Search for double anti-kaon nuclear bound states at J-PARC

F.Sakuma, RIKEN

Strangeness WS @ ECT*, 15-19, Oct, 2012.

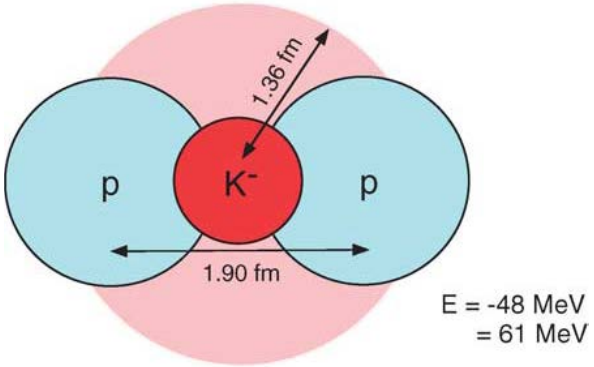
Outline

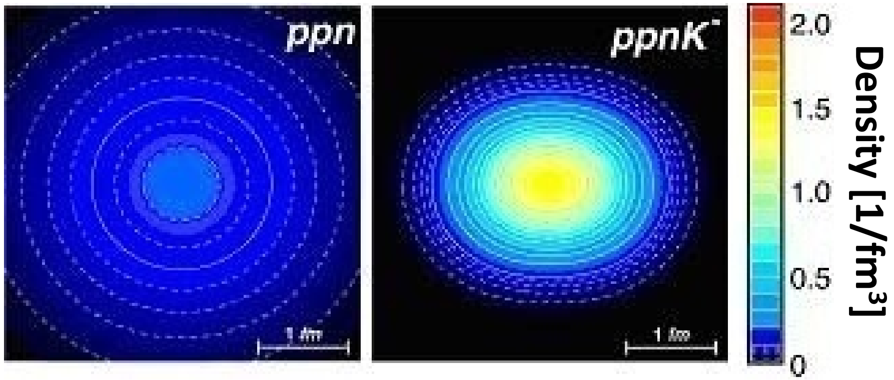
- (brief) Introduction of **"Kaonic Nuclear Cluster"**
- **"Double-Kaonic Nuclear Cluster" search**
  - ✓ using **$p^{bar}+{}^{3}He$ annihilation at rest**
  - ✓ using **p+p reaction**
  - ✓ using **anti-duetron beam?**
- **Summary**

Kaonic Nuclear Cluster (KNC)

- **K^bar N interaction** is clarified to be **strongly attractive** by Kaonic-atom experiments in 20th.
- This leads the prediction of **deeply-bound kaonic nuclear cluster (KNC)**, as many theorists pointed out.

some predictions show the density of the KNC is high density more than normal nuclear-density

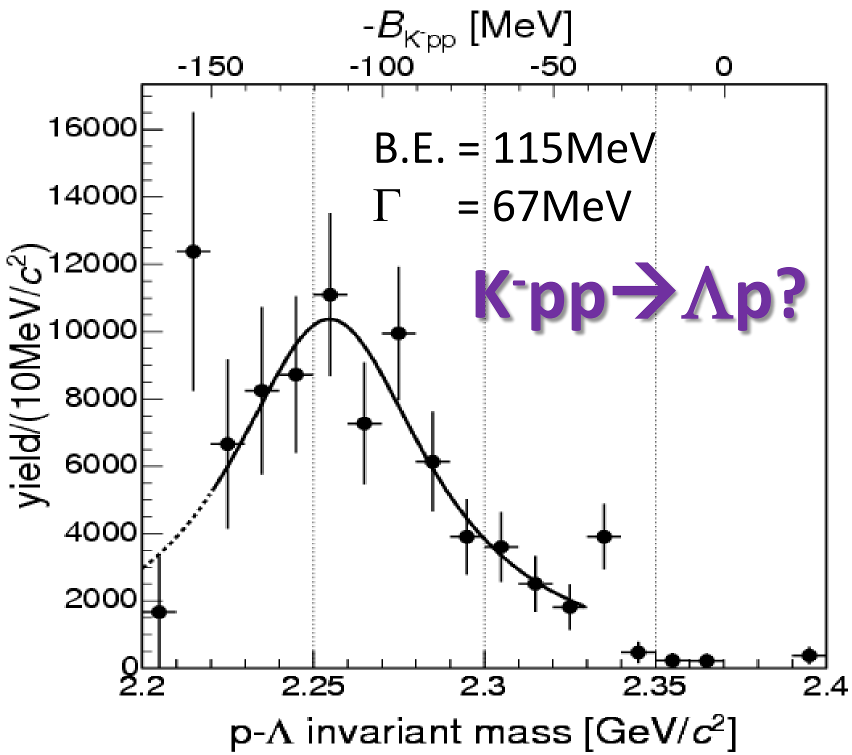




T.Yamazaki, A.Dote, Y.Akiaishi, PLB587, 167 (2004).

we will open new door to the high density matter physics, like the inside of neutron stars

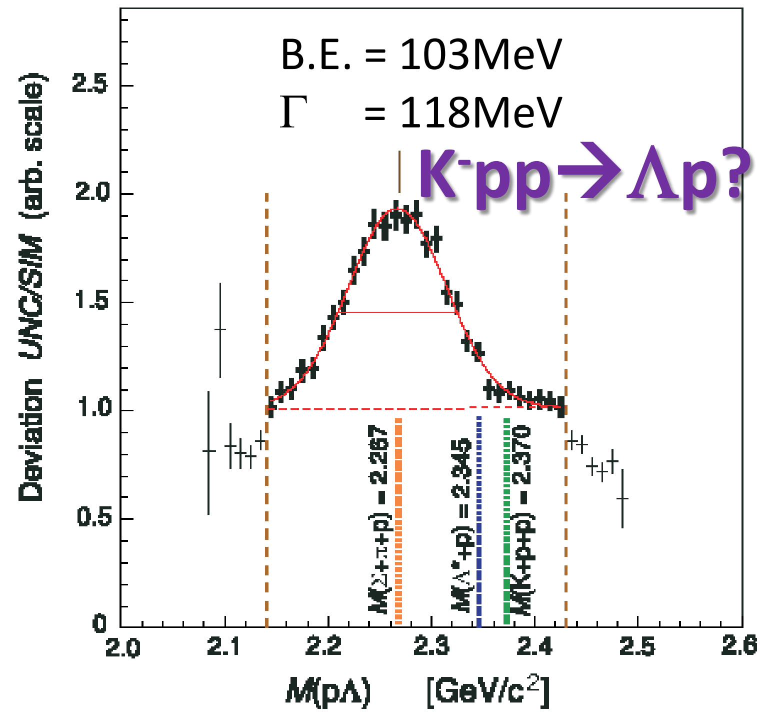
Experimental Situation of KNC



FINUDA@DAΦNE

PRL, 94, 212303 (2005)

stopped-K^- + A → (Λ + p) + X



DISTO@SATUREN

PRL,104,132502 (2010)

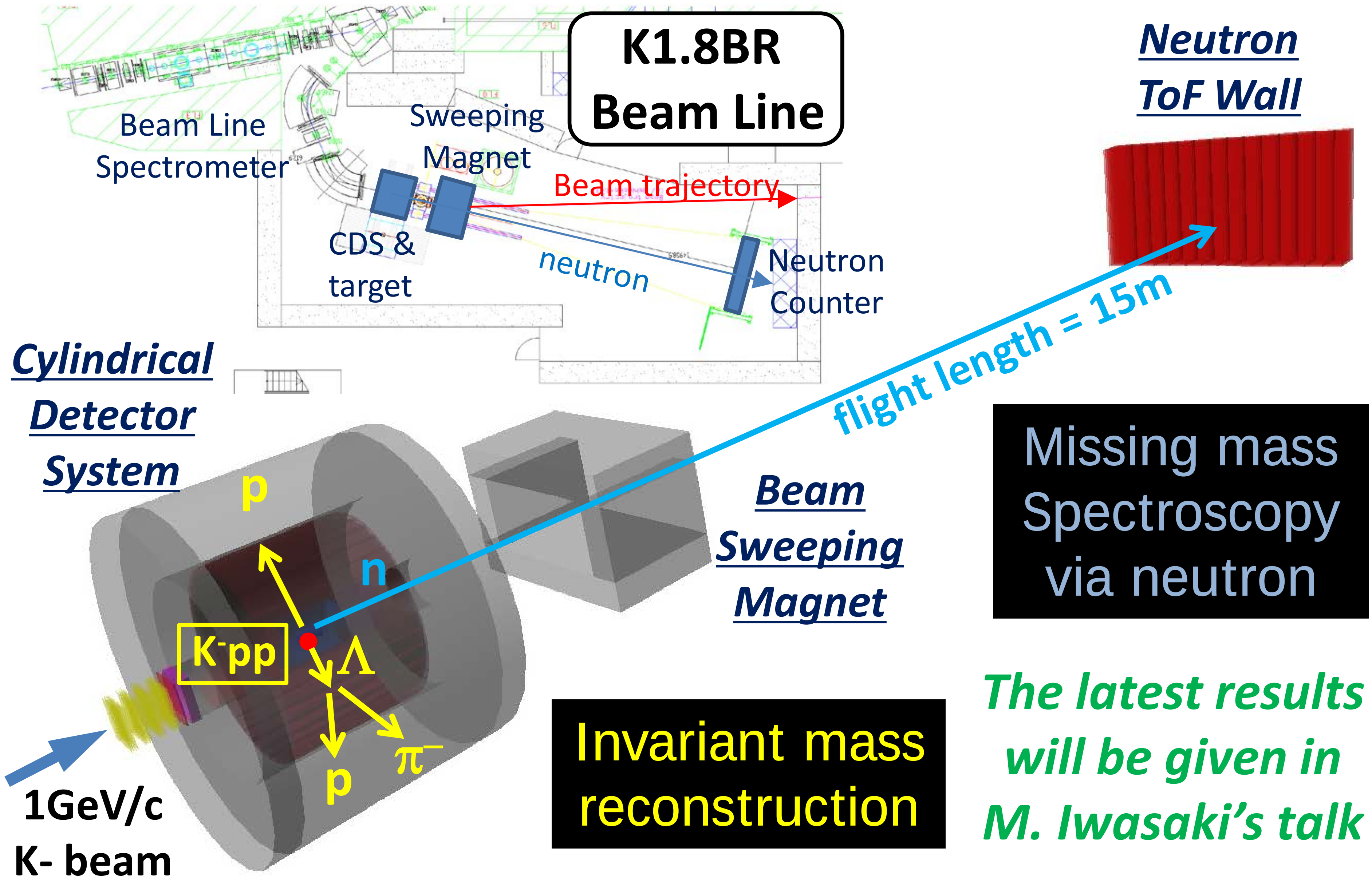
2.85GeV-p + p → (Λ + p) + K^+

We need more evidences in various channels!

Because there is a discrepancy
between THEORETICAL PREDICTIONS and EXPERIMENTAL OBSERVATIONS…

J-PARC E15 Experiment

search for the K^-pp using ^3He(in-flight K^-,n) reaction

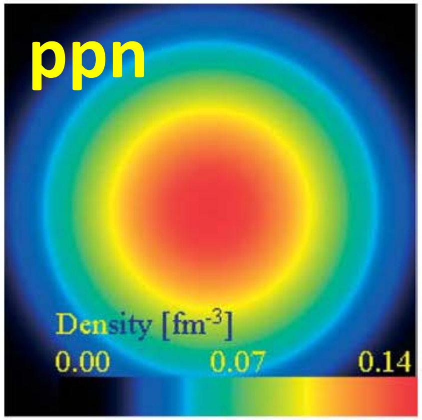


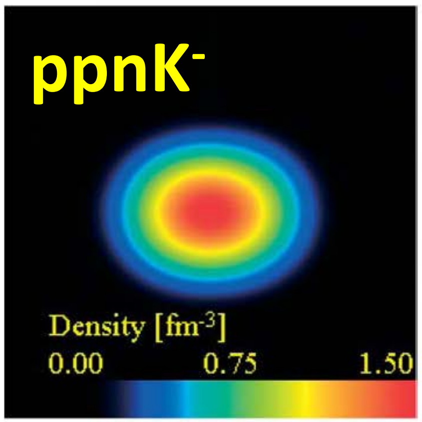
The latest results will be given in M. Iwasaki's talk

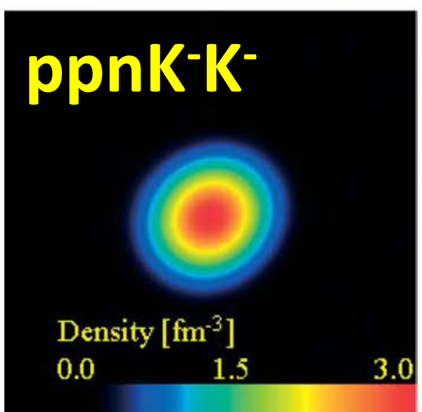
What will happen to put one more kaon in the kaonic nuclear cluster?

“Double-Kaonic Nuclear Cluster”

Double-Kaonic Nuclear Cluster (DKNC)







The double-kaonic nuclear clusters have been predicted theoretically.

$\bar{K}$ cluster	Mc^2 [MeV]	E_K [MeV]	Γ_K [MeV]	$\rho(0)$ [fm^{-3}]	R_{rms} [fm]	k_p [fm^{-1}]	k_K [fm^{-1}]
pK$^-$	1407	27	40	0.59	0.45	1.37	1.37
ppK$^-$	2322	48	61	0.52	0.99	1.49	1.18
pppK$^-$	3211	97	13	1.56	0.81		
ppnK$^-$	3192	118	21	1.50	0.72		
ppppK$^-$	4171	75	162	1.68	0.95		
pppnK$^-$	4135	113	26	1.29	0.97		
ppnnK$^-$	4135	114	34		1.12		
ppK$^-$K$^-$	2747	117	35				
ppnK$^-$K$^-$	3582	221	37	2.97	0.69		
pppnK$^-$K$^-$	4511	230	61	2.33	0.73		

PL,B587,167 (2004).

The double-kaonic clusters have

- **much stronger binding energy**
- **much higher density**

than single ones. (AMD calc.)

