Paper presentation for the PQ search "Search for a narrow baryonic state decaying to pK_S^0 and $\bar{p}K_S^0$ in deep inelastic scattering with the HERA II data"

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Update from the last draft circulation

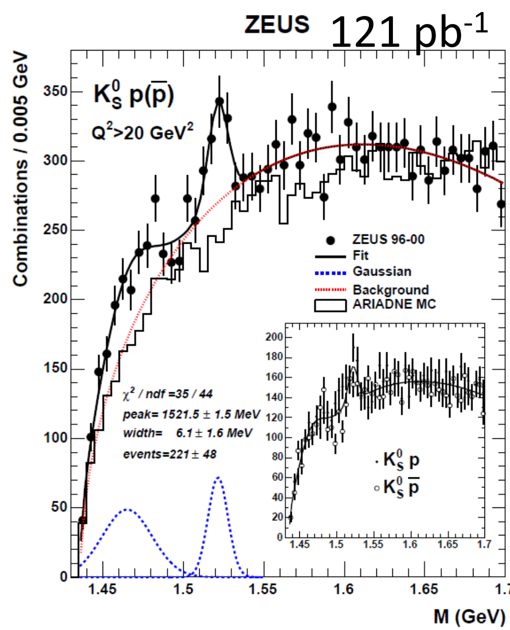
- The figures were updated.
  - pK mass plots for DIS and PHP samples with wider range to show Λ_C peak were added in fig.3(a, b).
  - The dashed line was added corresponding to the HERA I result on HERA II result in fig.3(c).
  - A pK mass plot was added with CTD-dE/dx-only PID in fig3.(d).
  - H1 HERA I result was shown in fig.4(b).
  - The results of cross section limit were added with the width determined by the mass resolution in fig.4(b).
- Pion rejection factor was calculated with various PID options by using pions from K_S^0 decay.
- Global proton PID efficiency correction was applied instead of event-by-event correction (a factor ~30% better limit).
- Cross section was presented for Θ-> pK^0 instead for Θ->pK_S^0 (a factor 2 larger than previous).
- The systematic errors were re-estimated.
- The cross section limit was shown for M(pK); 1.45-1.7GeV (it was 1.435-1.7GeV).
- The sentences was polishing. (Thanks to Iris, Matthew, Peter and Uri)
- Thanks to resent comments from Mikhaylo, Paul and Riccardo.

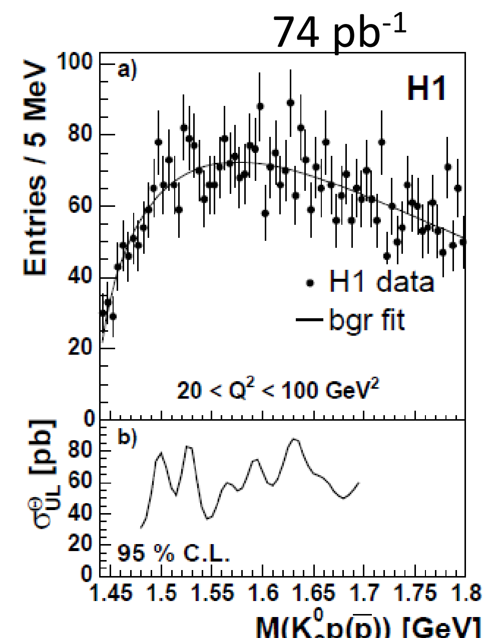
- PQ analysis web page was created (protected with the zeus password) and uploaded analysis materials.
  - https://www.desy.de/~ryuma/PQanalysis.html

Analysis Backgrounds

- ZEUS published the evidence of Θ(1530)-> pK_s^0 ($\bar{p}K_s^0$)with HERA I data (Phys. Lett. B591, 7-22 (2004)). But, H1 did not find a peak structure and set limit on Θ (Phys. Lett. B 639 (2006) 202, DESY Note 06-044). We need to check with HERA II data.
- MVD was installed in HERA II. Protons can be better selected with CTD and MVD dE/dx.

We are looking for pentaquarks DIS event with 20 < Q^2 < 100 GeV^2 in this paper in order to compare with the HERA I results.

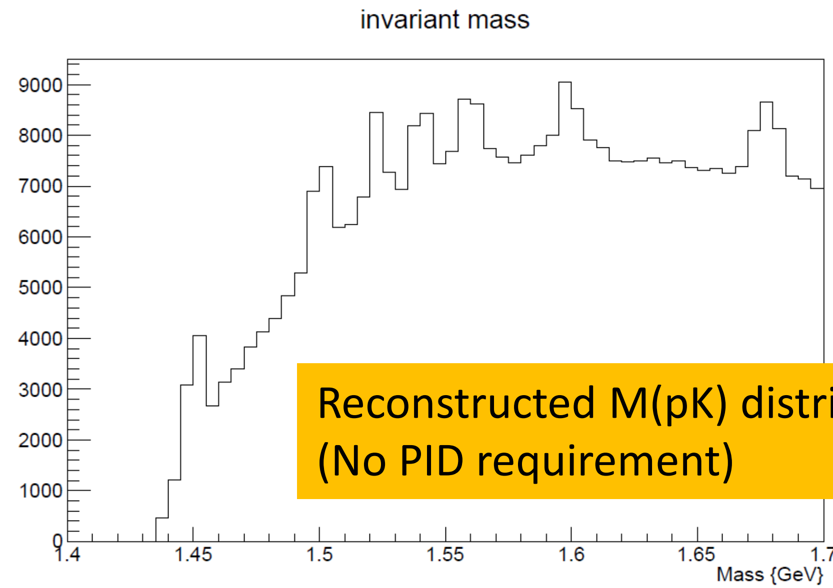




Event selections

PQ MC

- Pentaquark MC: RAPGAP 3.1030 by Formoza (to avoid MC seed problem, very thanks to Yury)
  - At first, $\Sigma^+(1189)$ is produced with its mass shifted to Θ's mass.
  - Σ^+ decays are limited to $p + K_S^0$.
  - Events are generated for the following masses.
    (1.45,1.5,1.522,1.54,1.56,1.6,1.65 GeV)
  - Q^2>1GeV
  - At lease one Θ in |y|<2.5
  - re-funneled with num07t4.1



Reconstructed M(pK) distribution for all MC
(No PID requirement)

Data Set (private ntuple)

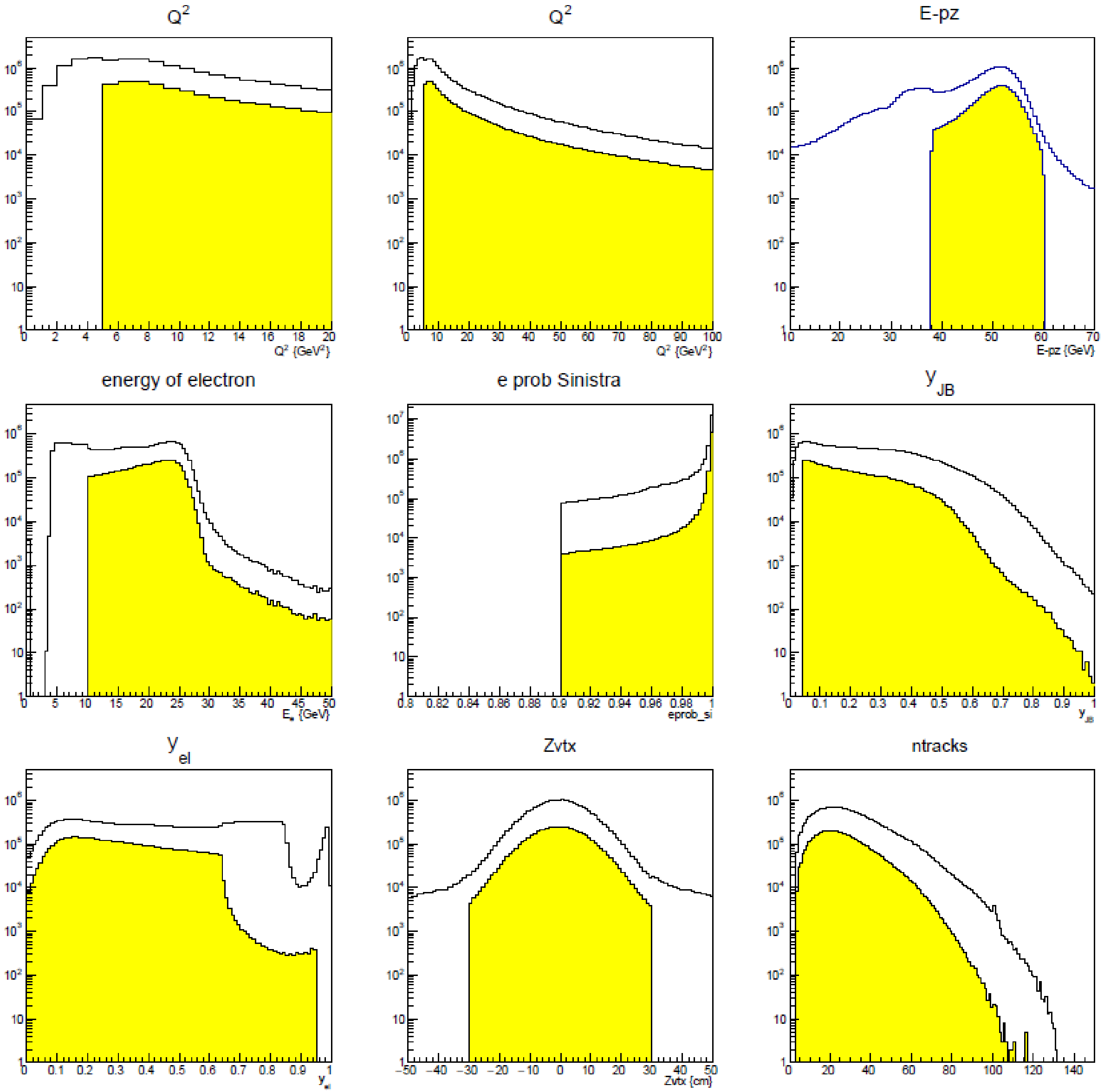
- HERA-II GR data
- Orange 2009a.1
- Pre-selections (ZesLite)
  - Common Section
    - Number of track > 0
    - |Zvtx| < 52cm
    - Number of V0lite (K_S^0) > 0
    - For DIS
      - DSTb9
      - Sinistra's number of electron > 0
    - Tracking RT+DAF (default tracking setting)

	Luminosity(pb^{-1})
2004e^+p	37.55
2005e^-p	135..47
2006e^-p	51.03
2006,7e^+p	135.87
total	358.93

Event selection

- DIS event selection for ntuple
  - $Q^2 > 5$ GeV^2
  - E_e > 10 GeV
  - 38 < E-pz < 60 GeV
  - y_{el} < 0.95
  - y_{JB} > 0.04
  - Electron Probability > 0.90
  - Electron position |x|> 12cm |y|> 12cm
  - |Zvtx| < 30cm
  - Number of track > 2 & < 400
  - At least one track from the primary vertex
  - TLT triggers (SPP02 SPP09)

DIS variables



White: pre-selected

Yellow: after DIS selection

K_S^0 selection

- Two tracks with opposite charge
- $p_T(\pi)$ > 150MeV
- $|\eta(\pi)|$ < 1.75
- π track's MVD hit > 2
- $p_T(\pi\pi)$ > 250MeV
- $|\eta(\pi\pi)|$ < 1.6
- χ^2 < 5.0 (of the two tracks refit with V0lite)
- DCA between two tracks < 1.5 cm (V0lite)
- DCA to beam spot > 0.2 cm (V0lite)
- 2D co-linearity < 0.06 rad
- 3D co-linearity < 0.15 rad
- K_S^0 decay length (DL) > 0.5 cm
- When we assign the electron mass to the track, M(ee) > 70MeV
- When we assign the proton mass to one of the tracks, M(pπ) > 1.121GeV
- Finally, we set a mass window (482MeV < M(ππ) < 512 MeV, blue lines).

