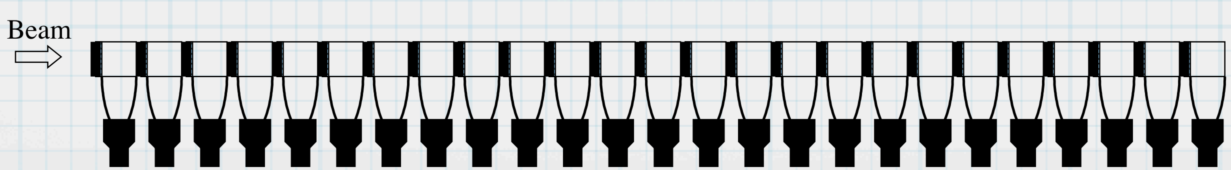




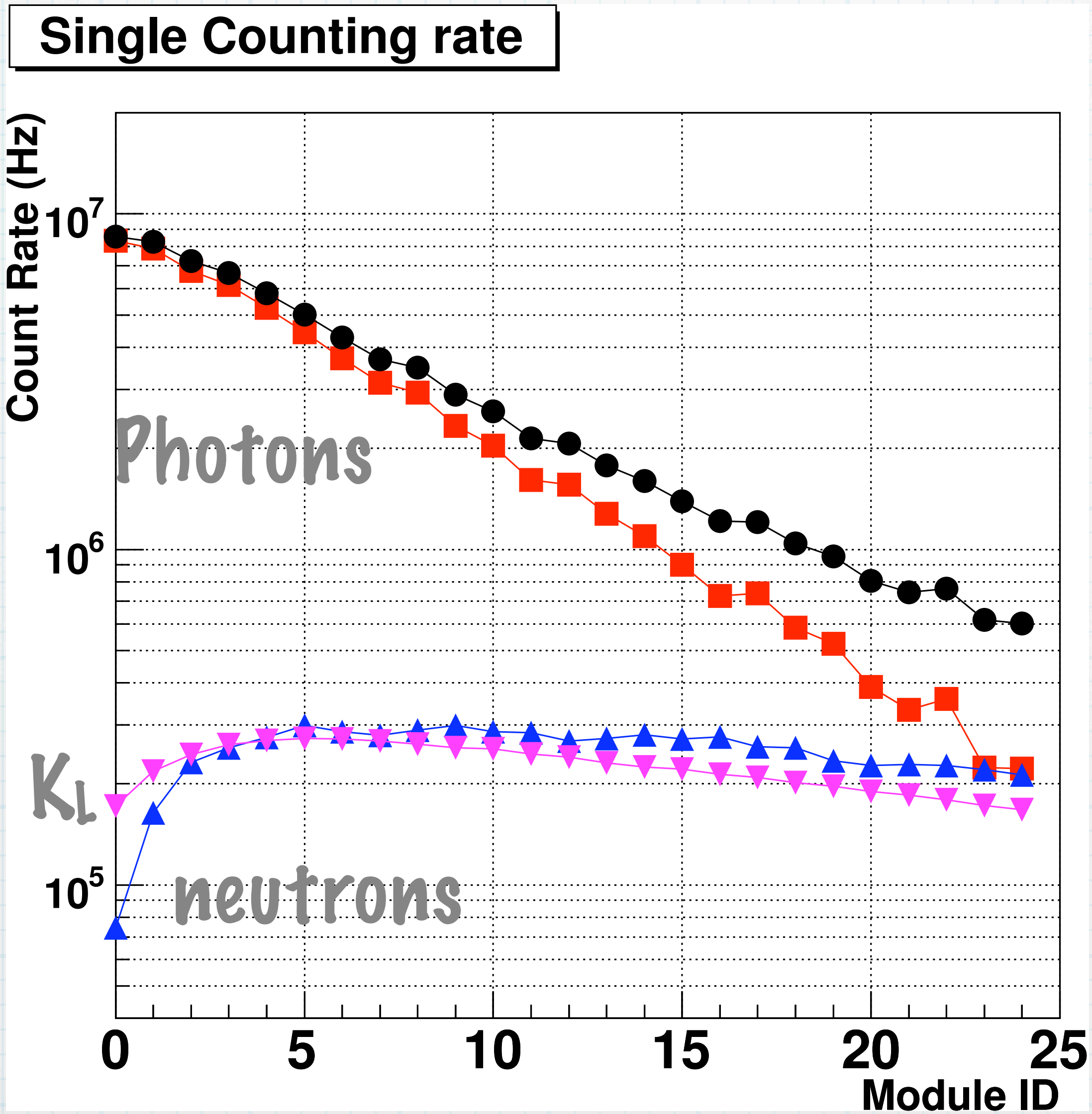
Beam Hole Photon Veto





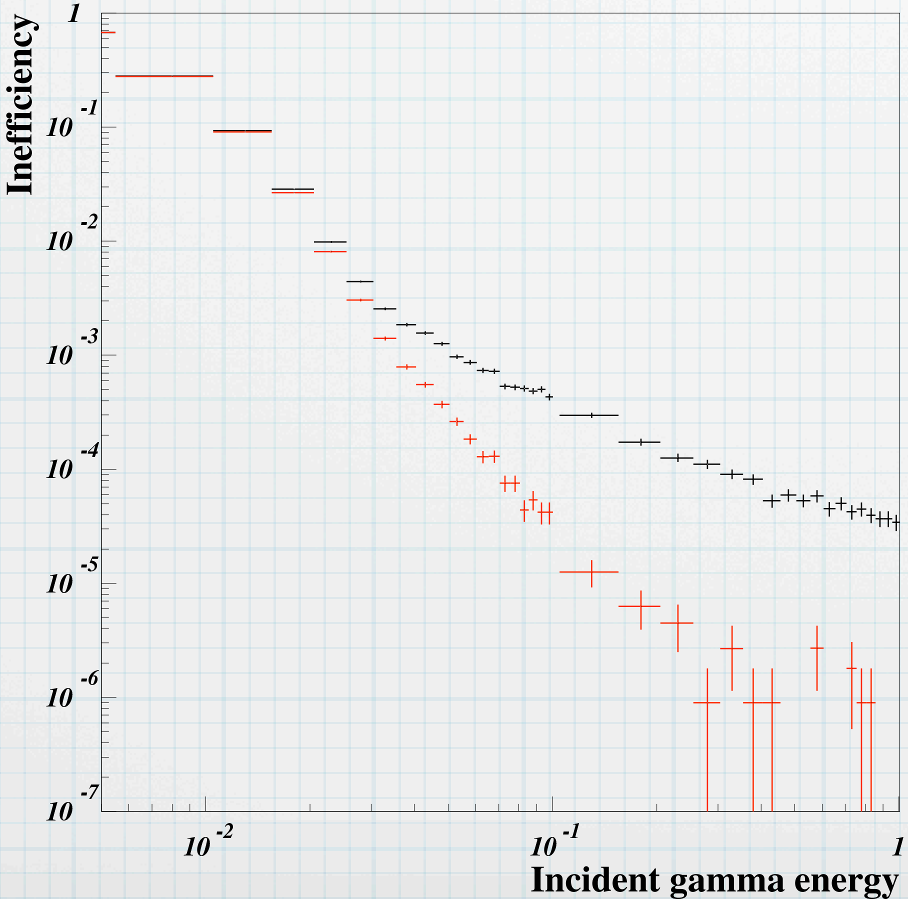


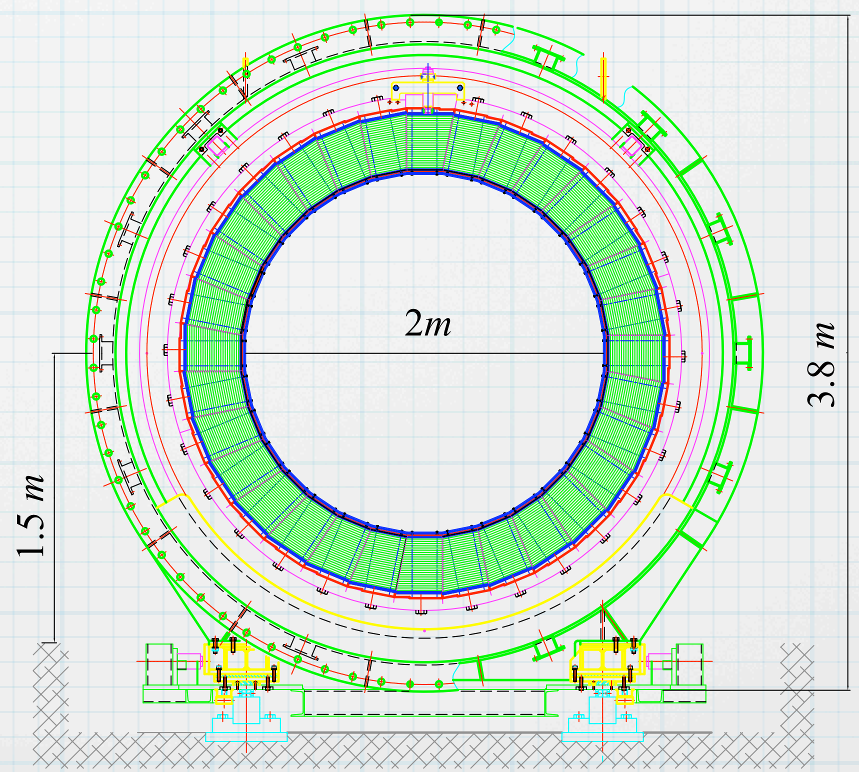
Beam Hole Photon Veto



Barrel Photon Veto

* Extra $5X_0$ for better efficiency





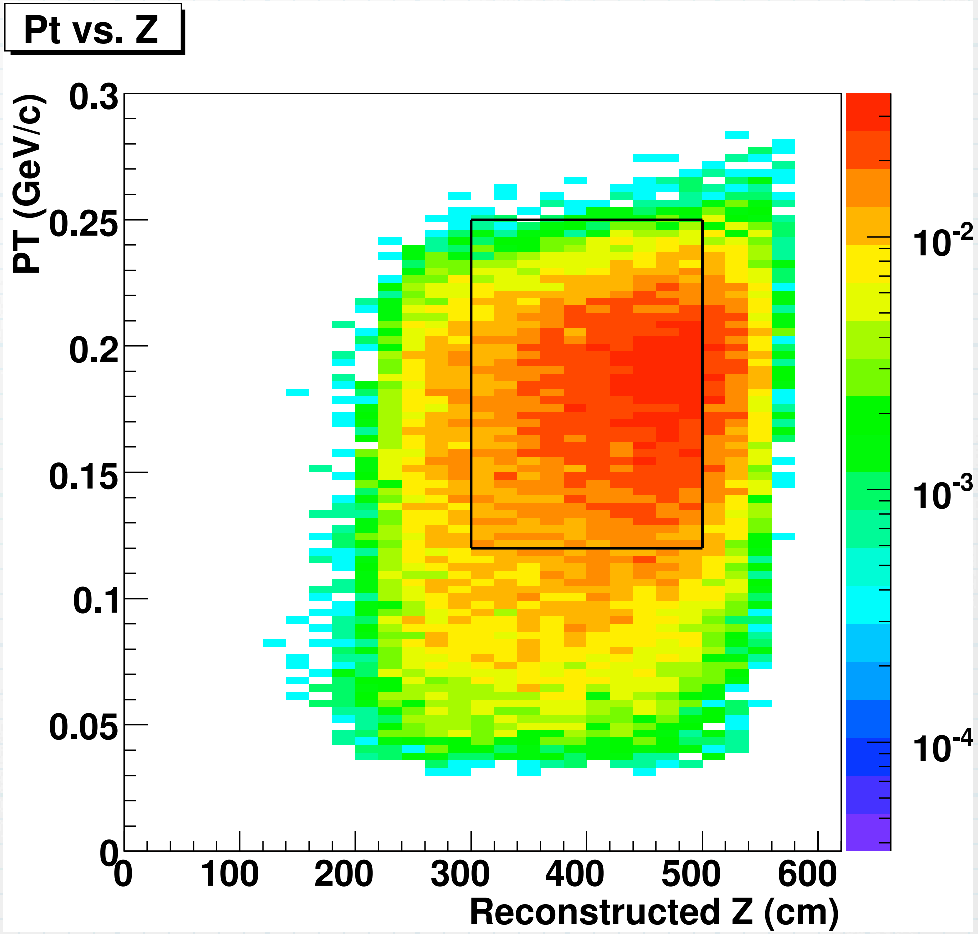
Frontend, Trigger, DAQ

* Record waveform near phototubes
    * to distinguish overlapping pulses
    * for lower noise
* Level 2 cluster counter
* Level 3 online filtering

