J-PARC E15実験に用いる円筒形検出器群のCOMMISSIONING(5)

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for the E15 collaboration

2012年 9月 物理学会(京都産業大学)

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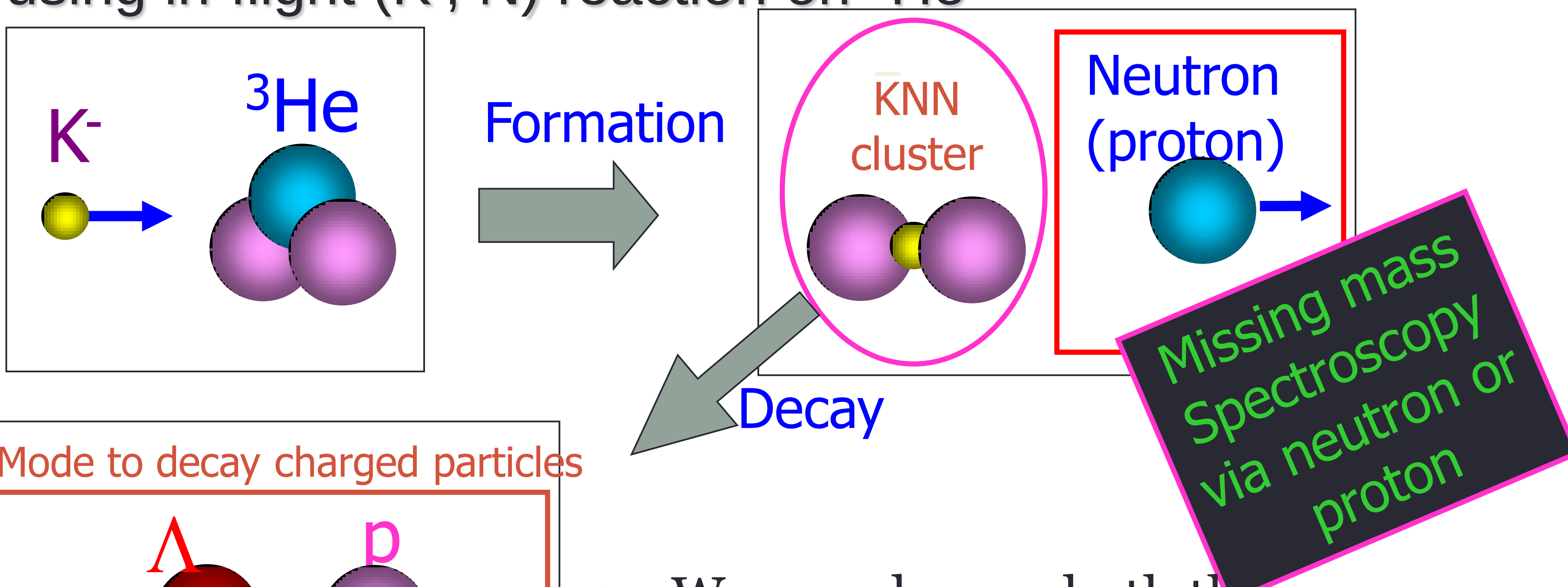
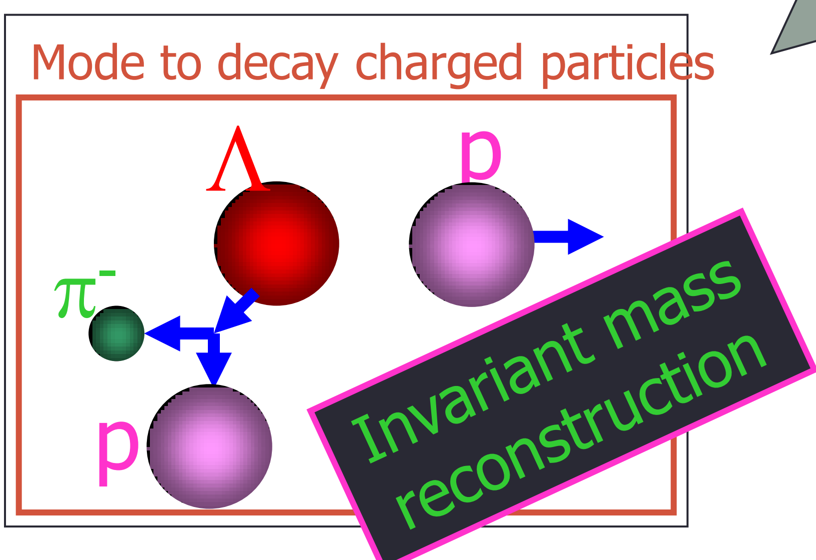
J-PARC E15 experiment

Experimental search for $K\bar{N}N$ bound states
using in-flight (K^-, N) reaction on ^{3}He





We can observe both the
"Formation" and **"Decay"**
of $\bar{K}NN$ bound state
(especially K-pp state is important)

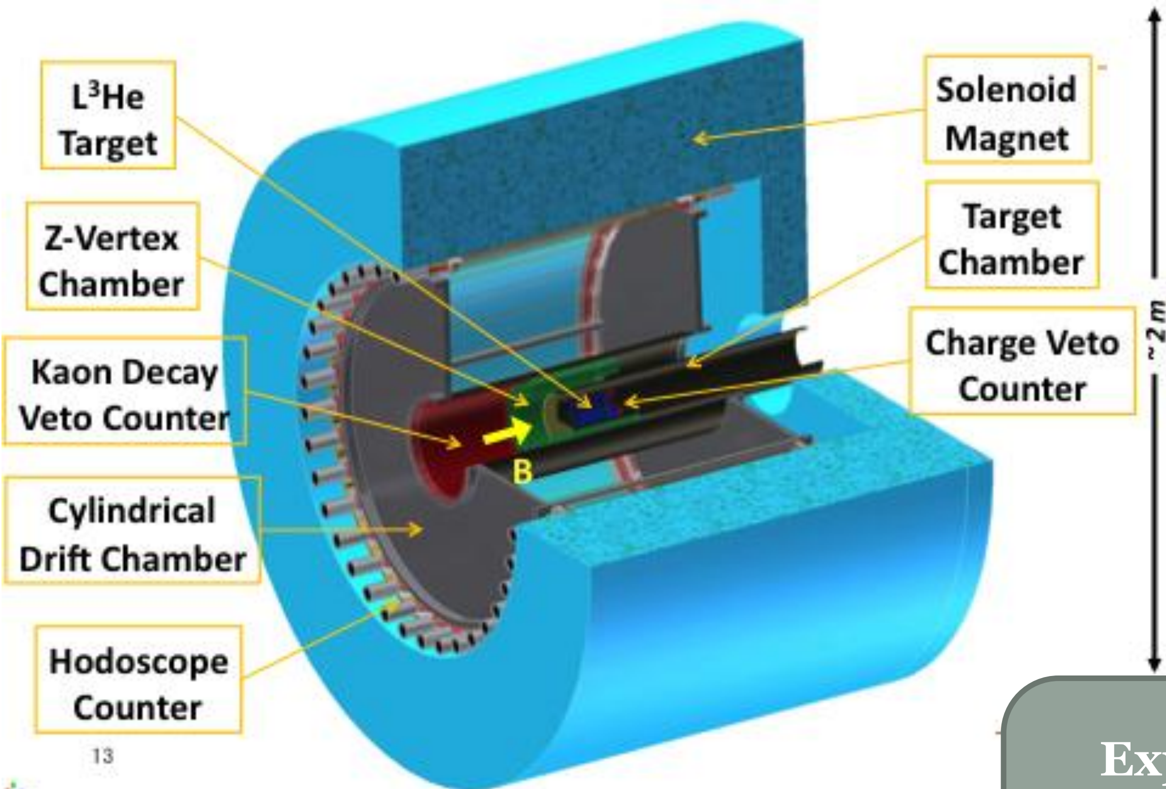
Status of J-PARC K1.8BR

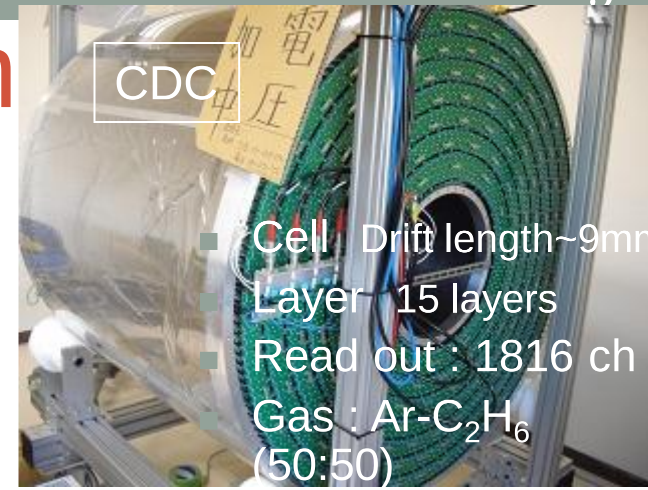
Beamline:橋本
CDS：佐田
NC：榎本
Backward Counters：井上

5

Cylindrical Detector System

- To detect the decay particles from ^{3}HeTarget
    - Momentum reconstruction
    - Particle identification

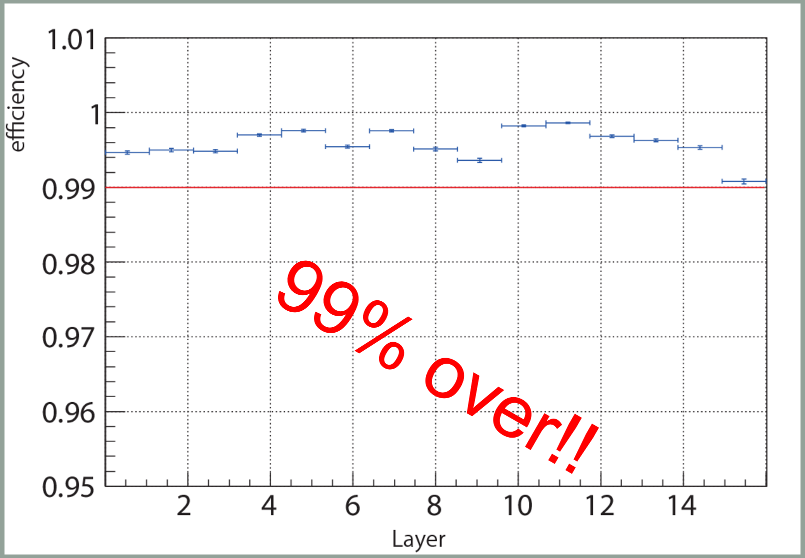




Expected mass resolution :
- $\sigma \sim$ 3.6 MeV/c^2 for Λ
- $\sigma \sim$ 10 MeV/c^2 for K^-pp
(σ_{cdc} = 200 μm / Field : 0.7 T)

Performance of CDC

Efficiency



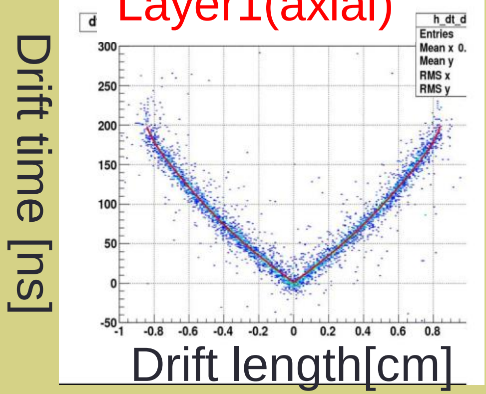
○　定義

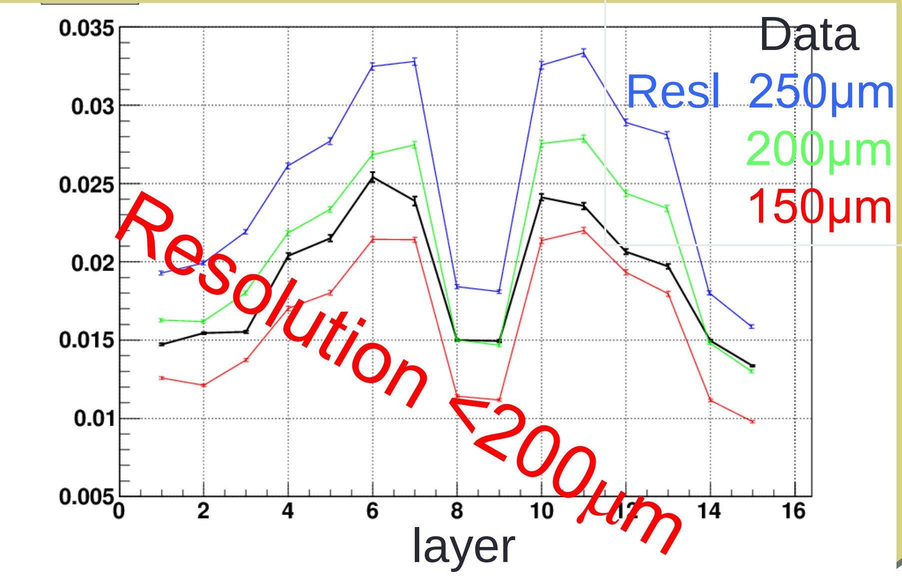
Eff= 対象LayerのHit数　/　ReconstructできたTrack数

（trackからCell size以内の距離）　（対象Layerを外す）

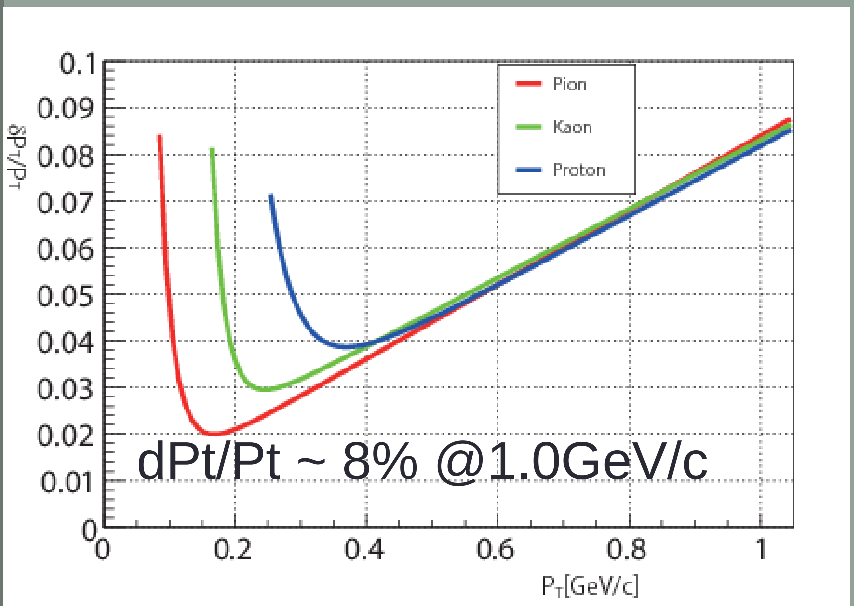
• Resolution

XT Curve
Layer1(axial)