Two New Calculations

M.Hassanvand, Y.Akaishi, T.Yamazaki

PRC84(2011)015204, Proc.Jpn.Acad.Ser.B87(2011)362

IV. CONCLUSION

In this paper we have presented the results of our calculations on the formation of the basic double-$\bar{K}$ cluster, K^-K^-pp, in pp collisions. Since K^-pp is well approximated by $\Lambda^* - p$, we have employed a Λ^* doorway model for K^-K^-pp formation. We have found that the $p + p \to K^+ + K^+ + K^-K^-pp$ reaction takes place at a large probability, so that the bound-state peak dominates the spectral shape. We have studied the dependence of the spectral intensity on the bound-state energy and the compactness of K^-K^-pp and confirmed that the large bound-state cross section results from its compactness probed by the colliding $p + p$ with a large momentum transfer and a short collision length. Adding the

Deeply bound
& Compact
B=50~200MeV, Γ~75MeV

N.Barnea, A.Gal, E.Z.Liverts

arXiv:1203.5234

4. Conclusion

In conclusion, we have performed calculations of three-body $\bar{K}NN$ QBS

For the four-body QBS systems $\bar{K}NNN$ and $\bar{K}\bar{K}NN$ we found relatively small binding, of order 30 MeV in both, with widths that range from about 30 MeV for the lowest $\bar{K}NNN$ QBS to about 80 MeV for the lowest $\bar{K}\bar{K}NN$ QBS. These systems are not as compact as suggested by Yamazaki et al. [17, 18, 19]. Their $\bar{K}N$ r.m.s. distances do not fall below that of the $\Lambda(1405)$-like $\bar{K}N$ QBS, and their NN r.m.s. distances exceed that of nuclear matter ($\approx$ 1.7 fm).

NOT Deeply bound
& NOT Compact
B~30MeV, Γ~80MeV

Experimental Approaches to Search for DKNC

How to produce the double-kaonic nuclear cluster?

- heavy ion collision
- (K^-,K^+) reaction
- $p^{bar}A$ annihilation → ① **K1.8BR**
- p+p reaction → ② **primary**

…

- $d^{bar}A$ annihilation → ③ **K1.8BR**

We would like to perform exotic states search at J-PARC!

① "Double-Kaonic Nuclear Cluster" search

Using

p^{bar}+^{3}He annihilation at rest

the DKNC in p^{bar}A annihilation?

The elementary p^{bar}-p annihilation reaction with double-strangeness production:

$$\bar{p} + p \rightarrow K + \bar{K} + K + \bar{K} \;\; \mathbf{-98MeV}$$

This reaction is **forbidden for stopped p^{bar}**, because of a negative Q-value of 98MeV

if multi kaonic nuclear exists with deep bound energy, following p^{bar} annihilation reactions **will be possible**!?

e.g. $\bar{p} + {}^{3}He \rightarrow K^{+} + K^{0} + K^{-}K^{-}pp + B_{KK}^{pp} - 109\mathrm{MeV}$

the most energetic favored decay mode

final state: $K^{+} + K^{0} + \underline{\Lambda + \Lambda}$

$K^0 \rightarrow \pi^{+}\pi^{-}$, $\Lambda \rightarrow p\,\pi^{-}$, $\Lambda \rightarrow p\,\pi^{-}$

Then we can investigate the DKNC with exclusive or semi-inclusive measurement

Past Experiments of Double-Strangeness Production in Stopped-p^{bar} Annihilation

several groups reported double-strangeness production in p^{bar}+A annihilation

hydrogen bubble-chamber experiment @ BNL

in association with the H-dibaryon search

They did NOT observe any double-strangeness event in p^{bar} - C, Ti, Ta, Pb annihilation (~80,000 events, *p* < 400 MeV/c)

[Phys.Lett., **B144**, 27 (1984).]

Reaction	Frequency (90% C.L.)
$p^{bar}A \rightarrow \Lambda^0\Lambda^0X$	**$<4\times10^{-4}$**
$p^{bar}A \rightarrow \Lambda^0K^-X$	$<5\times10^{-4}$
$p^{bar}A \rightarrow K^+K^+X$	**$<5\times10^{-4}$**
$p^{bar}A \rightarrow HX$	$<9\times10^{-5}$

Past Experiments of Double-Strangeness Production in Stopped-p^{bar} Annihilation

experiment	Channel	# of events	yield ($\times 10^{-4}$)
DIANA@ITEP [p^{bar}+Xe] PLB464, 323 (1999).	K^+K^+X	4	0.31+/-0.16
	K^+K^0X	3	2.1+/-1.2
OBELIX @CERN/LEAR [$p^{bar}+{}^4$He] NPA797, 109 (2007).	$K^+K^+\Sigma^-\Sigma^-p_s$	34+/-8	0.17+/-0.04
	$K^+K^+\Sigma^-\Sigma^+n\pi^-$	36+/-6	2.71+/-0.47
	$K^+K^+\Sigma^-\Lambda n$	16+/-4	1.21+/-0.29
	$K^+K^+K^-\Lambda nn$	4+/-2	0.28+/-0.14

Although observed statistics are small,
their results have indicated a high yield of $\sim 10^{-4}$

Expected K^-K^-pp Cross-Section?

--- the K^-K^-pp is assumed to be
produced by $\Lambda^*\Lambda^*$ collision ---

double-strangeness production yield in $p^{bar}A$: ~ 10^{-4}

free Λ^* production yield: ~ Λx0.1

free $\Lambda^*\Lambda^*$ production yield: ~ $\Lambda\Lambda$x0.01

$\Lambda^*\Lambda^*$ production yield in $p^{bar}A$: ~ 10^{-6}

even if all $\Lambda^*\Lambda^*$ become the K^-K^-pp state,
K^-K^-pp production yield in $p^{bar}A$: ~ 10^{-6}

small production yield is expected …

moreover, Q-value of $\Lambda^*\Lambda^*$ production in $p^{bar3}He$ reaction is negative (Q = -55MeV)

Experimental Strategy

present situation of the double-strangeness production in p^bar+A (A>2) annihilation at rest:

- NO results with a dedicated spectrometer and high intensity beam except for bubble chamber experiments.
- high-statistics measurement is NOT performed!

I. investigation of "double-strangeness production" in p^bar+^3He annihilation at rest

- $\overline{p} + {}^{3}He \rightarrow \boxed{K^{+} + K^{+}} + \Lambda + \Sigma^{-}$
- $\overline{p} + {}^{3}He \rightarrow K^{+} + K^{0} + \boxed{\Lambda + \Lambda}$

II. toward search for "double-kaonic nuclear cluster" in p^bar+^3He annihilation at rest

- $\overline{p} + {}^{3}He \rightarrow \boxed{K^{+} + K^{0}} + K^{-}K^{-}pp$

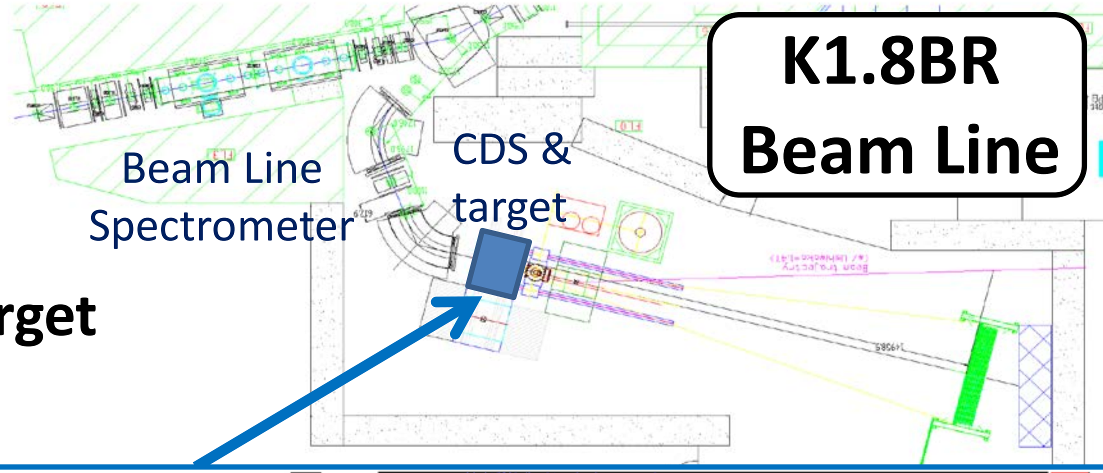
$\rightarrow \boxed{\Lambda + \Lambda}$

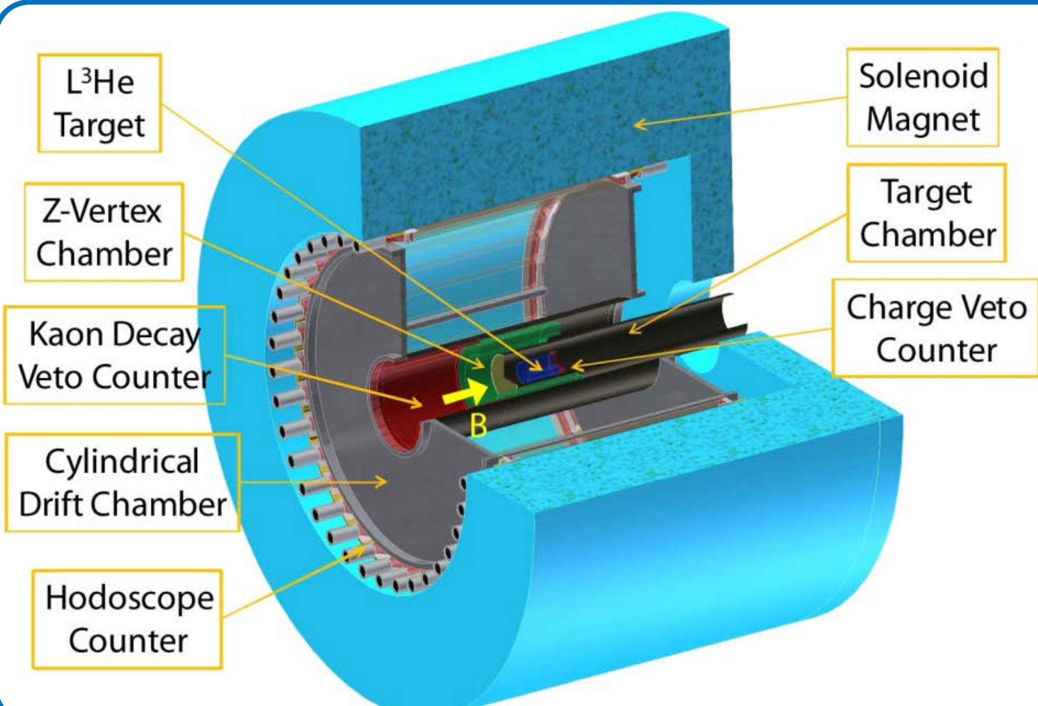
Experimental Setup

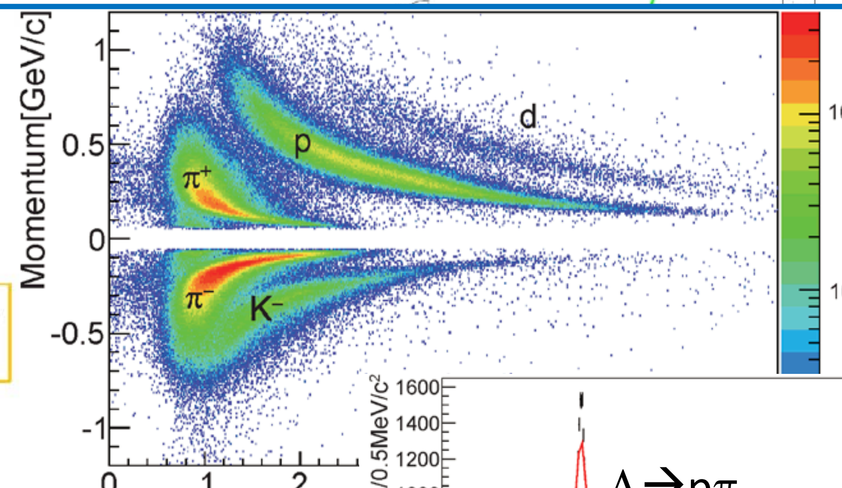
We will perform the experiment at J-PARC K1.8BR beam line

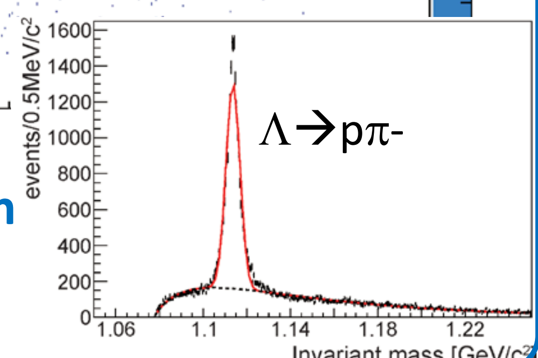
stopped-p^{bar} beam

initial beam mom. : 0.7GeV/c
w/ tungsten degrader (t=31mm)
460/spill(6s) @ 30kW, Pt-target









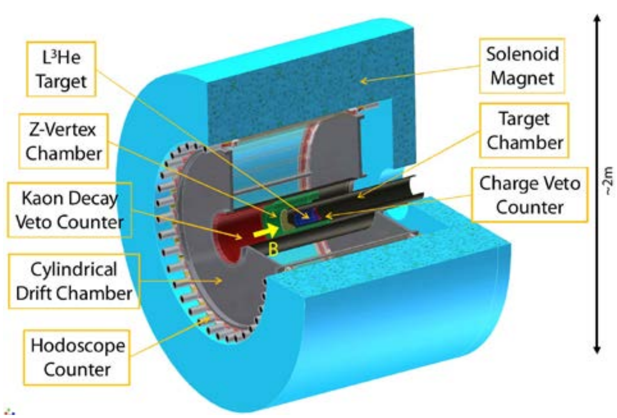
Engineering run (2012, Jun.)