Signal Sensitivity

- acceptance
  - 9.4% x 0.5 = 4.7%
- 2.6×10^{12} K_L decays w/ 2E14 protons x 3E7 sec
- Sensitivity $= 8 \times 10^{-12}$

  3.5 SM evts

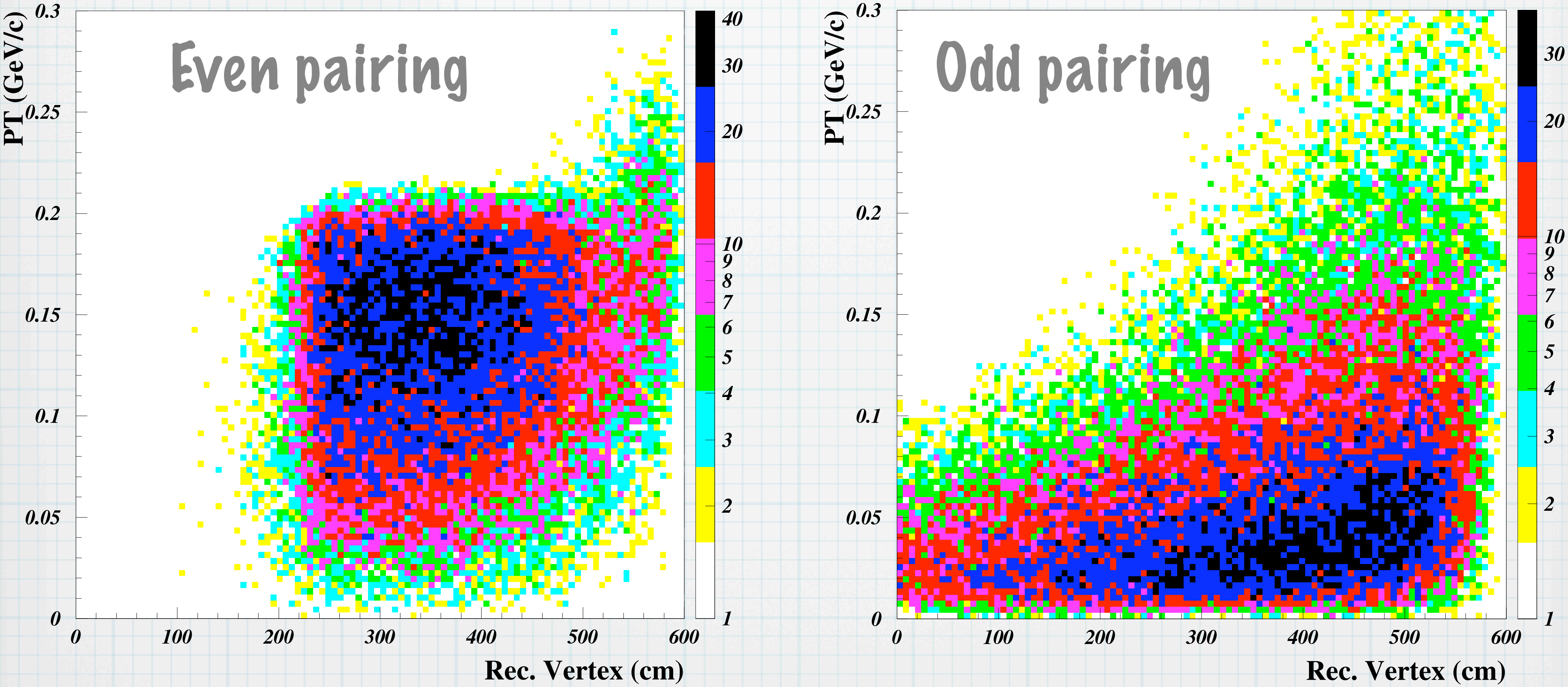


Backgrounds

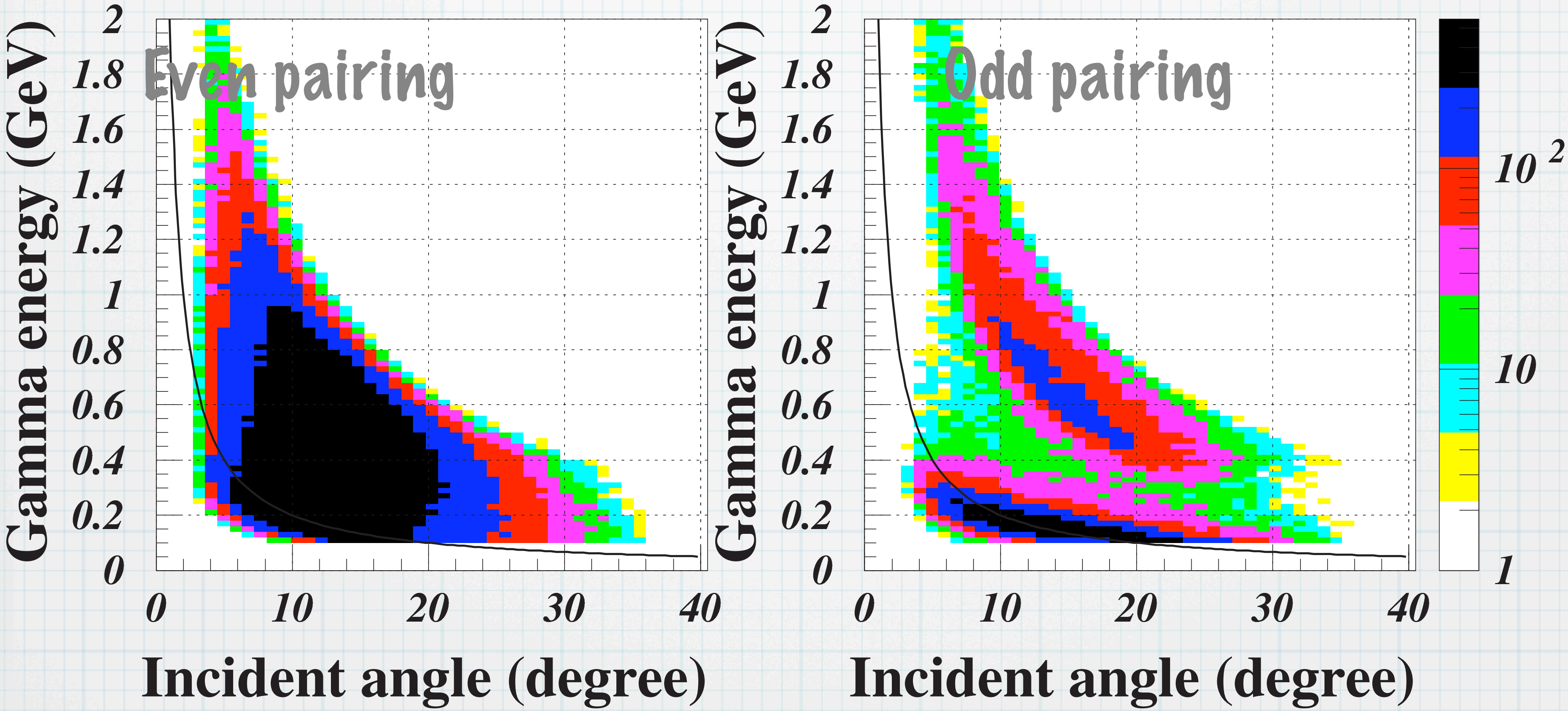
for 7 SM signal events

Background source	#Background events
Other K_L decays	
$K_L \to \pi^0\pi^0$	3.65
$K_L \to \pi^+\pi^-\pi^0$	0.93
$K_L \to \pi^- e^+ \nu$	0.01
$K_L \to \gamma\gamma$	negligible
$K_L \to \pi^0\pi^0\pi^0$	negligible
Neutron Interaction	
With Residual gas	0.07
At the CC02	0.26
At the C.V.	negligible
Accidental Coincidence	0.20

