Report from a task force on E14

J. Haba,T. Nakaya, H. Yamamoto, N. Saito,
M.Takasaki , M. Tanaka,

K. Nishikawa (chair),

- Task force to reply to PAC
  - J. Haba,T. Nakaya, K. Nishikawa, H. Yamamoto, N. Saito, M.Takasaki , M. Tanaka

The PAC considers that it is important for the IPNS/J-PARC management to develop a realistic plan for the completion of the beam lines. This plan should take into consideration the costs, manpower estimates, overall commissioning requirements, radiation safety and other complications associated with the nature of these projects. The PAC requests to hear a report on this plan at the next meeting, with the following guideline:

Guidelines given by PAC

1. Timely commissioning of slow extraction to the K1.8(BR) line and fast extraction for the neutrino program should be the highest priority.
2. In the completion of the other beamline, the safety aspects especially associated with radiation issues should be seriously considered.
   – Realistic plan of the commissioning accelerator / slow extraction
3. In the case that a step-by-step plan is required due to limited resources, the PAC considers the K0 beam line to be second priority, the K1.1BR+K0.8 beam lines for the E06 third priority followed by the high momentum and K1.1 lines as lower priority.
4. the upstream magnet installation should be planned carefully due to the safety aspects. Several of the K1.1BR magnets can be installed prior to the K0 beam line components, if this significantly improves the schedule and interference issues

Expected rate with 'best configuration' with a hadron production model (GEANT QGSP)

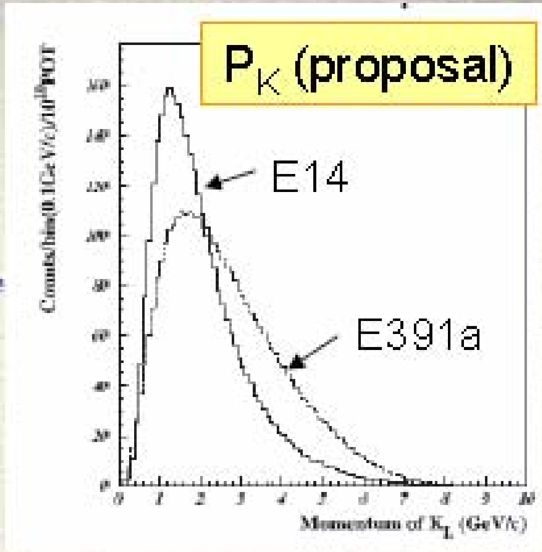
		standard cuts	CsI cluster shape cut	acceptance loss (50%)
Signal	$K_L \to \pi^0 \nu\overline{\nu}$	6.0 ± 0.1	5.4 ± 0.1	2.70 ± 0.05
K_L BG	$K_L \to \pi^0\pi^0$	3.7 ± 0.2	3.3 ± 0.2	1.7 ± 0.1
	$K_L \to \pi^+\pi^-\pi^0$	0.18 ± 0.08	0.16 ± 0.07	0.08 ± 0.04
	$K_L \to \pi^- e^+ \nu_e$	0.13 ± 0.01	0.03 ± 0.003	0.02 ± 0.001
halo n BG	CV	—	—	0.08
	η	8.1	0.6	0.3

- New limit $<6.7 \times 10^{-8}$ (@90% CL, new publication of E391a)
- $K^+ \to \pi^+\nu\nu$: 'Grossman-Nir limit' $< 1.4 \times 10^{-9}$
- $K^0 \to \pi^0 e^+ e^-$ (Lepton universarity + 3 generation ν $< 7.8 \times 10^{-10}$

- 3σ discovery limit is 1.1×10^{-10}
  - ~3 orders of magnitudes improvement of current limit
  - But small room for degrading (backgrounds, accidentals,…)

KL yield

E14 / E391a case



- 注目すべき m_t, y
  - E14 : P_K peak=1.3GeV/c, av.=2.1GeV/c
  - E391a : P_K peak=1.8GeV/c, av.=2.6GeV/c

P_K (GeV/c)	16 degree (E14) *				4 degree (E391a)			
	P_L	P_T	m_t-m_0	y	P_L	P_T	m_t-m_0	y
1.0	0.96	0.28	7.2e-2	1.3	1.00	0.07	4.9e-3	1.4
1.5	1.44	0.41	**0.15**	**1.5**	1.50	0.11	0.01	1.8
2.0	1.92	0.55	**0.25**	**1.7**	2.00	0.14	**0.02**	**2.1**
2.5	2.40	0.69	0.35	1.8	2.49	0.17	**0.03**	**2.3**
3.0	2.88	0.83	0.47	1.8	2.99	0.21	0.04	2.4

(*) データと比べる時、本当はP(proton)=14.6 → 30 GeV/c のスケーリングを考えなければならない。
m_t-m_0≒$P_T^2/2m_K$(P_T<<m_K) or P_T(PT>>m_K)なので、P_T∝$s^{1/2}$∝$E^{1/2}$として、目安は$E^{1/2}$~E つまり1.4~2か?