$20 < Q^2 < 100\ GeV^2$

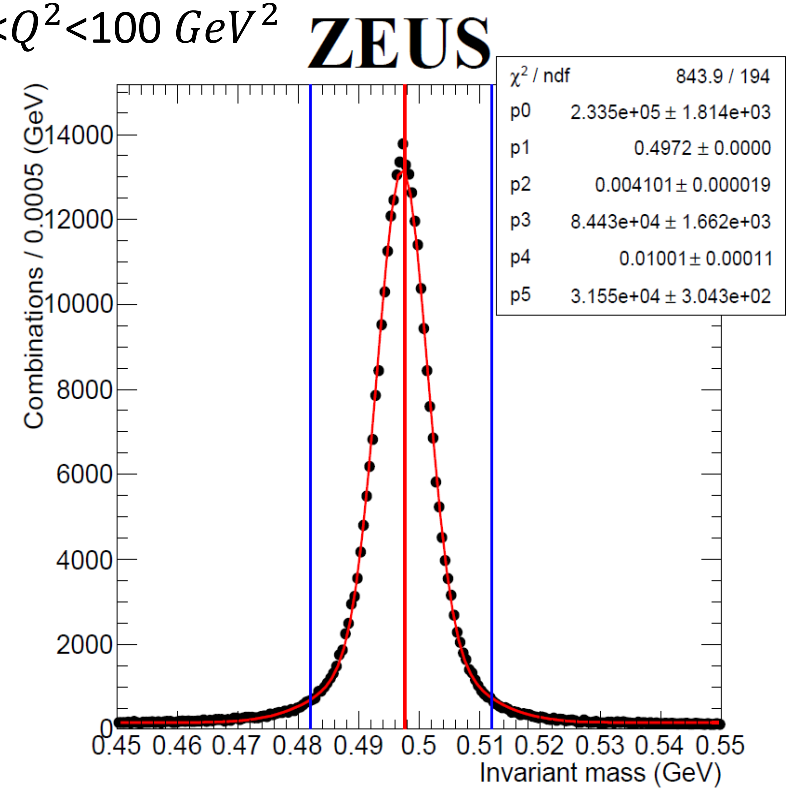
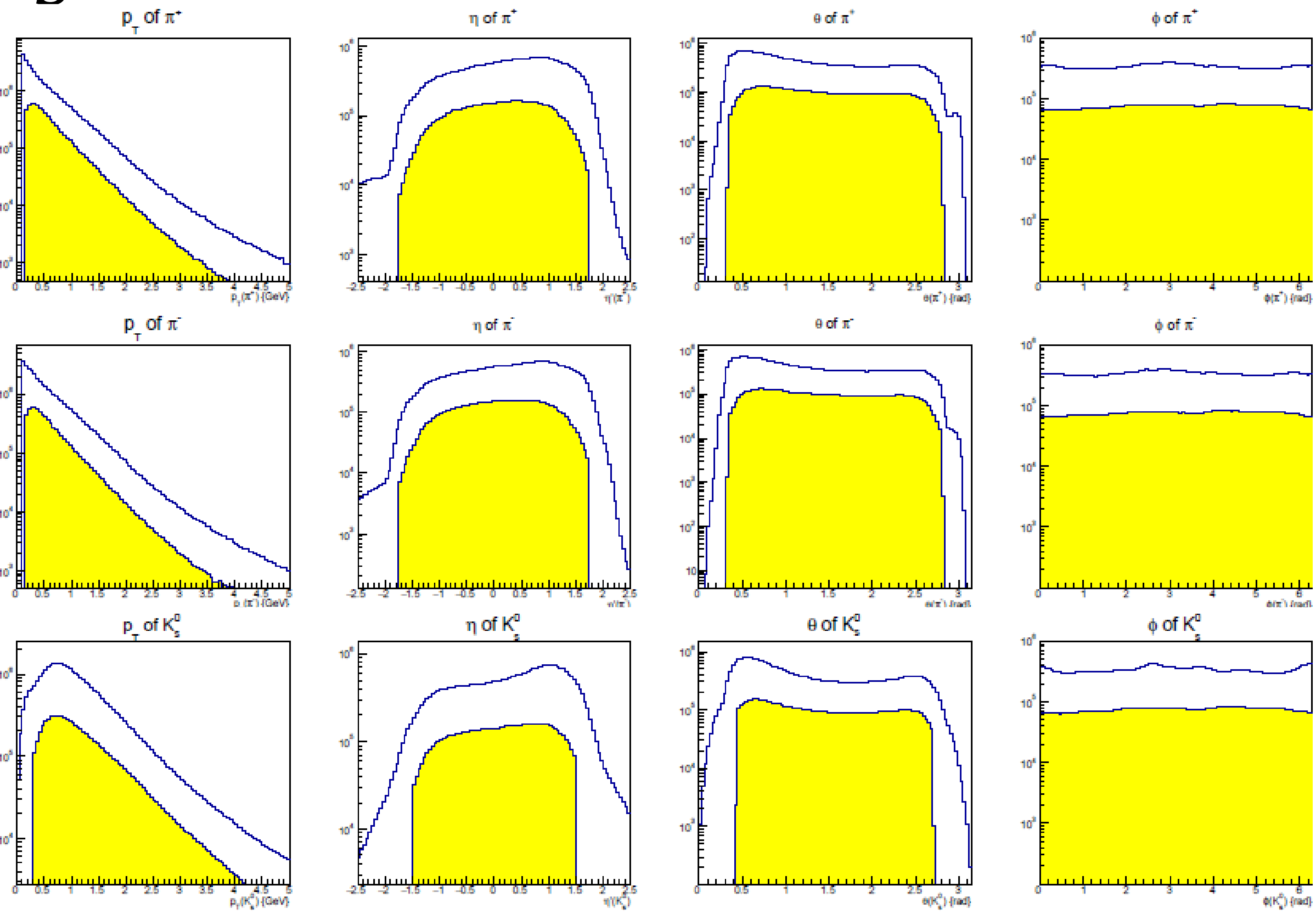


Fig.1 (with double Gaussian fit parameters)

Measured value = 497.178±0.010MeV

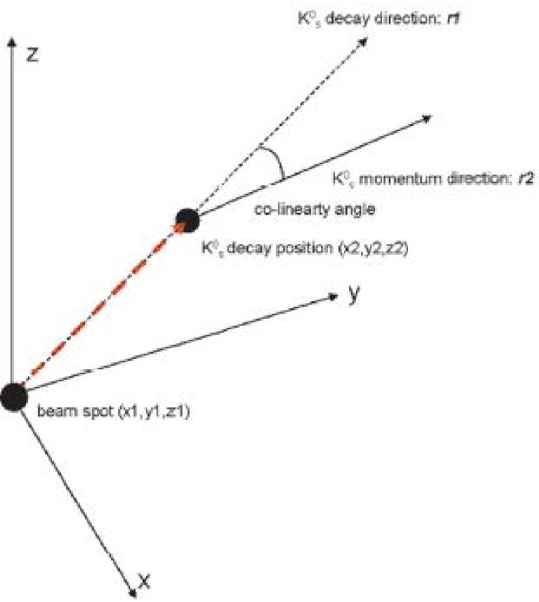
PDG value 497.614±0.024MeV

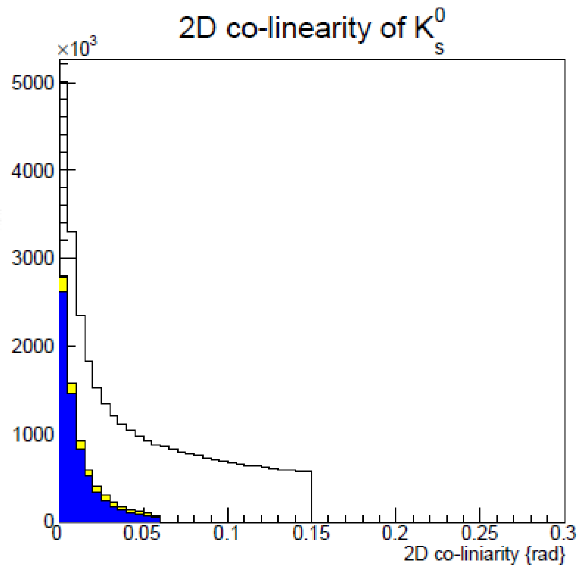
K_S^0 Kinematic variables (1)

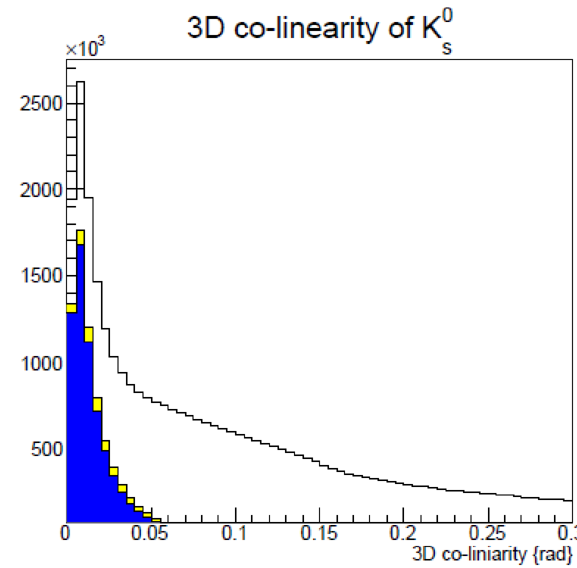


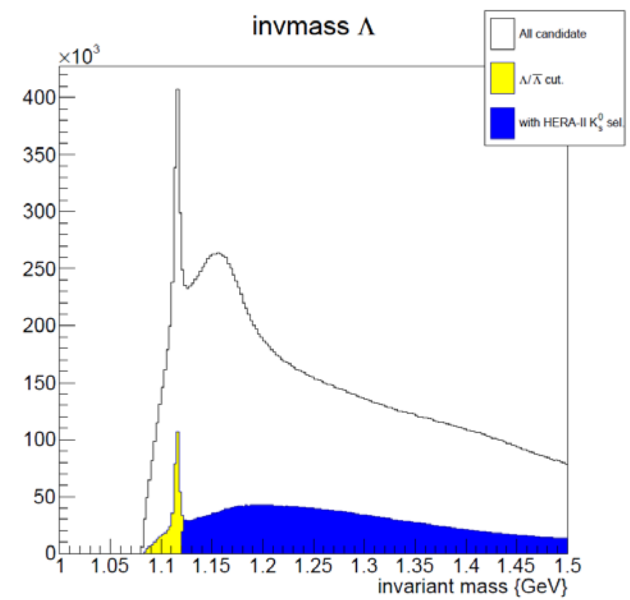
White: before K_S^0 selection, Yellow: after the selection.