$K_L \to \pi^0 \pi^0$ background



$K_L \to \pi^0\pi^0$ background

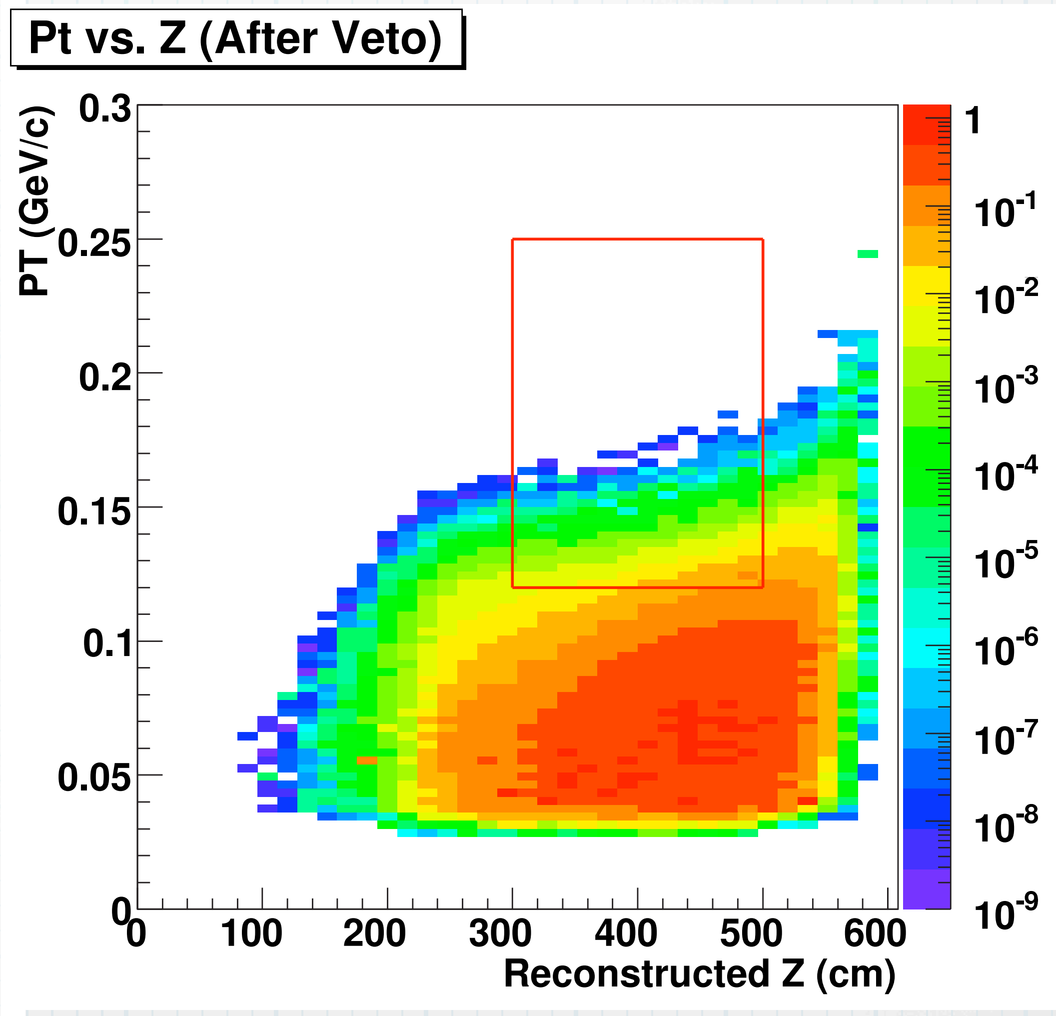


$K_L \to \pi^0 \pi^0$ background

- background/signal = 0.52
  - 0.47 : even pairing
  - 0.017 : odd pairing
  - 0.036 : fusion

$K_L \rightarrow \pi^+\pi^-\pi^0$ background

* bkg/sig = 0.13



Schedule

* 2006
  * Design collimators
  * Prepare transferring KTeV CsI
  * Start designing new readout
* 2007
  * Move KTeV CsI, upgrade detector
* 2008
  * Build K0 beamline => First beam survey
  * Assemble detector
* 2009
  * More beam survey and detector tuning
* 2010: PHYSICS DATA

Cost: $3.7M

* Beamline: $0.6M
* Calorimeter: $1.1M
* Main Barrel veto upgrade: $0.3M
* Vacuum system: $0.25M
* Beam hole photon veto: $0.3M
* Collar Counters: $0.2M
* Trigger and DAQ: $0.55M
* Transportation from KEK: $0.5M
* Detector assembly $0.2M

Summary

* Step 1 is the major and mandatory step to measure BR($K_L \to \pi^0 \nu\nu$)
* We need to:
  * build K0 beamline by 2008
  * replace calorimeter w/ KTeV CsI
  * build new DAQ
  * upgrade other detectors

J-Parc at LHC era

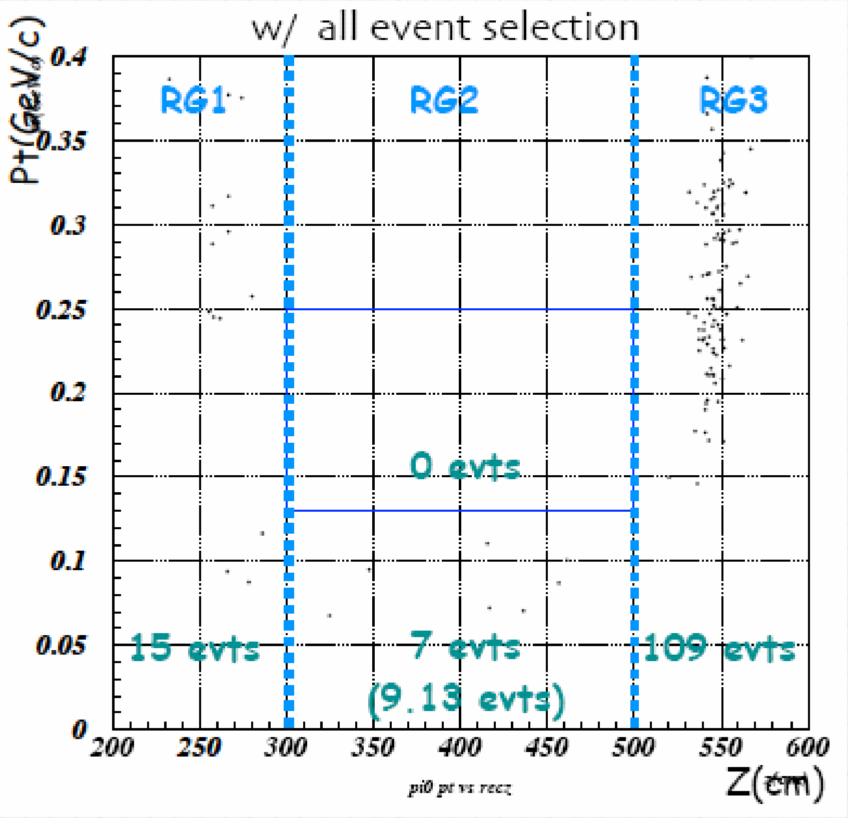
* J-Parc is the only facility that can run this experiment
* We are THE group who have the most experience

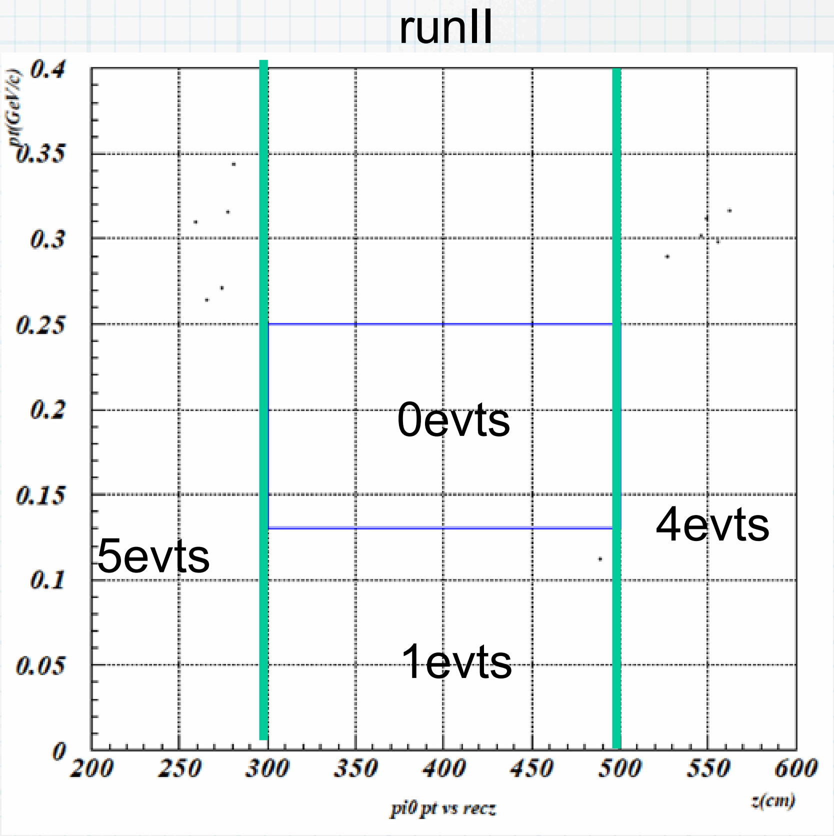
Backup slides

E391 analysis

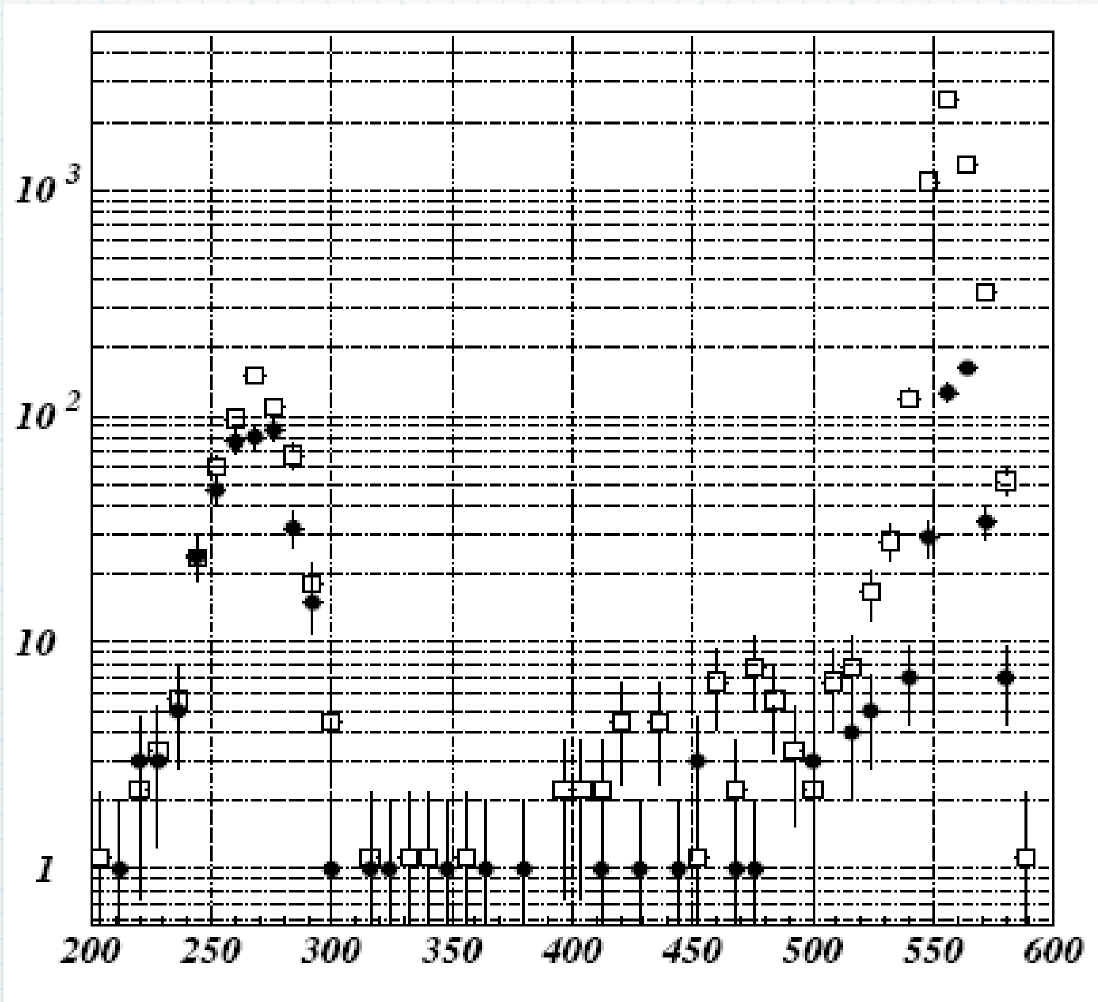
* Run 1 (2004), Run2, 3 (2005)
* Took time for:
  * calibration, bkg understanding, large MC
* Submit paper on Run 1 1-week data in July
* end of 2006: Open signal box for Run 2
* end of 2007: finish all the analysis