Double-Strangeness Measurement

$$\bar{p} + {}^3He \rightarrow \boxed{K^+ + K^+} + \Lambda + \Sigma^-$$
$$\bar{p} + {}^3He \rightarrow K^+ + K^0 + \boxed{\Lambda + \Lambda}$$

acceptances of K^+K^+ and $\Lambda\Lambda$

- ✓evaluated using **GEANT4** toolkit
- ✓Many-body decay are considered to be isotropic decay.
- ✓branching ratios of **$K^0 \rightarrow K^0_S / K^0_S \rightarrow \pi^+\pi^- / \Lambda \rightarrow p\pi^-$** are included.
- ✓acceptance is defined by CDC



CDS @ K1.8BR

$K^+K^+\Lambda\Sigma^-$ channel		$K^+K^0\Lambda\Lambda$ channel	
K^+K^+ detection	**24%**	**$\Lambda\Lambda$ detection**	**4.1%**
$K^+K^+\Lambda$ detection	4.4%	$\Lambda\Lambda K^+$ detection	2.1%
$K^+K^+\Lambda\pi^-$ detection	2.8%	$\Lambda\Lambda K^+K^0$ detection	0.29%

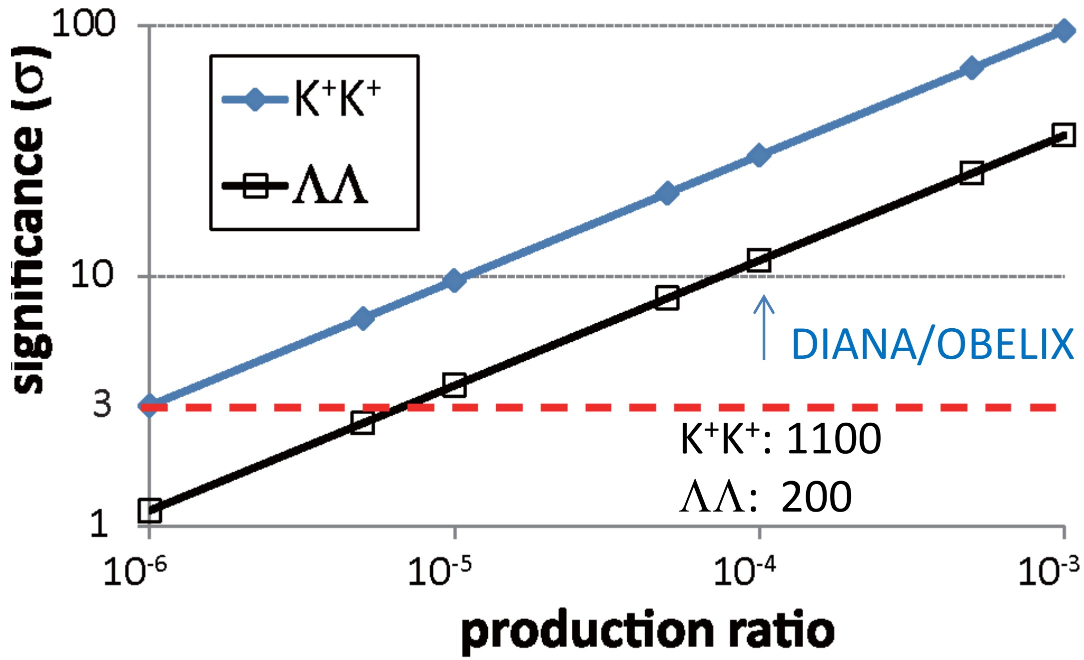
Double-Strangeness Measurement (Cont'd)

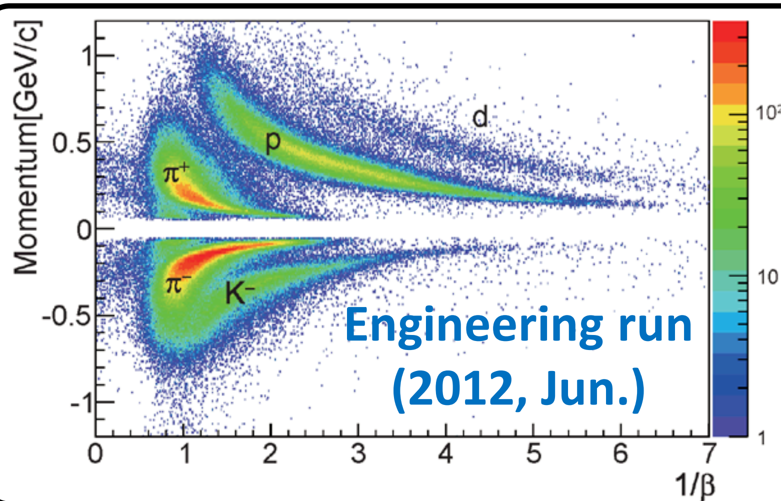
sensitivity

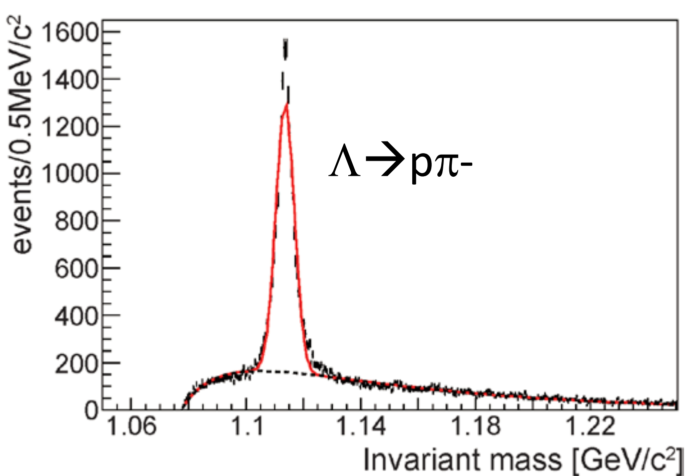
- σ=S/sqrt(S+B)
- backgrounds are assumed to be,
  K^-: S:B=9:1 → K^+K^+: S:B=8:2
  Λ: S:B=7:3 → $\Lambda\Lambda$: S:B=5:5
  from engineering run, and the S/N ratio is NOT depend on the production ratio

✓duty factor of the accelerator and apparatus : 21h/24h
✓DAQ and analysis eff. : 0.7

30kW, 3weeks







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- $\bar{p} + {}^3He \rightarrow K^+ + K^0 + \boxed{\Lambda + \Lambda}$

II. toward search for "double-kaonic nuclear cluster" in p^bar+^3He annihilation at rest

- $\bar{p} + {}^3He \rightarrow \boxed{K^+ + K^0} + K^-K^-pp$

$$\rightarrow \boxed{\Lambda + \Lambda}$$

Procedure of the K^-K^-pp Search

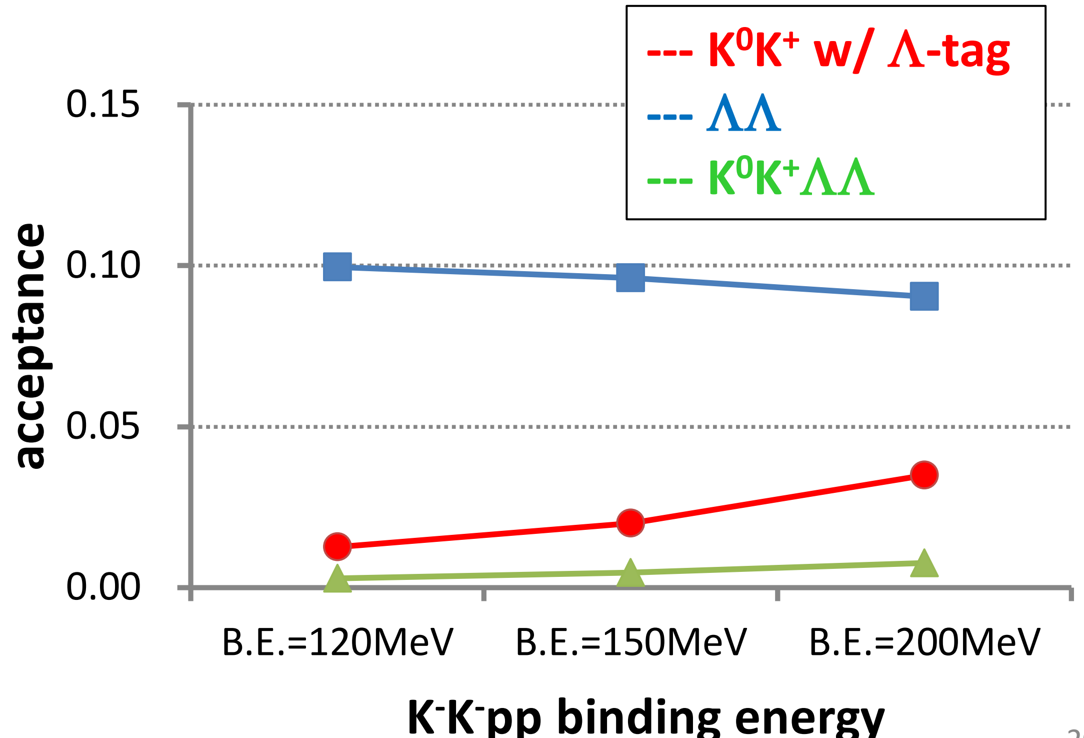
$$\bar{p} + {}^3He \rightarrow \boxed{K^+ + K^0} + K^-K^-pp$$
$$\rightarrow \boxed{\Lambda + \Lambda}$$

methods of the measuremt

- (semi-inclusive) K^0K^+ missing-mass w/ Λ-tag
- (inclusive) $\Lambda\Lambda$ invariant mass
- (exclusive) $K^0K^+\Lambda\Lambda$ measurement

acceptance

- evaluated using **GEANT4** toolkit
- $\Gamma(K^-K^-pp)$ = 100 MeV
- isotropic decay
- branching ratios of **$K^0 \rightarrow K^0_S / K^0_S \rightarrow \pi^+\pi^- / \Lambda \rightarrow p\pi^-$** are included.



Assumptions

evaluate sensitivity to the K-K-pp observation using these assumptions

assumptions

- **production yield:**
  - K^-K^-pp bound-state = ?
  - (3N) $K^-K^-\Lambda\Lambda$ phase-space = 5×10^{-5}
  - (3N) $K^+K^0\Sigma^0\Sigma^0\pi^0$ phase-space = 5×10^{-5}
  - (2N) $K^+K^0K^0\Sigma^0(n)$ phase-space = 3×10^{-4}

➢ **total yield :** upper limit of $p^{bar}A \rightarrow KKX$, 5×10^{-4}

➢ **3N :** 20% of yield, and 3N:2N = 1:3

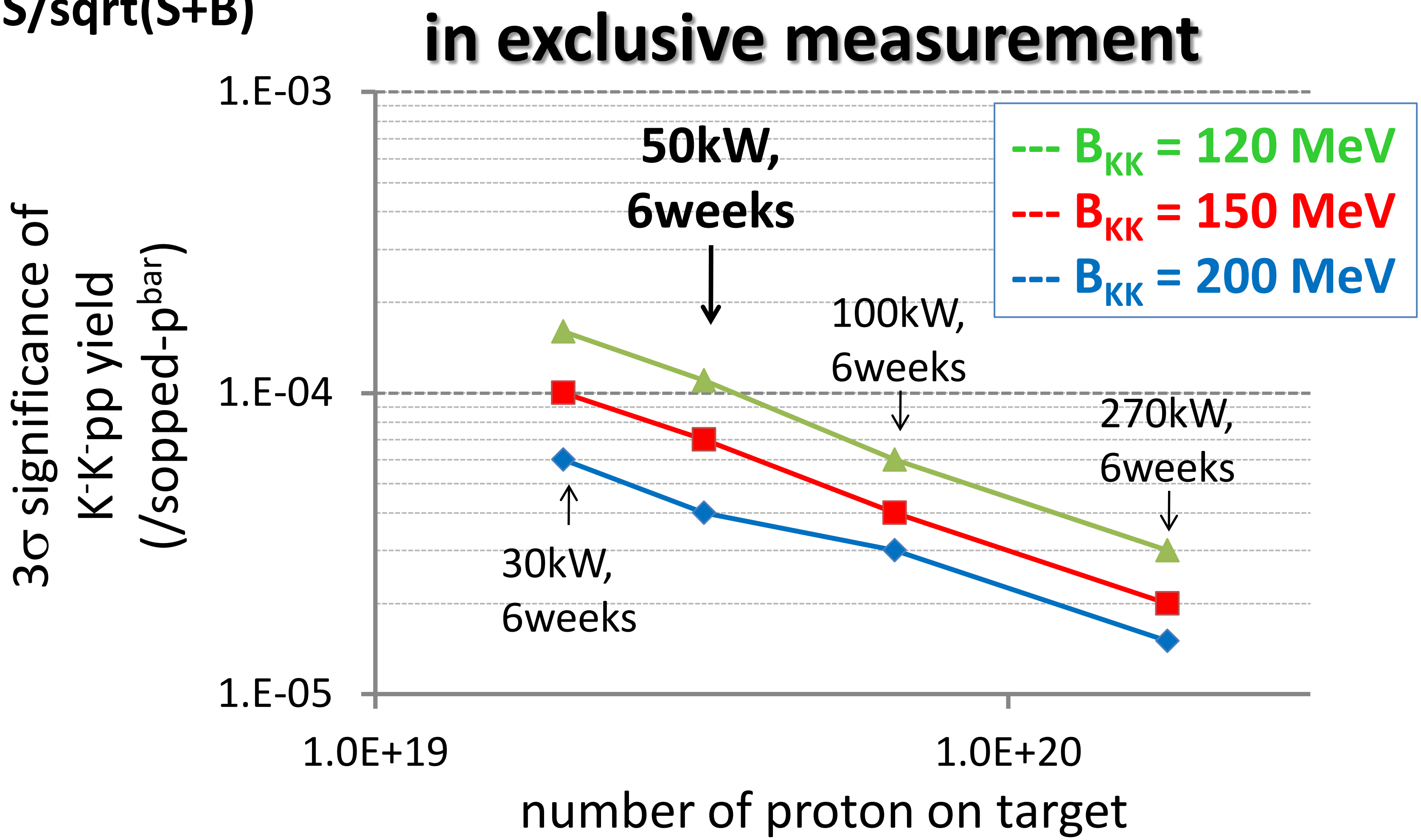
➢ **K^-K^-pp yield :** parameter

- **branching ratio:**
  - $BR(K^-K^-pp \rightarrow \Lambda\Lambda)$ = 0.25
  - $BR(K^-K^-pp \rightarrow \Sigma^0\Sigma^0$ = 0.25
  - $BR(K^-K^-pp \rightarrow \Sigma^0\Sigma^0\pi^0)$ = 0.5