BNL E802実験 (ref.1)

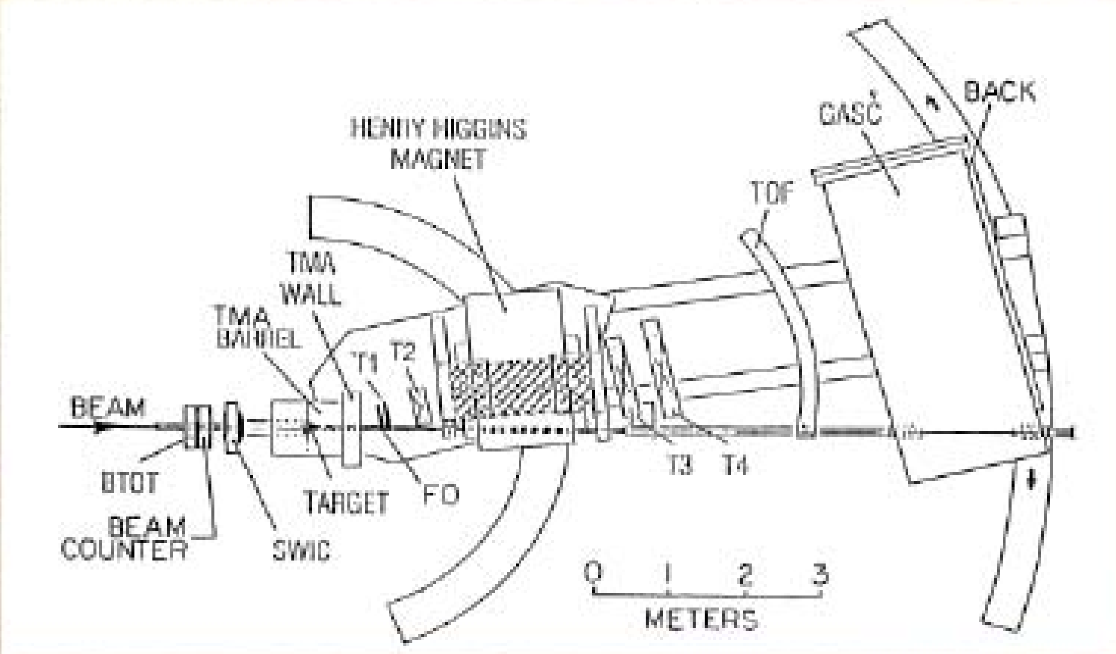
- Primary momentum = 14.6 GeV/c
- Target = Be, Al, Cu, Au
- Production angle = 5 to 58 degree
- Spectrometerによる運動量測定
- 粒子識別
  (TOF&ガスチェレンコフ)