Direct comparison Run-I and Run-II

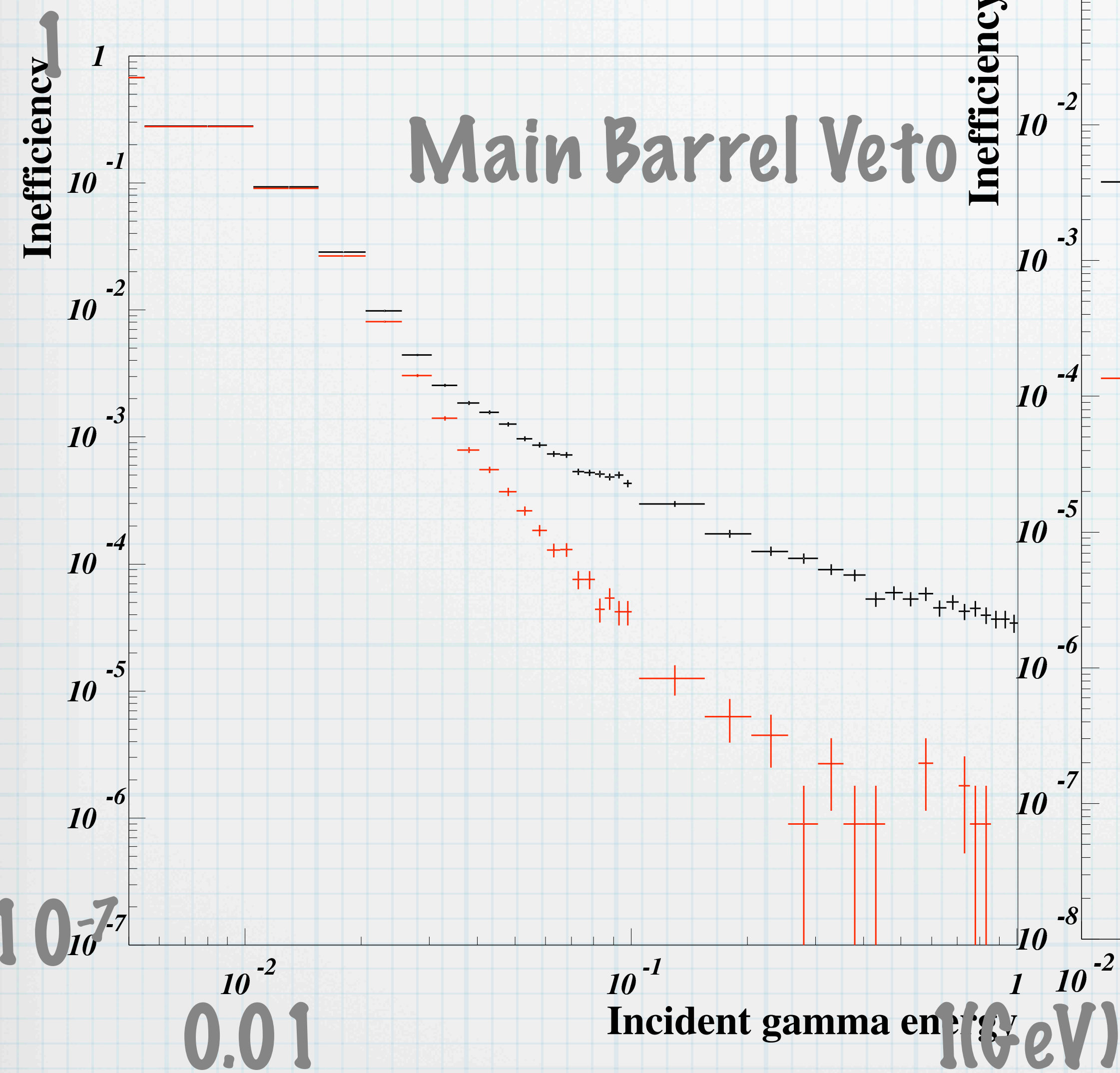


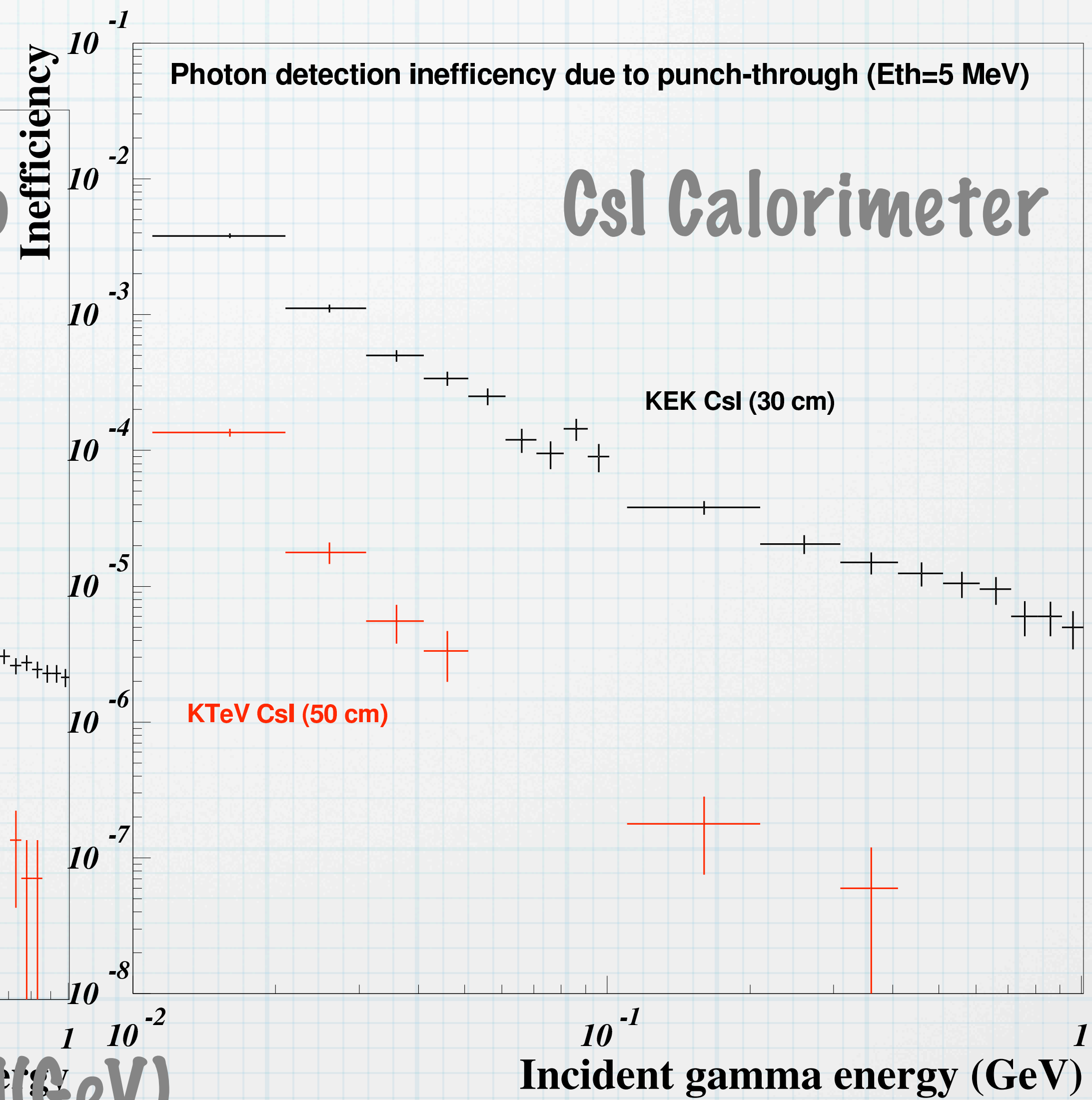


Run 2 vs Run 1 z dist.