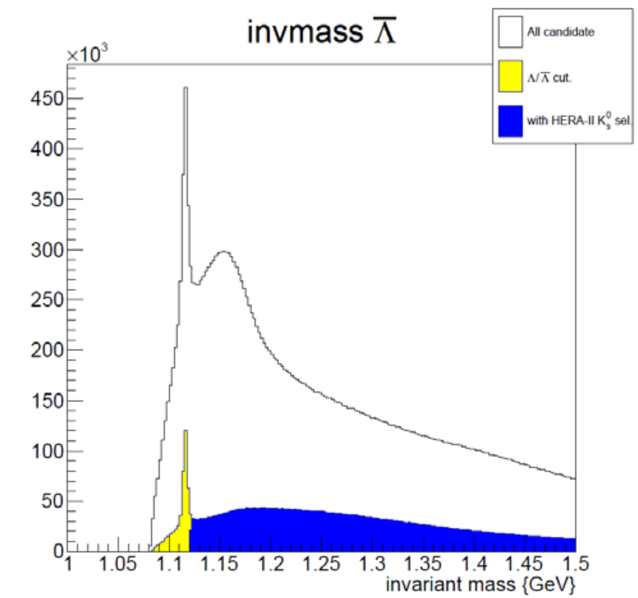
K_S^0 Kinematic variables (2)







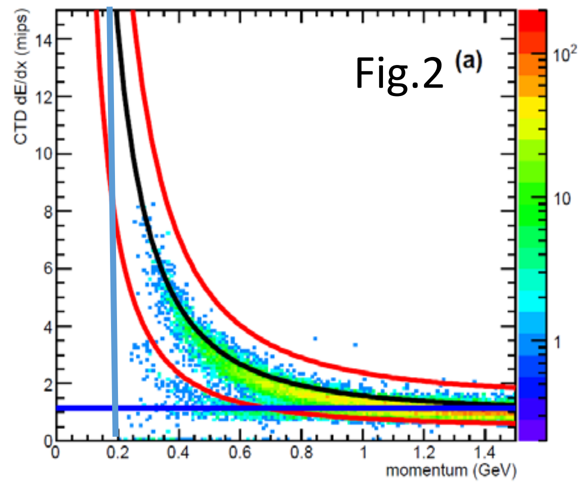




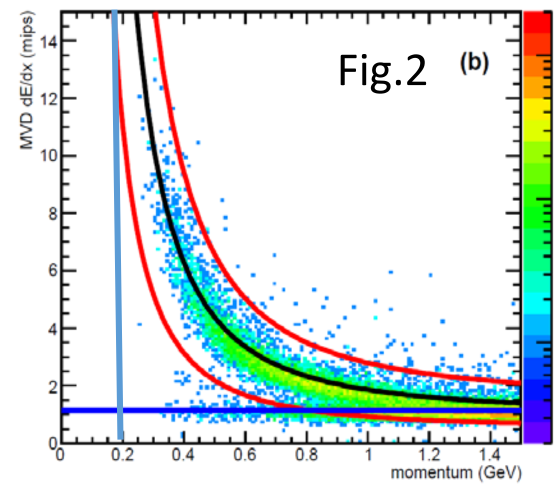
Proton identification for DATA

- Track selections
  - not used as π of K_S^0
  - 0.2 < p(p) < 1.5 GeV
  - CTD innermost layer = 1
  - CTD outermost layer >= 3

CTD dE/dx selected by MVD



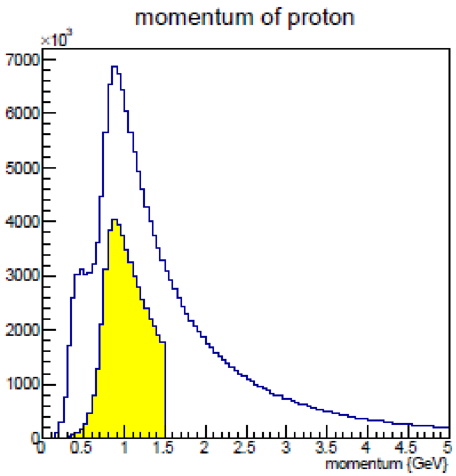
MVD dE/dx selected by CTD

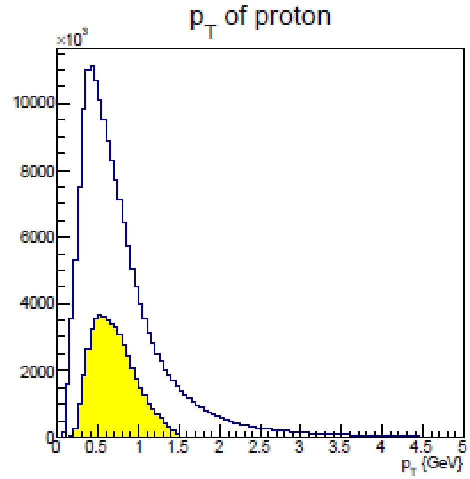


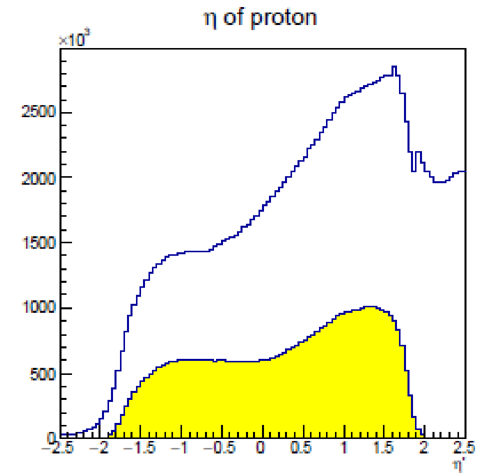
- dE/dx requirements
  - protons had to be within a band centered at the expectation of the parametrized Bethe-Bloch function F. The band is defined 0.5F < dE/dx < 1.5F.
  - dE/dx should be greater than 1.15 in units of mips
  - dE/dx probability likelihood of proton > 0.3.
- PID requirement
  - If CTD dE/dx is valid, both CTD and MVD dE/dx are in the proton bands.
    - If no CTD dE/dx due to saturation, only MVD dE/dx is required.

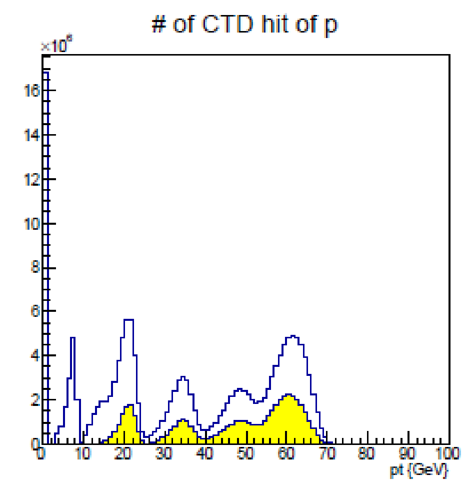
With this logic, we can save more low momentum protons.

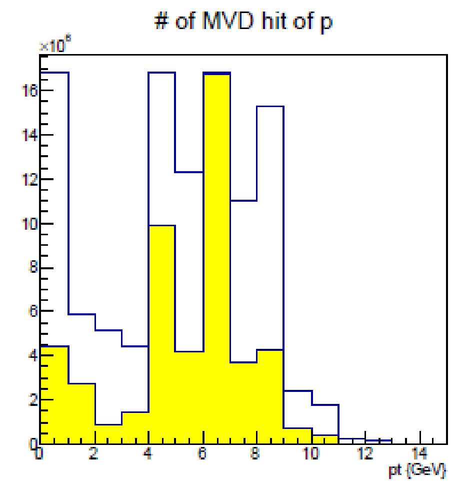
Proton kinematic variables











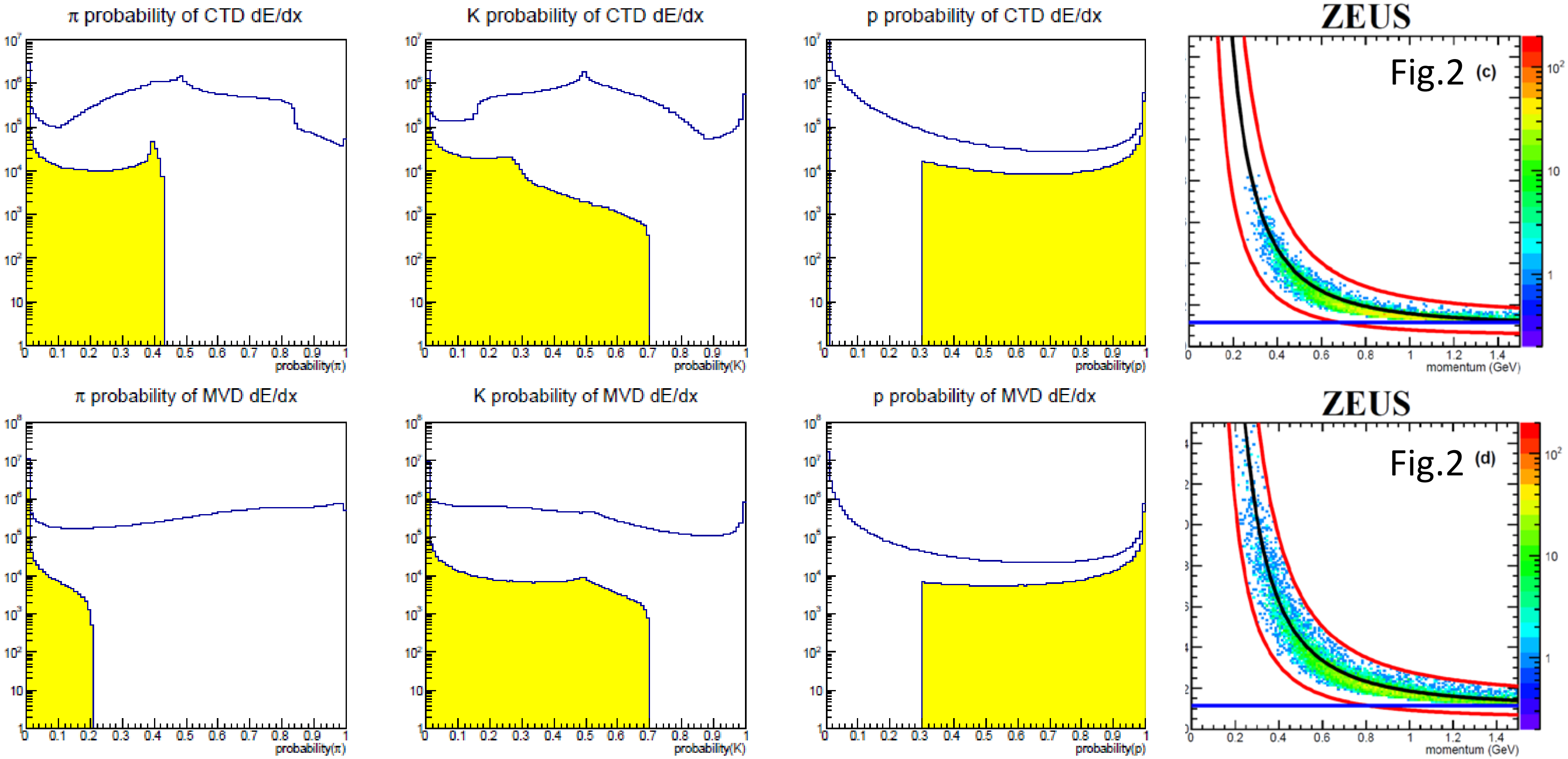
White: pre-selected

Yellow: after proton selection

proton PID (likelihood)