δPt/Pt (sim)



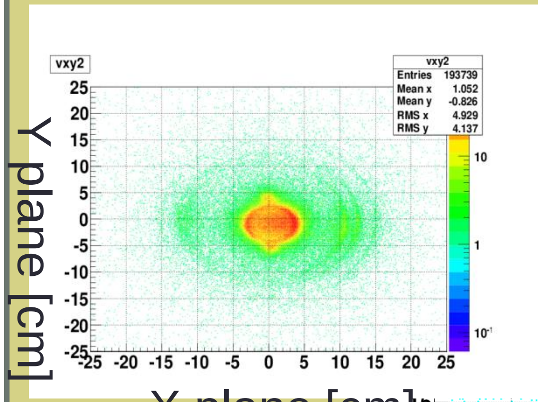
Generated Direction :4 pi uniformly

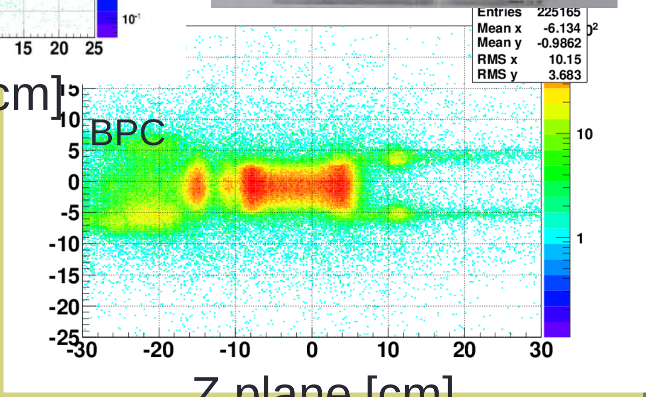
CDC resl. :200micron

Magneticfield :0.7T

dPt/Pt = 8.4%*pt+1.1%*1/beta

Target image



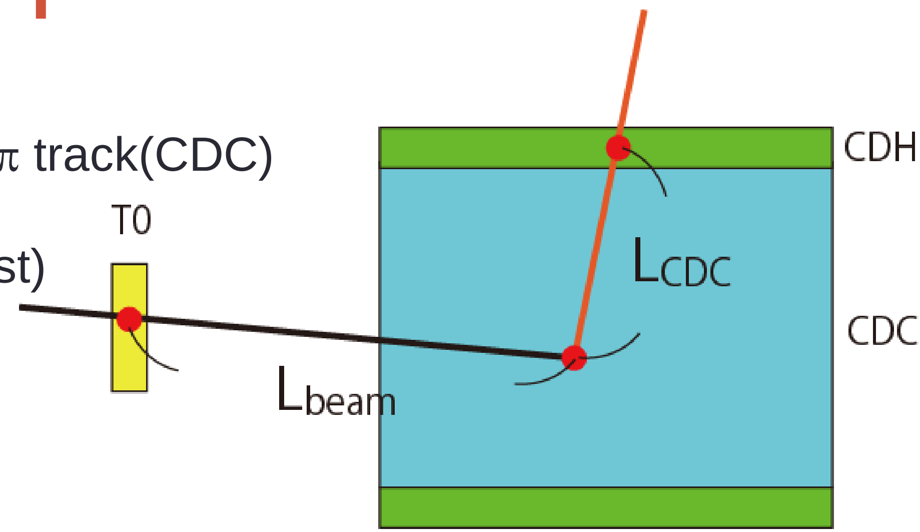


- Pi beam data
- DC of CDC 2track(pion)

Performance of CDH

TOF of T0 counter to CDH
corrected with events π beam(1.0GeV/c) and π track(CDC)

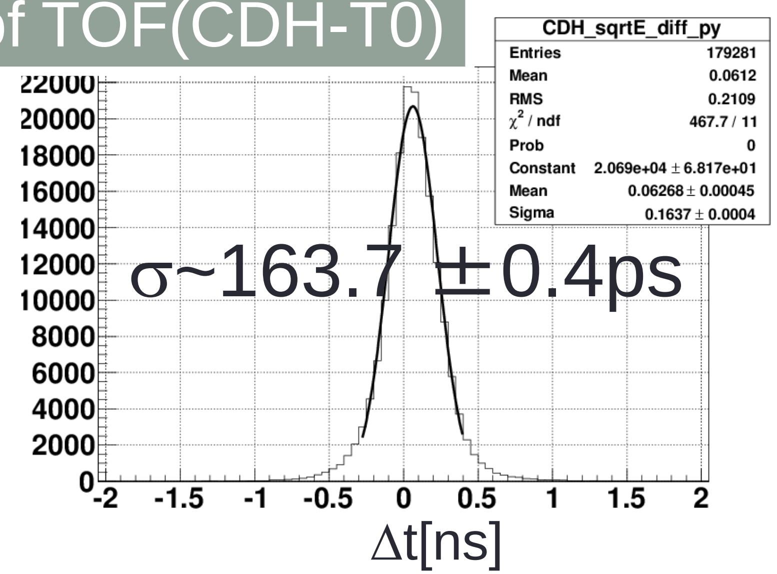
σT0 70~80ps , σCDH 70~80ps (cosmic ray test)
⇒σTOF 100~110ps (ideal)



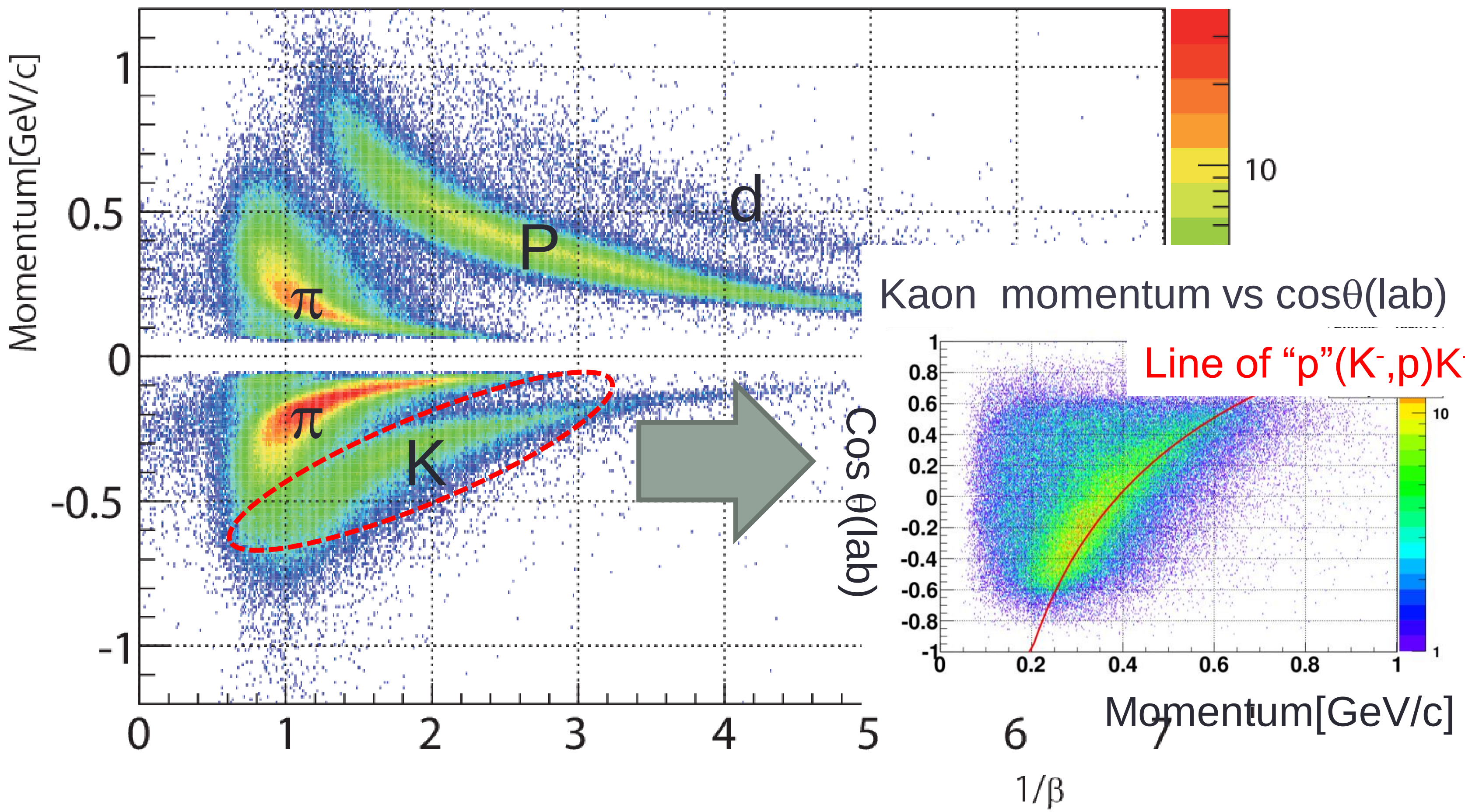
- $\Delta t = t_{calc} - TOF_{CDH-T0}$
- $t_{calc} = \dfrac{L_{beam}}{\beta_\pi c} + \boxed{\dfrac{L_{CDC}}{\beta_\pi c}}$

There are effect of CDC track resolution (momentum ,position)

Δt of TOF(CDH-T0)

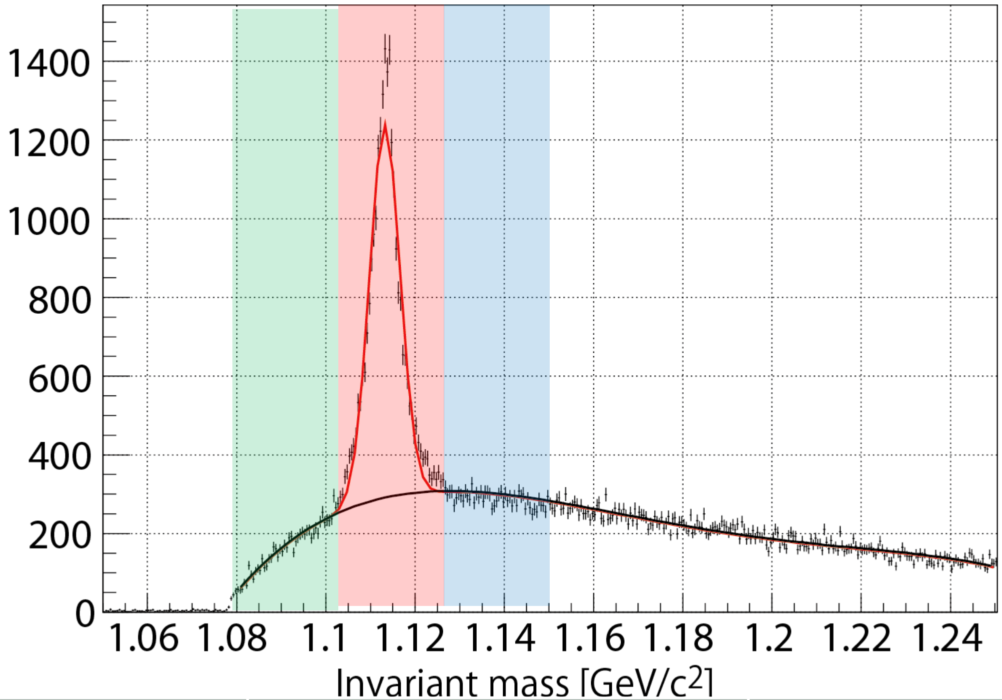


PID

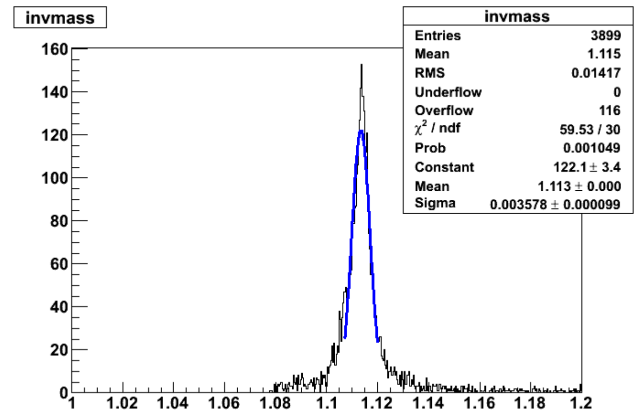


- PID is clear!
- Cos θ means angle between beam K- and scattered K-
- Correlation of K- 's cos and momentum is clear => elastic scattering

p π^- invariant mass (Lambda peak)



- Simulation

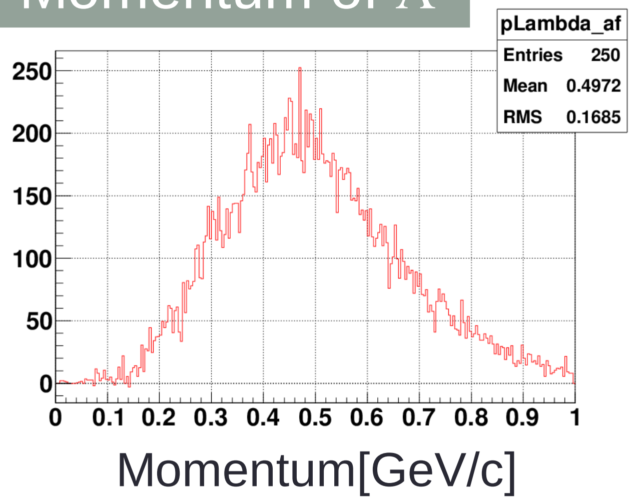


	Data	Sim
mean	1113.16 ±0.1[MeV]	1113.4[MeV]
σ	3.42±0.4 [MeV]	3.6[MeV]
Num. Λ	~16k	

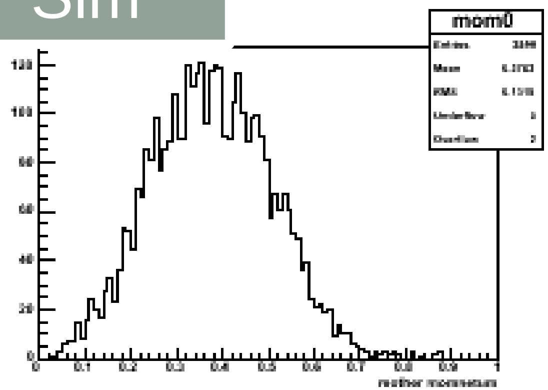
- Run43 data(2012 May -June)
- Data sum ~1kw*week
- K- beam (1.0GeV/c)
- ^{3}He target
- Target cell selected
- Simulated with CDC resl.=250μm