➢ **non-mesonic : mesonic** = 1 : 1

Sensitivity to the K^-K^-pp signal (Exclusive)

$\sigma = S/\mathrm{sqrt}(S+B)$



Expected K^-K^-pp production yield in $p^{bar}A$: ~ 10^{-6}

→ We have less sensitivity to the K^-K^-pp with the assumptions

Expected Spectra @ 50kW, 6weeks

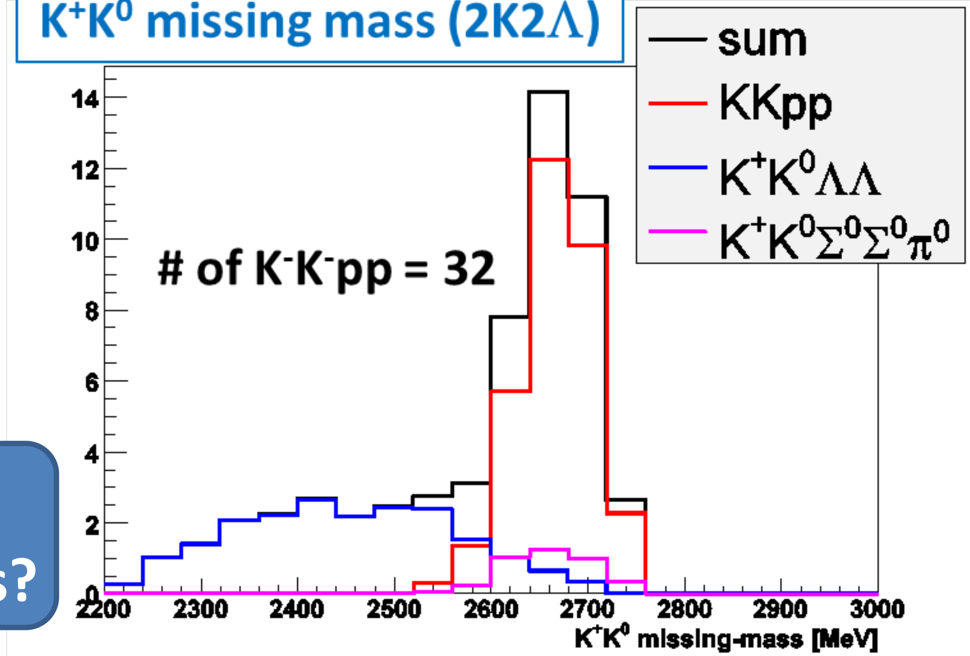
assumptions:

- K^-K^-pp production yield = **10^{-4}/stopped-p^{bar}**
- B.E. = 200 MeV
- Γ = 100 MeV

^{3}He(p^{bar}, $\Lambda\Lambda$/K^+K^0)X measurements give us some hints?

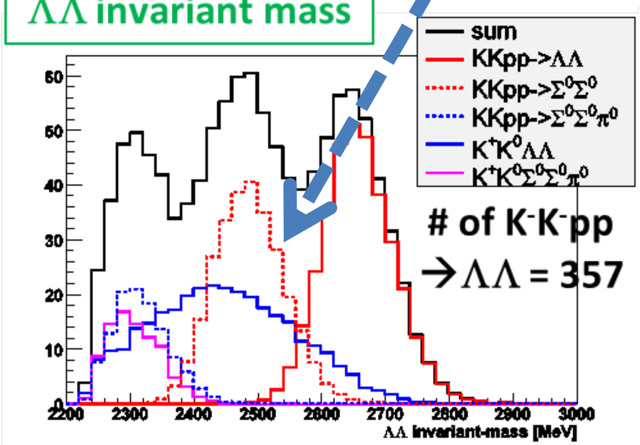
$$\bar{p} + {}^3He \rightarrow \boxed{K^+ + K^0 + \Lambda + \Lambda} (+X)$$

K^+K^0 missing mass (2K2Λ)



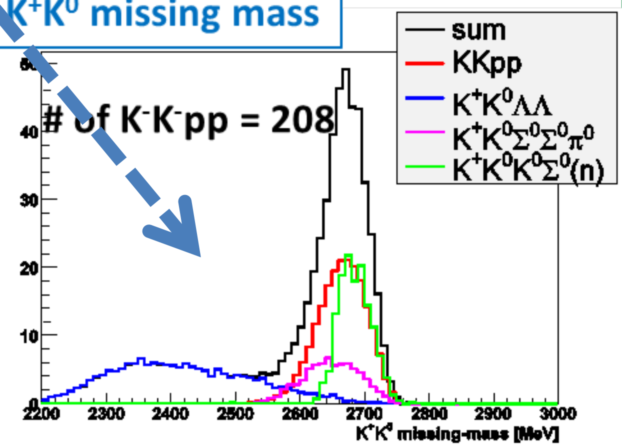
$$K^+ + K^0 + \boxed{\Lambda + \Lambda} + X$$

$\Lambda\Lambda$ invariant mass



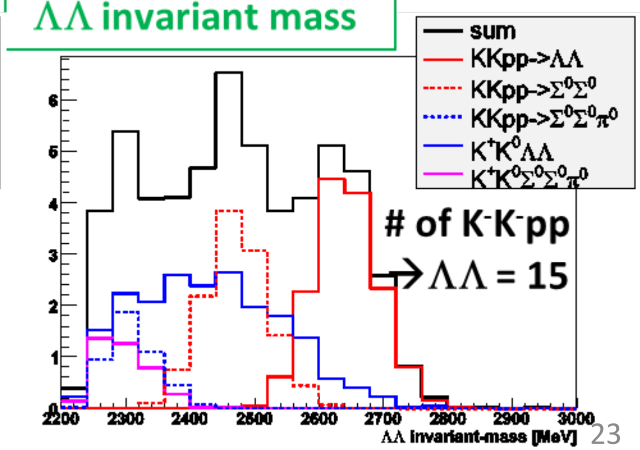
$$\boxed{K^+ + K^0 + \Lambda} + X$$

K^+K^0 missing mass



$$\boxed{K^+ + K^0 + \Lambda + \Lambda} (+X)$$

$\Lambda\Lambda$ invariant mass



Related Topics in $p^{bar}A$ annihilation

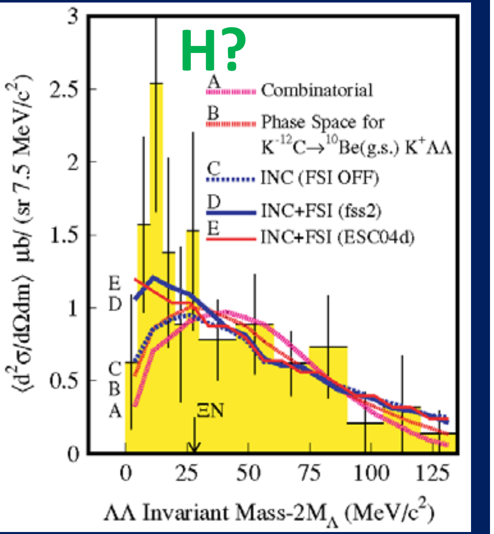
We can also search for H-dibaryon (H-resonance) by using $\Lambda\Lambda$ invariant mass / missing mass.

$$\bar{p} + {}^3He \rightarrow K^0 + K^+ + H$$
$$\rightarrow \Lambda + \Lambda$$

E522@KEK-PS

$${}^{12}C\left(K^-, K^+\Lambda\Lambda X\right)$$

PRC75 022201(R) (2007).



The exclusive H search with stopped-p^{bar} beam has never been done.

Of course we can measure K^-pp production <u>with the dedicated detector</u>, simultaneously.

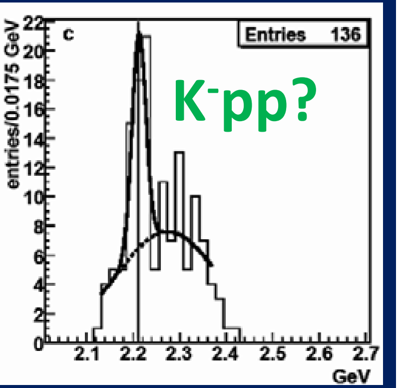
$$\bar{p} + {}^3He \rightarrow K^0 + K^-pp$$
$$\rightarrow \Lambda + p$$

OBELIX@CERN-LEAR

$$\bar{p} + {}^4He \rightarrow K^-pp + X$$
$$\rightarrow \Lambda + p$$

yield ~ 10^{-4}

NP, A789, 222 (2007).
EPJ, A40, 11 (2009).



Our experiment can check the OBELIX results of the K^-pp with a dedicated spectrometer

② "Double-Kaonic Nuclear Cluster" search using **p+p reaction**

Experimental Principle

8GeV $\quad p + p \rightarrow K^+ + K^+ + \underline{\Lambda^* + \Lambda^*}$

$$\underline{\Lambda^* + \Lambda^*} \xrightarrow{\text{production}} \Lambda^*\Lambda^* \rightarrow \underline{K^- K^- pp} \xrightarrow{\text{decay}} \Lambda\Lambda$$

the produced K^-K^-pp can be identified by both

- missing-mass spectrum $\Delta M(K^+K^+)$
- invariant-mass spectrum $M(\Lambda\Lambda)$

Expected Cross-Section

T.Yamazaki, et al., Proc.Jpn.Acad.Ser.B87(2011)362

- The free Λ production CS in p+p collision is **known** to be

  $\sigma_{\Lambda} \sim 10^{-3} \times \sigma_{total} \sim 50\mu b$

- The free Λ^* production CS at 2.83GeV is **known** to be

  $\sigma_{\Lambda*} \sim 4.5\mu b \sim 0.1 \times \sigma_{\Lambda}$

- The double-Λ production CS is **expected** to be

  $\sigma_{\Lambda+\Lambda} \sim 10^{-3} \times 10^{-3} \times \sigma_{total} \sim 50nb$

- Thus, the double-Λ^* production CS is **expected** to be

  $\sigma_{\Lambda*+\Lambda*} \sim 0.1 \times 0.1 \times \sigma_{\Lambda+\Lambda} \sim 0.5nb$

- The DISTO result indicates the K^-pp production CS is as much as Λ^* production CS, so we simply **assume** K^-K^-pp production CS to be

  $\boldsymbol{\sigma_{K\text{-}K\text{-}pp} \sim \sigma_{\Lambda*+\Lambda*} \sim 0.5nb}$

Of course, these are very rough estimations and depend on incident energy

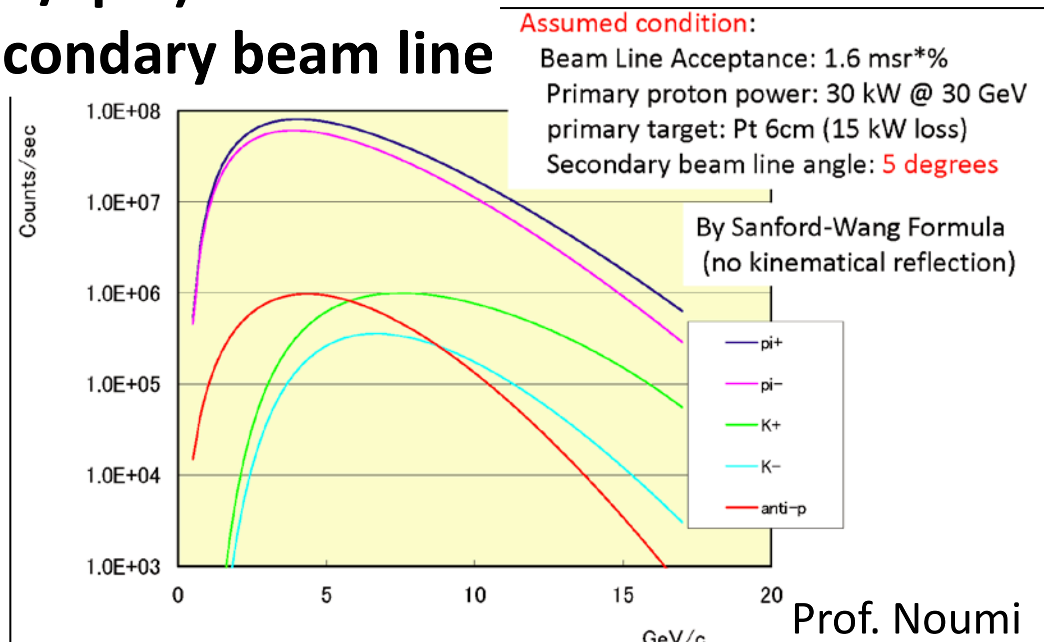
Proton Yield @ Primary Beam Line

Primary beam line ($10^{10\text{-}12}$ proton/spill) will be used as high-resolution <u>un-separated</u> secondary beam line

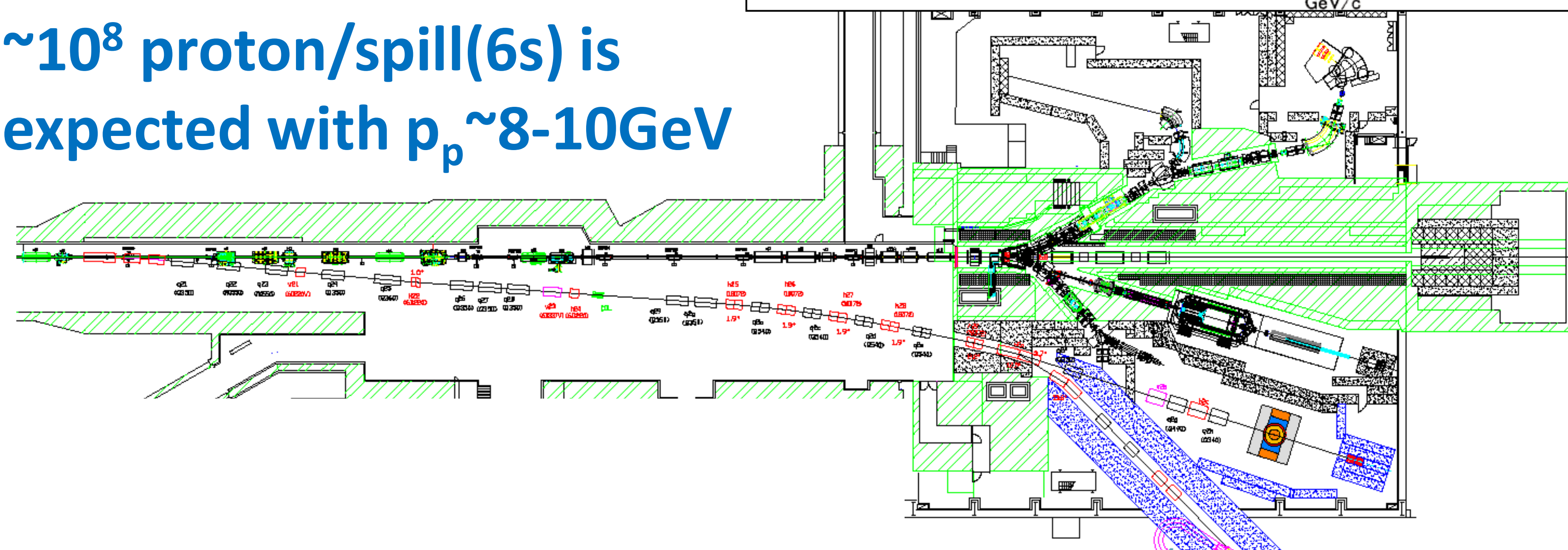
- Good momentum resolution: $\Delta p/p$~0.1%
- High Intensity Secondary Beam : 1.0×10^6 Hz (6×10^6 per spill, 6 sec spill length) @ 15GeV π