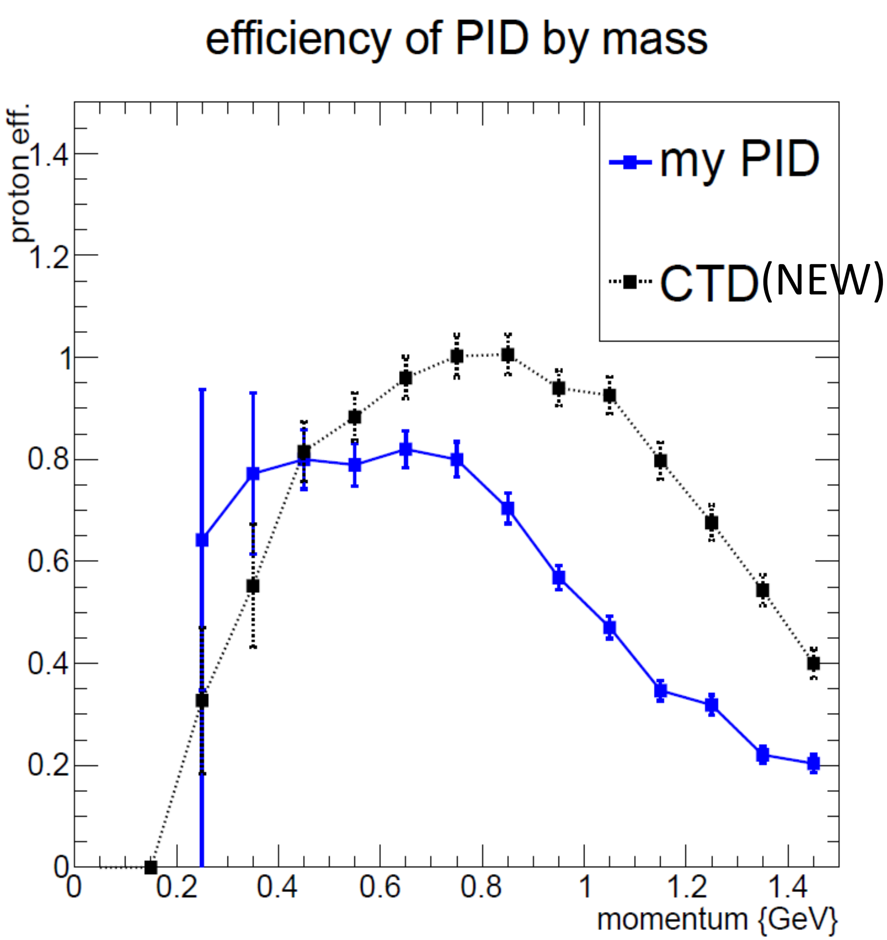
White: pre-selected

Yellow: after proton PID



- Proton dE/dx probability likelihood in PID;
  - dE/dx resolution was ~10% for both detectors.
  - The likelihood is defined $L(p) = prob(p)/\sum_i prob(i)\ \ (i = \pi, K, p)$.
  - This PID can select purely proton.

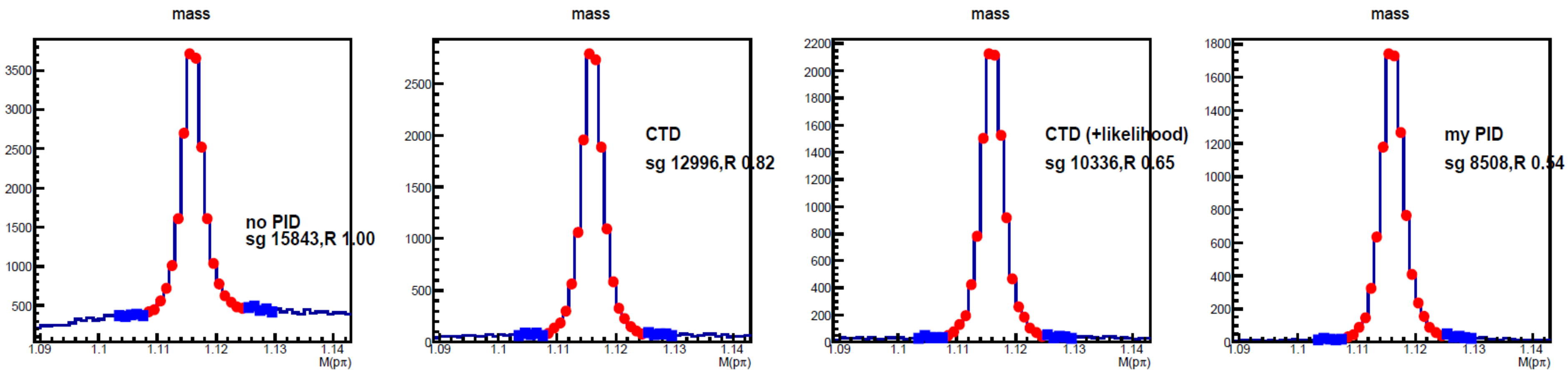
Proton PID efficiency (p in Λ sample)



- Λ sample is selected by V0lite routine which used only track information.
- **Efficiency**

  = (# of Λ w PID)/(# of Λ wo PID)
- my default PID.
  - Based on CTD & MVD + MVD(CTD fail event)
  - dE/dx Band + mip + likelihood
- CTD PID (dE/dx band + mip, HERA I like)
- Based on this figure, we wrote the proton PID efficiency factors. The quotation of the draft;
  - The efficiency (my PID) is about 80% for protons with momentum p < 0.8GeV and then almost linearly decreasing to 20% at p = 1.5GeV.
  - The proton identification efficiency (CTD PID) at high momentum is higher.

PID efficiency in momentum inclusive Λ sample

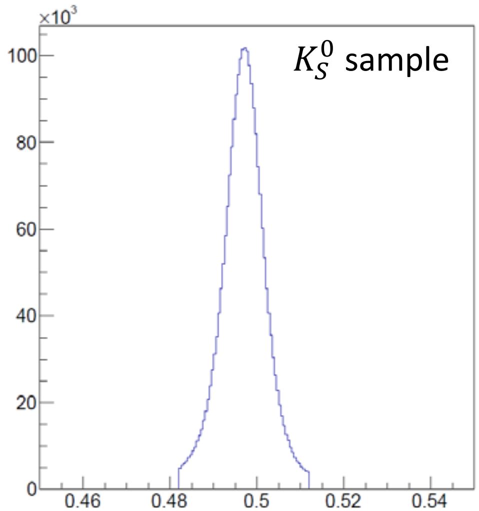


- Ratio = Signal bin (red) – B.G estimated from both sideband bin (blue)
- CTD (band+mip): 82%
- CTD (+likelihood): 65%
- My PID (based on CTD and MVD): 54%
- Based on this figure, we wrote efficiency values (CTD's about 80% and my PID's 54%).

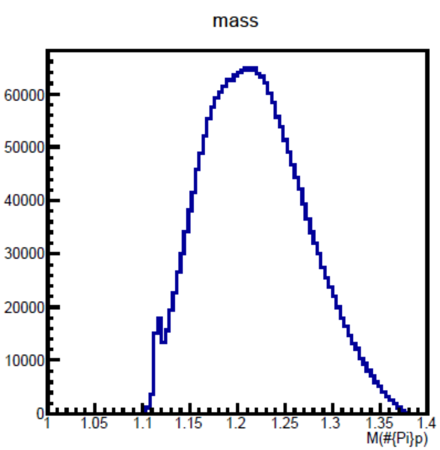
The pion-rejection factor: pions from K_S^0

- K_S^0 sample
  - K_S^0 is selected by std. selections in page.9 (however Λ rejection is removed in order to see the proton efficiency at the same time).
  - Pions of K_S^0 are used as proton candidates.
- PID
  - CTD PID; dE/dx band and CTD dE/dx > 1.15 mips
  - My PID; CTD and MVD + MVD (CTD fail event), dE/dx band, dE/dx > 1.15 mips and dE/dx probability likelihood.
- Check PID effects.

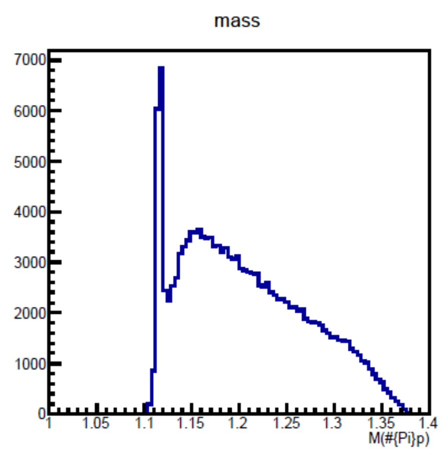
Mass distribution M(pπ) by K_S^0 sample



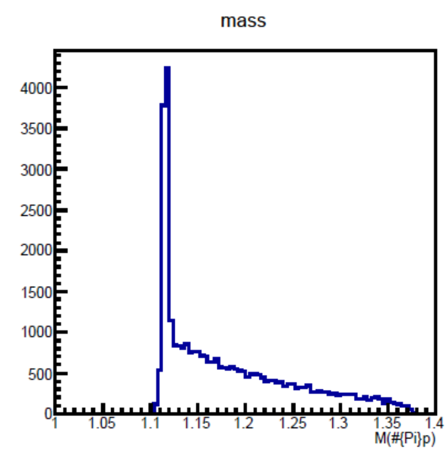
- K_S^0: HERA-II all sample (left plot)
- Check the contamination on (pπ) mass spectrum:
  - Track having higher-momentum is regards as proton.
  - Λ peak is clearly seen in the all samples. The numbers of the Λ are decreased, but pions B.G. are strongly reduced with the new PID.



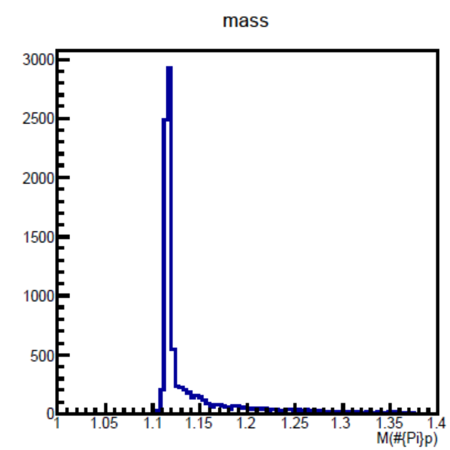
No PID



CTD PID(MIP and band)

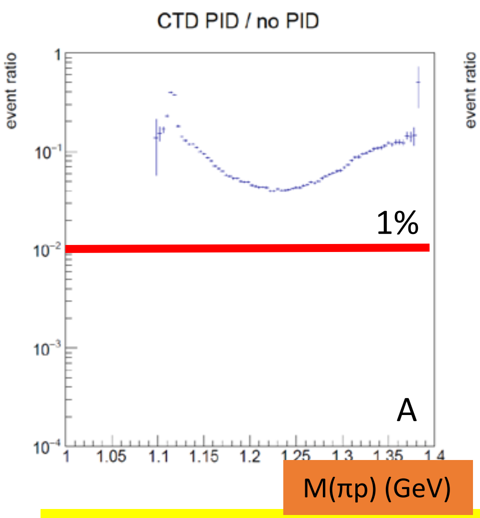


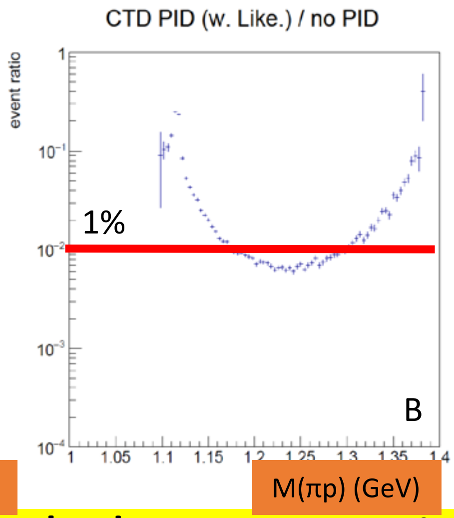
CTD PID(MIP and band + likelihood)