Kinetic distribution of Λ

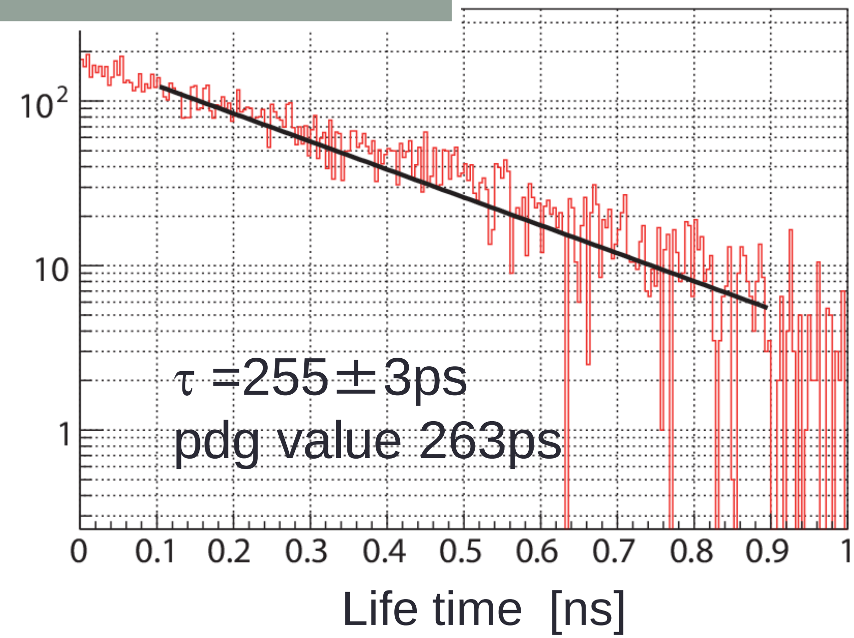
Momentum of Λ



Sim



Lifetime of Λ

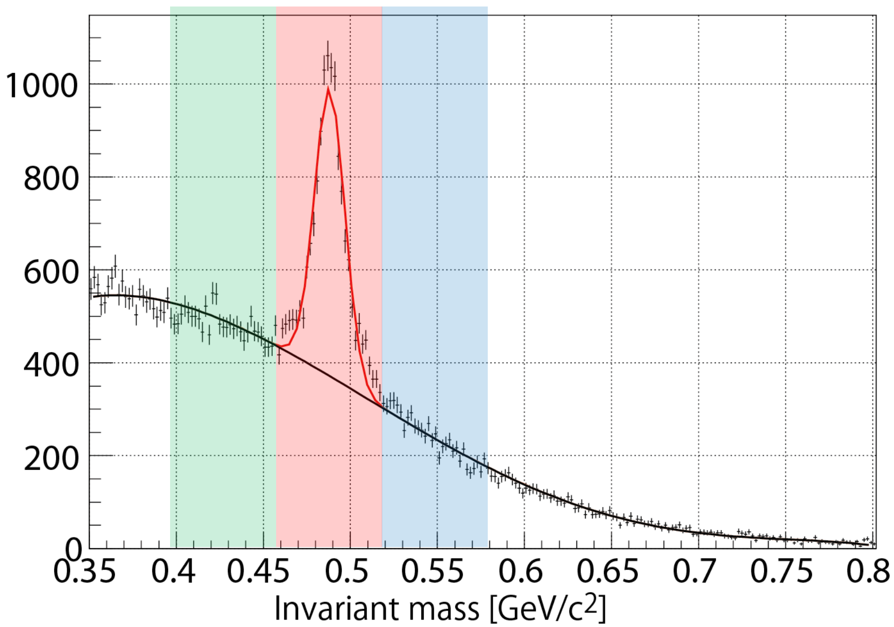


- Momentum dis. Λ is almost same as simulation’ s one

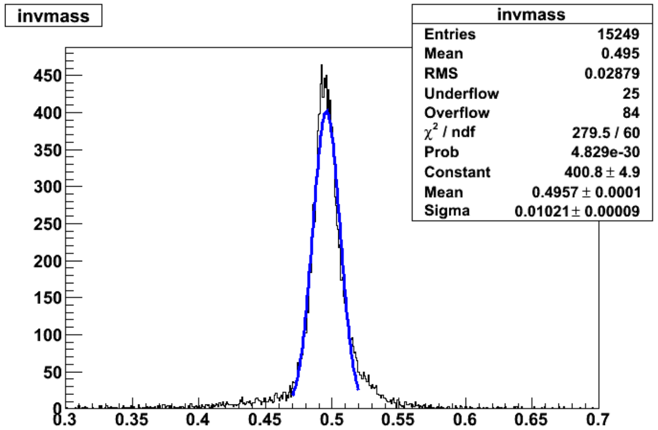
peak (data) ~0.45GeV/c

peak (sim)_ ~0.4GeV/c

π^+ π^- invariant mass (K0s peak)



- Simulation

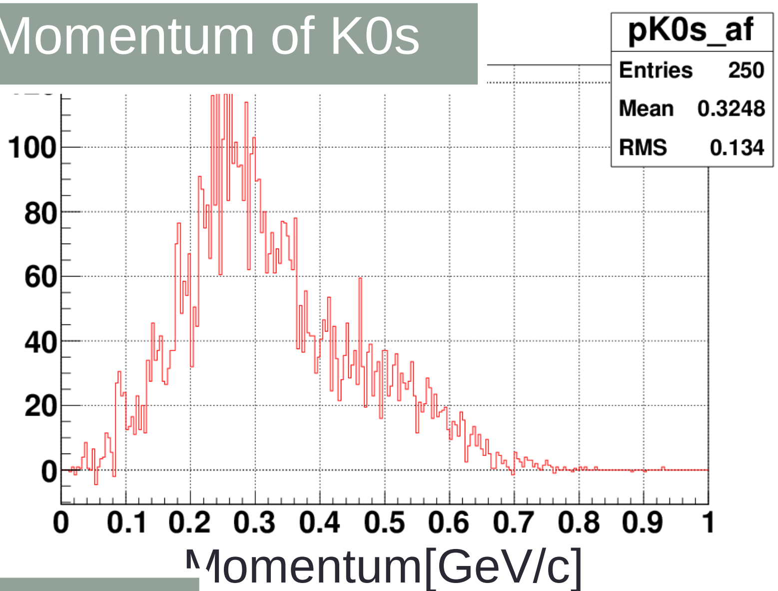


	Data	Sim
mean	488.1 ±0.2 [MeV]	495.7[MeV]
σ	8.8±0.2[MeV]	10.2[MeV]
Num K0s	~6.8k	

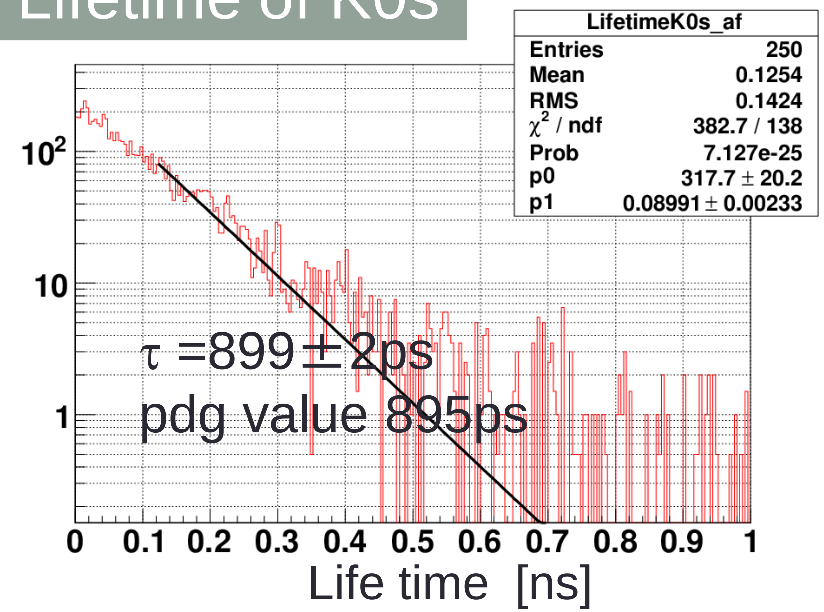
- Run43 data(2012 May -June)
- Data sum ~1kw*week
- K- beam (1.0GeV/c)
- ^{3}He target
- Target cell selected
- Simulated with CDC resl.=250μm

Kinetic distribution of K0s

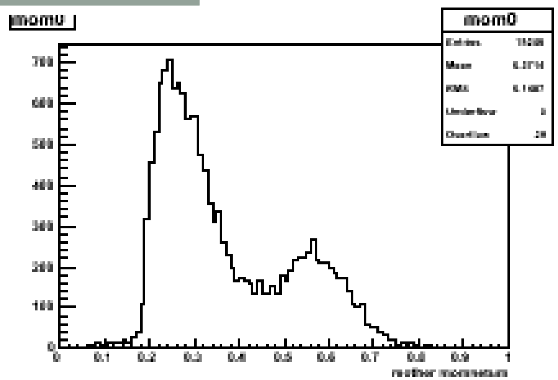
Momentum of K0s



Lifetime of K0s



Sim



- Momentum dis. K0s is almost same as simulation’ s one

(there are 2 peak)

Summary

- CDS Performance
  - CDC (chamber)
    - Efficiency =>99% over!
    - Residual distribution ⇒resolution 200μm以下を達成
    - δPt/Pt ~8%(@1.0GeV/c)
  - CDH(Hodoscope)
    - Time resolution ~160ps (TOF of CDH –T0)
    - PID=> p ,K ,p,d を分離 =>"p"(K-,p)K-のelastic scattering が綺麗に見えているよう
- Preliminarily result of Run43
  - Invariant mass of (p π) or(π+ π-)
    - Λ ,K0s共にpeakが綺麗に見えている

      =>mass resolutionなど、simulationと比較的合っている(K0sのmass centerのずれは検証中)
    - Momentum distributionの形は予想と合っている
    - Lifetimeも比較的合っている

⇒CDS にてL K0sのreconstructionに成功、

K1.8BRdetetorsの総合的な解析へ

J-PARC E15 collaboration list

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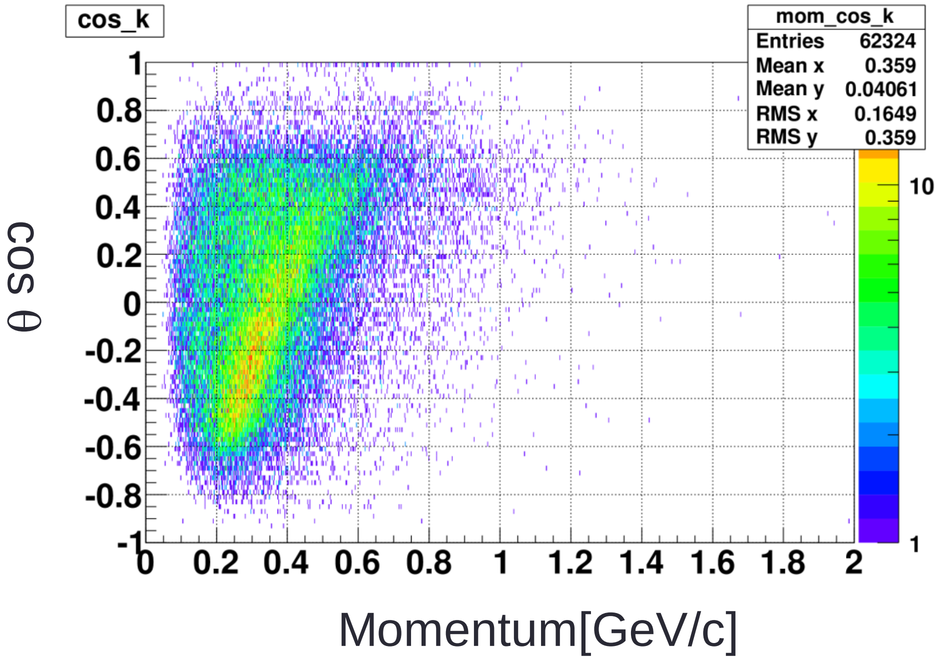
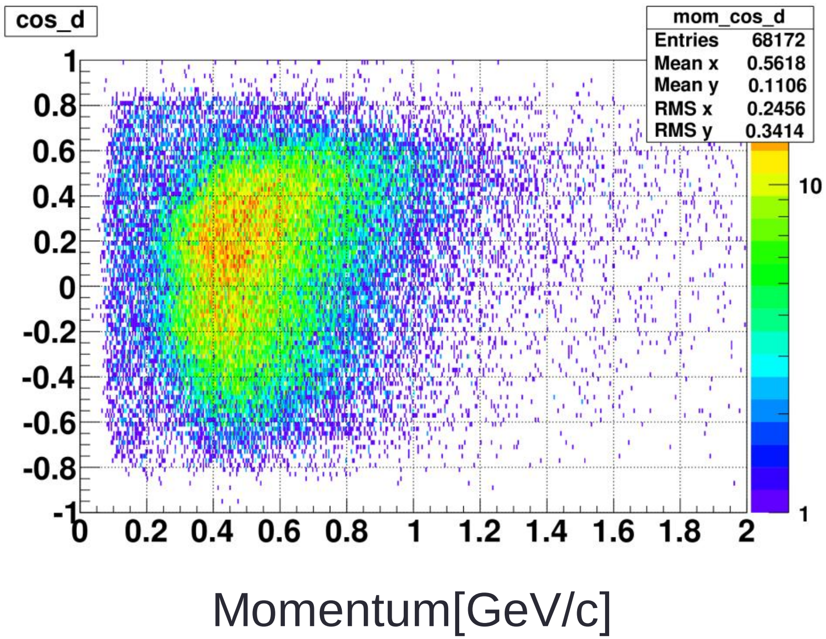
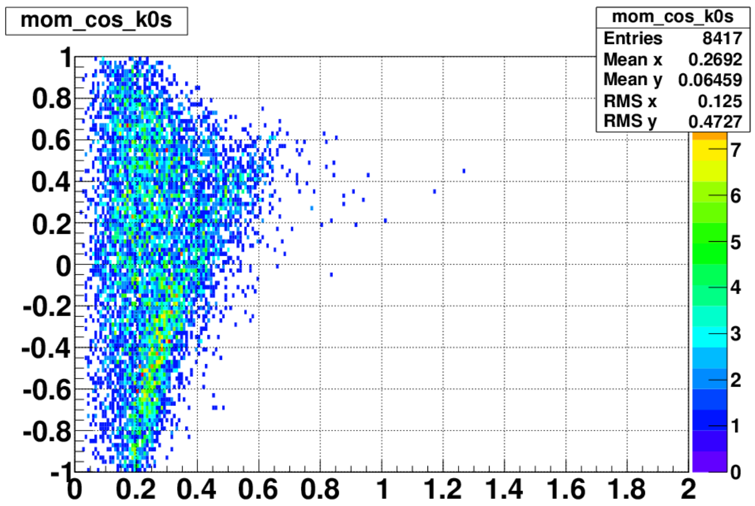
Momentum vs cos θ(Lab sys.)