If yield of proton is assumed to be as same as that of pion,

~10^8 proton/spill(6s) is expected with p_p~8-10GeV



Prof. Noumi



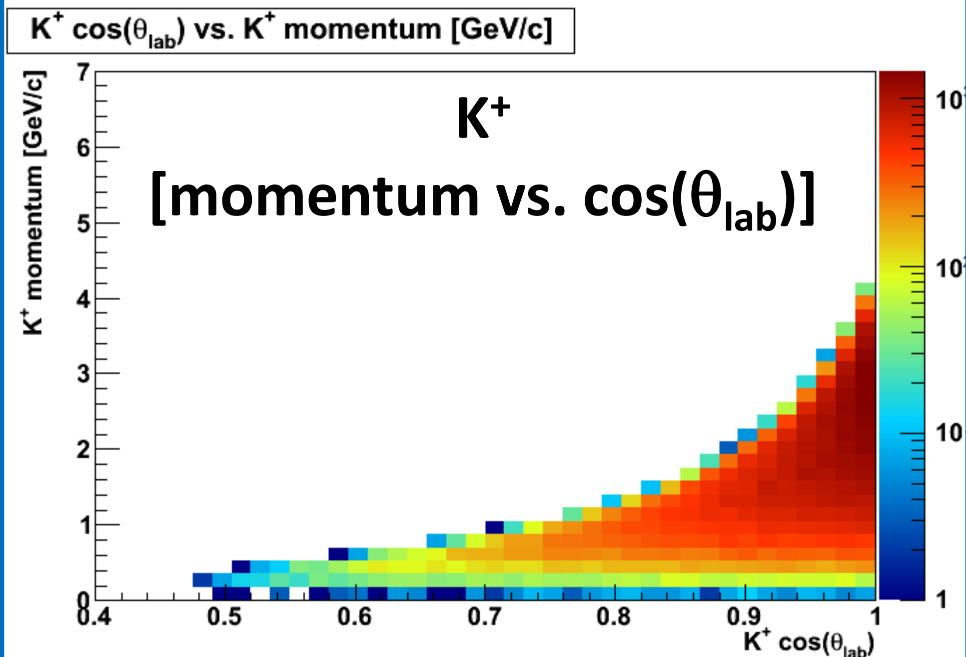
Expected Production Yield

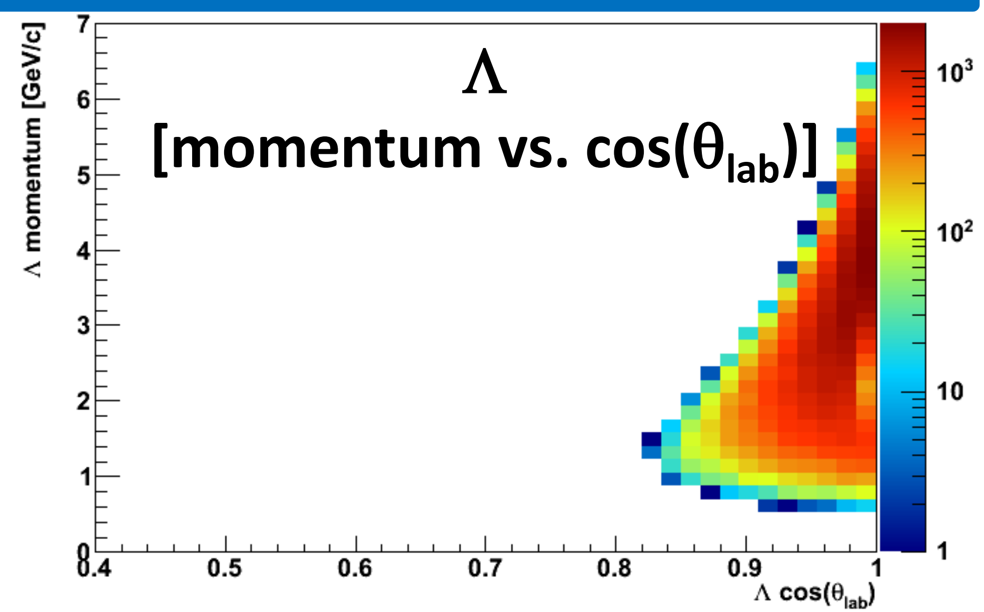
- CS : $\sigma_{K\text{-}K\text{-}pp}$ ~ **0.5nb**
- Beam : 8 GeV proton **10^8 / 6s x 1 month** (30d) = 4×10^{13}
- Target : LH_2 target 0.85 g/cm^2

  (= SKS target, 0.0708 g/cm^3 12 cm)

~10^4 / month K^-K^-pp

Kinematics



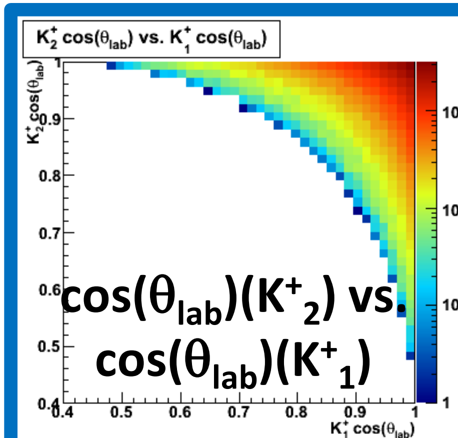


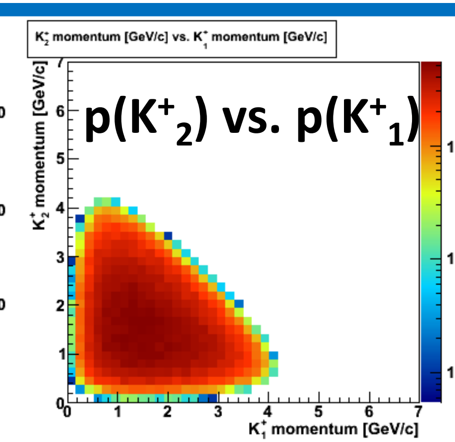
8GeV $p + p \rightarrow \boxed{K^+ + K^+} + \underline{X}$ **B.E = 200MeV**

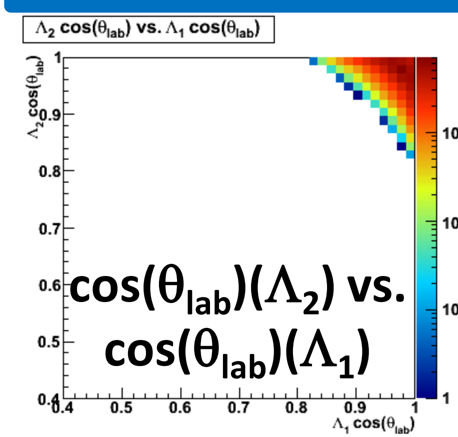
decay

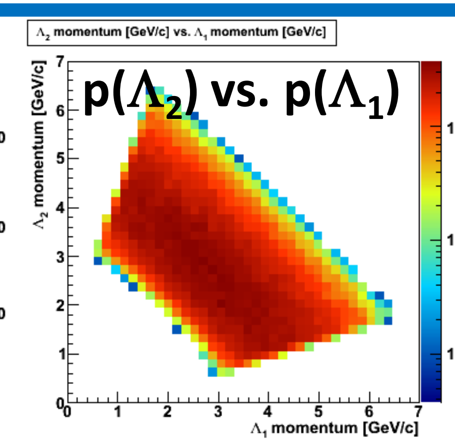
$\boxed{\Lambda\Lambda} \rightarrow pp\pi^-\pi^-$

production & decays are assumed to be isotropic





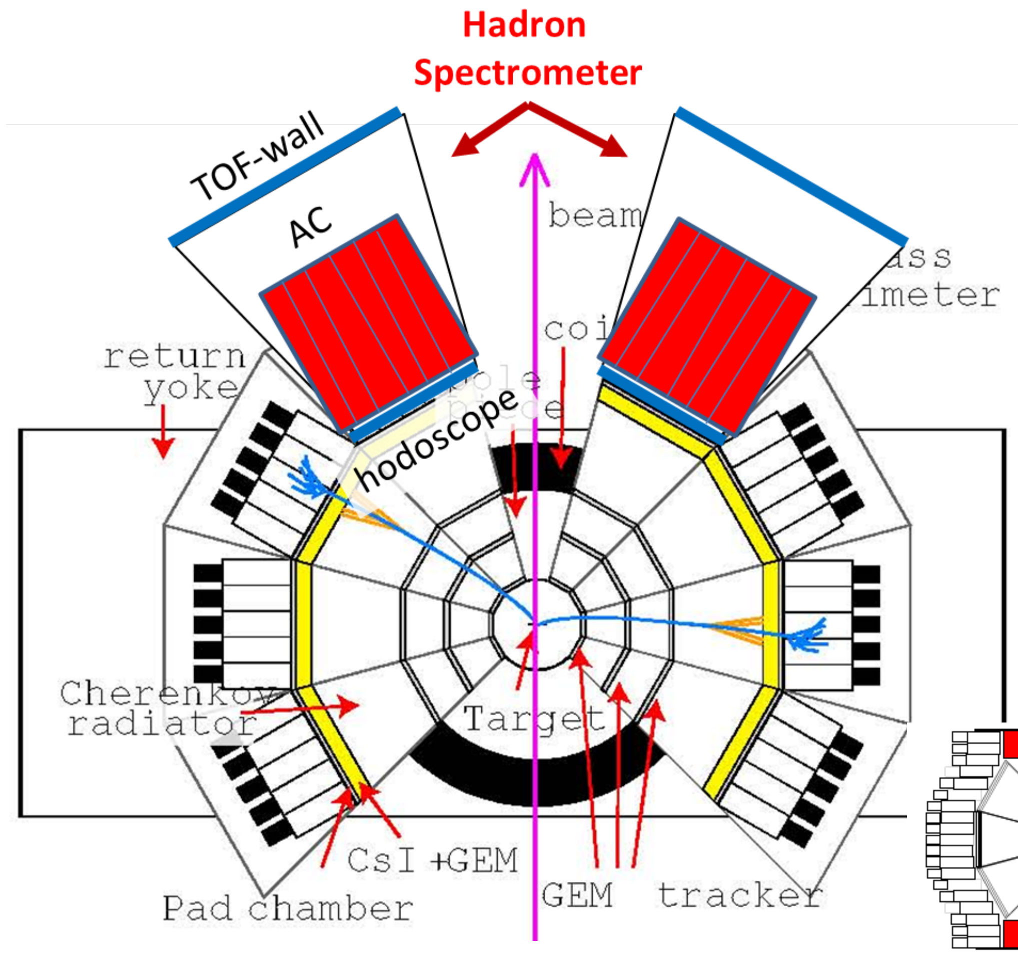




Experimental Setup

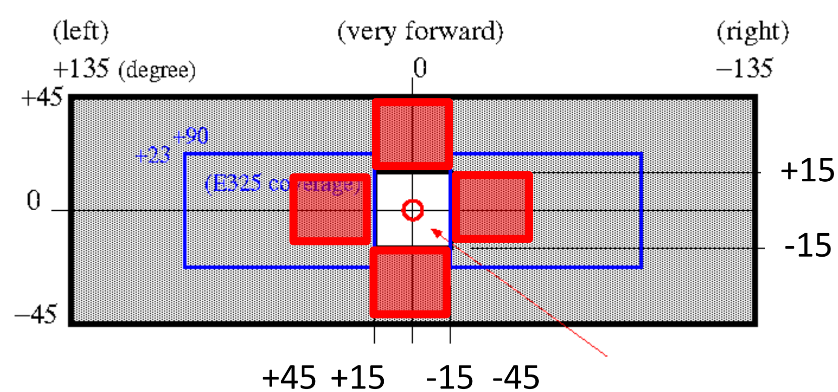
for example …

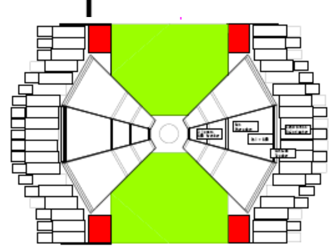
E16 spectrometer + hadron-spectrometer upgrade