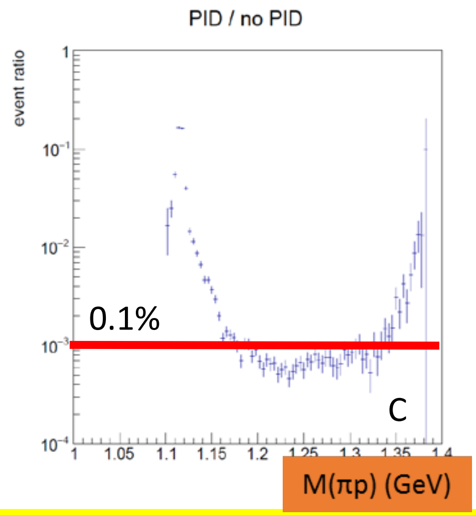


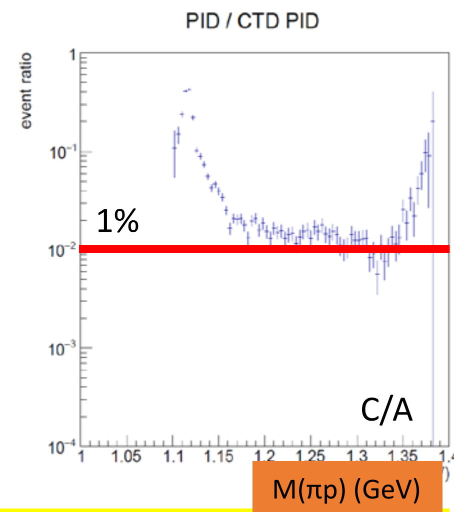
My PID

Ratio of event number (log plot)



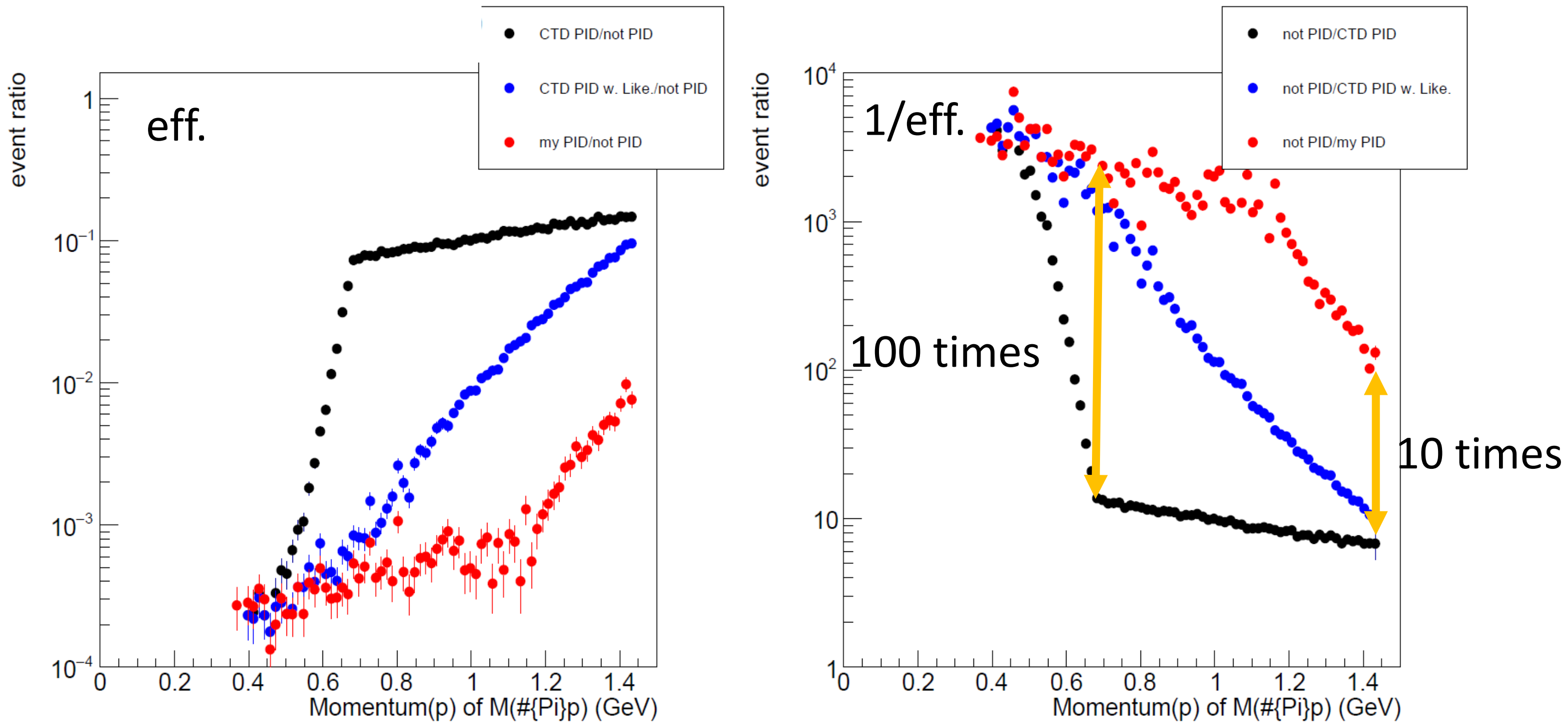






- My PID can exclude π contamination 10 times stronger than CTD only PID.
- This is the base on the statement in paper “The reason of this large reduction is mainly attributed to the tighter PID selection for the proton candidates.”

Ratio of momentum (π event in K0s sample) (eff. = # of event w PID / # of event wo PID)

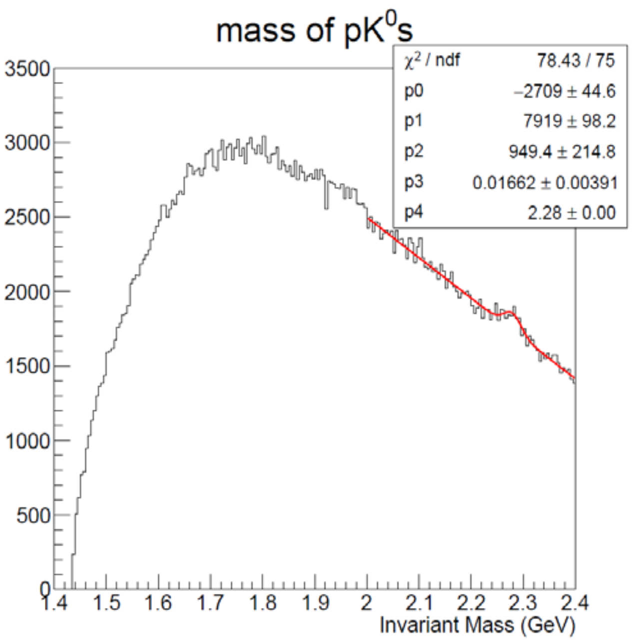


- Red (my PID) decreases pion contamination (10-100 times) than Black (CTD PID, factor ~10) above 0.6 GeV.
- Based on this figure, we wrote the pion-rejection factors.
    - the quotation of the draft; The factor is above 1000 for momenta below 1.2GeV and rapidly decrease to 100 at 1.5GeV.

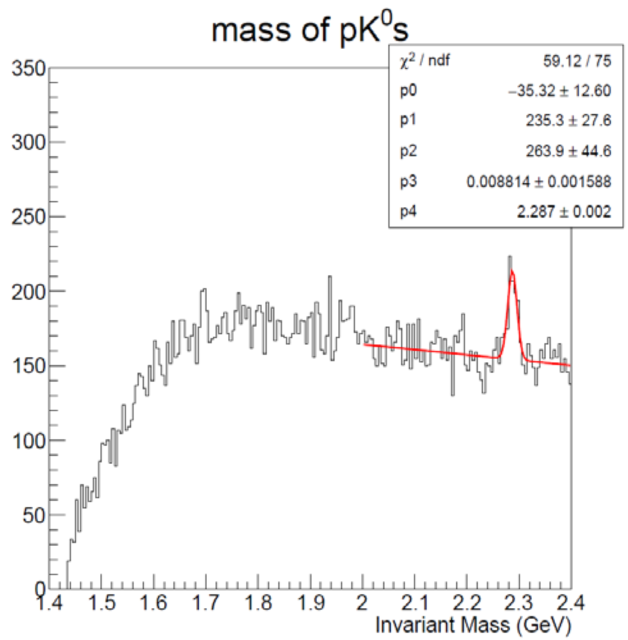
Results

Λ_c^+ Mass

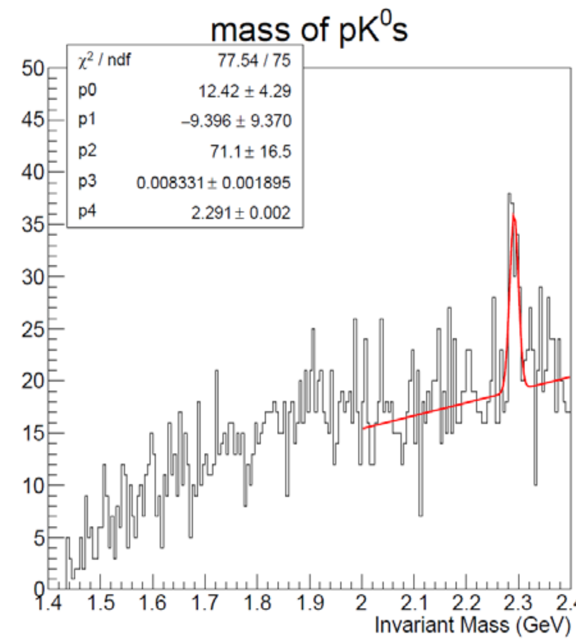
- We show the mass plots with DATA (including PHP)
  - With $\frac{p_T}{E_{Tcone10}}$ cut to enhance charmed jet event.
  - Fit Λ_c^+ by Gaussian (signal) and the resolutions are compared with the MC.