pion : 5 GeV/cまで

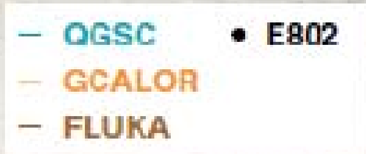
kaon : 3.5 GeV/c まで

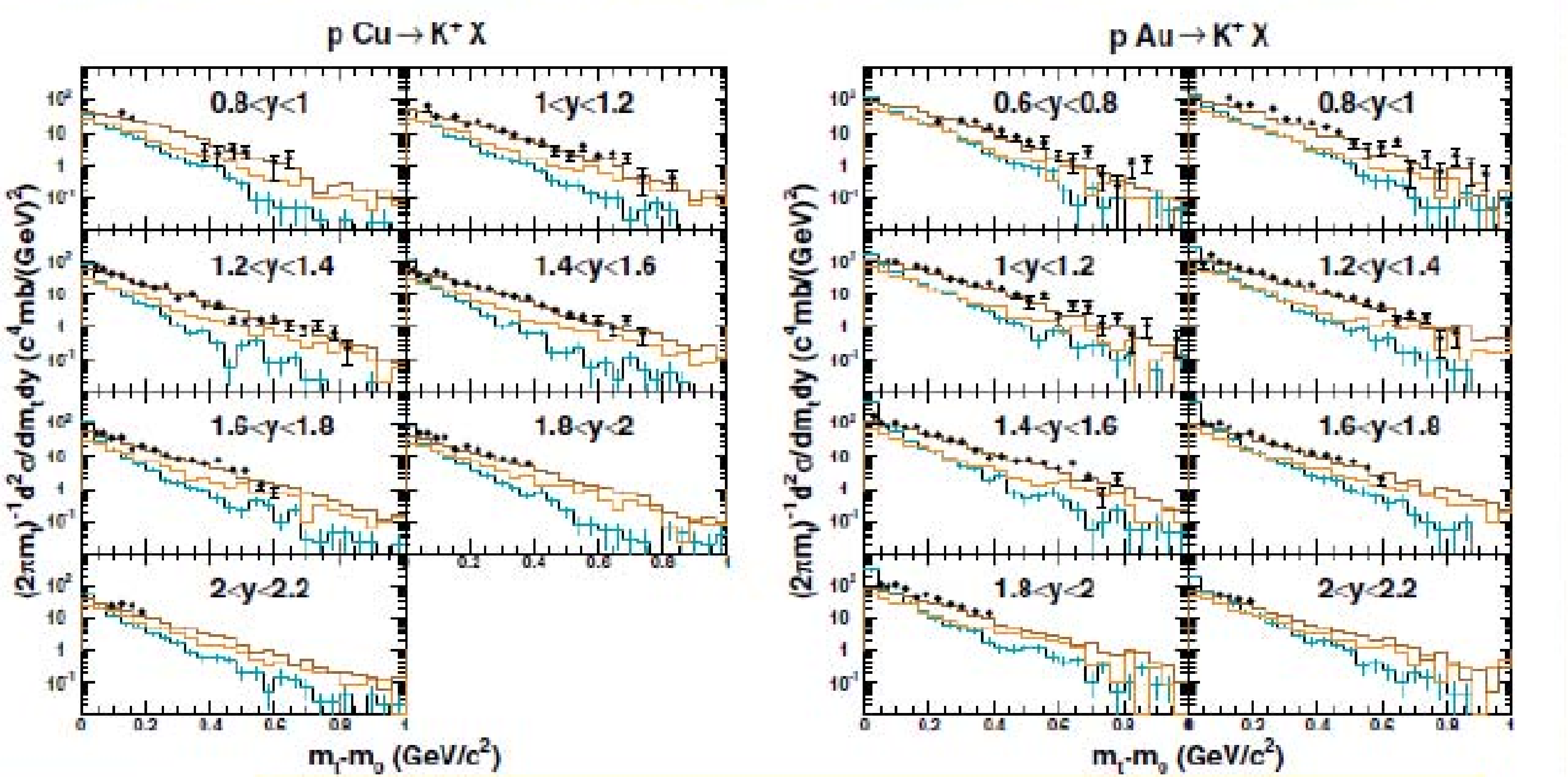
proton : 8 GeV/c まで

PRD 45 (1992) 3906-3920
NIM B246 (2006)309-321



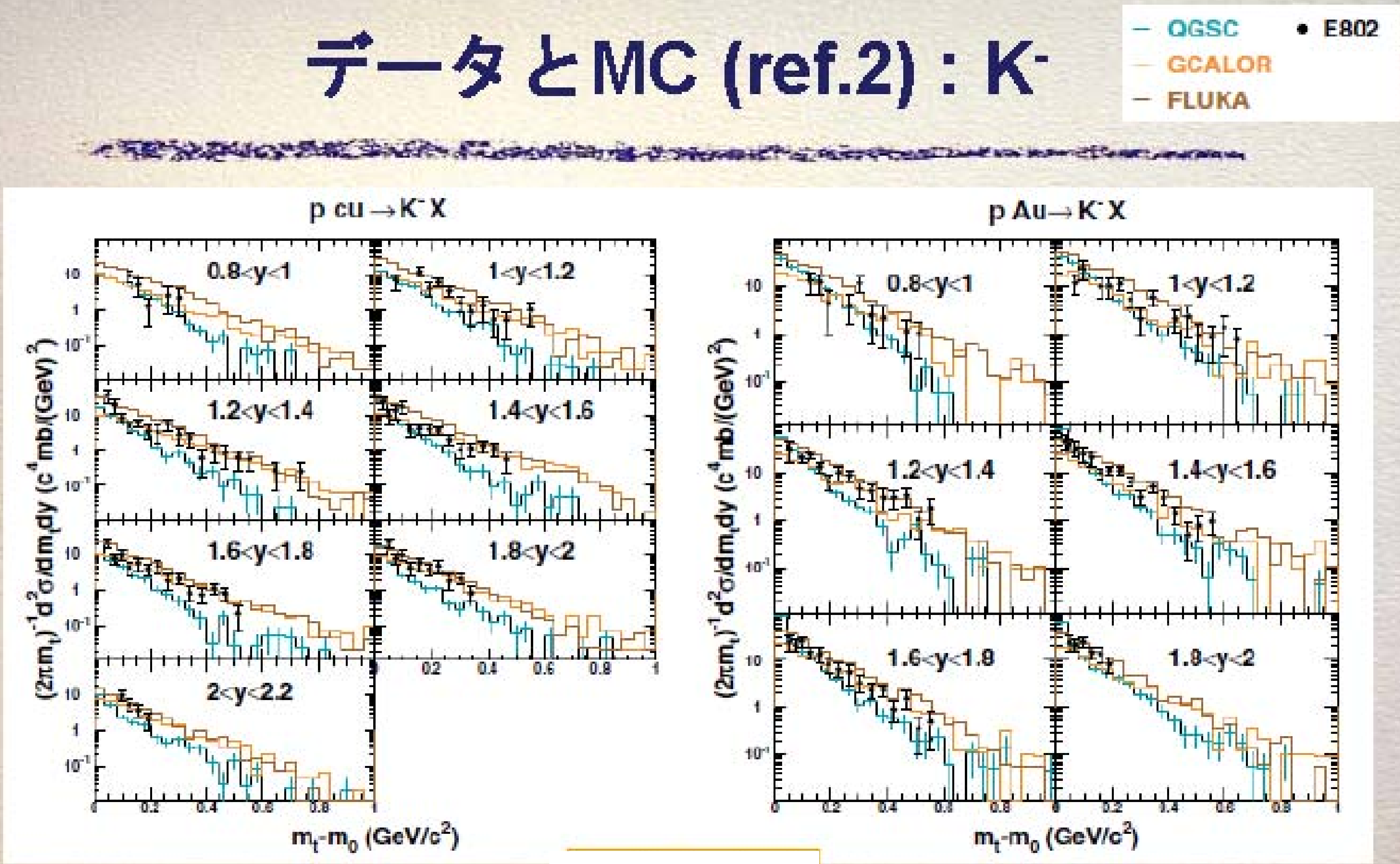
データとMC (ref.2) : K^+





- 合いの良さは FLUKA、G3(GCALOR)、G4(QGSC)の順
- FLUKA以外はExponential shapeのスロープが再現できていない

データとMC (ref.2) : K⁻



similar to K+

KL yield estimation

E391a

	K_L Yield per POT
Run-II data	$(1.36 \pm 0.08)\times10^{-7}$
GEANT3	$(1.32 \pm 0.03)\times10^{-7}$