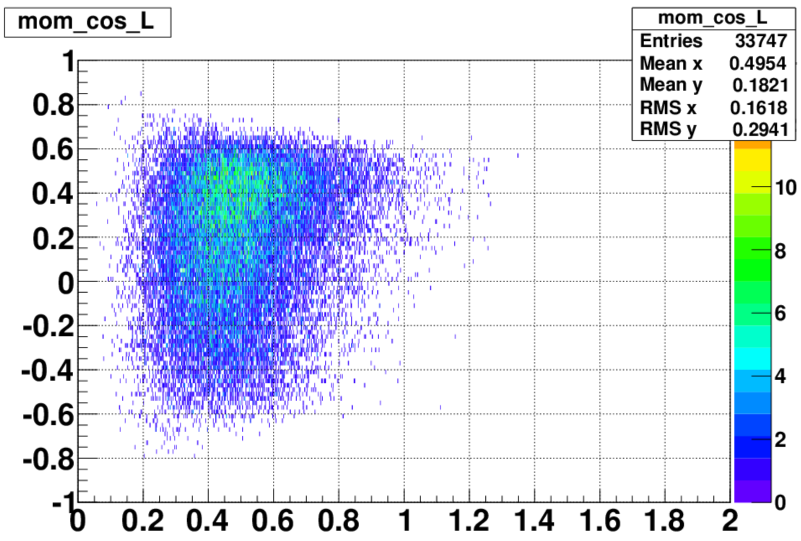




- K- or deuteron in CDS
- Cos θ means angle between beam K- and particles(K- or d)
- Correlation of K- 's cos and momentum is clear => elastic scattering ?

Momentum vs cos θ(Lab sys.)

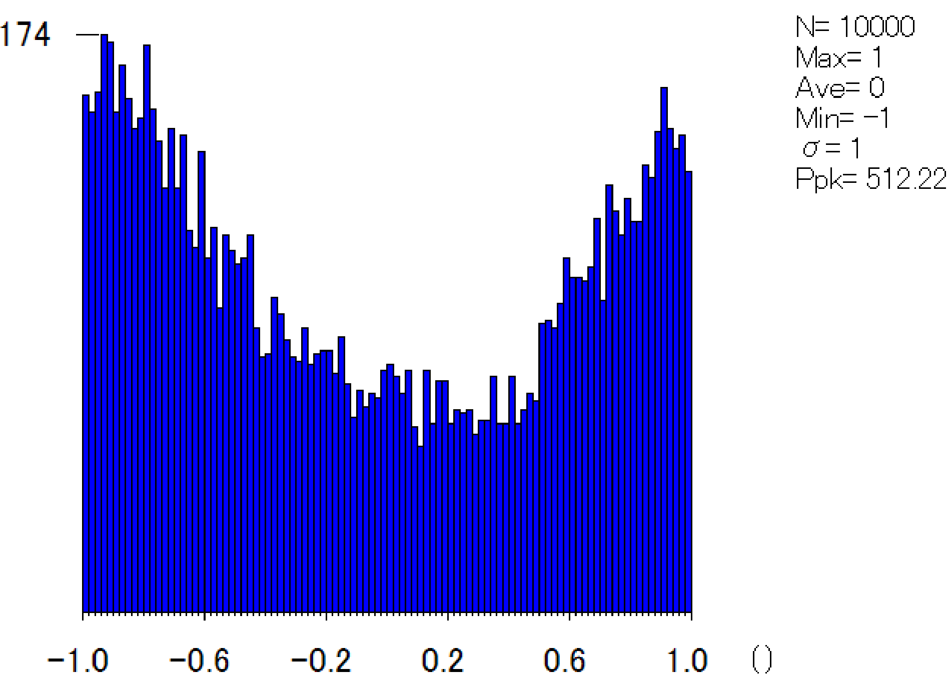




- K0s or Lambda in CDS
- Cos θ means angle between beam K- and particles
- Non-Correlation events @ K0s are background events ?

Generated angular distribution

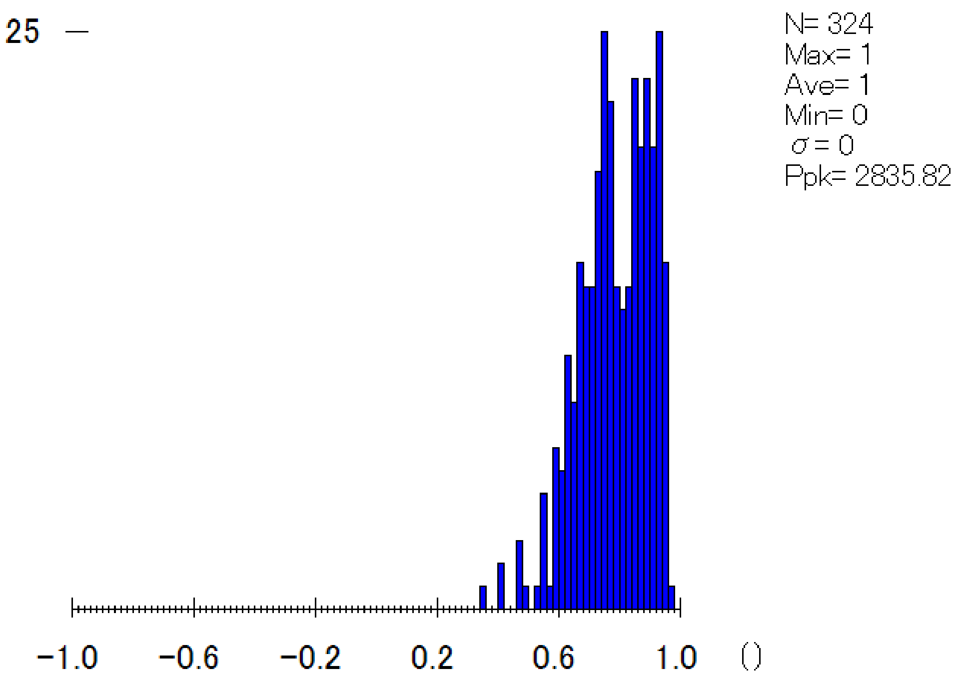
$K^-p \rightarrow \Lambda\pi^0$ @ 1001MeV/c



$\cos\theta_{\pi 0}$ at CM

CDS accepted angular distribut

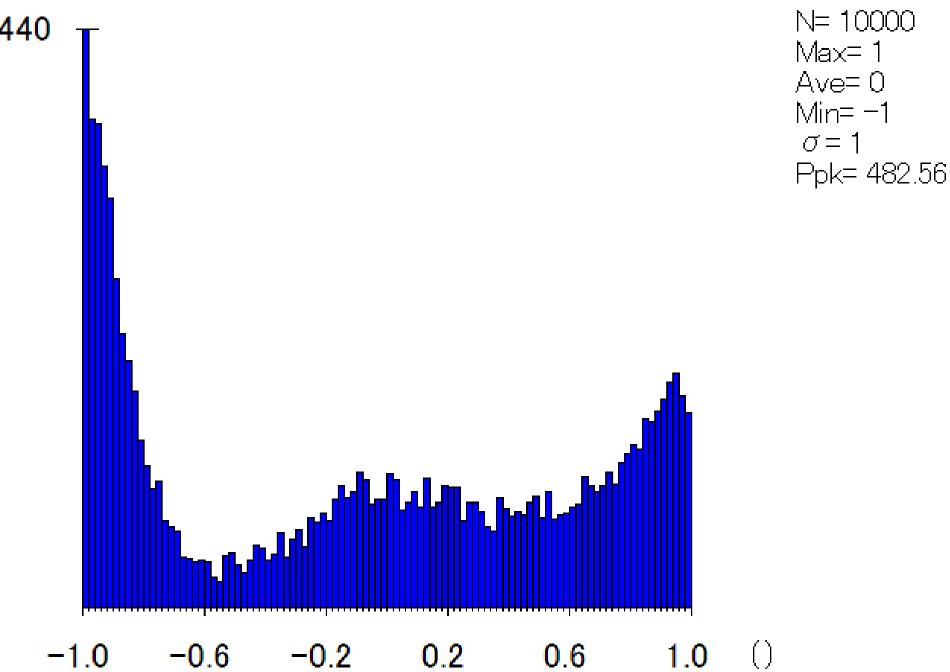
$K^-p \rightarrow \Lambda\pi^0$ @ 1001MeV/c



$\cos\theta_{\pi 0}$ at CM

Generated angular distribution

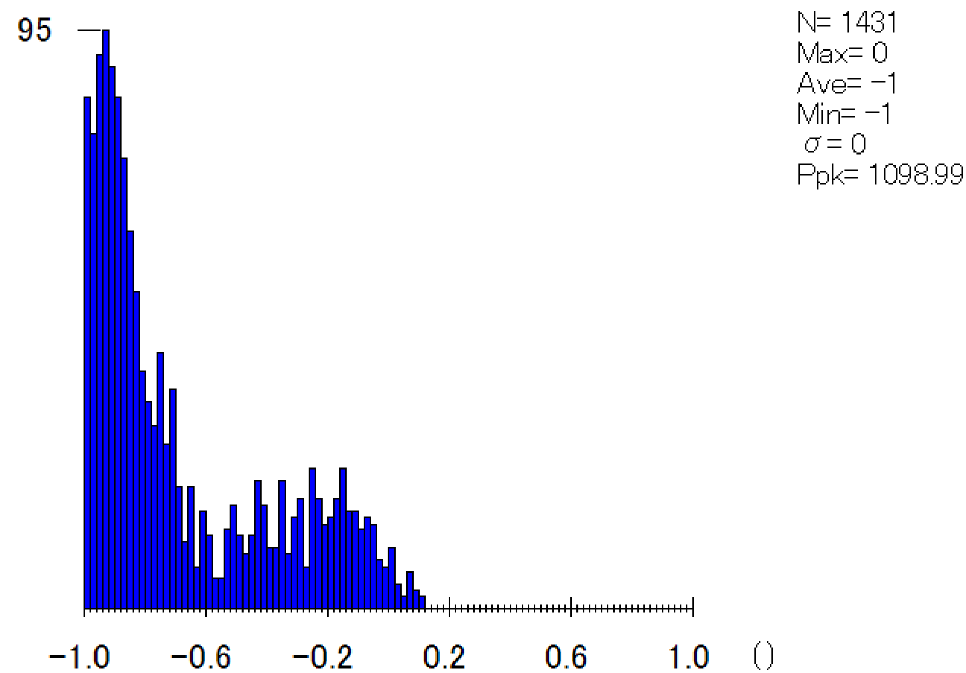
$K^- p \rightarrow K^0 n$ @ 1001MeV/c



$\cos\theta_{K0}$ at CM

CDS accepted angular distribut

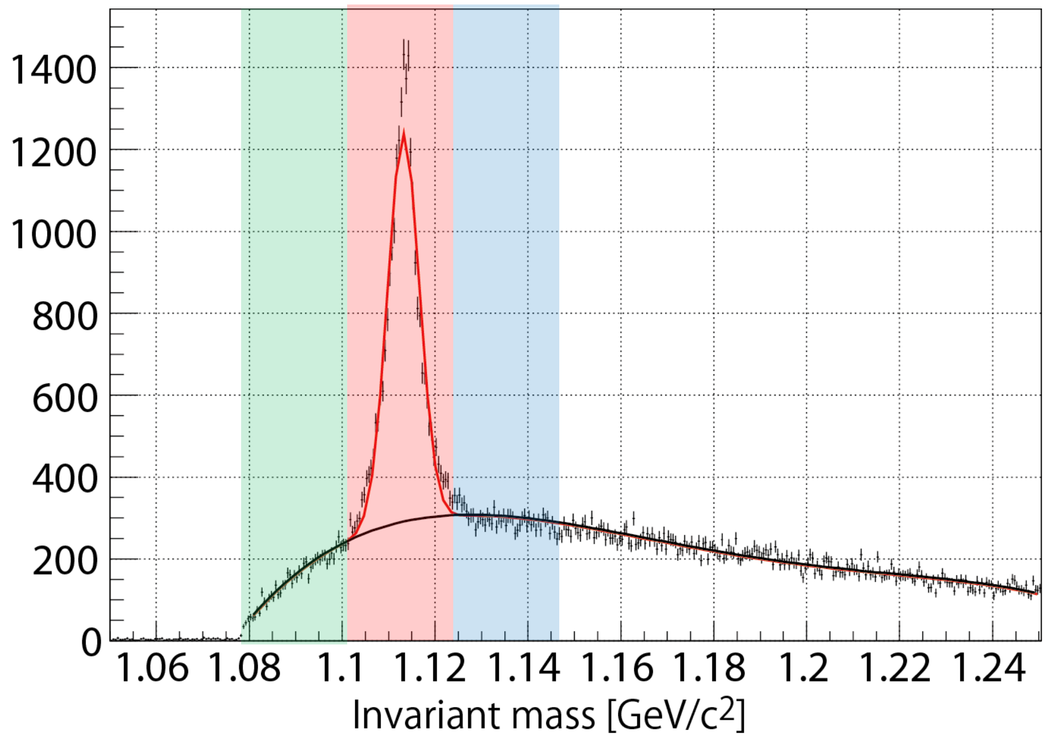
$K^- p \rightarrow K^0 n$ @ 1001MeV/c



$\cos\theta_{K0}$ at CM

Lambda peak

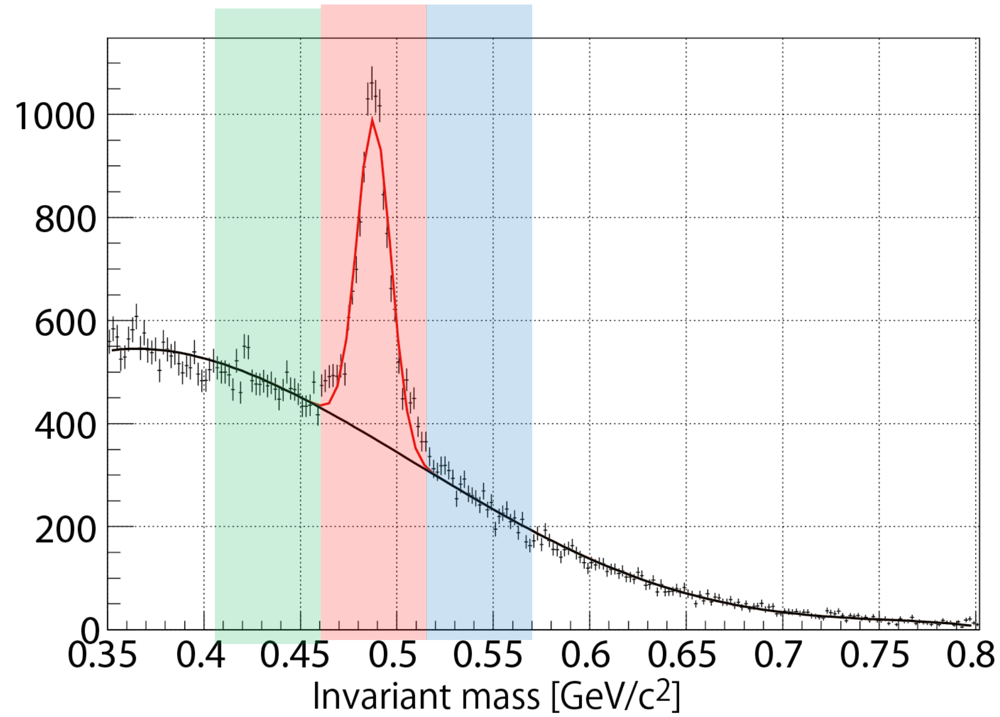
- 3 zone (red , green ,blue)
  - Width 24MeV/c2
- Red =lambda peak
  - Center =1114.0MeV/c2
- Blue and green
  - Using estimation of BG
- Getting Lambda kinetic specrum
  - (Red spectrum) – (averge of blue and green)