No cut

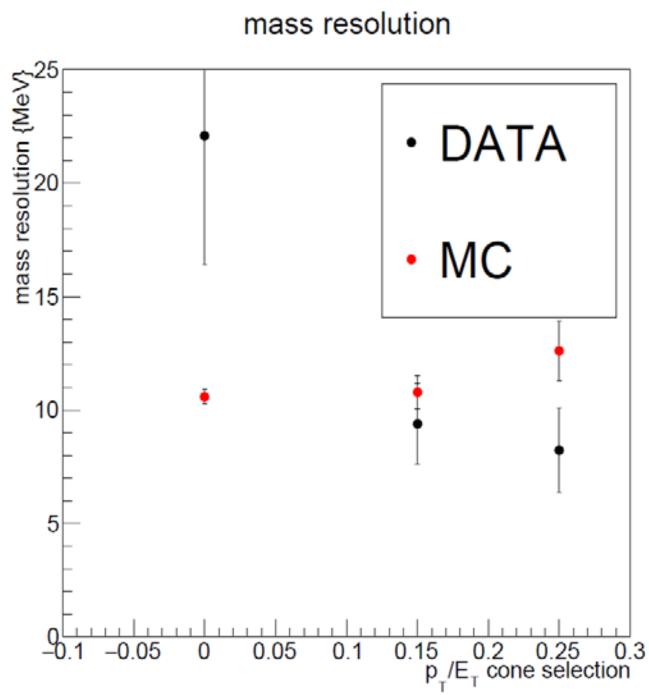


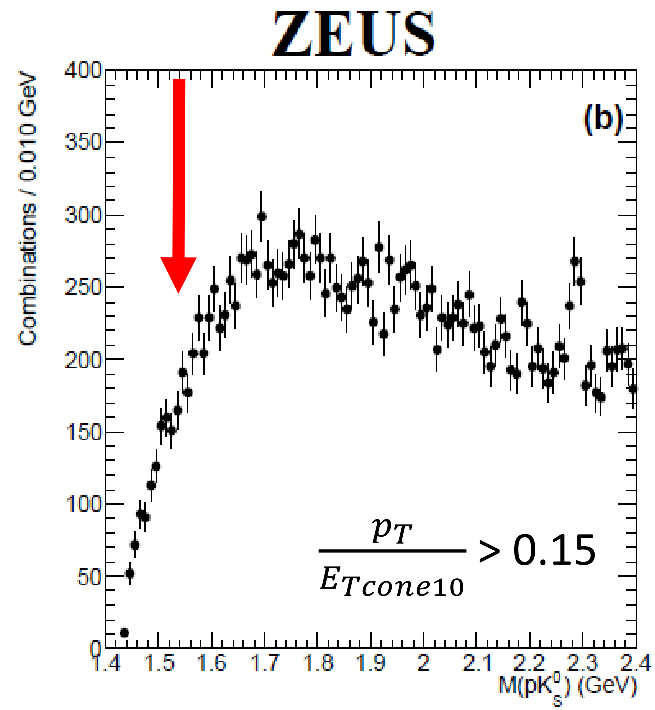
$\frac{p_T}{E_{Tcone10}} > 0.15$



$\frac{p_T}{E_{Tcone10}} > 0.25$

Λ_c^+ Mass resolution and mass plot





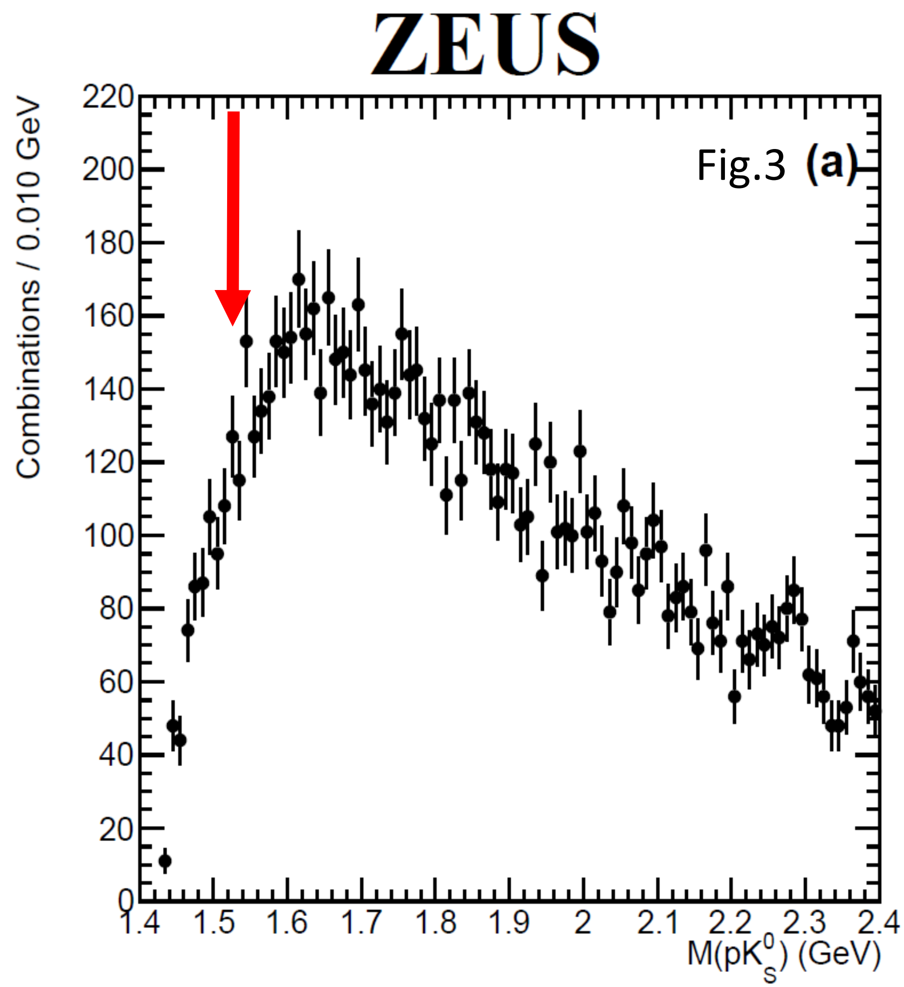
- Λ_c^+ masured mass resolution is consistent between MC and DATA.
- It is noted that $\frac{p_T}{E_{Tcone10}}$ selection enhanced the Λ_c^+ peak but there is no signal emerged in the (1530) area of fig.3(b).

PQ Selection and Mass distribution

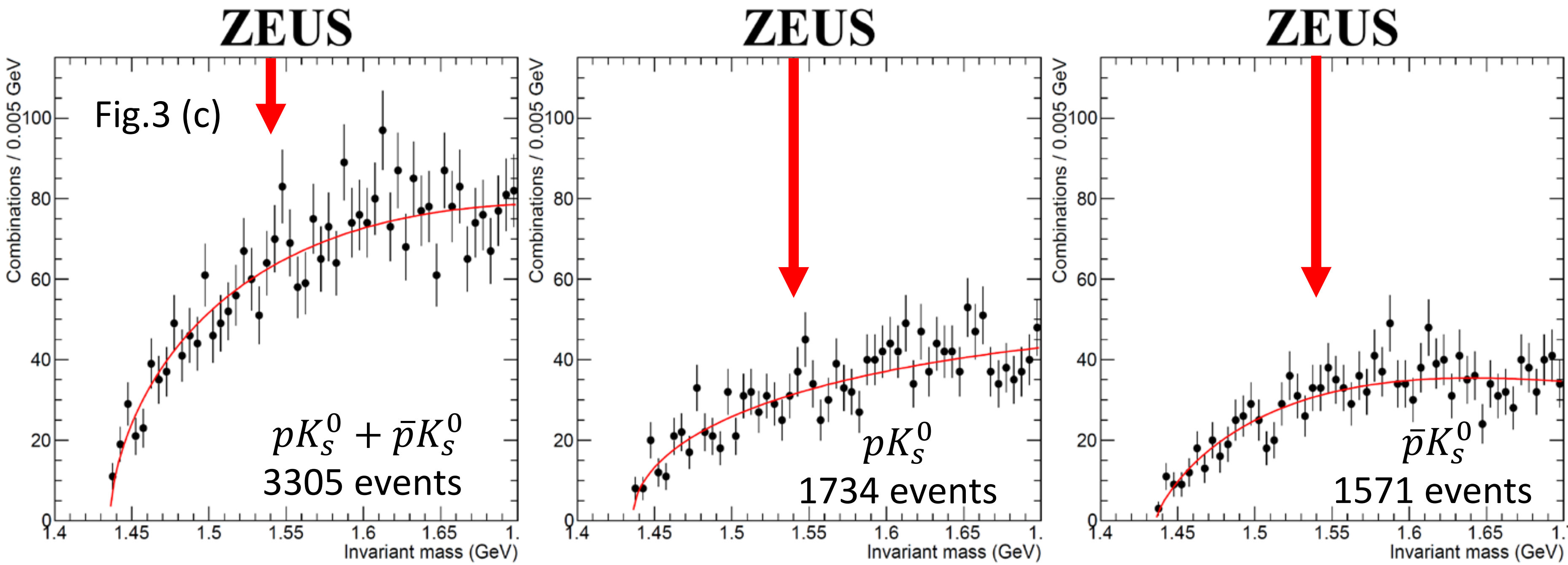
- Q^2 requirement
  - $20 < Q^2 < 100$ GeV²
- pK^0s requirements
  - $0.5 < p_T < 3.0$ GeV
  - $|\eta| < 1.5$

- PQ mass peak is not seen.

=> The limit calculates for production cross section.



Narrower mass distribution and charge separation



Red arrows point to ~1.54 GeV

- Charge separation;
  - Distributions are fitted by the same function.
  - Quotation of the draft: number of event in line 205-210.

Mass peak corresponding to PQ the HERA I results at ICHEP2004

6 Results

The cross section for the Θ^+ baryons and their antiparticles measured in the kinematic region given by $Q^2 \geq 20\,\mathrm{GeV}^2$, $0.04 < y < 0.95$, $p_T > 0.5\,\mathrm{GeV}$ and $|\eta| < 1.5$ was:

$$\sigma(e^{\pm}p \to e^{\pm}\,\Theta^+\,X \to e^{\pm}\,K^0 p\,X) = 125 \pm 27(\mathrm{stat.})^{+36}_{-28}(\mathrm{syst.})\ \mathrm{pb}.$$

Figure 2 shows the cross section integrated above $Q^2_{\min}$. Figure 3 shows the ratio of this cross section to that of the Λ cross section integrated above $Q^2_{\min}$, where the ratio, defined in the same kinematic region as above, is

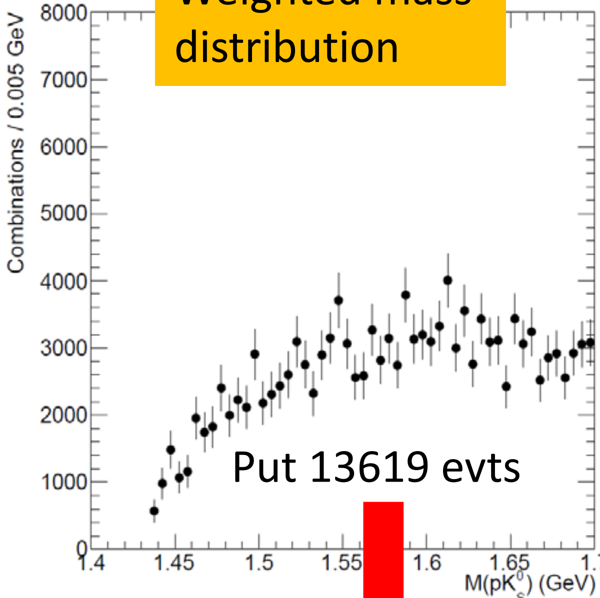
$$\mathrm{ratio} = \frac{\sigma(e^{\pm}p \to e^{\pm}\,\Theta^+\,X \to e^{\pm}\,K^0 p\,X)}{\sigma(e^{\pm}p \to e^{\pm}\Lambda X)}.$$

This ratio, for $Q^2_{\min} = 20\ \mathrm{GeV}^2$, is $4.2 \pm 0.9(\mathrm{stat.})^{+1.2}_{-0.9}(\mathrm{syst.})\%$ and, in the current data, shows no significant dependence on $Q^2_{\min}$. Since the Θ^+ has other decay channels in addition to $\Theta^+ \to K^0 p$, this ratio sets a lower limit on the production rate of the Θ^+ to that of the Λ-baryon.