GEANT4(QGSP)	$(1.31 \pm 0.11)\times10^{-7}$
GEANT4(QBBC)	$(1.54 \pm 0.12)\times10^{-7}$
FLUKA	$(1.40 \pm 0.02)\times10^{-7}$

We got good agreement in KL yields among different packages and obtained data at E391a.

E14

	K_L Yield per POT
GEANT3	$(3.8 \pm 0.1)\times10^{-8}$
GEANT4(QGSP)	$(2.3 \pm 0.1)\times10^{-8}$
GEANT4(QBBC)	$(2.7 \pm 0.3)\times10^{-8}$
FLUKA	$(8.3 \pm 0.2)\times10^{-8}$

In the E14 case, there are discrepancy among packages. We are studying the reason.

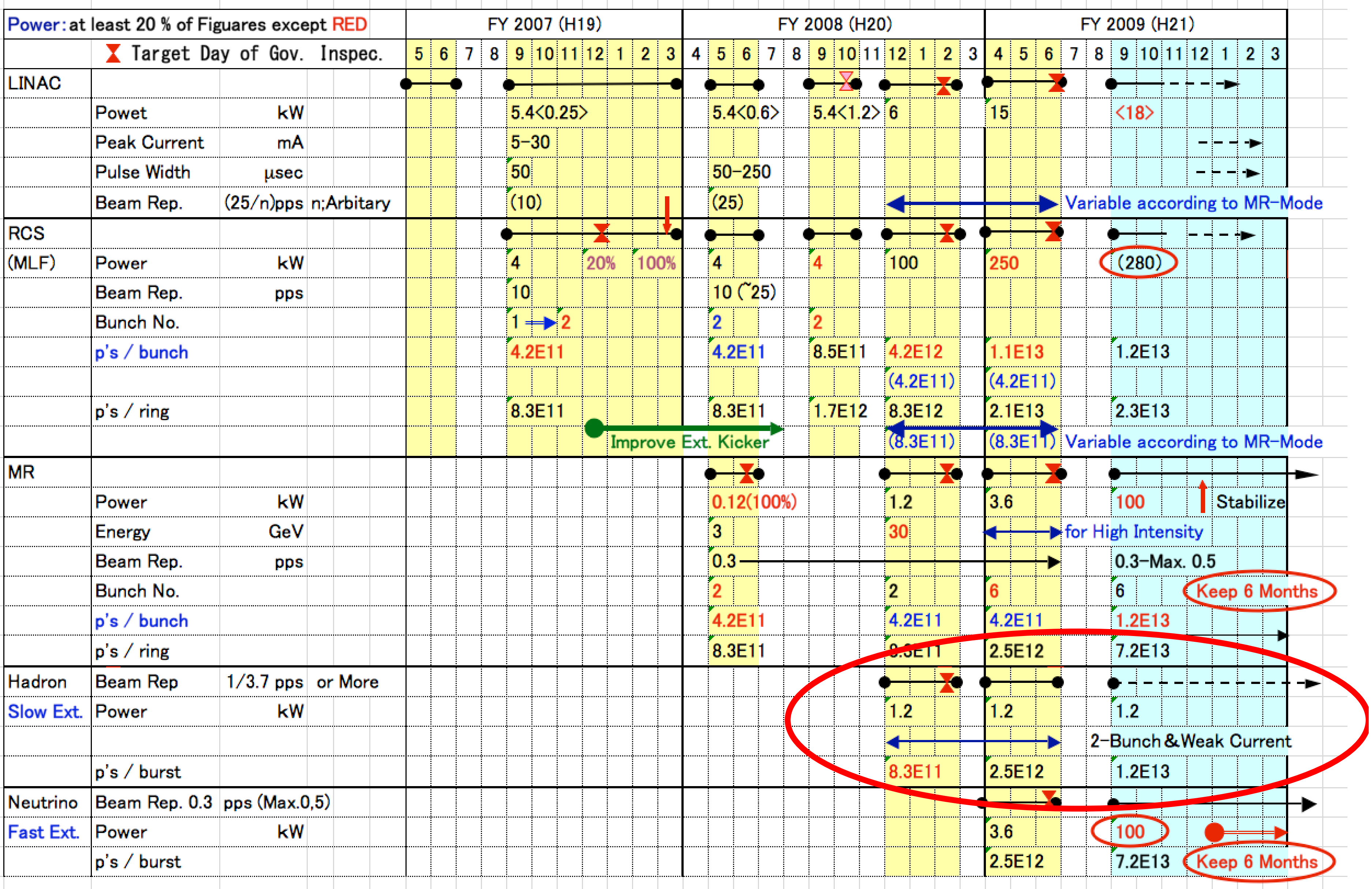
Some hope?