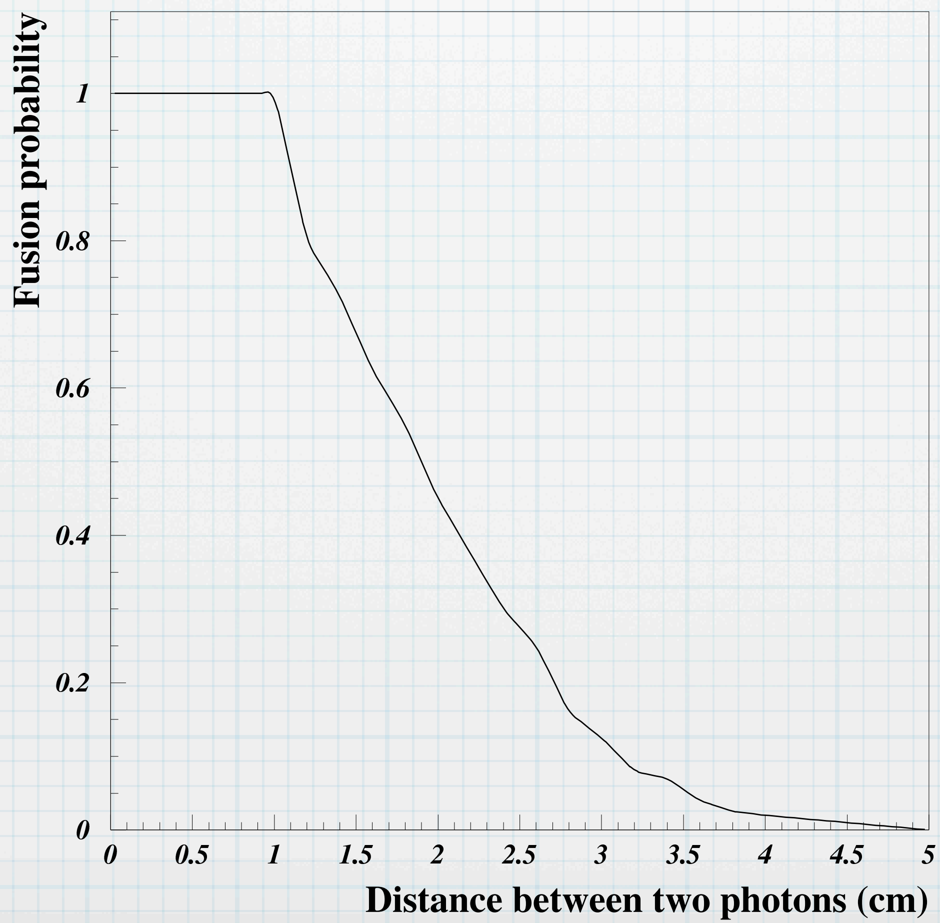
Veto inefficiencies





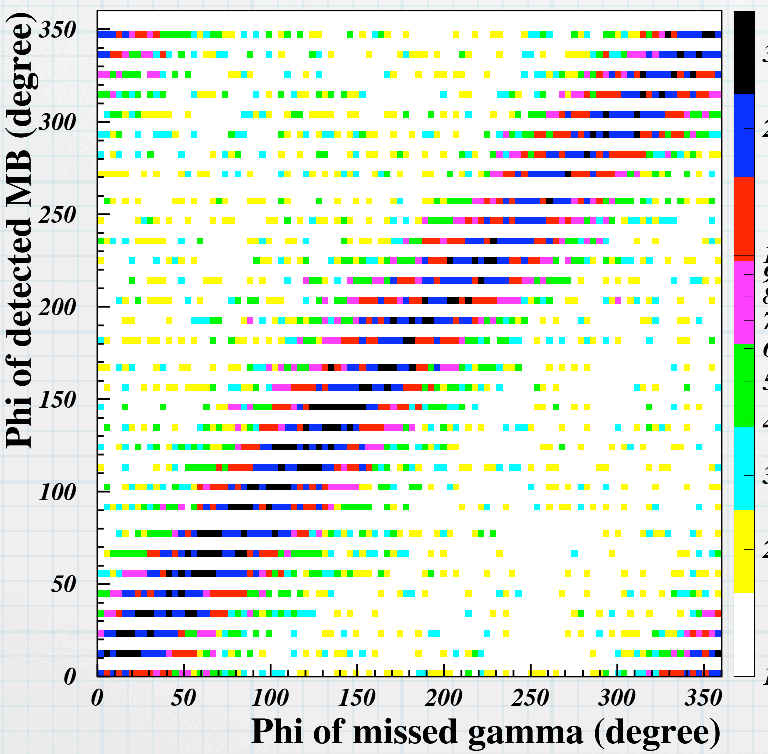
Gamma fusion probability

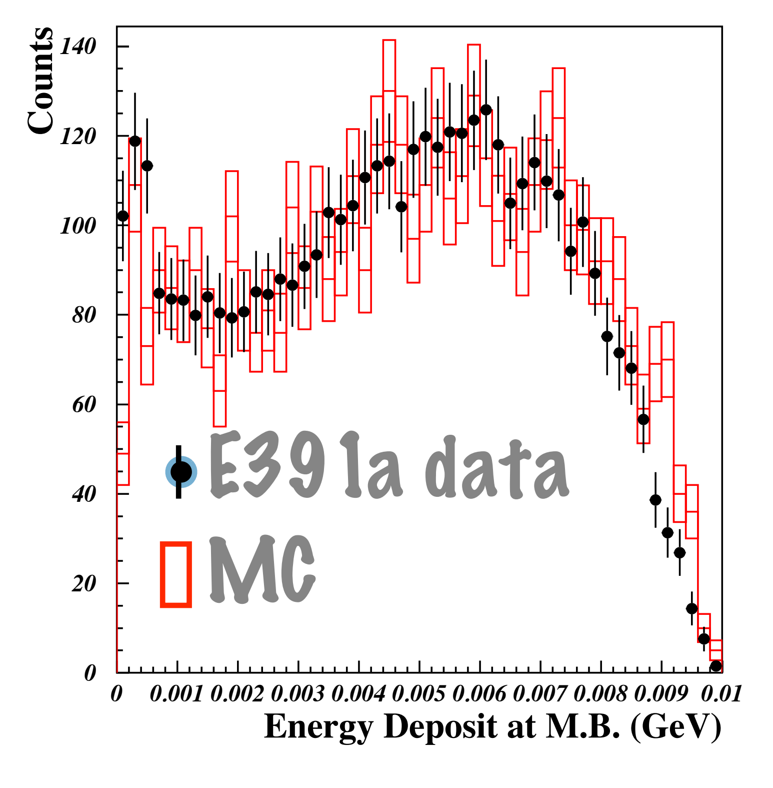
* Studied by KAMI@Fermilab



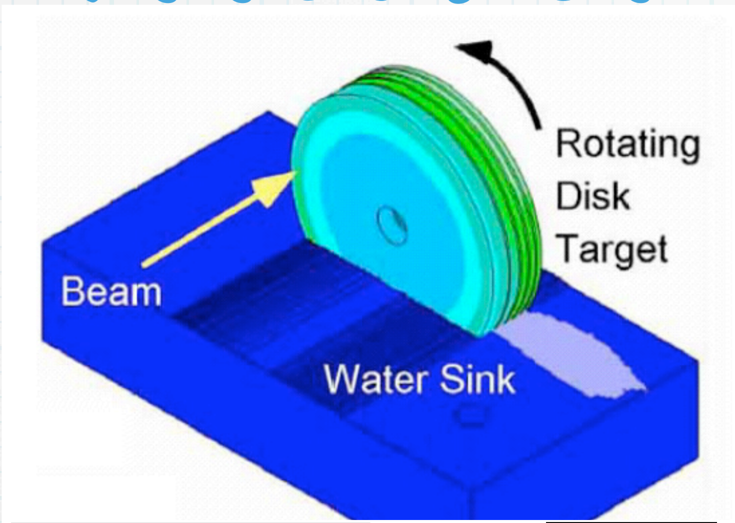
Background measurement

- 5gammas in CsI from $K_L \to 3\pi^0$
- point missing photon to Main Barrel veto