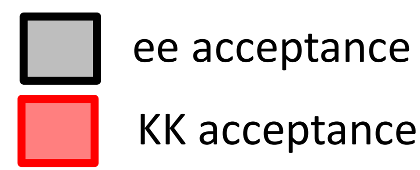


<u>**E16 experiment:**</u>

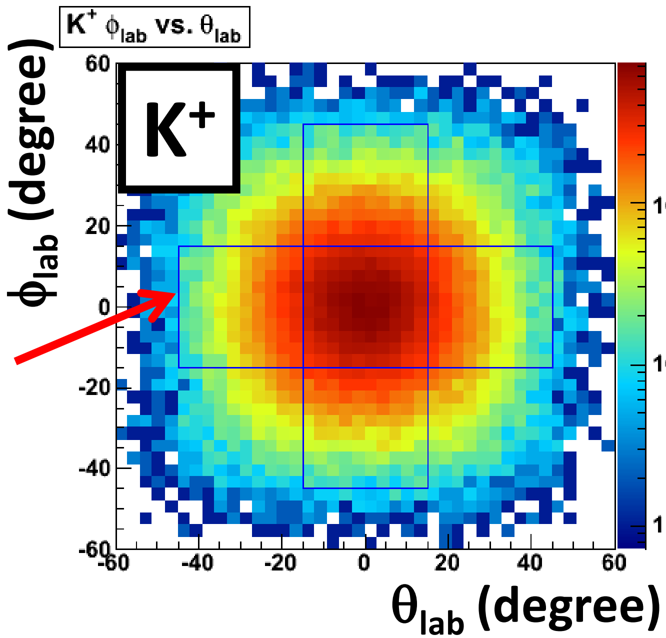
- investigation of vector meson modification in medium (p+A)
- precise di-lepton measurement with high statistics
- 10^{10} proton /spill with thin targets







Detector Acceptance

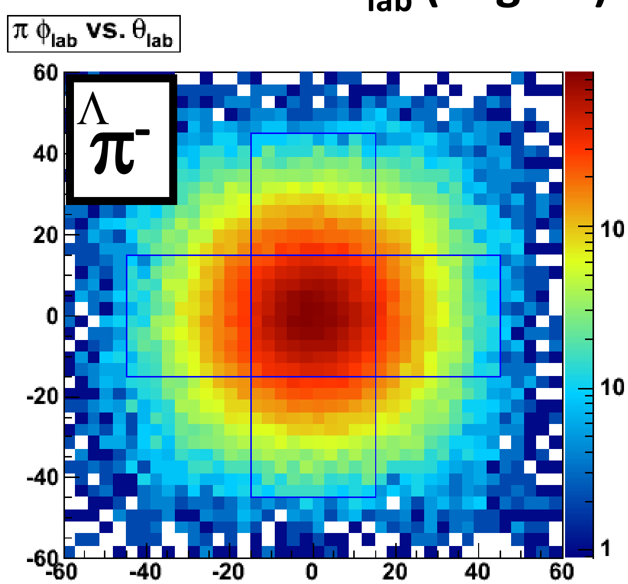


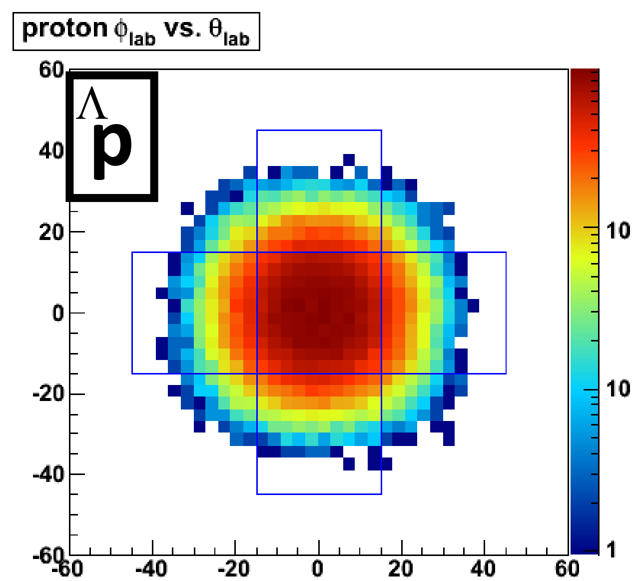
detector acceptance

generated events

8GeV $p + p \rightarrow K^+ + K^+ + X$ **B.E = 200MeV**

$X \xrightarrow{\text{decay}} \Lambda\Lambda \rightarrow pp\pi^-\pi^-$

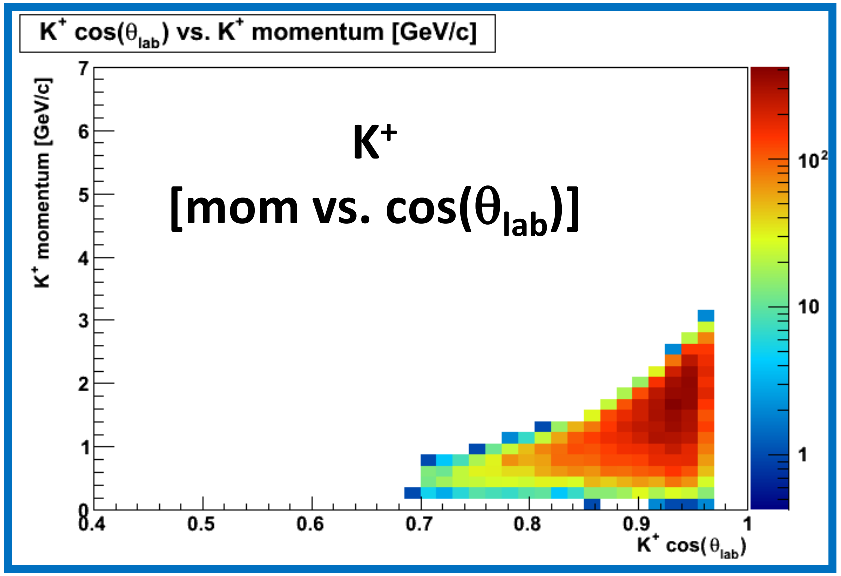


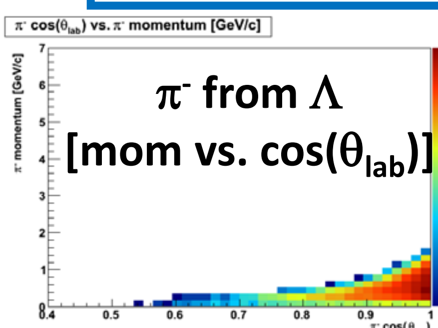


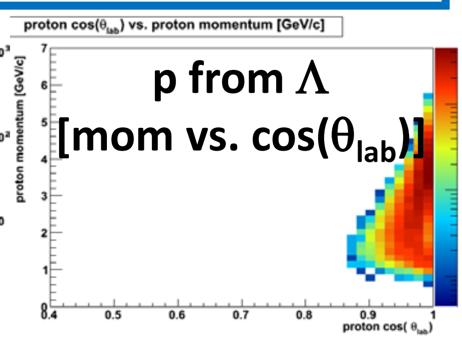
Detector Acceptance (Cont'd)

double-K^+ accepted event

acceptance = 16% → 1600 / month



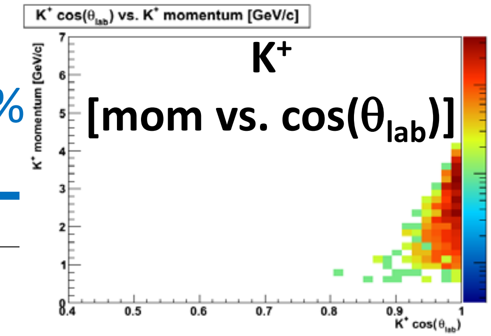


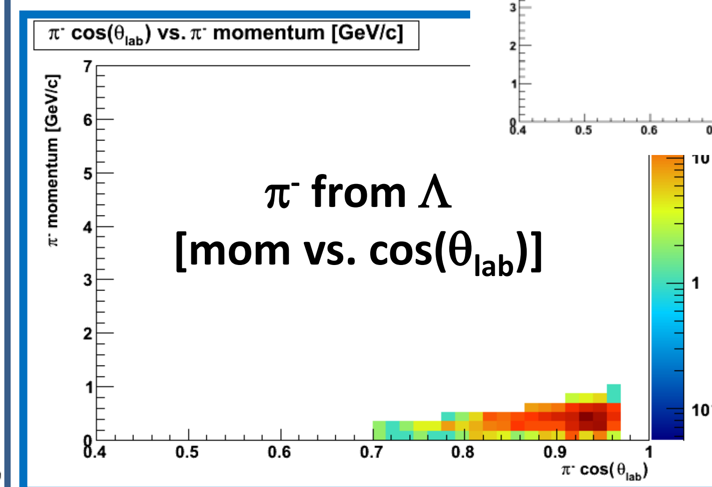


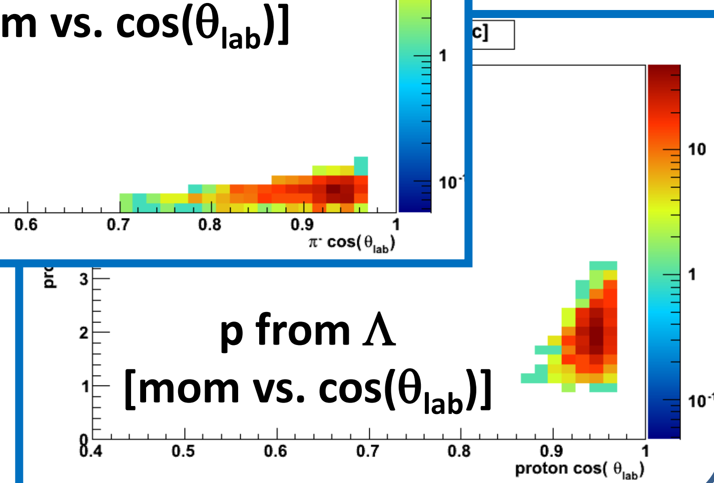
double-Λ accepted event

acceptance = 0.7% → 30 / month

- ✓ $\Lambda\Lambda$ decay :100%
- ✓ $pp\pi^-\pi^-$ decay: 40%







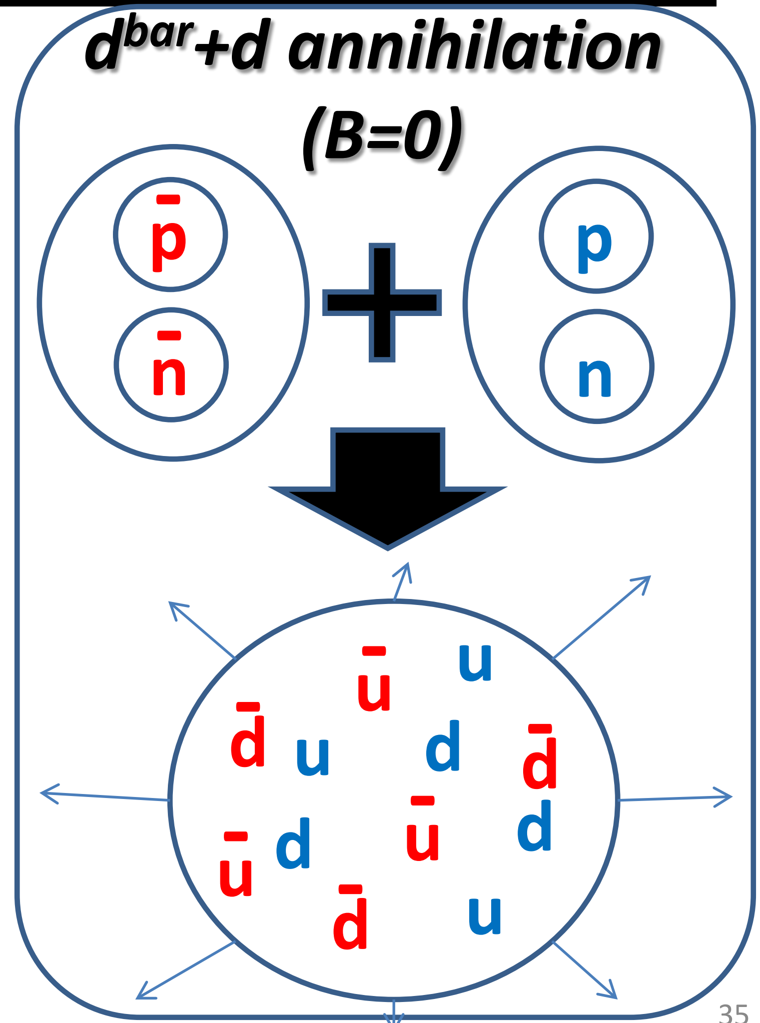
acceptance for the exclusive measurement is 0.0%

measurement of $p(p, K^+K^+)X$ reaction could be feasible

③ "Double-Kaonic Nuclear Cluster" search using d^{bar} beam?

d^{bar}+A annihilation?

Anti-deuteron (d^{bar}) beam has never been realized.
Using high-power proton accelerator (~270kW), we could use the world's first d^{bar} beam at J-PARC!



Why d^{bar}+A annihilation?

- **Nobody has done, and nobody knows.**
- In baryonic number B=0 annihilation, four nucleon masses are released in small region, followed by creation of the highly energetic/excited blob.
- In B>0 annihilation, more exotic matter could be produced.

- Increase of strangeness production could be observed as same as QGP/hadronic-gas formation in A+A reaction.
- Such anomalous condition, exotic state such as H-dibaryon and K^-K^-pp could be generated.

d^{bar} beam @ J-PARC?

d^{bar} production in p+A reaction

At AGS, d^{bar} production was studied in 30GeV p+Be reaction in 1960's

- production angle: 4.5 degrees
- $d^{bar}/\pi^- = (5.5 \pm 1.5) \times 10^{-8}$ @ 5GeV/c after π^- decay & d^{bar} abs. correction

→ $d^{bar}/p^{bar} \sim 10^{-6}$

30GeV p+Be, 4.5 degrees @ AGS

Mom. (GeV/c)	# of events	d^{bar}/π^- yield
4.5	41	$(3.0 \pm 1.5) \times 10^{-8}$
5.0	118	$(3.9 \pm 0.8) \times 10^{-8}$
5.4	55	$(2.4 \pm 1.0) \times 10^{-8}$
6.0	17	$(6.0 \pm 3.0) \times 10^{-8}$

D.E.Dorfan, et al., PRL14(1965)1003

d^{bar} beam @ J-PARC K1.8BR

- p^{bar} intensity in 30GeV p+Pt reaction at 6 degrees is 7×10^3 /1kW/spill(6s) from the commissioning result in 2012 Feb.

  → 2×10^5 p^{bar}/spill(6s) @ 30kW, Pt-target

- Assumptions:
  - $d^{bar}/p^{bar} \sim 10^{-6}$
  - decrease of d^{bar} yield caused by absorption in 60mm Pt-target is twice of p^{bar} yield

d^{bar} intensity @ K1.8BR = 0.1 d^{bar}/spill(6s) @ 30kW, Pt-target

d^{bar} production @ K1.8BR will be checked toward realizing d^{bar} beam

Summary

- **Single-Kaonic Nuclear Cluster Search (K^-pp):**

  The E15 experiment will finally start physics run in this FY.