Beam line design and
a possible construction scenario

Factors to be considered

Small room for degrading factors to achieve 10^{-10} 3 σ discovery limit

1. Accelerator and slow extraction schedule
2. Quality of slow extracted beam must be studied
   - Beam stability (spot size and position, spill structure)
   - Beam halo effect on n-BKG
3. Effects of upstream materials
4. Optimization of the beam line (KL yield vs. n BKG), collimator design (material, acceptance etc.), detector

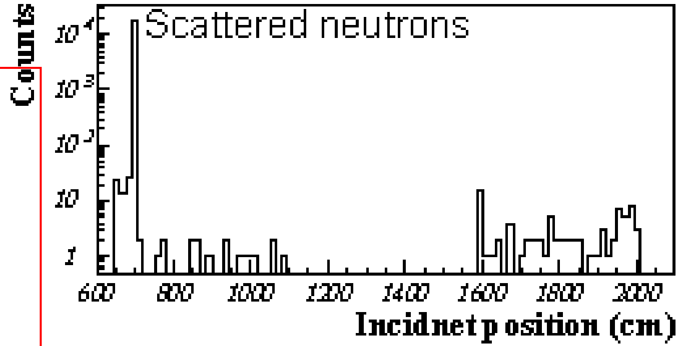


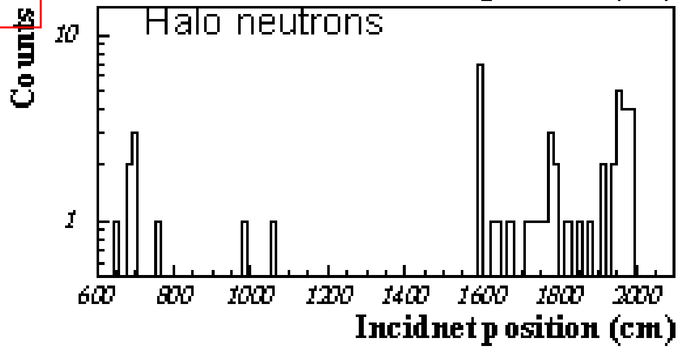
It looks beam studies will be the goal for 2009 and we expect not much radiation in the area

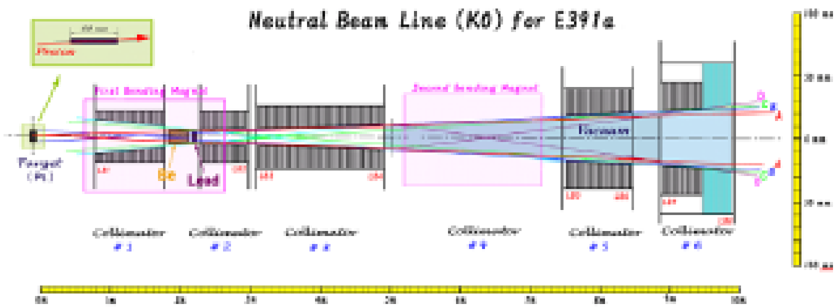
Beam line design

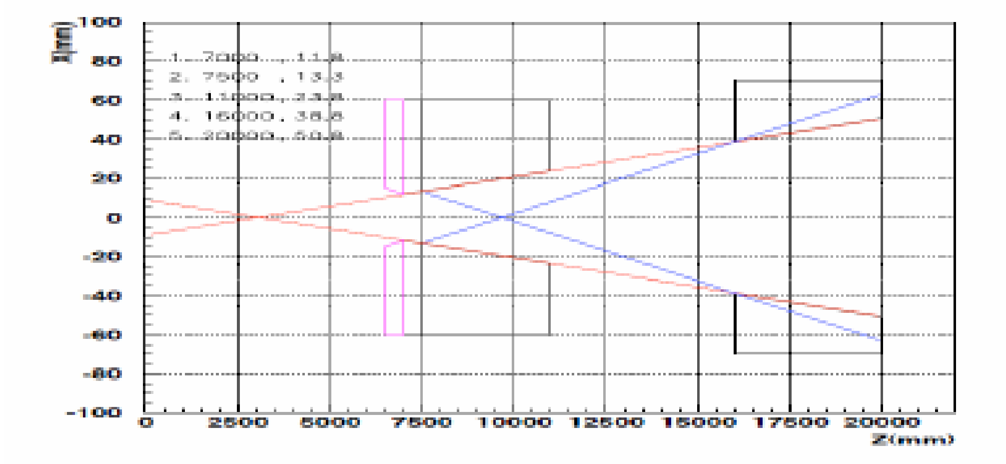
from a report by Lim

- **Different situation compared to E391a**
  - Finite size of target image
  - Start collimator far from production target
  - Beam Sharing with K1.1
  - Longer beam line : Beam size V.S. KL Yield
  - Larger extraction angle:bettter KL/n ratio, soft neutron
- **E391a results shows reliability of M.C. study**
  - We got consistency
  - GEANT3, GEANT4, FLUKA
  - Reduce multiple scattering inside collimator