Events of Run0126~017

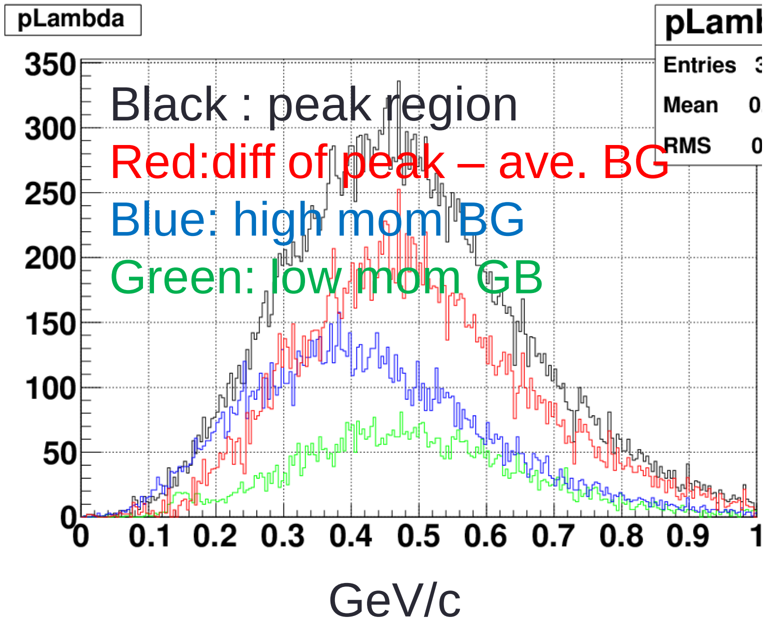
Lambda K0s peak

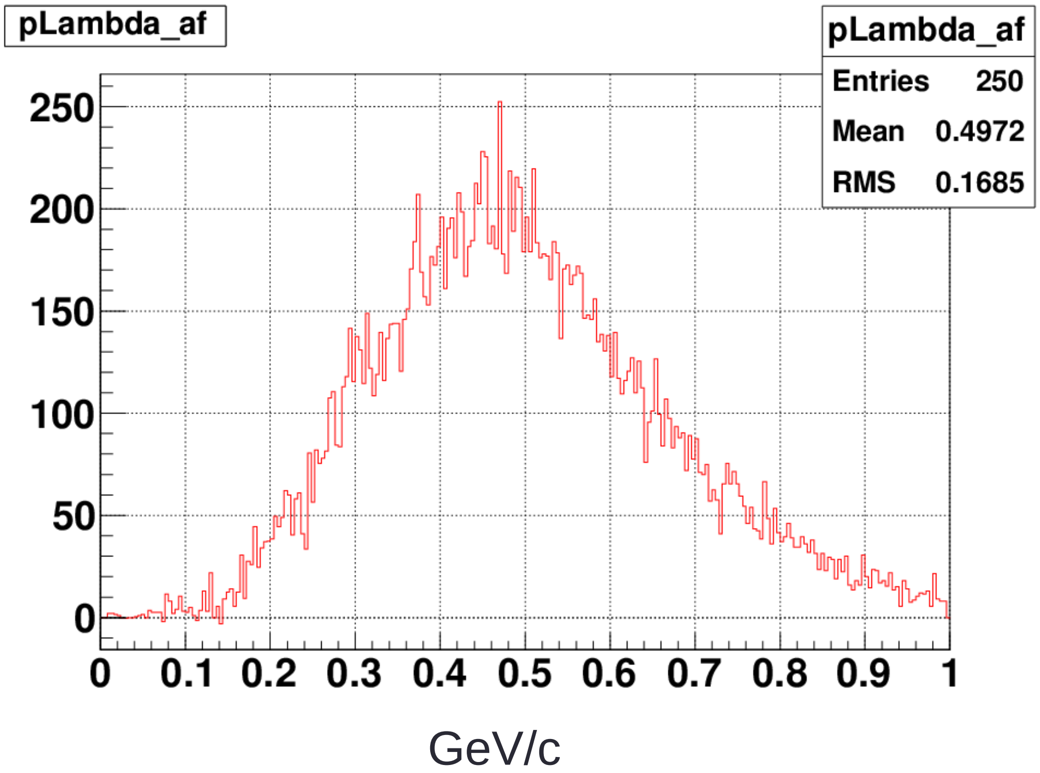
- 3 zone (red , green ,blue)
  - Width 4MeV/c2
- Red =K0s peak
  - Center =490.0MeV/c2
- Blue and green
  - Using estimation of BG
- Getting K0s kinetic specrum
  - (Red spectrum) – (averge of blue and green)



Events of Run0126~0172

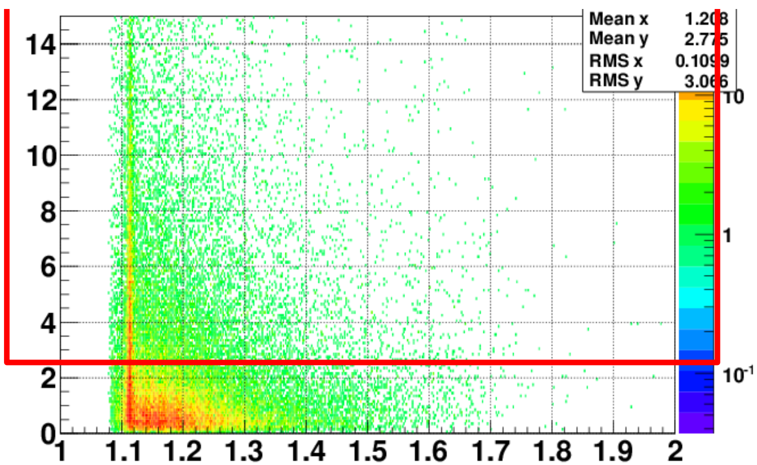
Lambda momentum





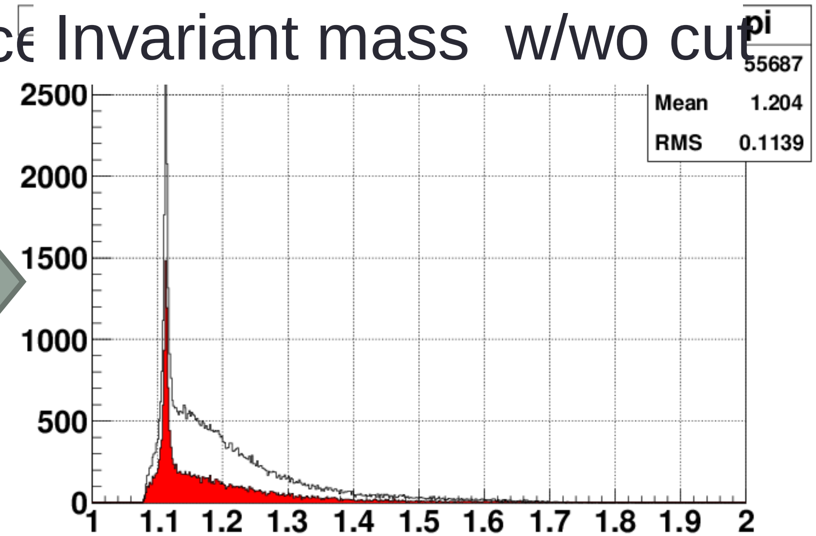
Invariant mass proton pi-

Invariant mass v.s. DC distance



Invariant mass GeV/c2

Invariant mass w/wo cut

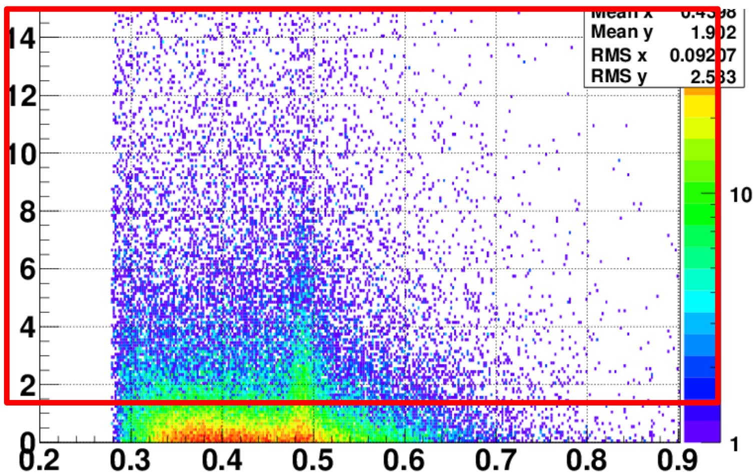


Invariant mass GeV/c2

- Invariant mass p π – (lambda peak)
- DC dis =(DC of pπ) to (BPC track) ~ distance from reaction point
- Cut up to DC dis >2cm

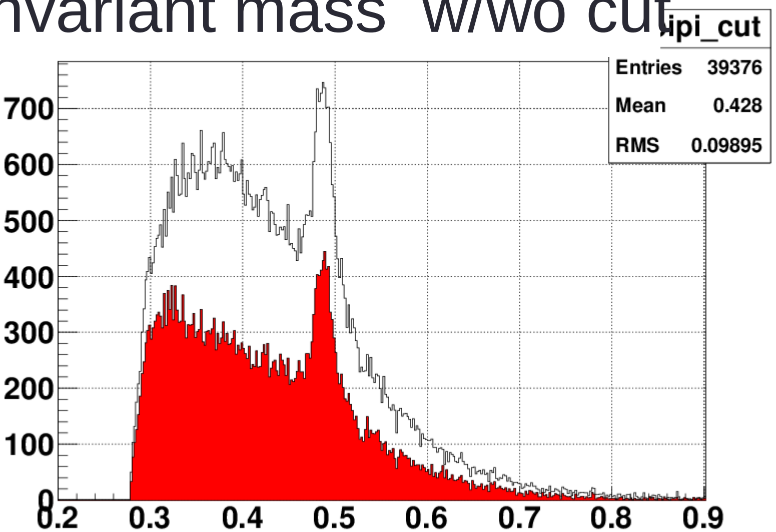
Invariant mass p+ pi-

Invariant mass v.s. DC distance



Invariant mass GeV/c2

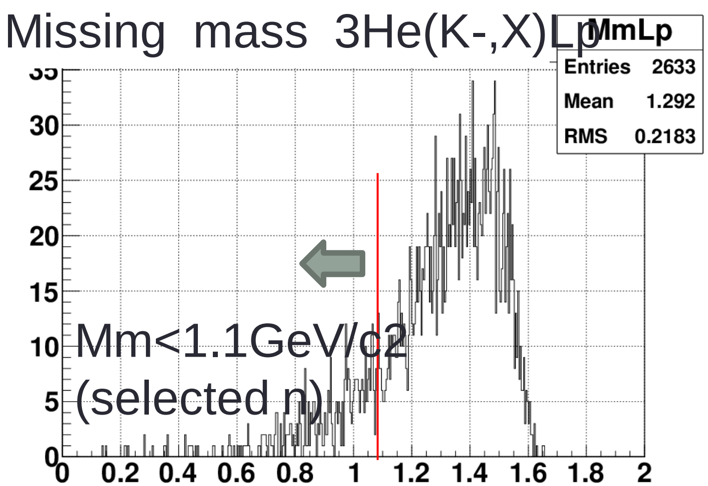
Invariant mass w/wo cut

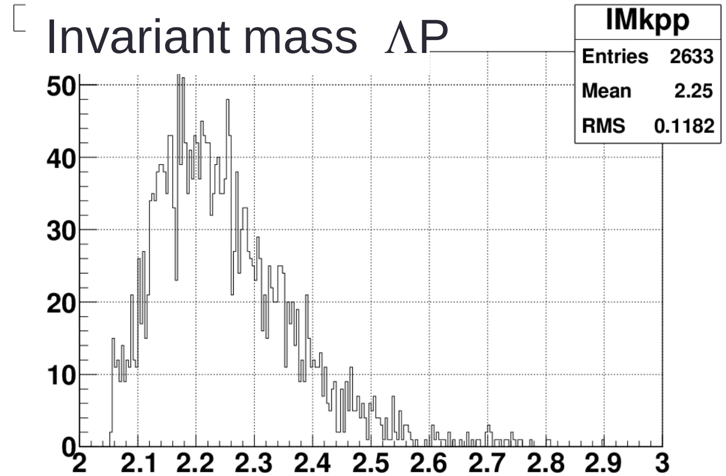


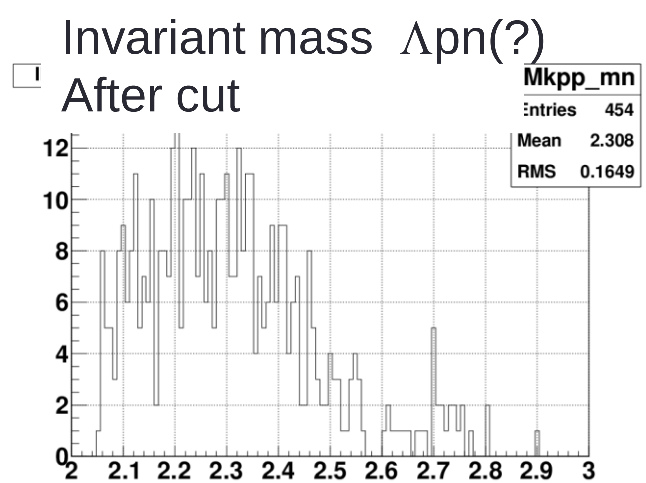
Invariant mass GeV/c2

- Invariant mass π+ π – (K0s peak)
- DC dis =(DC of $\pi\pi$) to (BPC track) ~ distance from reaction point
- Cut up to DC dis >0.6cm

Lp event (invariant mass & missing mas)





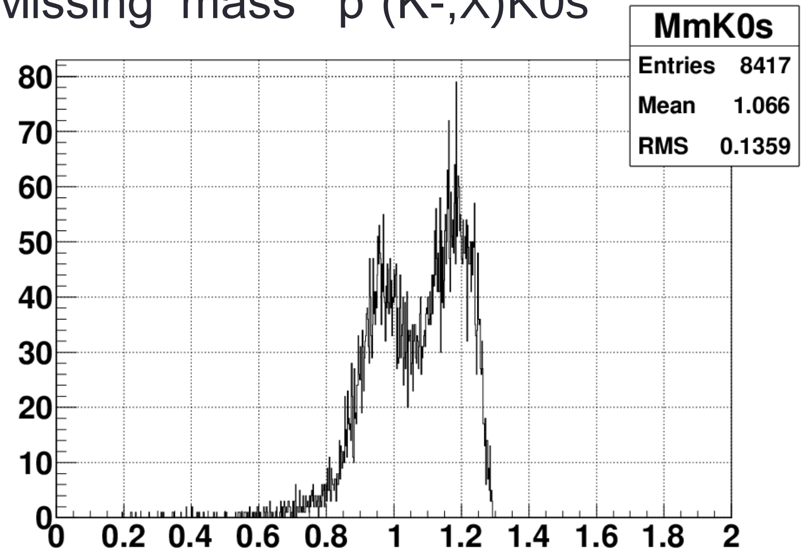


- Moemntum of beam K- is fixed 1.0GeV/c(not use D5 spectrometer s)
- Neutron Cut means events of whitc missing mass is under 1.1GeV/c2

"p"(K-,n)K0s event for NC efficency estimation

- To estimate NC efficiency
  - => using "p"(K-,X)K0s reaction
  - From Missing mass spectrum , there is neutron peak
  - S/N ratio ~ 50%?