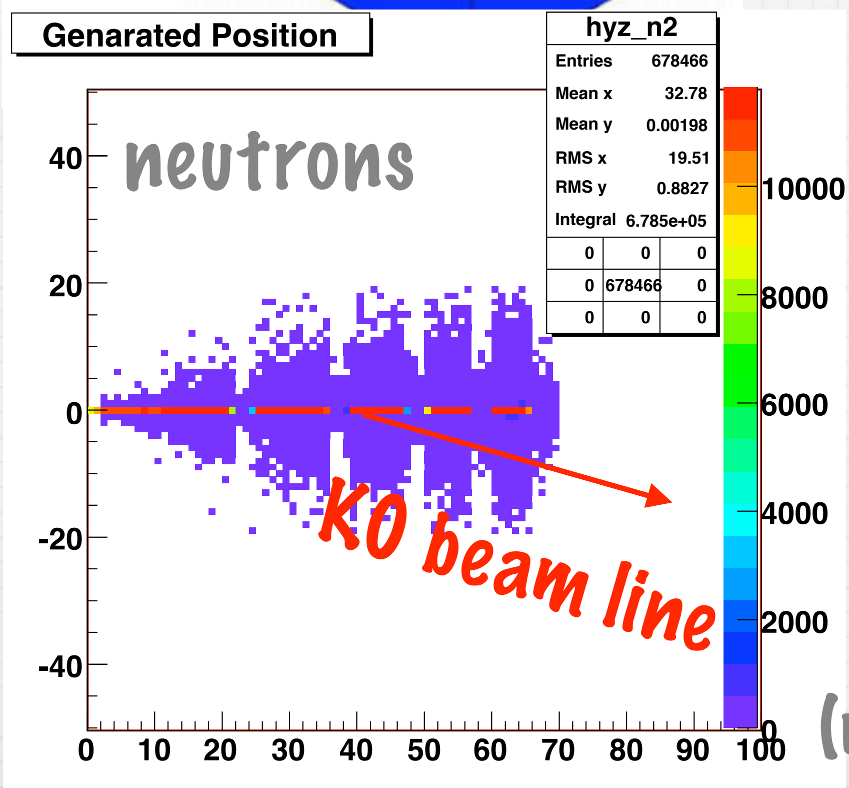


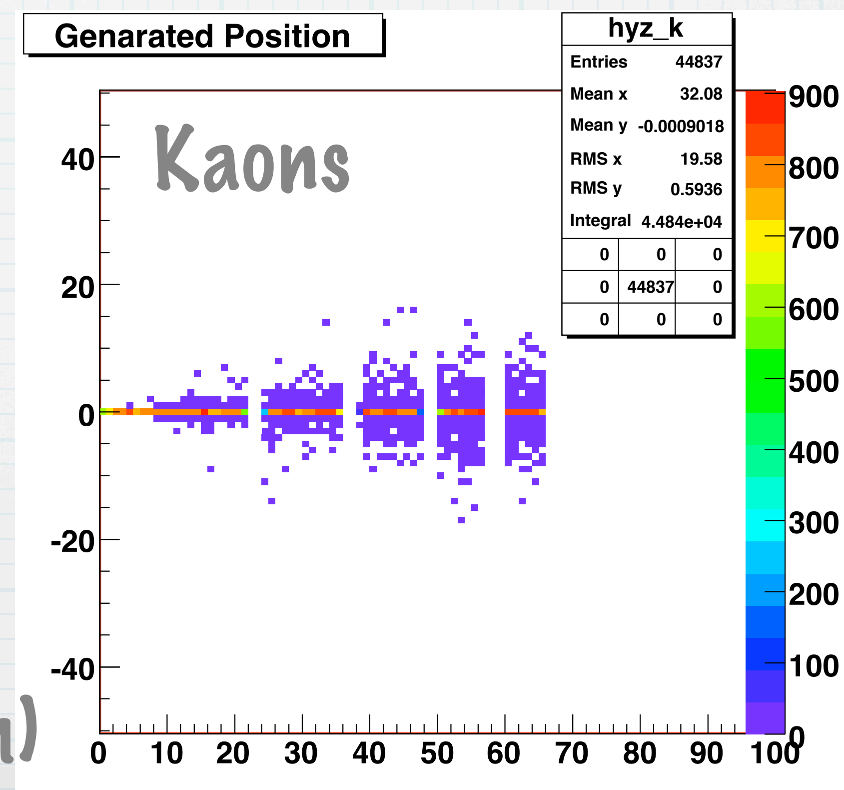


Effect of T1 disc target



16 degree extraction angle

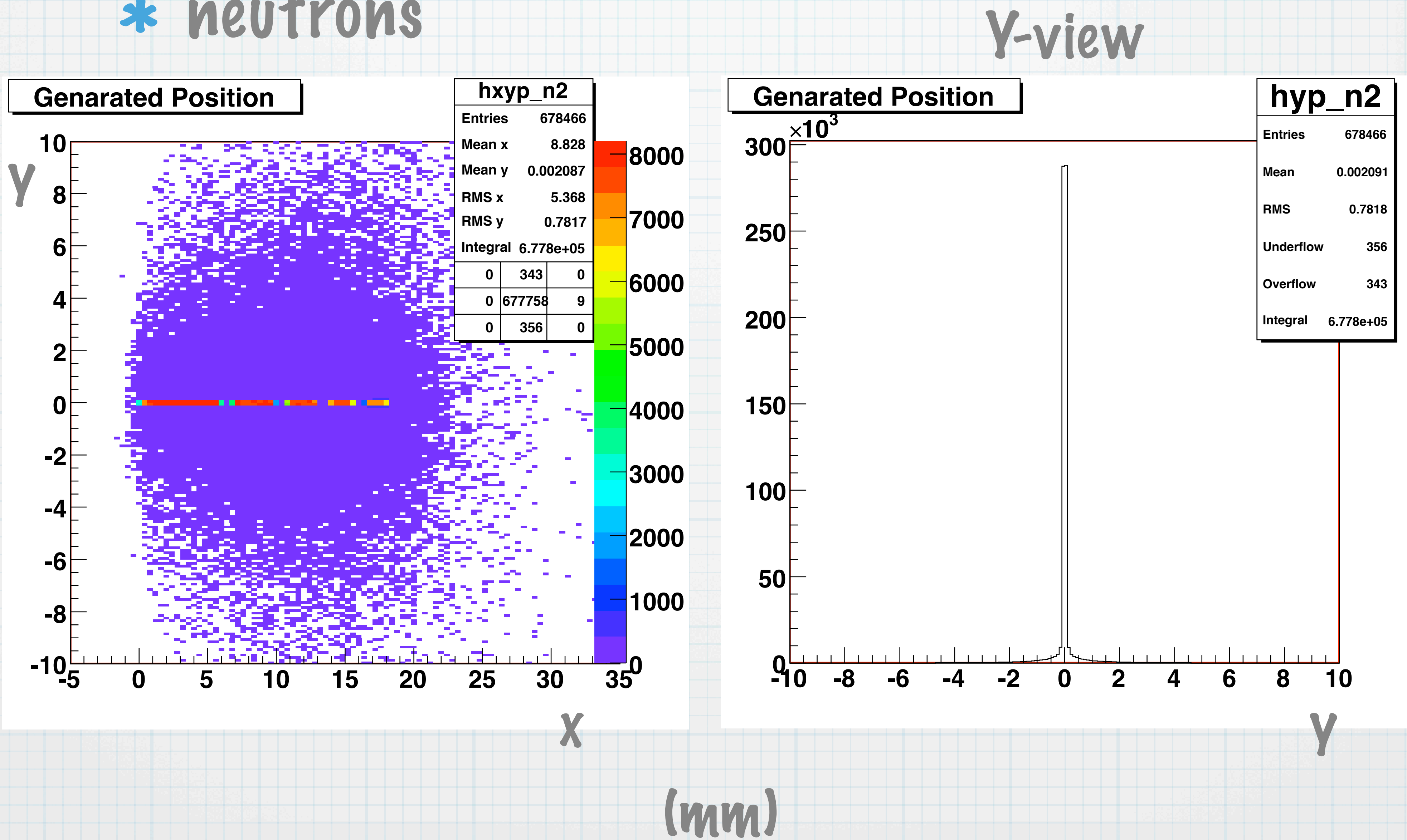




(mm)

View from K0 beamline

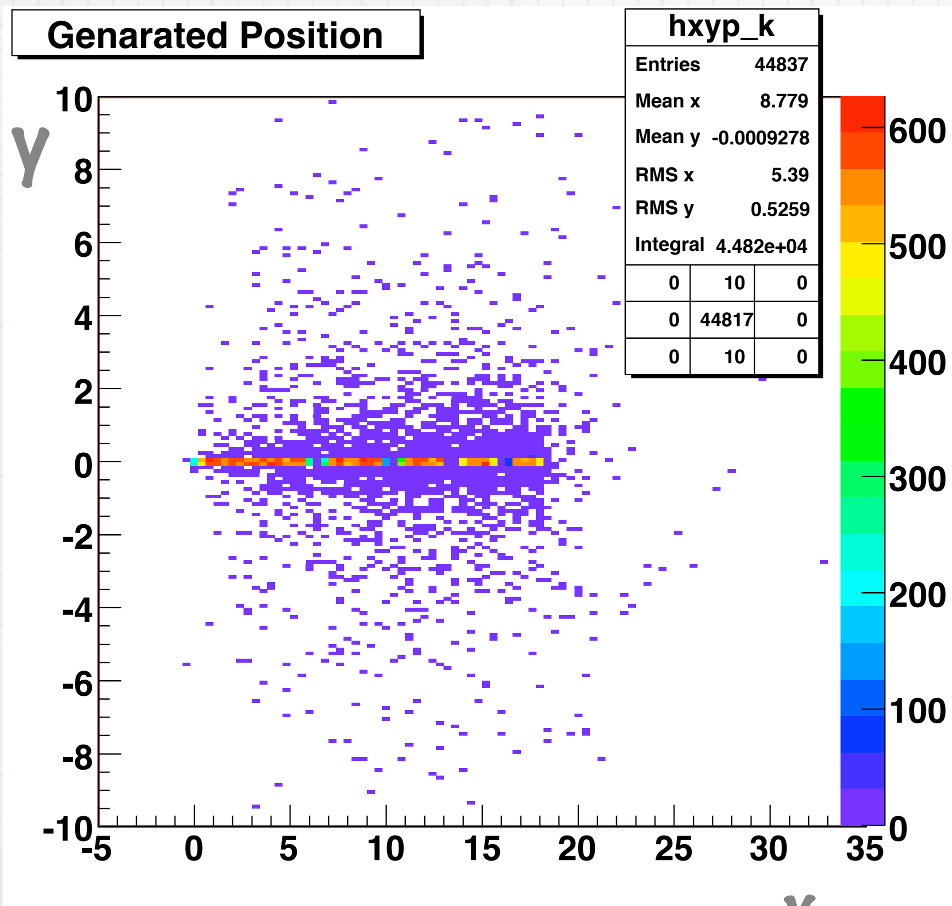
* neutrons



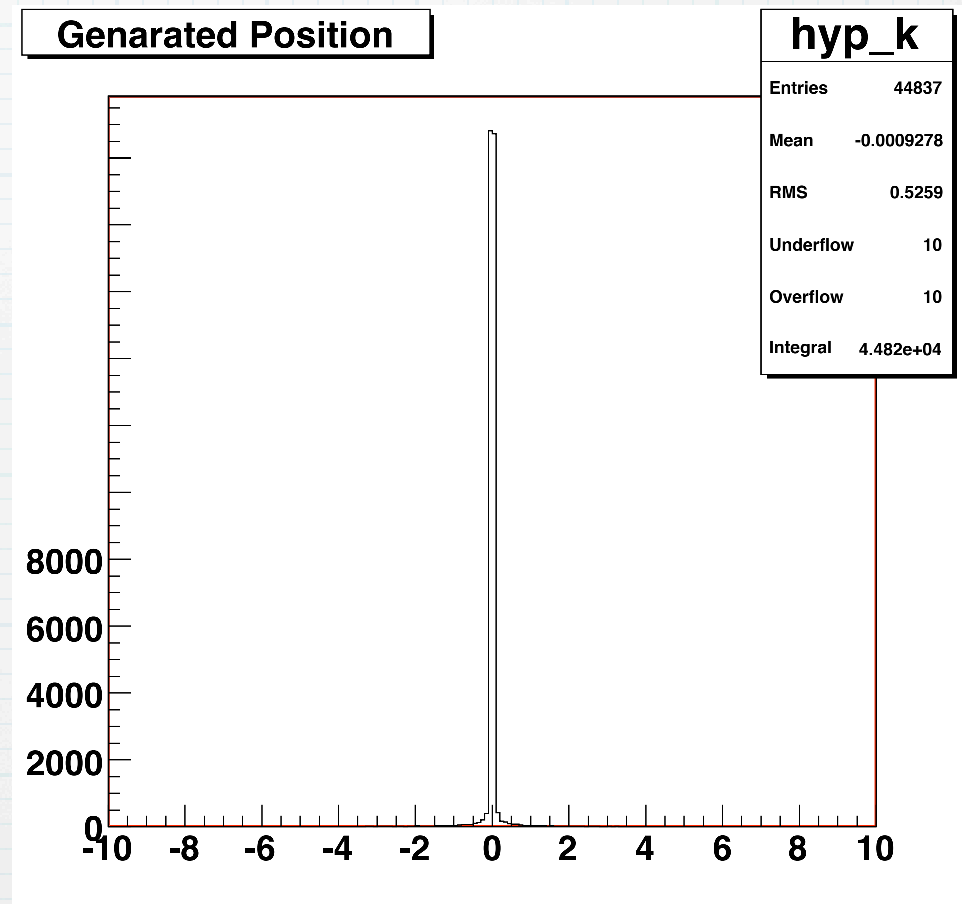
View from K0 beamline

* kaons

Y-view



x

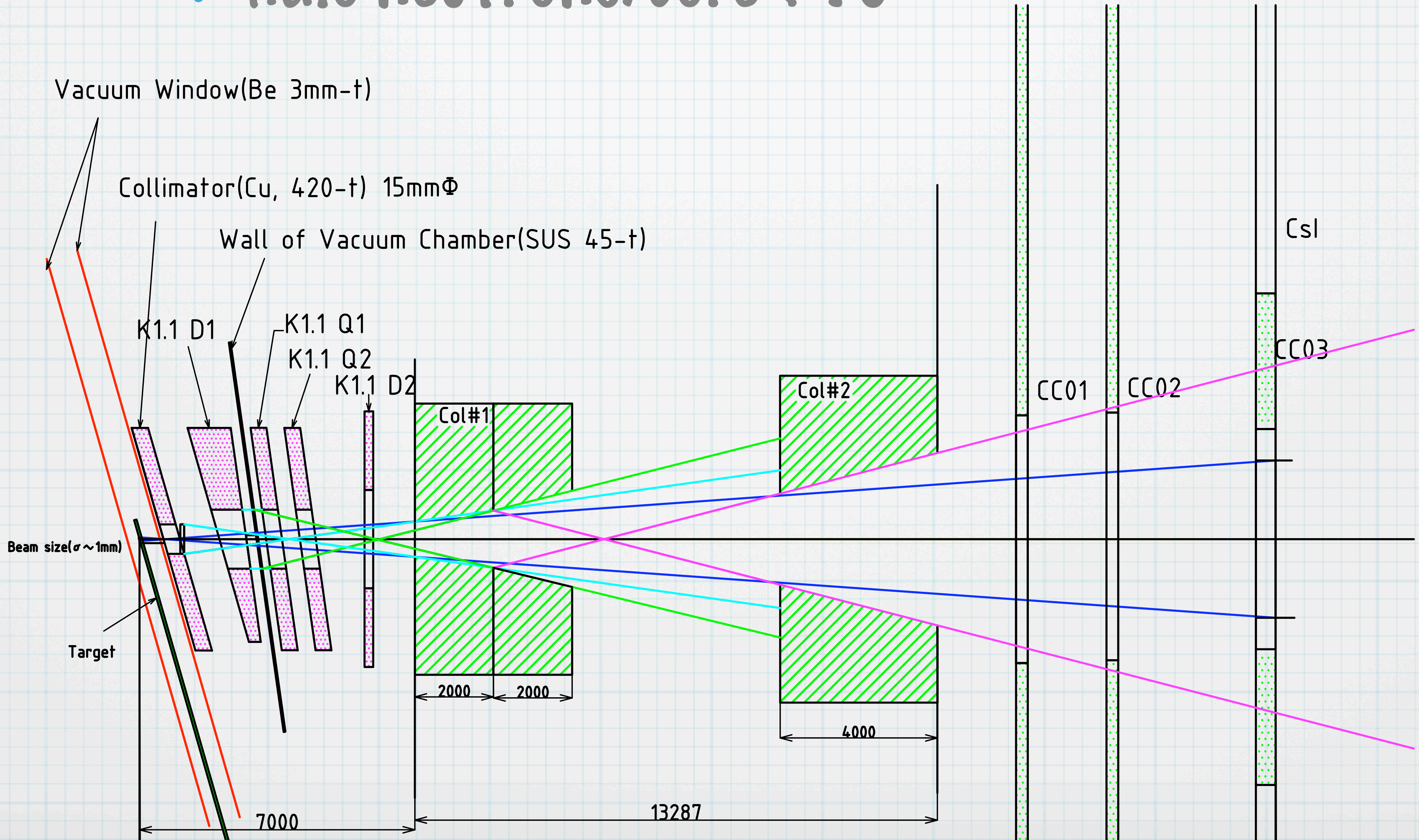


y

(mm)