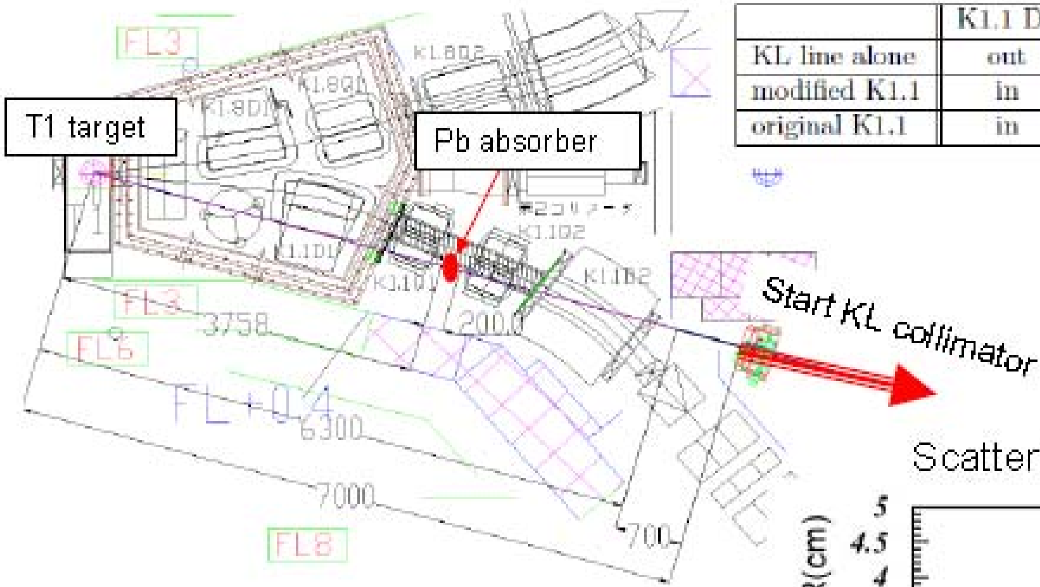






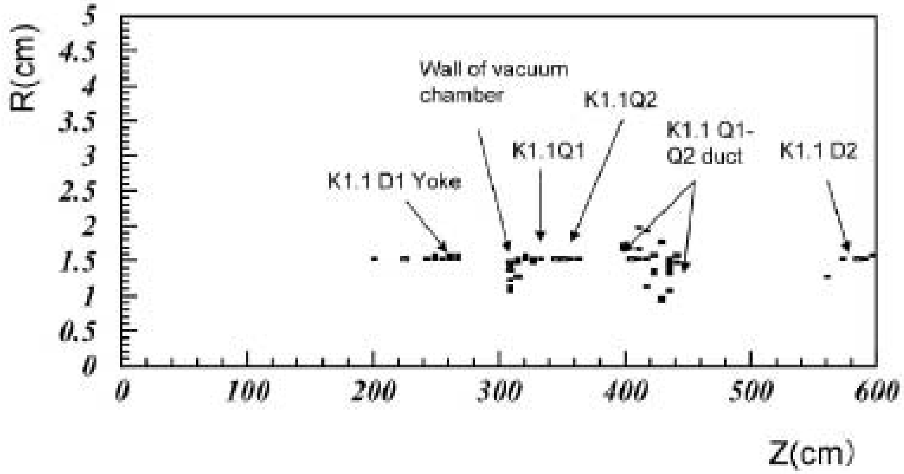


The effect of upstream materials



	K1.1 D1	flange	K1.1 Q1, Q2	K1.1 duct	K1.1 D2
KL line alone	out	t=0.2mm	out	out	out
modified K1.1	in	t=0.2mm	in	t=0.2mm	in
original K1.1	in	t=20mm	in	t=5mm	in

Scattering points to produce halo neutron



from a report by Lim

Comparison among three different configurations.

With and without K1.1 materials

Table 3: Number of the core neutrons, halo neutorns and K_L's per spill (2×10^{14} protons) at the three different configurations.