- **Double-Kaonic Nuclear Cluster Search (K^-K^-pp):**

- **p^{bar}+^{3}He annihilation at rest @ K1.8BR**
  - ✓ double-strangeness measurement will be conducted as a first step
  - ✓ measurement of ^{3}He(p^{bar}, $\Lambda\Lambda$/K^0K^+)X reaction will be given us some hints of the K^-K^-pp
- **8 GeV/c p+p reaction @ primary**
  - ✓ p(p, K^+K^+)X measurement using the E16 spectrometer could be feasible
- **d^{bar} beam @ K1.8BR**
  - ✓ expected yield: 0.1 d^{bar}/spill(6s) with 30kW, Pt-target

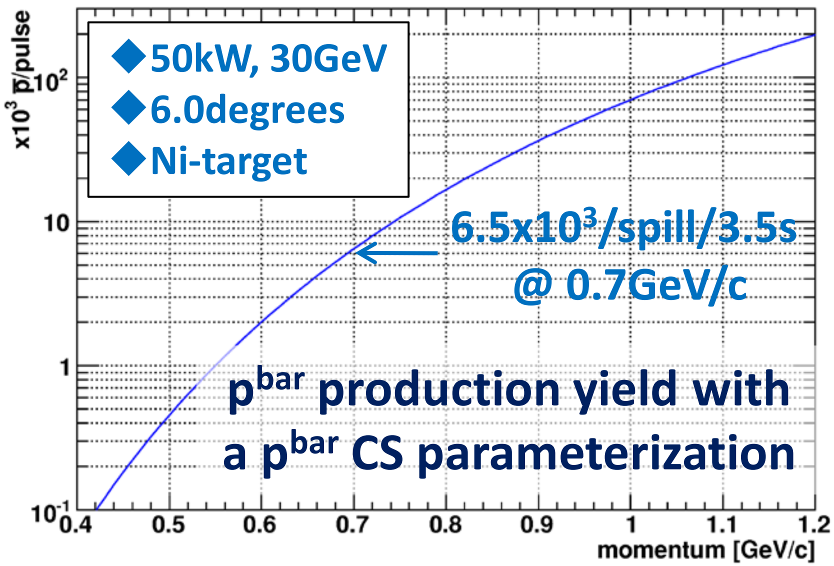
Thank you!

Schedule

Year (JFY)	K1.8BR (p^{bar},d^{bar})	high-pt (p)
2009	beam-tune	
2010	beam-tune	
2011	**recovery**	
2012	**E15**	
2013	**E15/shutdown**	construction?
2014	E17/E31/**here?**	construction?
2015	…	E16?
2016	…	E16?

Backup

p^{bar} Beam @ J-PARC K1.8BR



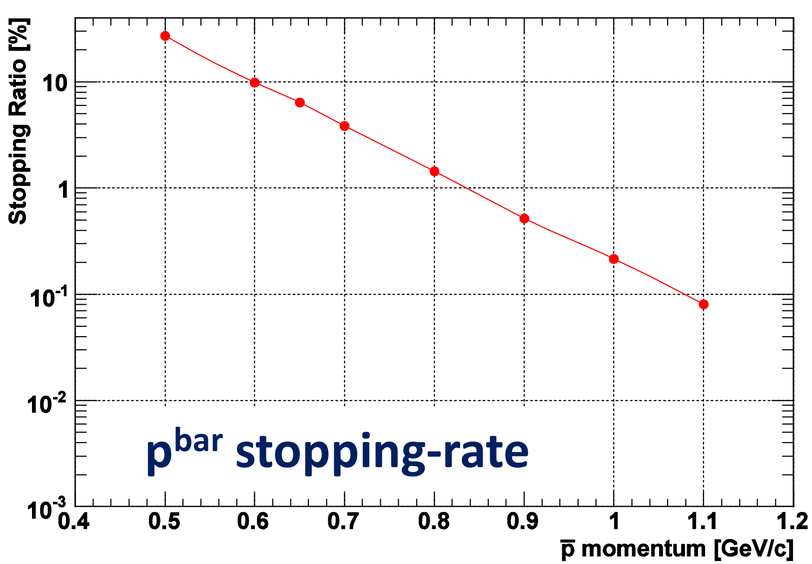
p^{bar} stopping-rate evaluation by GEANT4

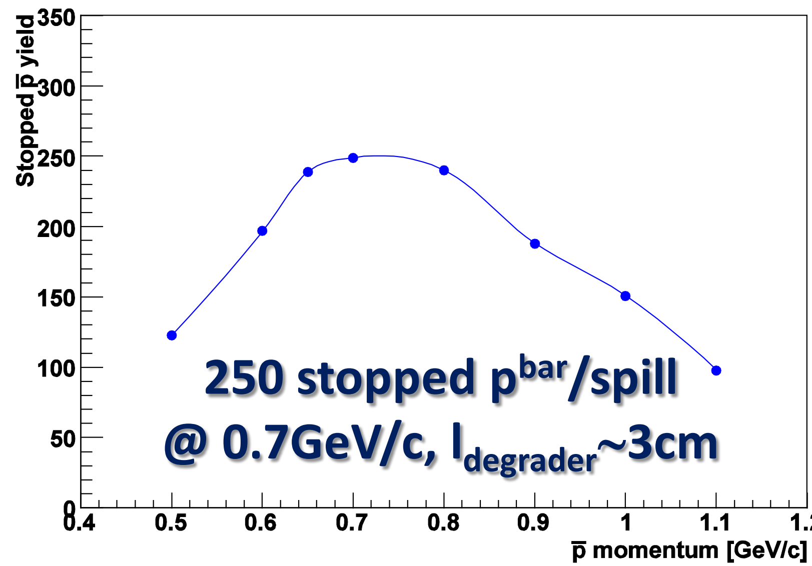
Incident Beam

- momentum bite : +/-2.5% (flat)
- incident beam distribution : ideal

Detectors

- Tungsten Degrader : ρ=19.25g/cm³
- Plastic Scintillator : l=1cm, ρ=1.032g/cm³
- Liquid He3 target : ϕ=7cm, l=12cm, ρ=0.080g/cm³





Trigger Scheme

expected stopped-p^{bar} yield = 250/spill @ 50kW

All events with a scintillator hit can be accumulated

p^{bar}+^{3}He charged particle multiplicity at rest

CERN LEAR, streamer chamber exp. NPA518,683 (1990).

Nc	Branch (%)
1	5.14 +/- 0.04
3	39.38 +/- 0.88
5	48.22 +/- 0.91
7	7.06 +/- 0.46
9	0.19 +/- 0.08
<Nc>	**4.16 +/- 0.06**

expected K-K-pp event

Backgrounds

(semi-inclusive) K^0K^+ missing-mass w/ Λ-tag

signal

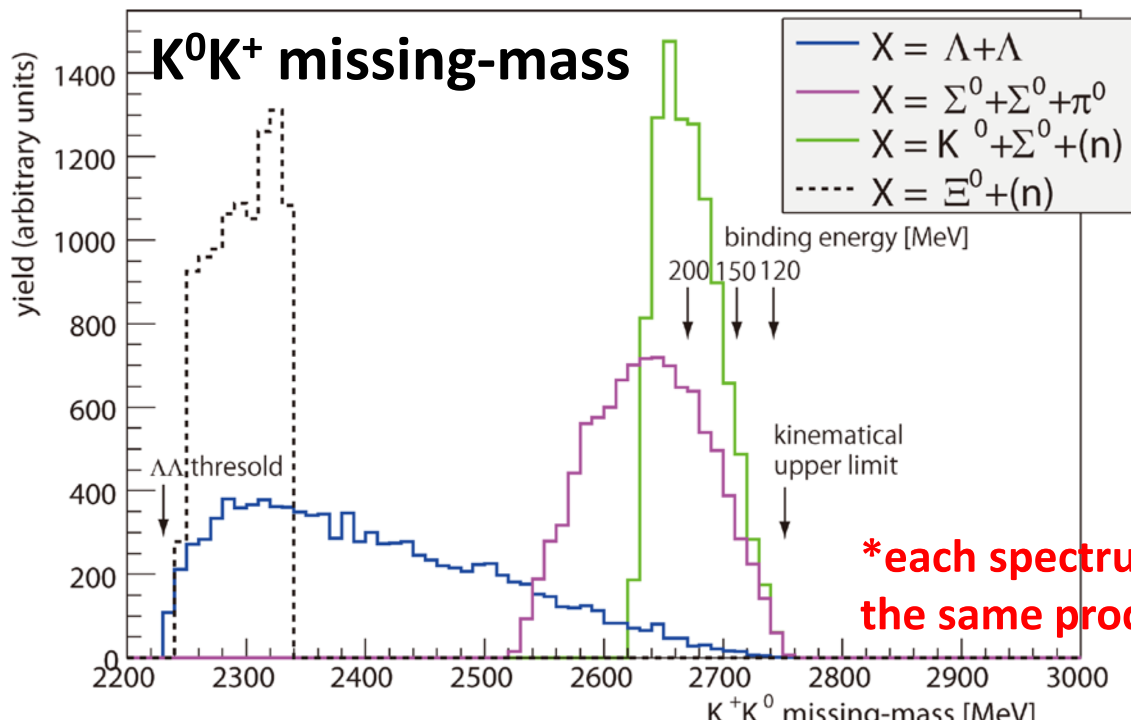
- stopped-p^{bar} + ^{3}He → K^0 + K^+ + K-K-pp

3N annihilation

- stopped-p^{bar} + ^{3}He → K^0 + K^+ + Λ + Λ
- stopped-p^{bar} + ^{3}He → K^0 + K^+ + Λ + Λ + π^0 …

2N annihilation

- stopped-p^{bar} + ^{3}He → K^0 + K^+ + K^0 + Σ^0 + (n)
- stopped-p^{bar} + ^{3}He → K^0 + K^+ + Ξ^0 + (n) …



***each spectrum is obtained with the same production yield**

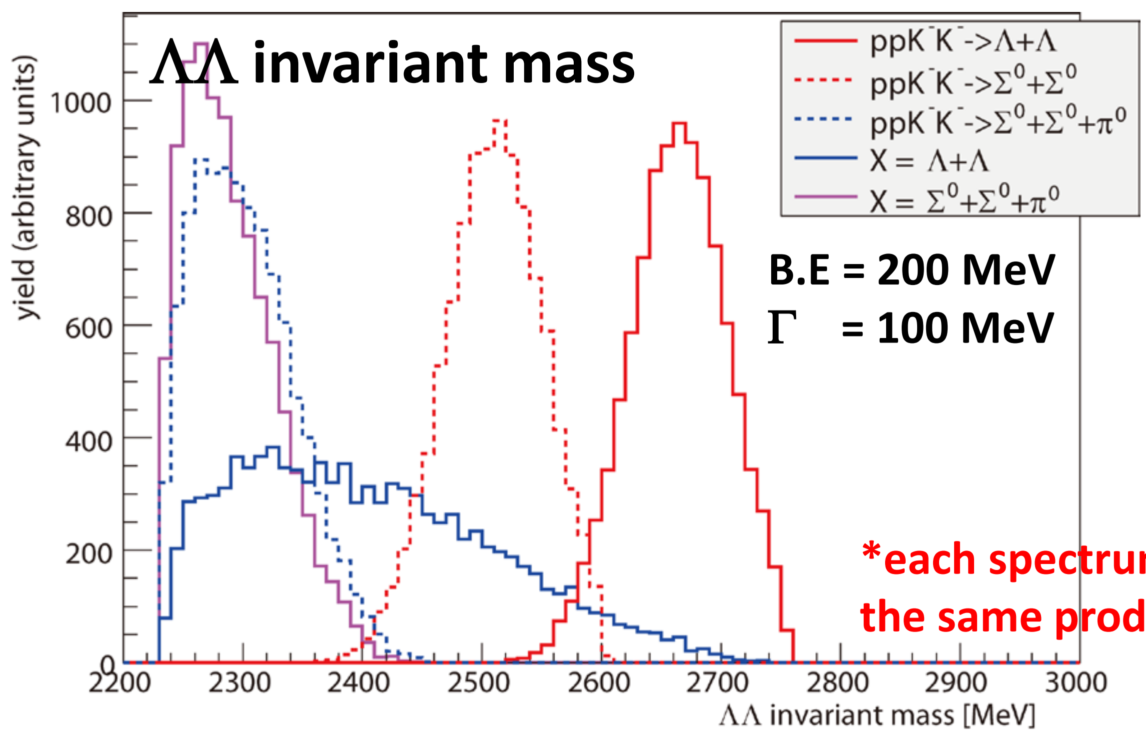
Backgrounds (Cont'd)

(inclusive) ΛΛ invariant mass

signal ◆ stopped-p^{bar} + ^{3}He → K^0_S + K^+ + K-K-pp
→ Λ + Λ

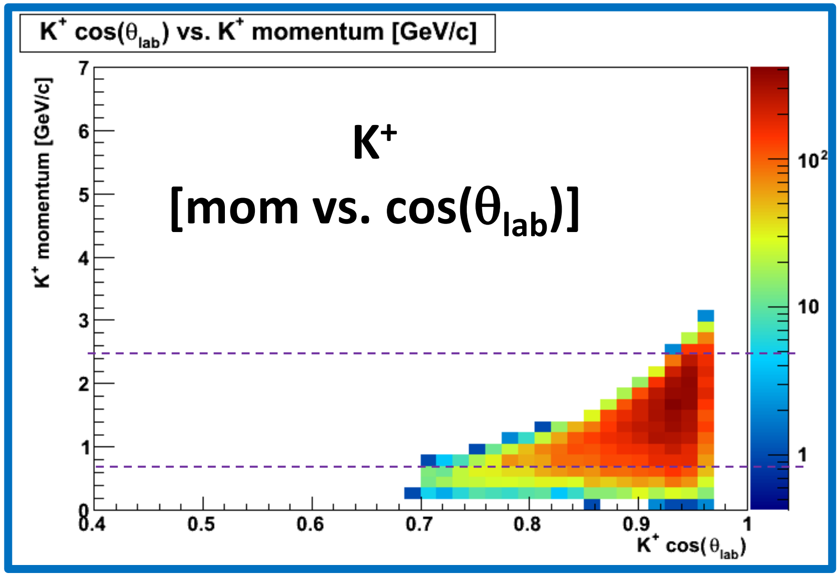
missing 2γ ◆ stopped-p^{bar} + ^{3}He → K^0_S + K^+ + K-K-pp
→ $\Sigma^0 + \Sigma^0$