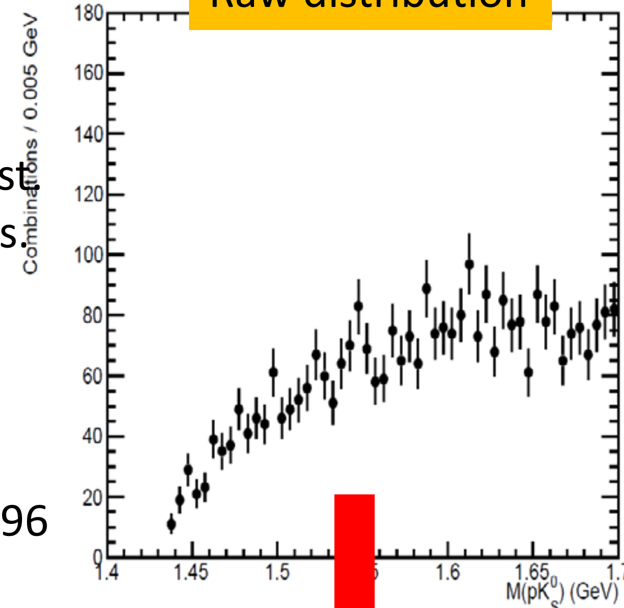
- Integrate luminosity;
  - (121 pb^{-1}; HERA-I)
  - 358.93 pb^{-1}; HERA-II
- Same kinematical Range (y , p_T and η)
- Θ cross section (125 pb)
- Changing factors to event number.
  - Branting mode includes K_S and K_L mode; 0.5
  - K_S→$\pi^0\pi^0$branch correction; 0.69
  - Q^2-range change from Q^2>20 to 20-100 GeV^2 (estimated by MC); 0.85
- Estimation of number of events
  - (HERA-II luminosity)*(cross section)*(factors) = 13619 evts
- A peak puts on invariant mass distributions in next page.

expected signal from HERA I result

Weighted mass distribution



Raw distribution

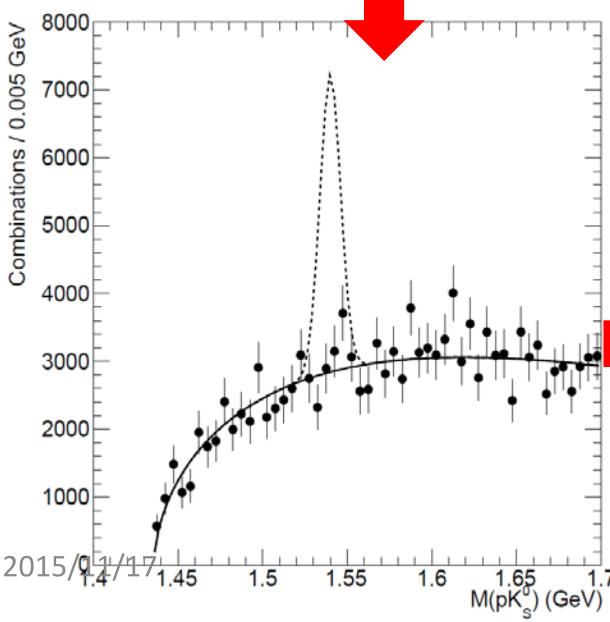


Efficiency weighted dist.
@1.54 GeV ~ 2896evts.

Raw distribution
@1.54 GeV = 64 evts.

Weight factor ~ 60/2896

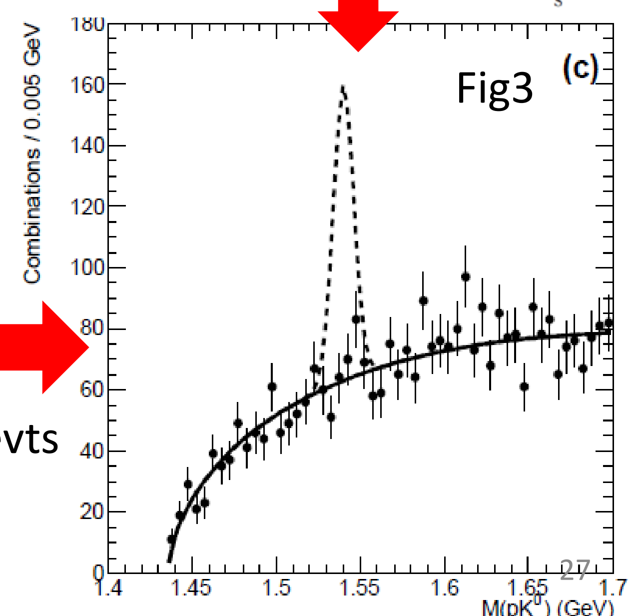
Put 13619 evts



Convert by factor

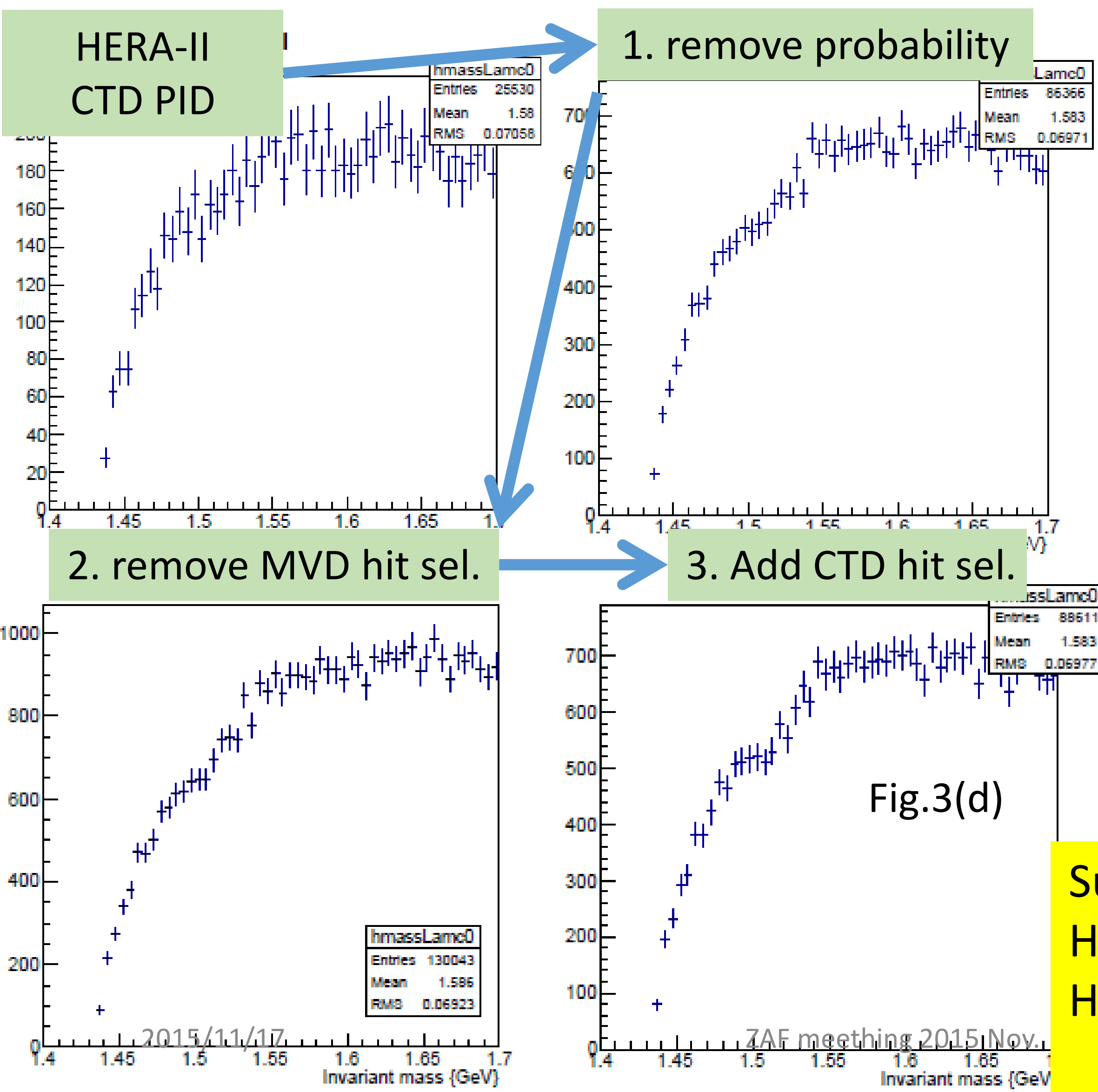
13619 evts -> 276 evts

Fig3



Modification of CTD PID selections to like-HERA I logic

L=358.93 pb^{-1}



- PID is modified to HERA I-logic following 3 requirements.

1 Remove dE/dx likelihood L(p) > 0.3 selection

-> increase ~3 times

(25530->86366evts)

2 Remove MVD hit > 2 selection for pions from K_s^0

->increase ~1.5 times

(86366->130043evts)

3 Add CTD hit > 40 requirement for proton.

-> decrease ~0.7 times

(130043->88611evts)

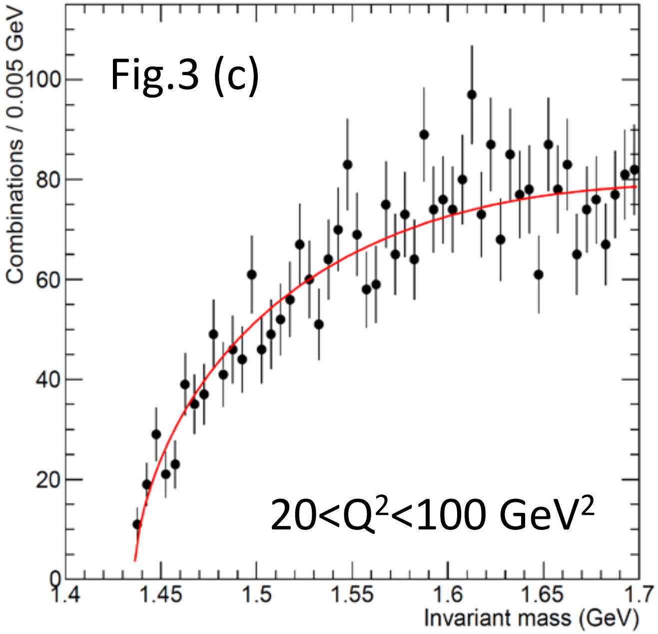
Summary:
HERA II(MVD+CTD) : 10604 Events
HERA I -like: 88611 Events
-> x 8.4 times increase

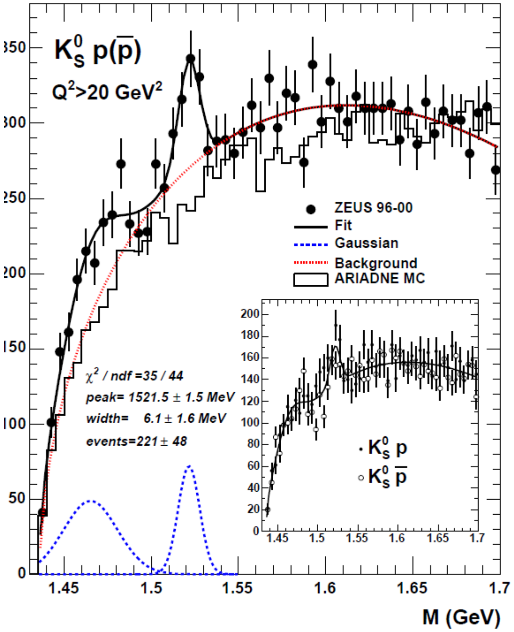
pK_S^0 mass plot comparison

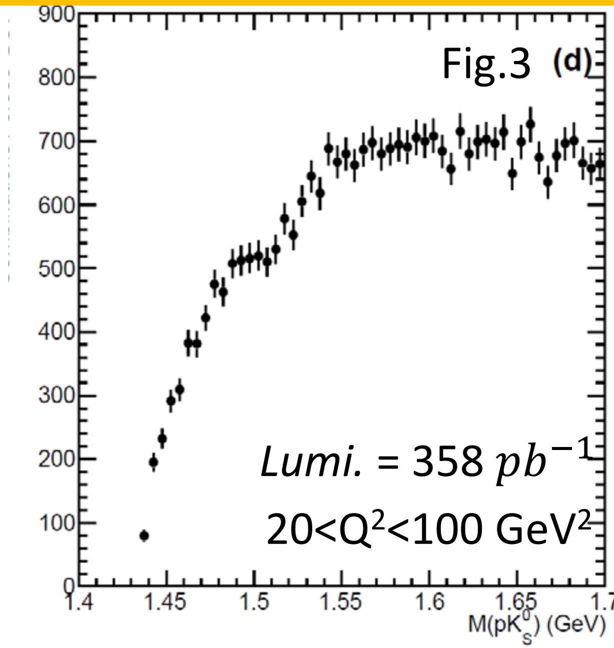
my PID selections

Lumi. = 121 pb^{-1}

CTD PID selections to HERAI logic







- HERA II event yield per luminosity is ~1/10 of HERA I. This reason seems that Pion rejection factor of my PID is higher than HERA I-logic PID.
- If we use only CTD PID as same selections in HERA I analysis as possible, the number of event per luminosity increases back to ~75% of HERA I yield.