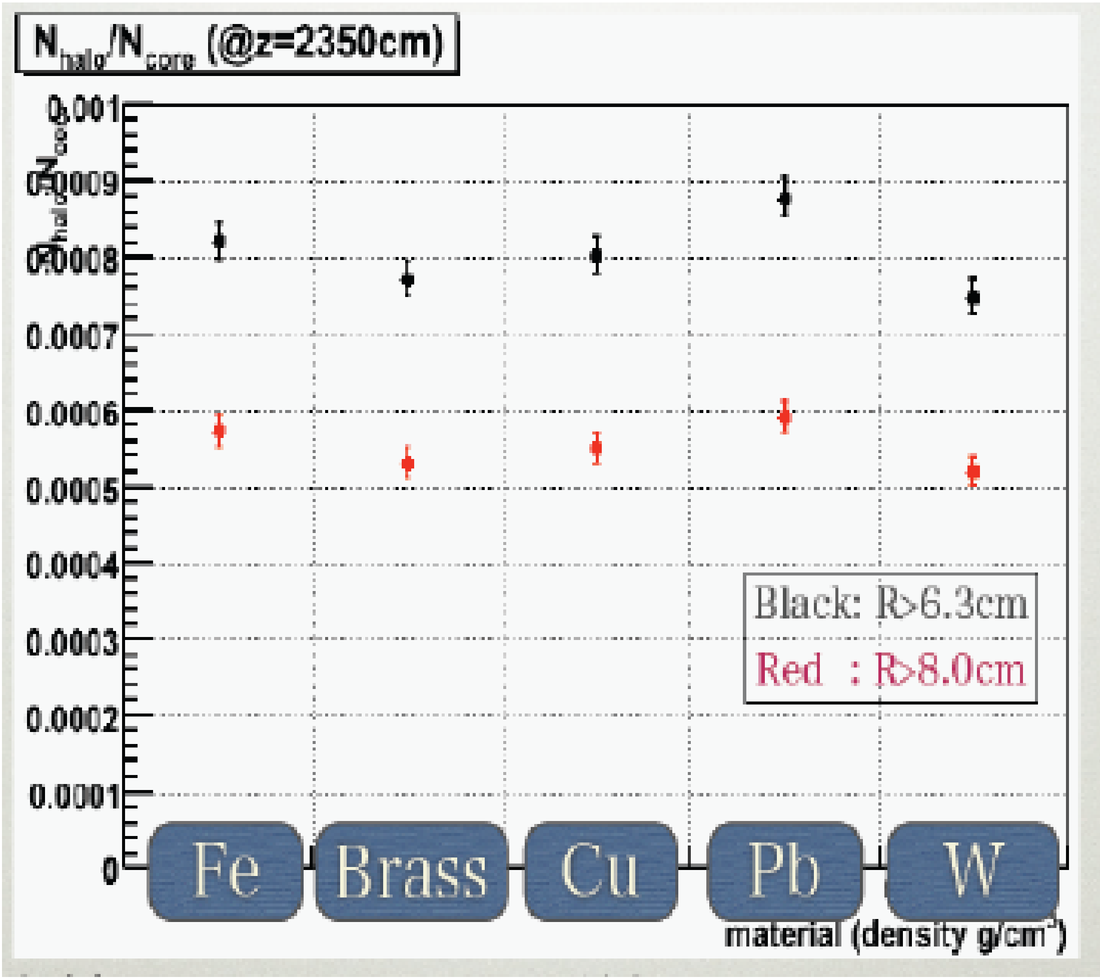
	Core neutron ($E_n > 100MeV$)	halo neutron ($R > 8cm$ at CsI Surface, $P_n > 2GeV/c$)	K_L (At the exit of beam line)
KL line alone	3.21×10^8	$(0.72 \pm 0.15) \times 10^4$	$(7.79 \pm 0.11) \times 10^6$
modified K1.1	3.15×10^8	$(1.17 \pm 0.19) \times 10^4$	$(7.77 \pm 0.11) \times 10^6$
original K1.1	1.53×10^8	$(1.38 \pm 0.20) \times 10^4$	$(4.56 \pm 0.08) \times 10^6$

- 'KL line alone' reduces N_halo/N_KL as factor of 3.3 compared to that of 'original K1.1'.
- 'Modified K1.1' recovers N_KL, however the number of halo neutrons is still larger as factor 1.6 compared to that of 'KL line alone'.
  - We need to check feasibility to make large holes (r=2.5cm) in K1.1 magnets.

will depends also on extracted beam condition
(position stability, halo etc.)

Collimator Material effect

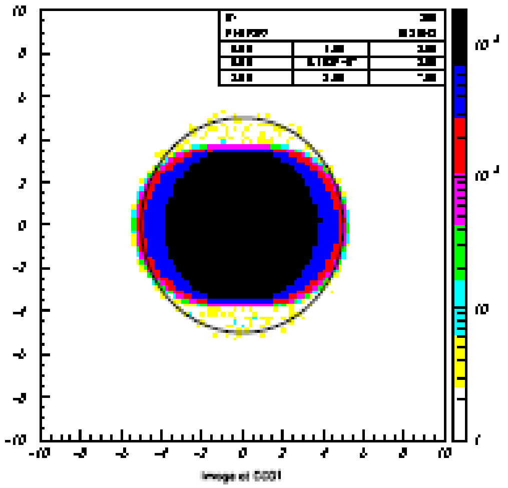
Must be carefully decided

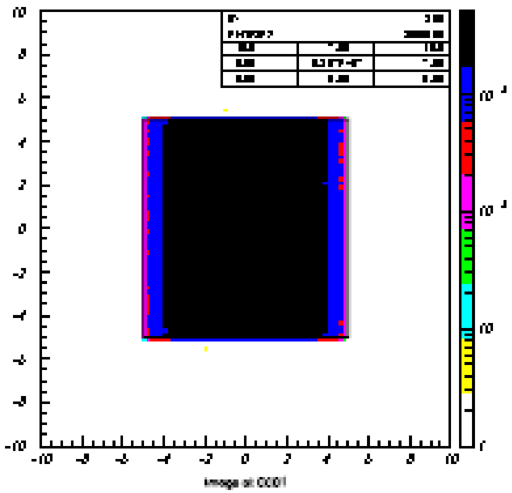


Halo neutron production weakly depends on material of collimator.