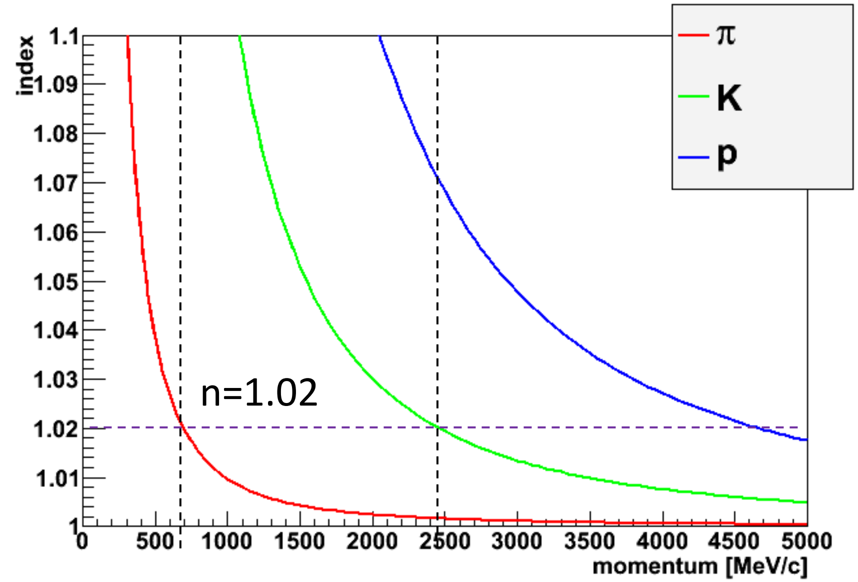
missing 2γ+π^0 ◆ stopped-p^{bar} + ^{3}He → K^0_S + K^+ + K-K-pp
→ $\Sigma^0 + \Sigma^0 + \pi^0$ …



*each spectrum is obtained with the same production yield

Kaon identification





Nuclear Instruments and Methods in Physics Research A 668 (2012) 64–70

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however, proton contamination is … ???

Hydrophobic silica aerogel production at KEK

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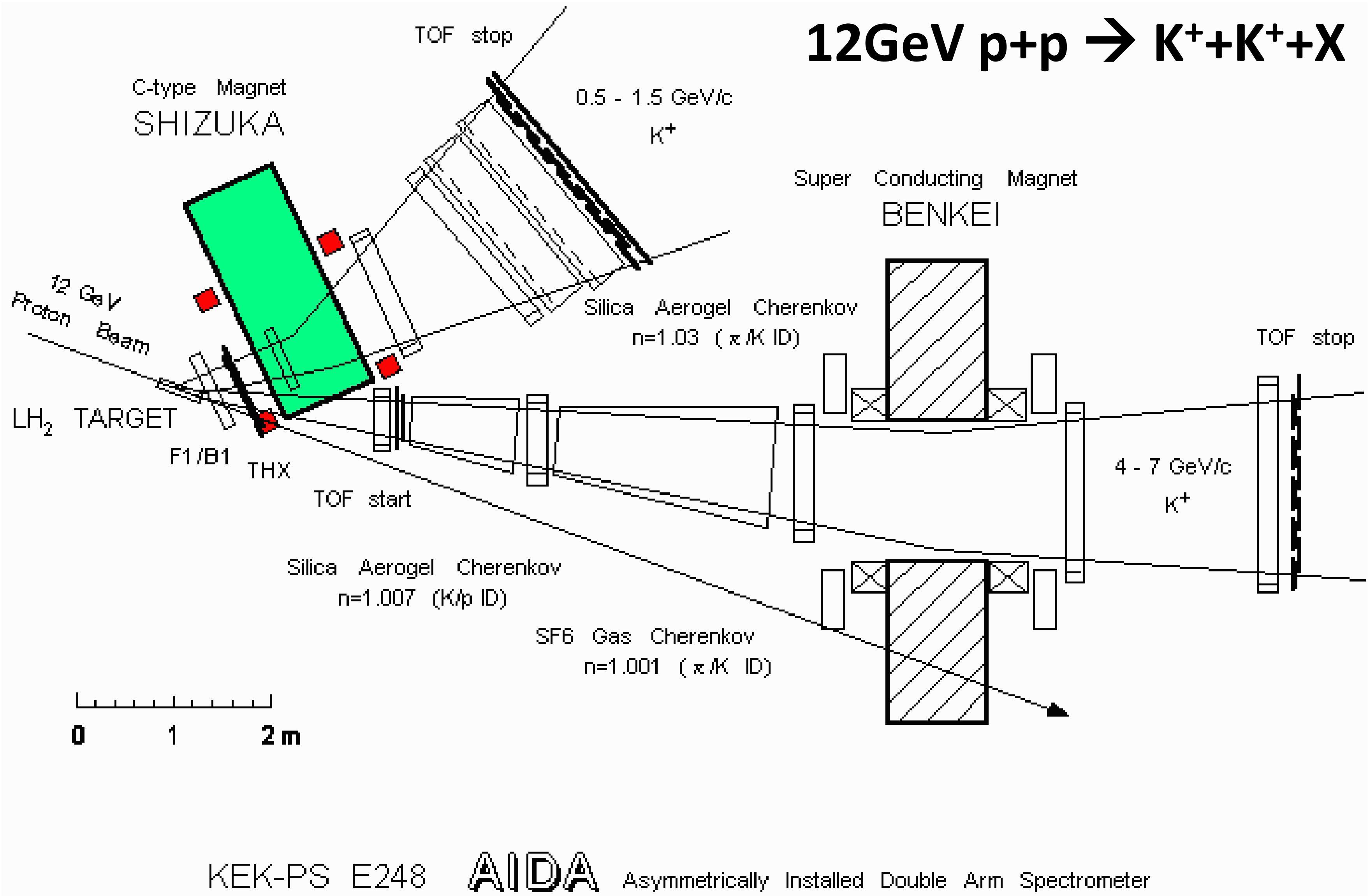
ABSTRACT

We present herein a characterization of a standard method used at the High Energy Accelerator Research Organization (KEK) to produce hydrophobic silica aerogels and expand this method to obtain a wide range of refractive index ($n = 1.006–1.14$). We describe in detail the entire production process and explain the methods used to measure the characteristic parameters of aerogels, namely the refractive index, transmittance, and density. We use a small-angle X-ray scattering (SAXS) technique to relate the transparency to the fine structure of aerogels.

Past Experiment …

KEK-PS E248 (AIDA)



d^{bar} beam line @ J-PARC

Proceeding of "Low Energy Antiproton Physics Conference (LEAP 98)"

ELSEVIER

Nuclear Physics A655 (1999) 371c–380c

NUCLEAR PHYSICS A

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An antideuteron beam at JHF

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The future japanese hadronic machine (JHF) could offer the possibility not only to continue experiments with the antiproton in both the low and high energy ranges but also to start to study the antinuclei physics. In the present paper the production of antinuclei is reviewed and first results of a design for an antideuteron beam line at JHF are reported. Moreover, some particular aspects of the antideuteron physics are discussed together with the basic features of the experimental apparatuses involving an antideuteron beam and the antideuteron annihilation detection.

6. Acknowledgements

The author wish to thank Prof. T. Bressani for many helpful discussions.

1GeV/c d^{bar} beam line

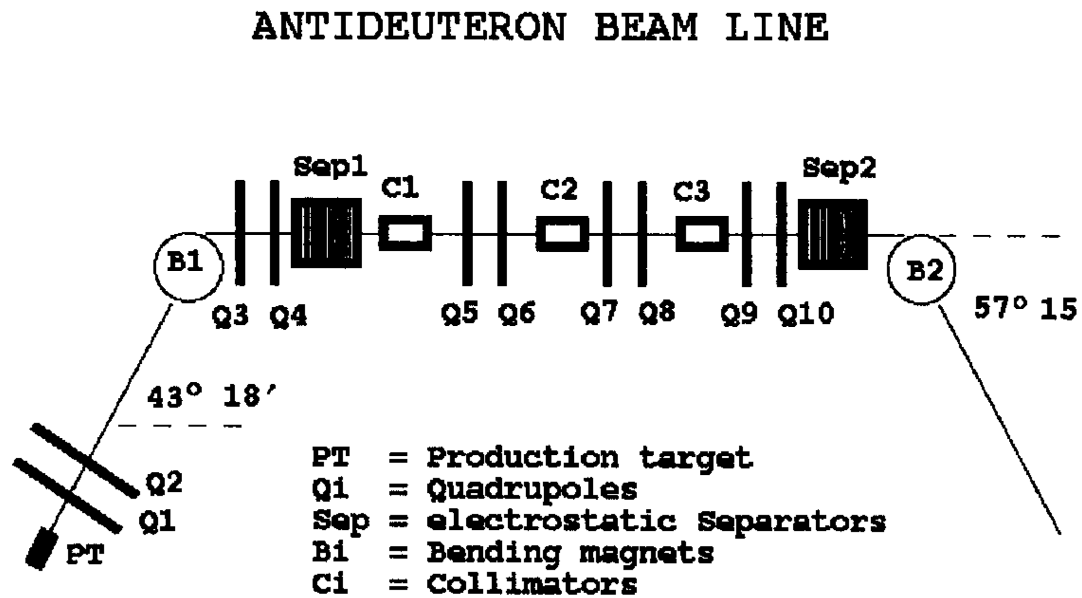
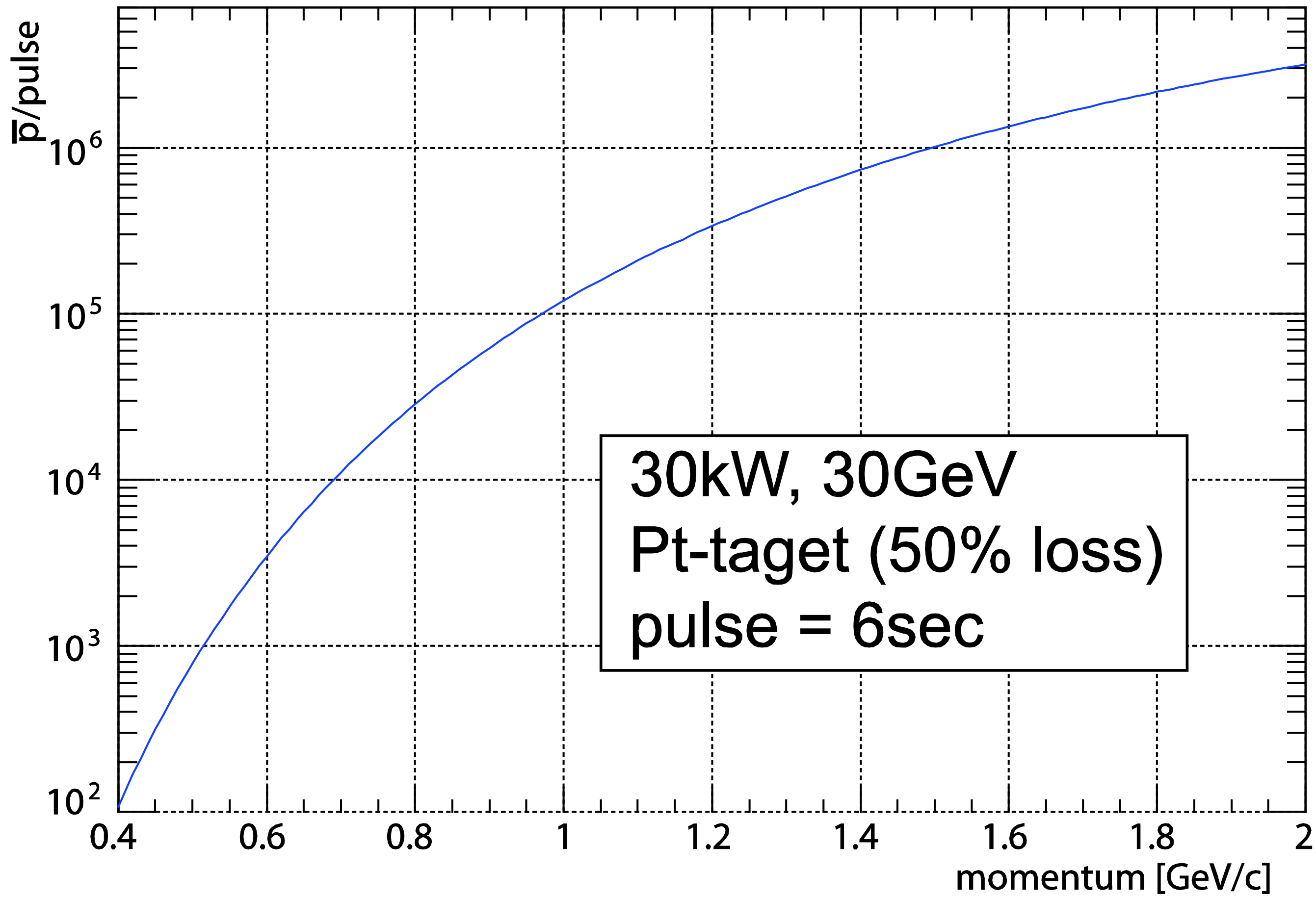


Table 1
Parameters of the $\bar{d}$ line components

	Effective Length (cm)	Angle (deg)	Magnetic field (KGauss)
B1, B2	140, 175	43° 18', 57° 15'	18, 19
		Electric Field Gradient (kV/cm)	
Sep1, Sep2	400, 300	80, 70	0.56, 0.496
		Aperture (cm) at pole tips	
Q_1, Q_2	80, 40	10.2	15, -14
Q_3, Q_4	10, 10	10.2	4, -1
Q_5, Q_6	30, 30	6	-8, 14
Q_7, Q_8	25, 30	6	9, -15
Q_9, Q_{10}	60, 30	6	12.5, -10

~ 30 d^{bar}/pulse @ 50GeV (full power?)



$\bar{p}$/pulse
10^6
10^5
10^4
10^3
10^2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
momentum [GeV/c]
30kW, 30GeV
Pt-taget (50% loss)
pulse = 6sec