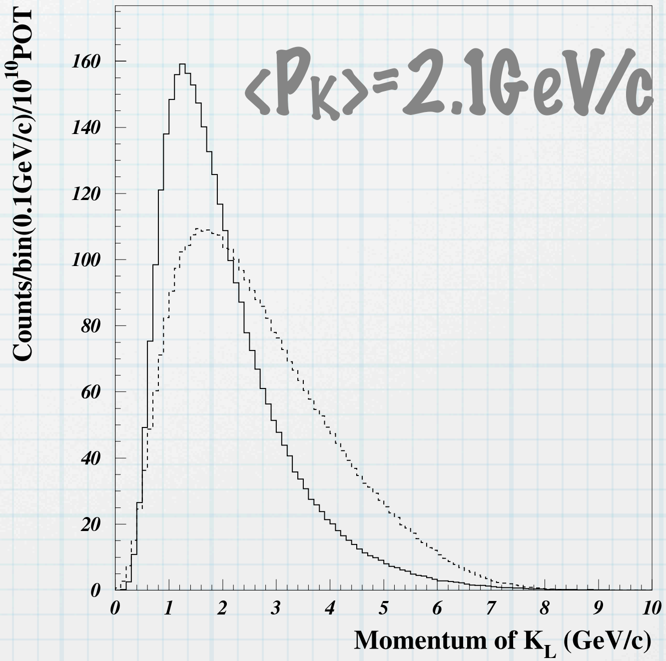
Step 1 beamline

* halo neutrons/core < 10^{-5}



Beam intensity

- 2E14 30GeV protons/spill
- 16deg extraction angle
- 9μstr beam
- 8.1E6 K_L/spill @ beam exit
- 3E5 K_L decays/spill in 2m



Step 1 Rates

* 2E14 protons on target
* 11.6MHz KL, 490MHz n
* Overall rate in detector = 26MHz
  * = 22MHz accidental rate
  * + 4MHz KL decay in 21m

Rates/channel

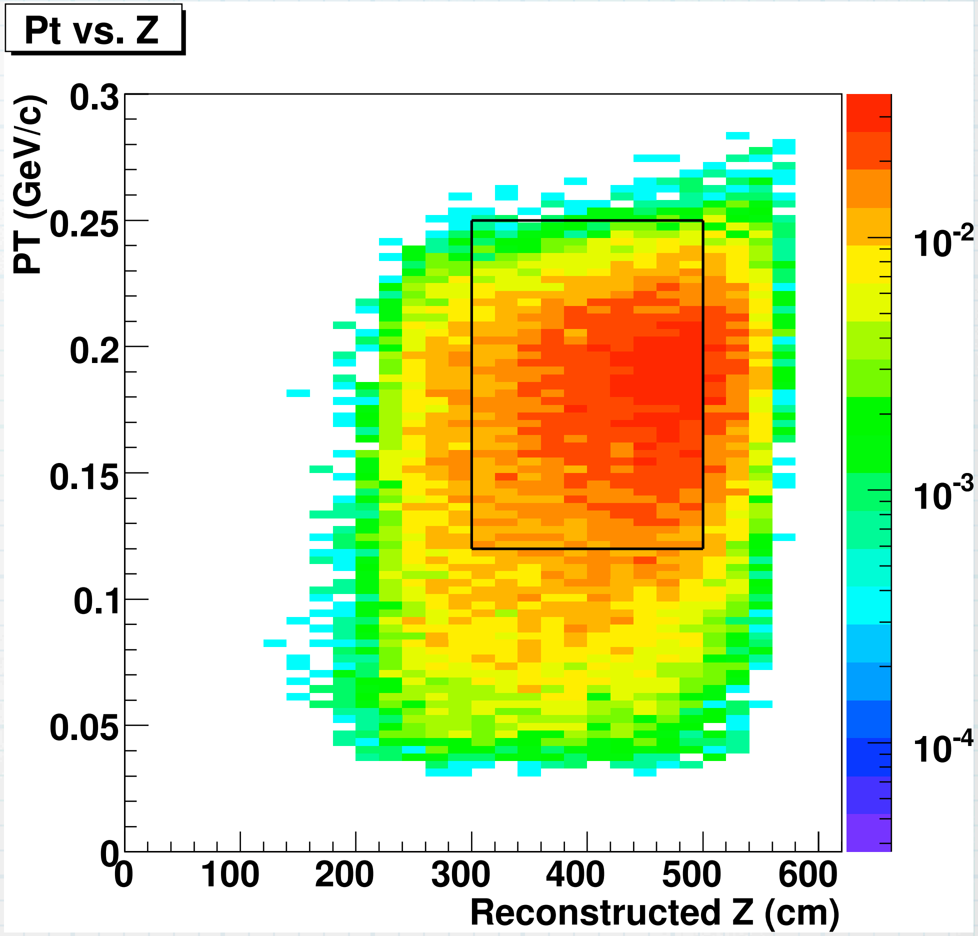
Detector	Counting Rates (kHz)
Main Barrel	7.5
Front Barrel	10
Charged Veto (CV)	3.5
Inner CV	11
Barrel CV	15
Beam hole CV	45
CC02	8
CC03	11
CC04	24
CC05	28
CC06	50
CC07	125
Beam Hole Photon Veto	600

Accidental hits in detector except for BA, CC06, CC07

Multiplicity	Counting Rates (kHz)
1	312
2	67
3	25
4	14
5	8
> 5	30

Acceptance

* Acceptance = 94%
  * Egamma>0.1GeV, extra Edep<1MeV,
  * 3m < z < 5m, 0.12GeV/c < P_T < 0.25GeV/c,
  * ...



Acceptance loss

* Expect/assume 50% loss due to
  * accidental activities: 27%
  * cluster shape cut: 30%
  * isolated low energy cluster (by low E neutrons): 10%

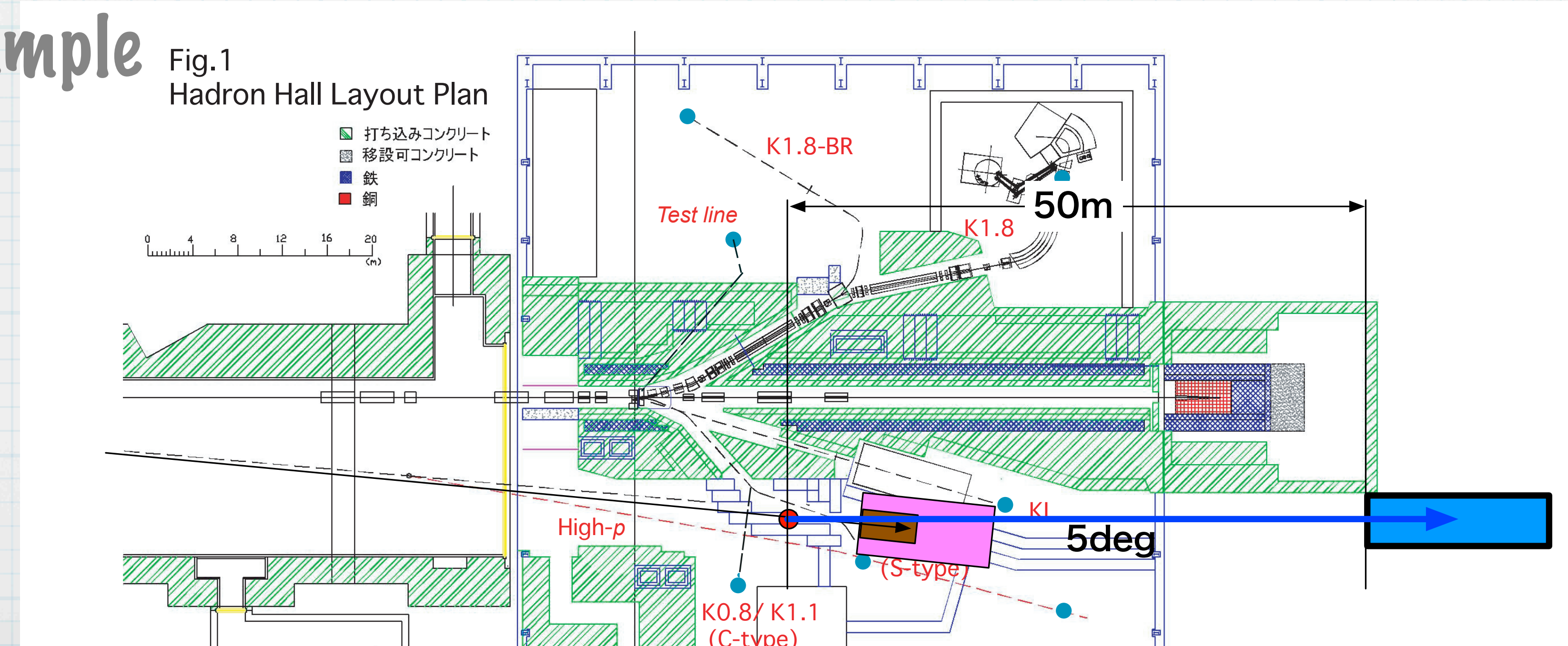
Single Event Sensitivity

* 2E14 protons/3.3s x 3E7sec gives
  2.6E12 K_L decays in 2m
* SES =1/(N_K x decay prob. x acceptance)
  = 4.0E-12 (w/o acceptance loss)
  = 8.0E-12 (w/ 50% acceptance loss)
* 3.5 standard model events (w/acc. loss)

Step 2

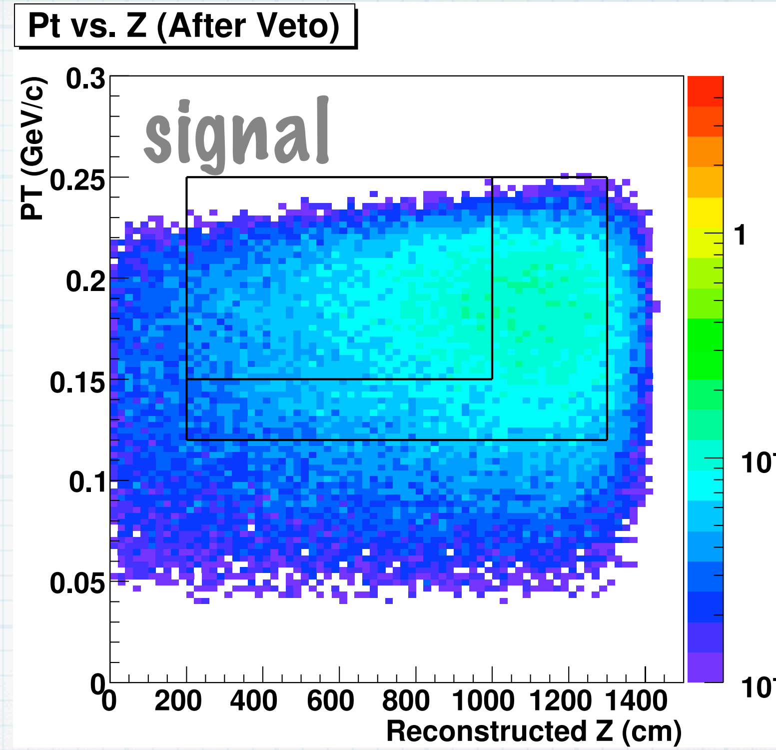
- Optimized beamline with 5deg angle for
  - higher KL momentum <PK>=5.2GeV/c
  - higher yield: 4.4E7/2μsr /3E14pot