Further study

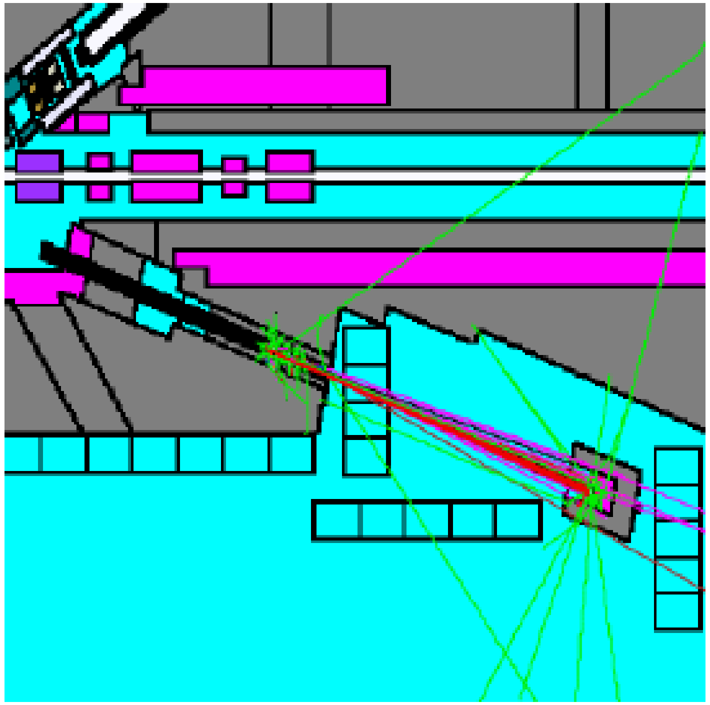
- Square shaped beam
  - Motivations
    - To adapt target image.
    - To get better KL yield and/or smaller beam size.
  - Things to do
    - We installed the collimators into GEANT4/GEANT3.
    - Quantitative comparison between circular and squared beam. - Promising.
    - Check background level for neutron/KL related.
  - We aim to make a decision by the end of 2007.
    - Final design within FY2007.
- Fine tuning of absorber position.
- Fine tuning collimator lines.

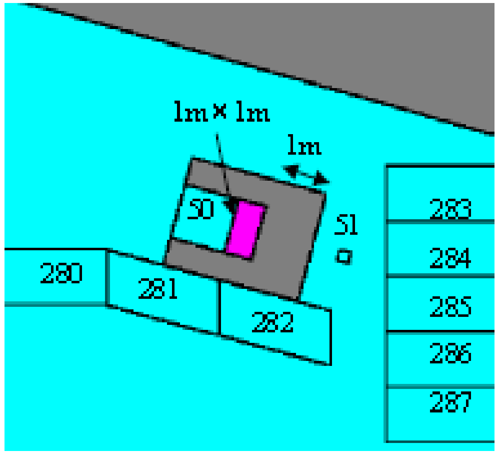




Expected radiation level (μSv/h)

30GeV 1.2kW





鉄50 cmコンクリート50cm

Unit: μSv/h

Region	Dose rate	Error
48	5.32E+03	4.95E+01
50	8.18E+01	9.38E-01
51	**1.88E+01**	**1.48E+00**

鉄50 cmコンクリート100 cm

Unit: μSv/h

Region	Dose rate	Error
48	5.34E+03	1.35E+01
50	8.10E+01	2.42E-01
51	**3.94E+00**	**1.96E-01**
280	4.63E-01	1.45E-02
281	3.59E-01	1.15E-02
282	1.95E-01	8.41E-03
283	1.40E-01	6.90E-03
284	5.95E-01	1.45E-02
285	6.83E-01	1.61E-02
286	1.83E-01	7.61E-03
287	7.94E-02	5.41E-03

鉄100cmコンクリート100cm

Unit: μSv/h

Region	Dose rate	Error
48	5.29E+03	5.16E+01
50	7.97E+01	8.57E-01
51	1.28E-01	2.59E-02

2007/11/12 鈴木健訓

We need only beam dump under the 1.2kW condition!

- Complete design beam line components in FY2008
- Start survey in late 2009 : estimated by beam channel group
  - 2008 (k¥) total 21,500
    - Beam plug (5,000)
    - Sweeping magnet and power (9,000)
    - Counting hut (7,500)
  - 2009 (total 100,100k¥)
    - Placement of collimators (500)
    - Shields (80,000)
    - Magnet transportation / installation (16,100)
    - Counting hut interior works (2,500)
    - Area preparation (1,000)

Time scale depends on financial situation

Conclusion

- The experiment is worth pursuing as an intermediate step for designing the next.
- Small room of loosing safety factor of sensitivity for the experiment to be a meaningful one
- Given priority set by PAC, the upstream magnet installation for K1.1 should be planned carefully for not degrading E14 performance. Step-by-step of review/construction needed.
  - It seems the radiation problem will be minor to access target area in 2008 and in 2009.
  - Optimizations of beam line should be examined in KL yield, n-BKG, and detector acceptance. We encourage the collaboration to develop a detailed plan of the beam studies to address the issues of KL yield and n-BKG.
  - We also encourage that studies on primary beam by close collaboration with beam channel group
- I feel that everything, down stream of T1 target, should be taken care of by the collaboration