Missing mass "p"(K-,X)K0s

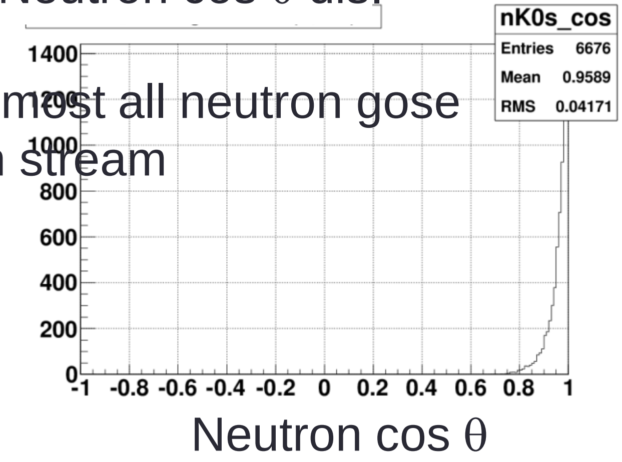


- Moemntum of beam K- is fixed 1.0GeV/c(not use D5 spectrometer s)
- Neutron Cut means events of which missing mass is under 1.1GeV/c2 & up to 0.8GeV/c2

Neutron direction

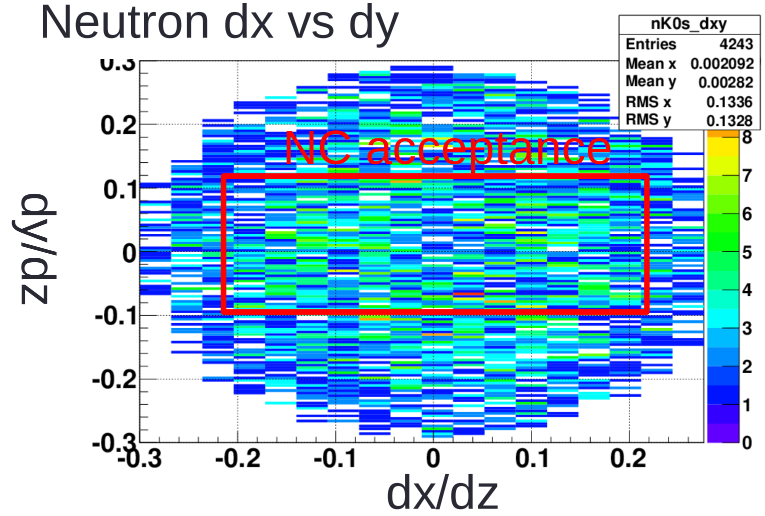
- Neutron of “p”(K-,n)K0s events direction distribution
- Neutron in NC acceptance ~1850 event
- => from S/N 50% ,we can use ~1000 neutrons

Neutron cos θ dis.

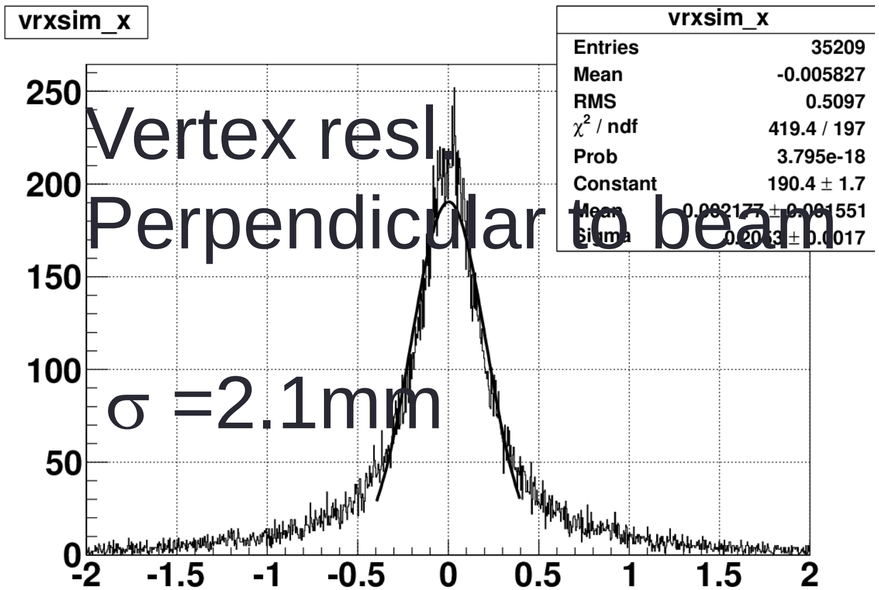


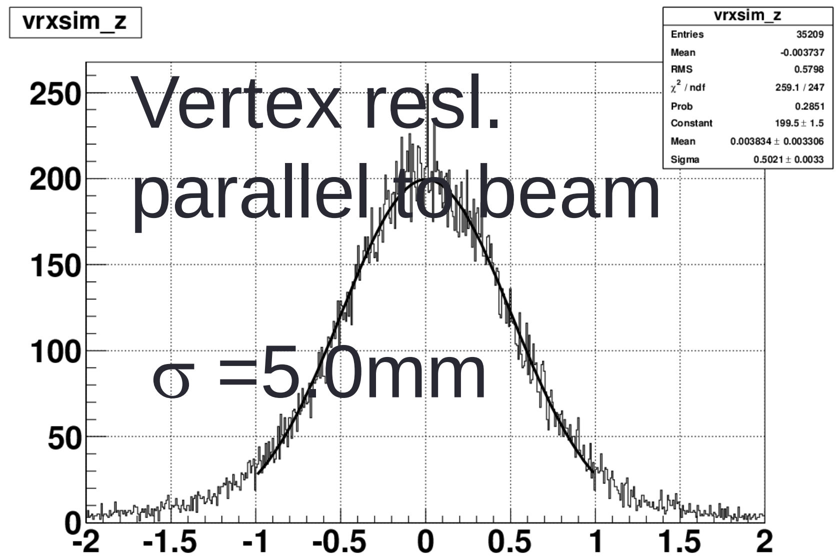
=> Almost all neutron gose down stream

Neutron dx vs dy



Vertex resolution (simulation)





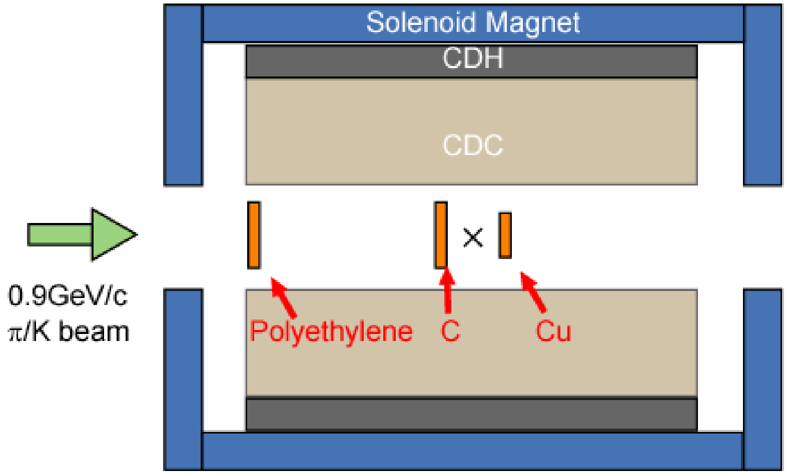
- Particle 2 pions
- Generated Direction : 4pi
- Generated pos : uniform in Target
- CDC resl :200micron
- Magnetic field :0.7T

Schedule

2012.3	**14^{th} PAC**	
2012.3-4	*Preparation*	*Neutron Counter:* *REASSEMBLING/INSTALLATION @ J-PARC*
2012.5	*Preparation*	*Beam-Sweeping Magnet :* *TRANSFER, KEK→J-PARC & INSTALLATION @ J-PARC*
2012.6	**Commissioning Run**	**3.3kW, a few days: trigger/detector tuning**
2012.7	**15^{th} PAC**	
2012.7-9	**Shutdown**	
2012.10 -	**Production Run**	**5-10kW, 3weeks: 3He(K-,n/p)**

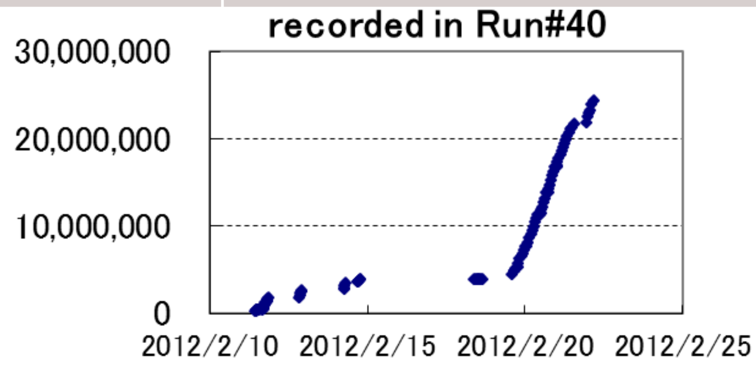
Data with Secondary beam

Run #35	
Run time	2010/10/22~10/24
Goal	CDS commissioning
Beam	K^-, π^+ beam 0.9GeV/c
Recorded Trig.	~9M event
Target	C, Cu , Polyethylene



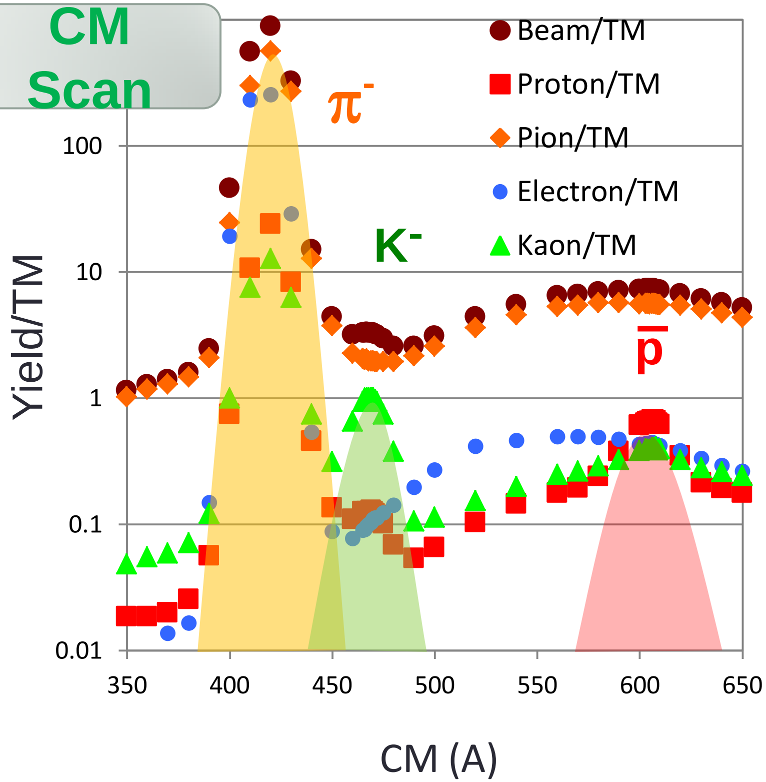
NEW!