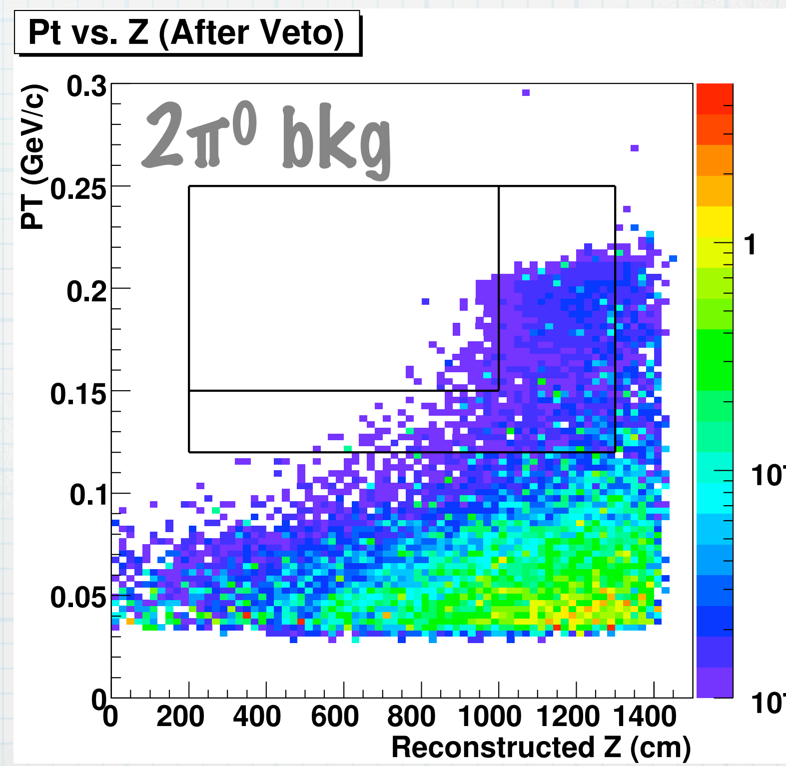
Example



Step 2

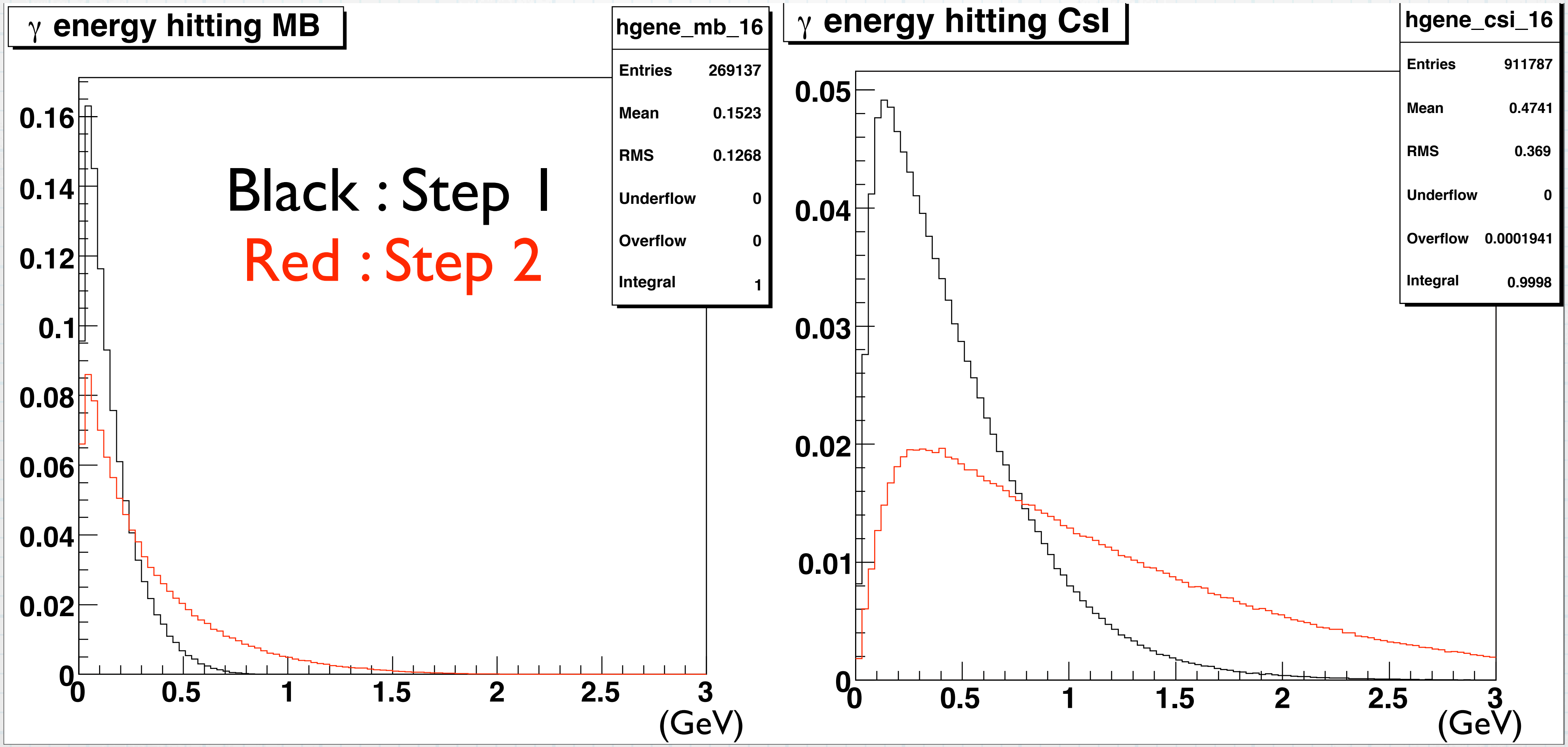
* Longer(15m) and larger (3m) detector for
    * longer decay volume: 6% decay in 11m
    * higher KL momentum
    * higher acceptance
* 133 SM events/ 3E14 x 3E7sec
* S/N = 4.8
    * 19 2pi0 bkg
    * 8 $\pi^+\pi^-\pi^0$ bkg





Egamma is higher at Step 2

* Thus better veto inefficiency



KTeV CsI loan request

THE UNIVERSITY OF CHICAGO
THE ENRICO FERMI INSTITUTE
5640 South Ellis Avenue
Chicago, Illinois 60637-1433
March 18th 2006

Dr. Pier Oddone, Director
Fermi National Accelerator Laboratory
Batavia, Illinois 60510

Dear Dr. Oddone,

We would like to ask for your consideration and support to use the Fermilab E832/E799 CsI crystal array for a JPARC rare kaon decay experiment.

The experiment E391a at KEK aims to measure the rare neutral kaon decay mode K_L-> $\pi^0\nu\nu$ with a single event sensitivity of $\sim 10^{-9}$. The last data taking period ended in December 2005 and we are in the midst of analyzing three runs of data collected in the past two years. An important goal of E391a is to validate the principles of the measurement techniques and to show that there is no fundamental show stopper for future JPARC followup.

The JPARC complex starts to operate in 2007, and likely to be ready for physics experiments in 2008 if not earlier. If the loan is favorable, we will work towards the logistics and a timeline. We appreciate your consideration and thank much in advance.

Sincerely yours,

Yau W. WAH
Professor, Physics Department
The College & The Enrico Fermi Institute

Taku Yamanaka
Professor, Physics Department
Osaka University

Schedule

2006	• Start preparing the beam collimators. • Prepare for transferring and shipping CsI crystals. • Start designing the new CsI readout electronics. • Start designing the new DAQ.
2007	• Build beam collimators. • Start assembling the additional MB layers. • Ship KTeV CsI crystals. • Move some of the E391a detector parts to J-Parc. • Start assembling the new DAQ.
2008	• Finish installing the beam line by the summer shutdown. • Move most of the E391 detector components from KEK to J-Parc. • Construct the CsI Calorimeter. • Build the DAQ system. • December: Start a beam survey during night.
2009	• Construct and install rest of the detector components. • Continue beam survey, and tune the detector.
2010	• The first physics data taking run.

最終年度に設備備品費が必要な場合は、その理由も記入してください。

年度	品名・仕様	数　量	単価	金　　額	主として使用する研究者及び設置機関名	購入予定時　　期
H18	VME クレート, 9U	1	500	500	山鹿、阪大	11 月
	DAQ テスト回路	1	1,000	1,000	山鹿、阪大	11 月
	DAQ テスト用 PC 一式	1	500	500	山鹿、阪大	11 月
H19	ビームライン設置用架台	1	7,000	7,000	稲垣、KEK	10 月
	波形記録用回路	20	450	9,000	山鹿、阪大	8 月
	PC farm 周辺機器	1	500	500	小松原、KEK	7 月
H20	ビームライン用ポンプ	2	1,000	2,000	稲垣、KEK	7 月
	移設に伴う設置器具	1	8,000	8,000	稲垣、KEK	6 月
	大型円筒型検出器架台	1	12,000	12,000	Lim、KEK	9 月
	CsI 較正用レーザー	1	3,000	3,000	Lim、KEK	7 月
	真空ポンプ	1	1,000	1,000	稲垣、KEK	7 月
	DAQ 一式 (FADC 等)	1	23,000	23,000	山鹿、KEK	10 月
	PC farm 周辺機器	1	500	500	小松原、KEK	9 月
H21	移設に伴う設置機器	1	2,000	2,000	Lim, KEK	6 月
	高/低真空分離薄膜	1	5,000	5,000	Lim, KEK	7 月
	コリメータ検出器架台	1	4,000	4,000	Lim, KEK	7 月
	DAQ 一式 (VME)	1	9,000	9,000	山鹿、KEK	8 月
	DAQ 用分散計算機一式	1	3,000	3,000	山鹿、KEK	8 月
	PC farm 一式	1	2,000	2,000	小松原、KEK	8 月
	結晶開発用分光計	1	1,000	1,000	鈴木、佐賀大	8 月
H22	真空用備品一式	1	5,000	5,000	Lim, KEK	7 月
	PC farm 一式	1	6,500	6,500	山鹿、KEK	8 月
	ガンマ線方向検出器読み出し装置一式	1	3,000	3,000	小松原、KEK	9 月
	結晶開発用 ADC 回路	2	500	1,000	鈴木、佐賀大	9 月
H23	ガンマ線方向検出器読み出し装置一式	1	1,000	1,000	小松原、KEK	7 月
	結晶開発用測定装置	1	1,000	1,000	鈴木、佐賀大	7 月