Run #40	
Run time	2012/2/19~2/22
Goal	**Multi-nucleon absorption** (Background study of Λp event) **Study of Calibration method for NC**
Beam	K^-, π^- beam 1.0GeV/c
Recorded Trig.	~25M event
Target	Liquid 4He



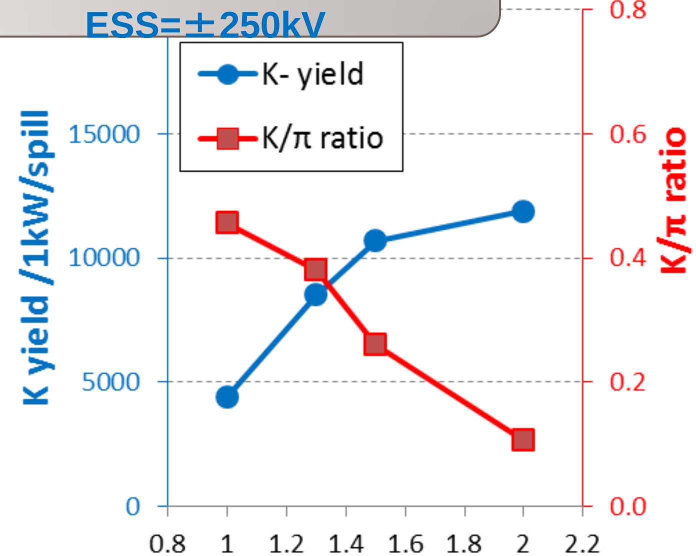
1.0GeV/c Beam tuning (Run#40)

CM Scan



K yield, K/π vs Slit Width

ESS=±250kV



Trig rate

IF-V, MS (W)

expected

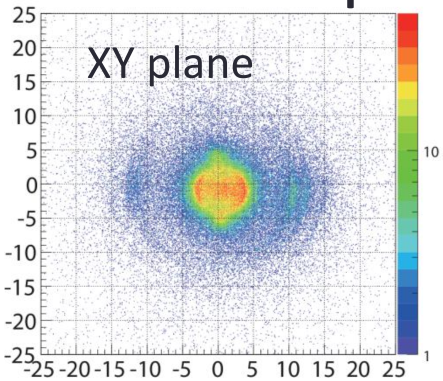
[/spill]	3.3k W	10kW
beam intensity	100k	300k
K^- yield	33k	100k
E15 trig. rate	700	2.1k

Slit 幅やCM scan etc.　1.0GeV/c K beam tuneの必要なparameterは決定済み
Trigger rateも10kWまで問題なし

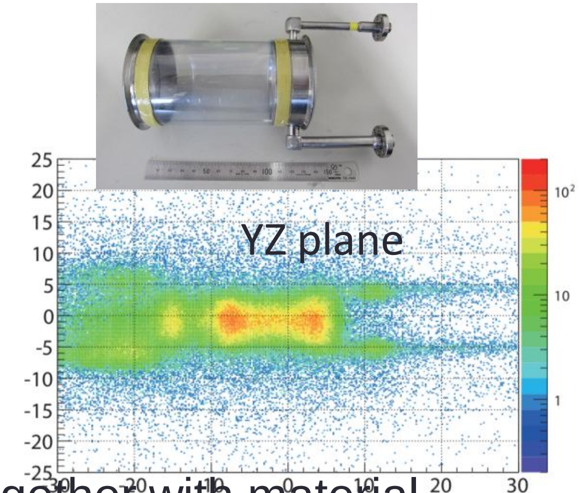
- **1.0 GeV/c beam tuning was completed!**

Preliminary Results of Run#40

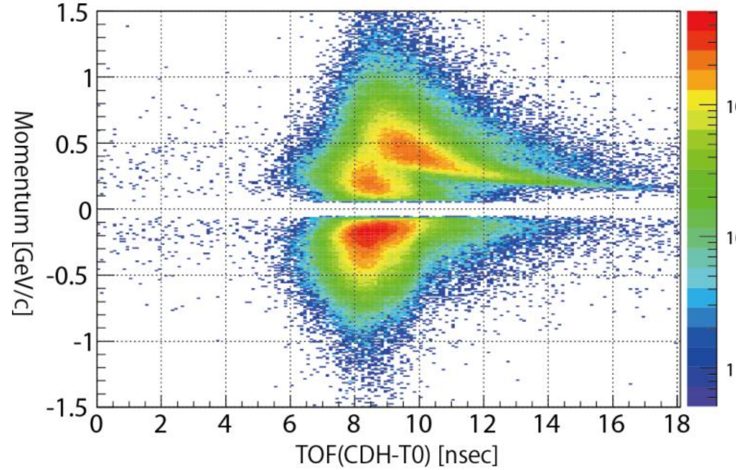
- **CDS and Liquid Helium target system successfully worked!**



Liquid ^{4}He inside

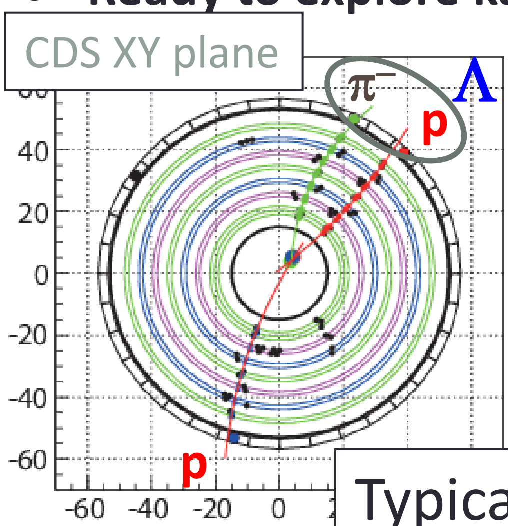


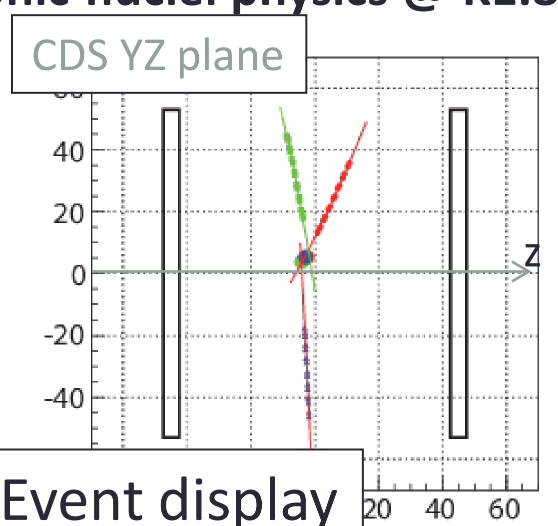
Target-images together with material around has been reconstructed by the CDS



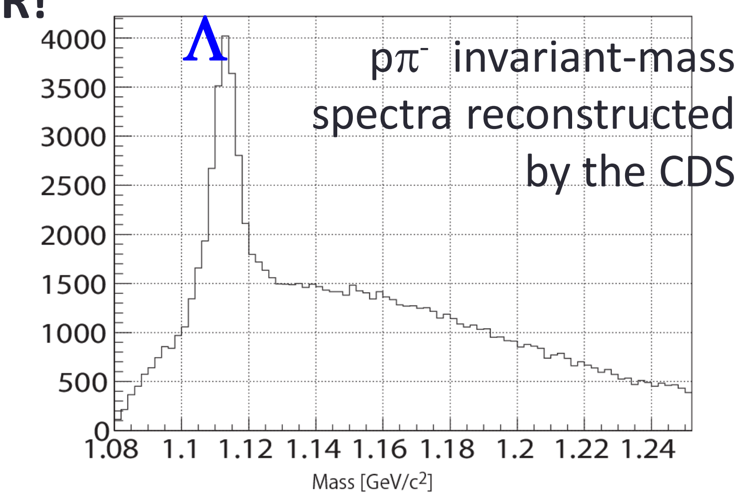
Particles from the target have been successfully identified by the CDS

- **Ready to explore kaonic-nuclei physics @ K1.8BR!**





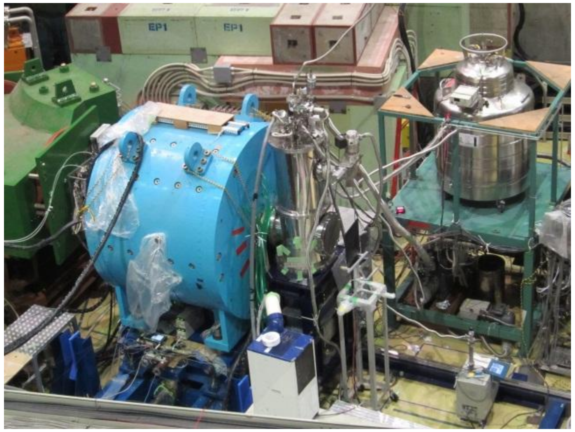
Typical Event display



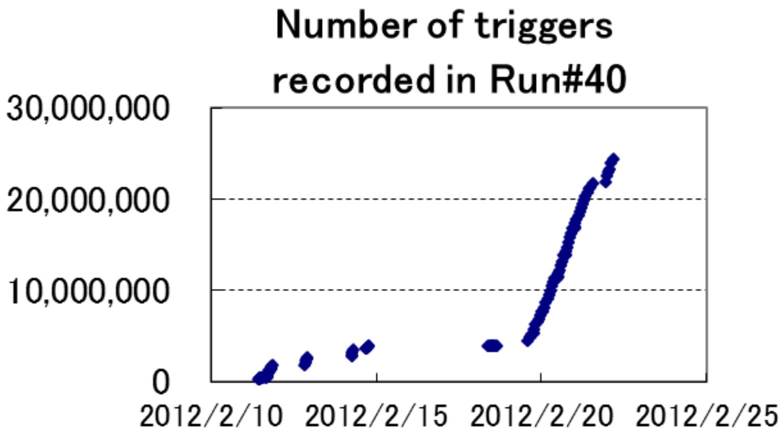
$p\pi^-$ invariant-mass spectra reconstructed by the CDS

~10,000 Λs have been accumulated

Summary of Run40



Run time: 19-22 Feb
Beam PW: 3.3kw
~ 6×10^{8} K^{-} on Target
~25M events recorded

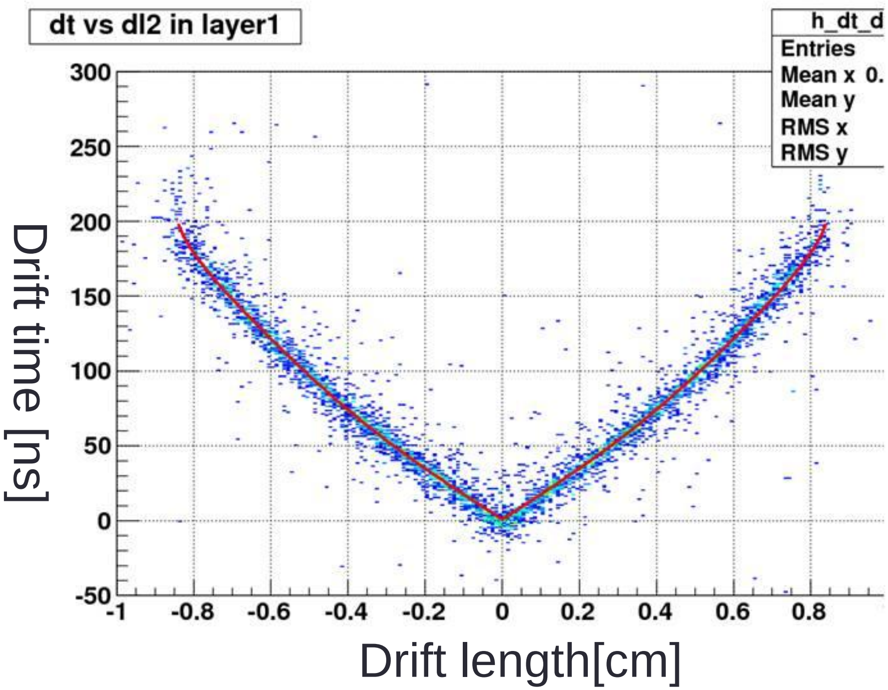


- Trigger
  - CDH2Hit X (K or π) ~40/50 run
  - CDH2Hit X K + CDH1Hit X K ~10/50 run

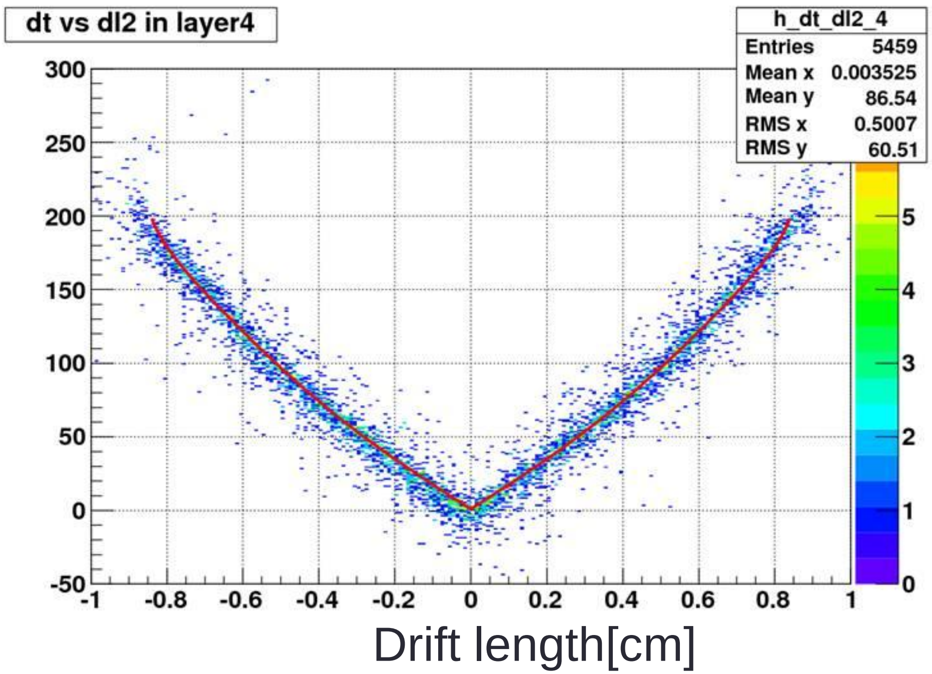
うち、いくつかに試験的にprescaled beam or K を混ぜる

XT Curve

Layer1(axial)

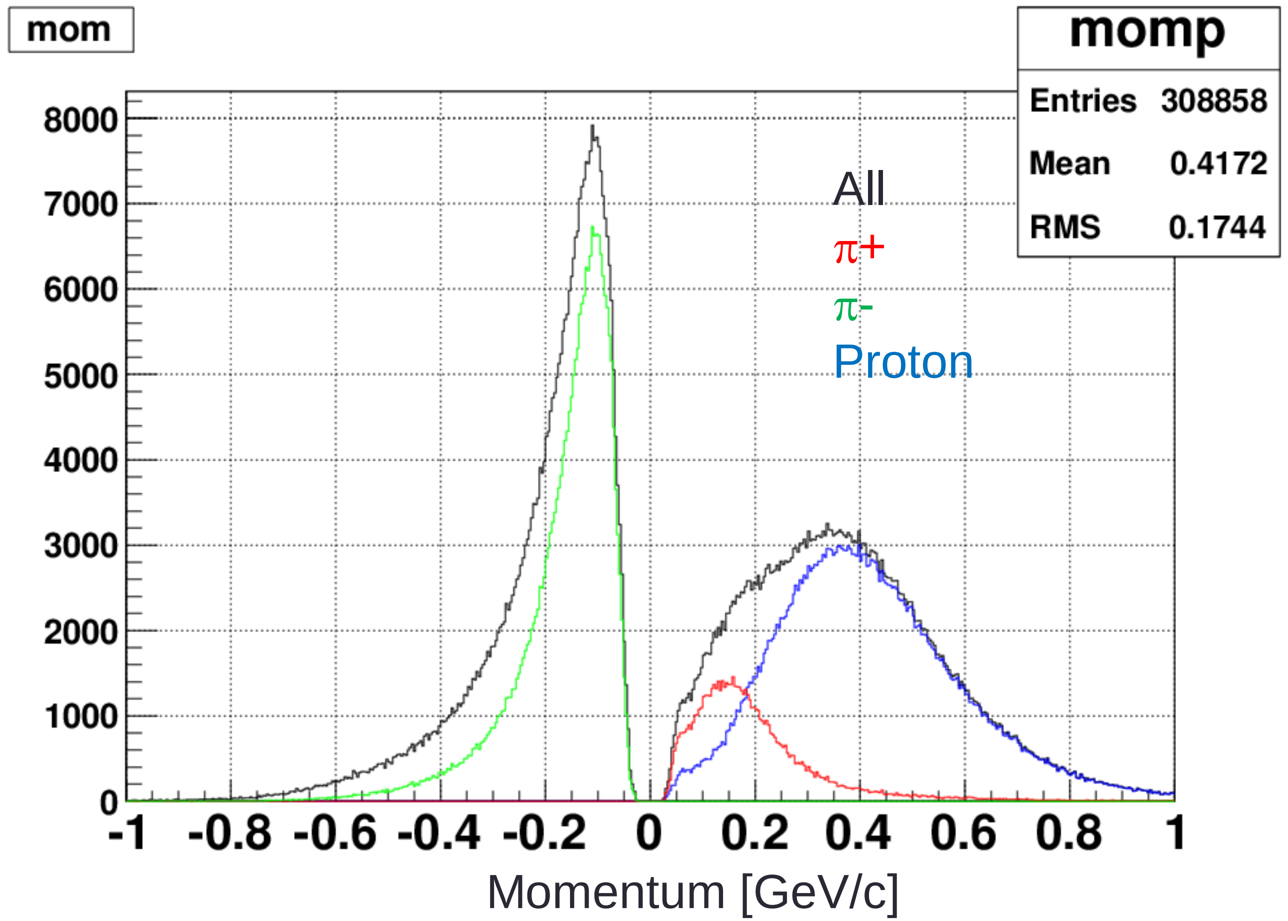


Layer4(stereo)

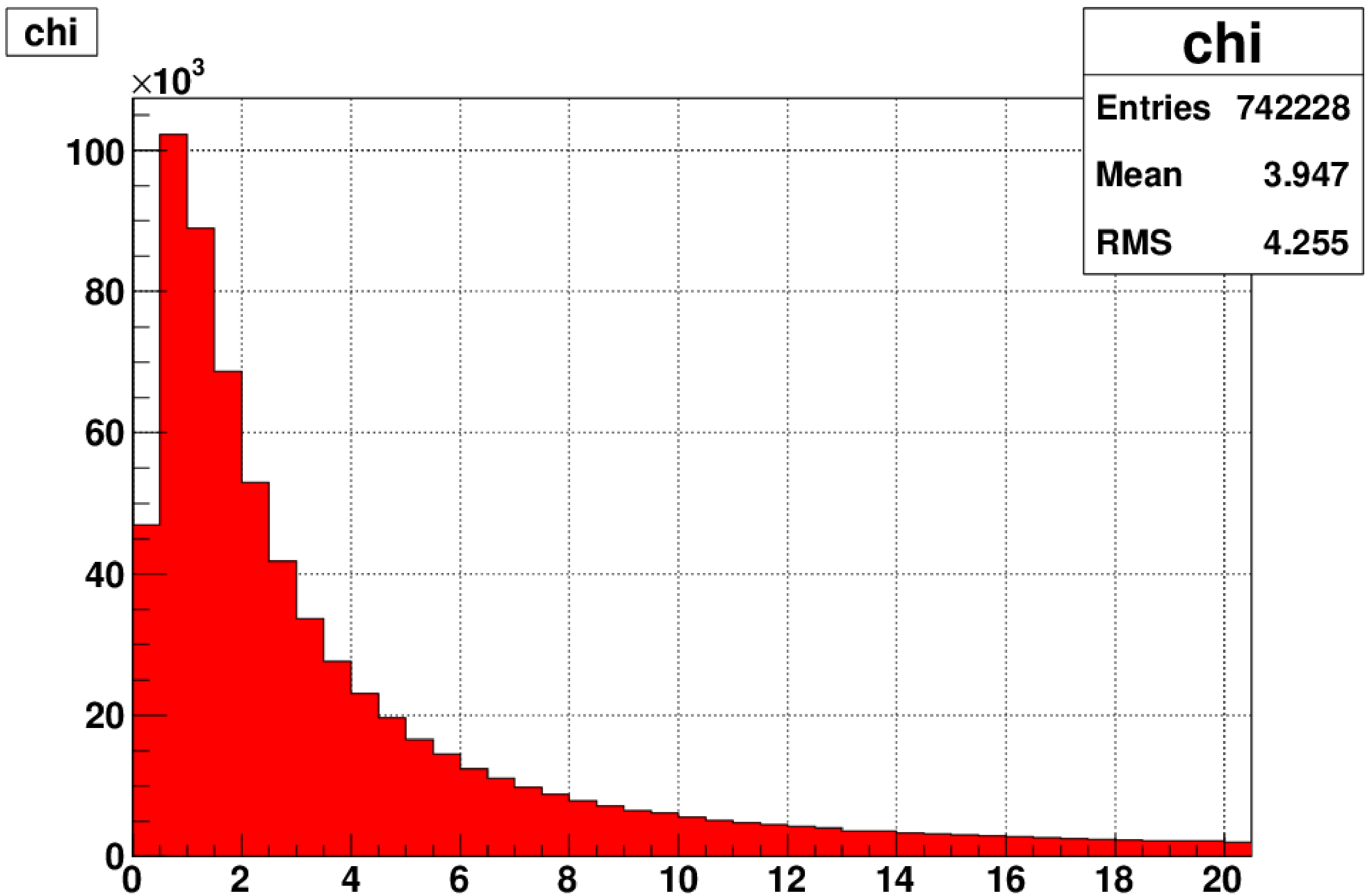


- XT curve of first axial layer(layer1) and first stereo layer (layer4)
- Fitting with "$f(t)=a^0+a^1t+a^2t^2+a^3t^3+a^4t^4+a^5t^5$"

Momentum distribution



Reduced Chi-squares



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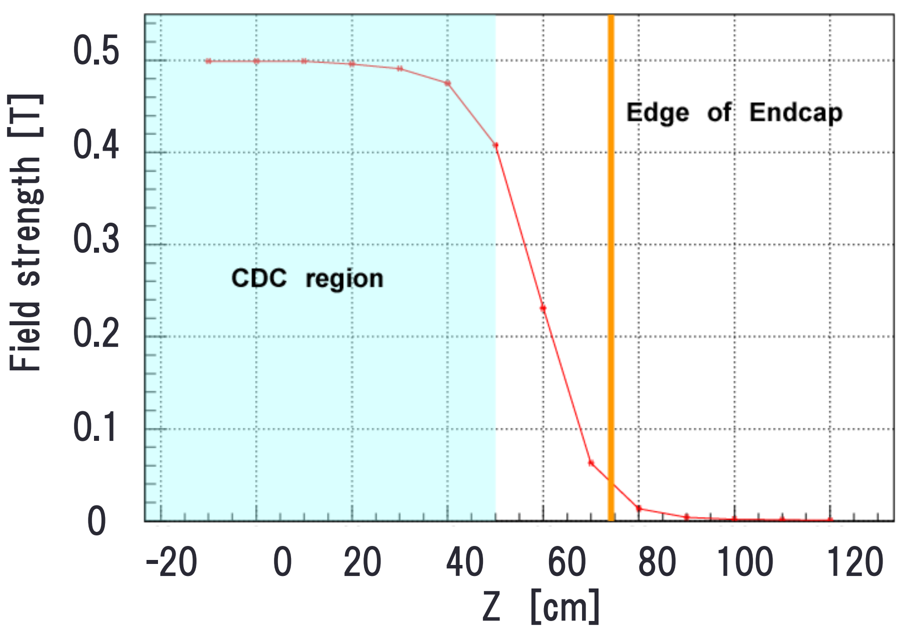
Magnet

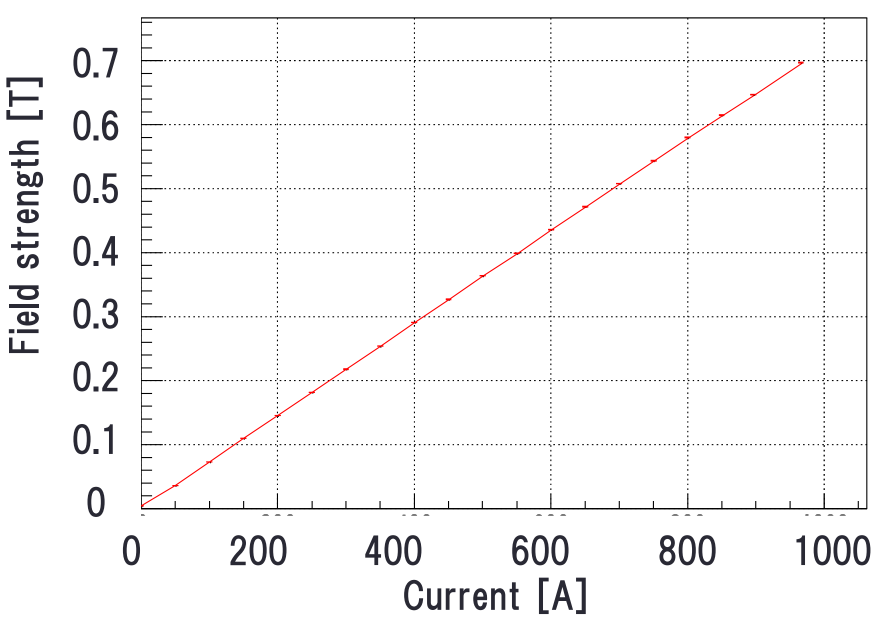
Achieved Design value!
(max field : 0.7T)

- Field strength : 0.5 T
(maximum field : 0.7 T)
- Aperture : 1.2 m
- Length : 1.2 m

Field strength of Z dependence



Characteristic curve (B vs A)

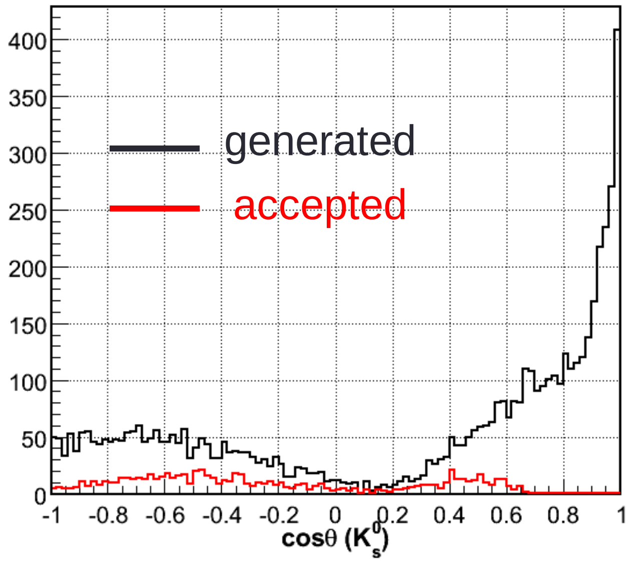


K^0s simulation

assumptions

- Incident momentum of K^- : 900 GeV/c
- Target : Carbon (5mm thickness)
- $K^-p \rightarrow K^0s\ n$, $K^0s \rightarrow \pi^-\pi^+$
  (including angular dep.)
- Magnetic field : 0.5 T
- CDC spatial resolution : 200~350 μm

Nucl.Phys.B 39 (1981) 21.



Yield estimation for K^0s

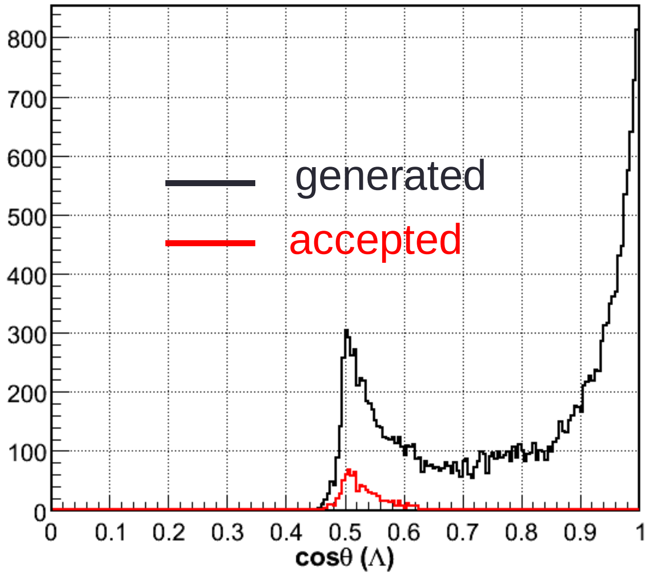
- **Yield = N_{kaon} x *t* x σ x *r* x A x ε x 1/e**
  - **N_{kaon}** : number of incident kaon per spill -> **10k/spill**
  - ***t*** : target -> 1.80 [g/cm^3] / 12 [g/mol] x 6.02 x 10^{23} [mol^{-1}] x 0.5 [cm] ~ **4.5 x 10^{22} [cm^{-2}]**
  - **σ** :total cross section ($K^-p \to K^0_s n$) -> **7.16 x 2 [mb]**
  - ***r*** : branching ratio ($K^0s \to \pi^+\pi^-$) -> **0.69**
  - **A** : acceptance (%) -> **14.1 [%]**
  - **ε** : overall efficiency (trigger, detector, ana., etc)-> **0.7**
  - **1/e** : vertex cut
- Yield ~ **1.6 x 10^{-1} K^0s's/spill**
- 600 [spills/hour] x 8 [hours/shift] x 1.6 x 10^{-1} [K^0's/spill] ~ **7.8 x 10^2 K^0s's/shift**

Λ simulation

assumptions

- Incident momentum of K^- : 900 MeV/c
- Target : Carbon (5mm thickness)
- $K^-N \rightarrow \pi\Lambda$, or $K^-N \rightarrow \pi\Sigma^0 \rightarrow \pi\gamma\Lambda$,
  $\Lambda \rightarrow \pi^- p$
  (including angular dep.)
- Magnetic field : 0.5 T
- CDC spatial resolution : 200 μm

Nucl.Phys.B 115 (1976) 82.



Yield estimation for $K^-n \rightarrow \pi^-\Lambda$

- **Yield = N_{kaon} x *t* x σ x *r* x A x ε x 1/e**
  - **N_{kaon}** : number of incident kaon per spill -> **10k/spill**
  - ***t*** : target -> 1.80 [g/cm^3] / 12 [g/mol] x 6.02 x 10^{23} [mol^{-1}] x 0.5 [cm] ~ **4.5 x 10^{22} [cm^{-2}]**
  - **σ** : cross section ($K^-n \rightarrow \pi^-\Lambda$) -> **11.3 x 2 [mb]**
  - ***r*** : branching ratio ($\Lambda \rightarrow \pi^- p$) -> **0.63**
  - **A** : acceptance (%) -> **6.9 [%]**
  - **ε** : overall efficiency (trigger, detector, ana., etc)-> **0.7**
  - **1/e** : vertex cut
- Yield ~ **1.1 x 10^{-1} Λ's/spill**
- 600 [spills/hour] x 8 [hours/shift] x 1.1 x 10^{-1} [Λ/spill] ~ **5.5 x 10^2 Λ's/shift**
- **Total 7.6 x 10^2 Λ's/shift (include all reactions)**