Upper limit of the production Cross section.

Mass weighting Procedures

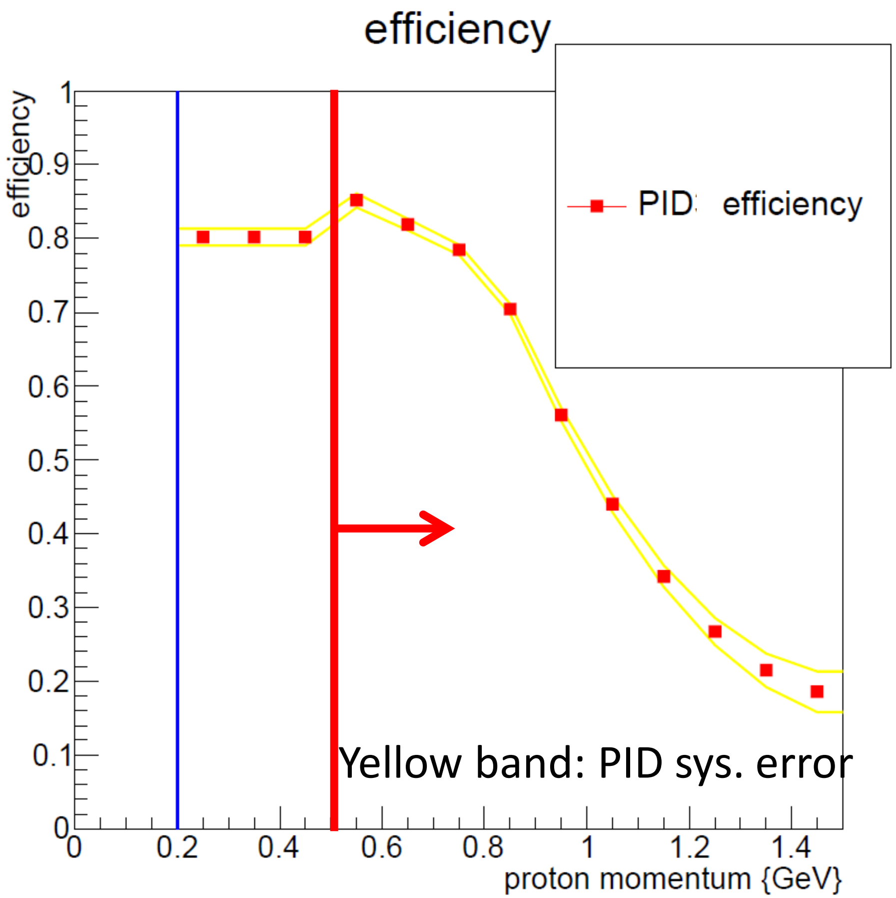
- For each M(pK_S^0), a weight(ε) is determined to correct for the following;
  - (1) Efficiency of proton identification.
  - (2) Acceptance of Θ:
    correction for decay angle assuming isotropic decay.

$$\varepsilon = \varepsilon_{\text{proton PID}}(p^{\text{proton}}) * \varepsilon_{\text{decay angle}}(p_T^{pK}, \eta^{pK})$$

  - (3) In addition, acceptance of DIS selection is calculated.
- The weight factors are calculated by MC.

In the following slides, we will explain these one by one.

(1) Proton PID efficiency with the data using Λ(1115)



Λ sample selected from DATA sample by V0lite routine which used only track information (Λ mass plots shown in backups)

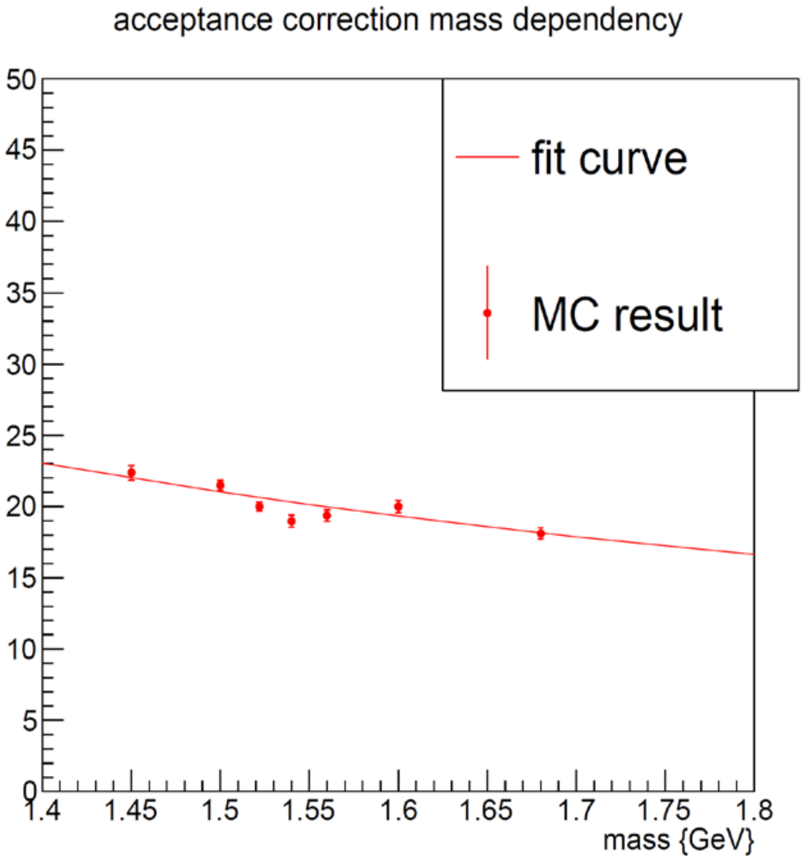
Efficiency $\varepsilon_{proton\ PID}(p^{proton})$

= (# of Λ w PID)/(# of Λ wo PID)

Parametrized as function of momentum.

- p(p) < 0.5 GeV
  - Use 0.5GeV bin's value.
- 0.5 GeV < p(p) < 0.8 GeV
  - Use the measured values.
- p(p) > 0.8 GeV
  - Use a quadratic function as shown in the figure.

(2) $\varepsilon_{decay\ angle}(p_T^{pK},\eta^{pK})$ mass dependency



- For each (p_T, η) bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic error, the factor is fitted with a linear function and a quadratic function. But, the difference between fit function is very small .

$$\varepsilon_{decay\ angle}^{pol1}(p_T^{pK},\eta^{pK}) = A*M_\Theta + B$$

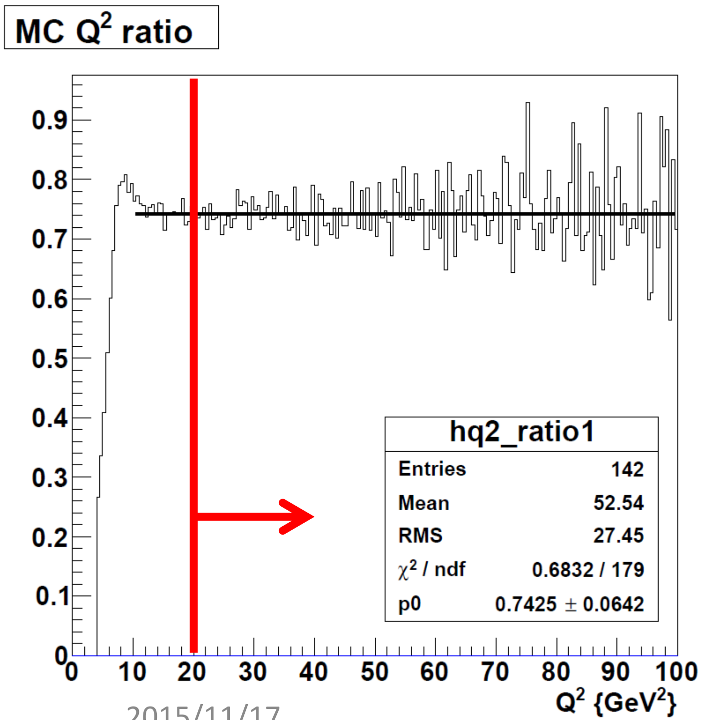
- p_T reweighted factors are also performed to estimate systematic error coming from PQ momentum changing.

(3) DIS efficiency

- DIS efficiency estimated by Q^2(DA) of PQ MC sample

  ε = # of after DIS selection/# of before DIS selection (MC true information).

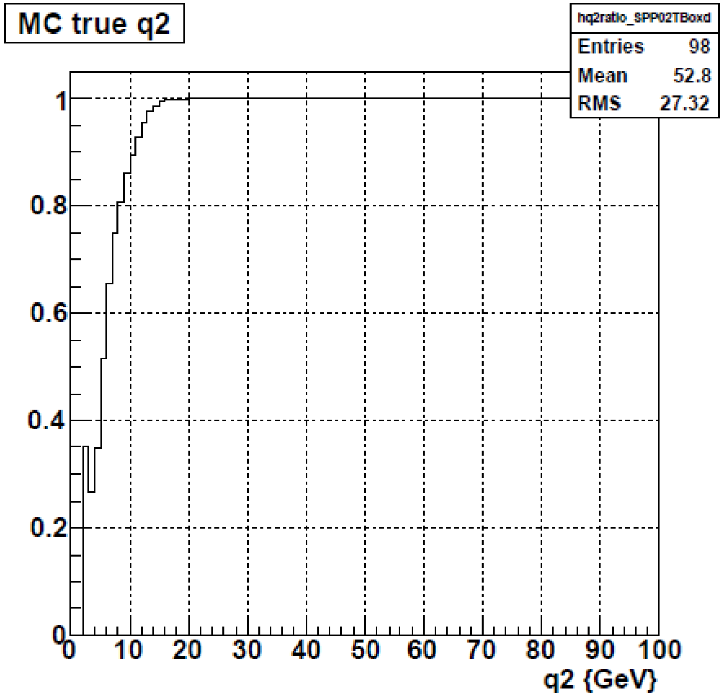
- Calculate as Q^2 function.
- $20 < Q^2 < 100$ GeV^2 in order to compare with HERA-I analysis



- For $Q^2 > 20$ GeV^2: acceptance can be regarded as flat ($\varepsilon_{DIS} = 0.7425 \pm 0.0642$).
- TLT efficiency ~ 100% for these Q^2 (next page)

Etc.; TLT trigger efficiency

- **TLT trigger efficiency is estimate by MC.**
- **In HERA-II, SPP02 is used to take DIS event . But SPP02 is pre-scaled in 2006, SPP09 is also used to take DIS event.**
- **-2005**
  - **SPP02** Inclusive DIS prescale 1
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 12x12cm cm
- 2006-
  - **SPP02** Inclusive Low Q^2 DIS prescale 10
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 12x12cm cm
  - **SPP09** Inclusive (a bit less) Low Q^2 DIS prescale 1
    - SLT SPP1
    - 30 GeV < E-pz < 100 GeV
    - Eel > 4 GeV
    - Boxcut 15x15cm cm



- TLT Trigger efficiency

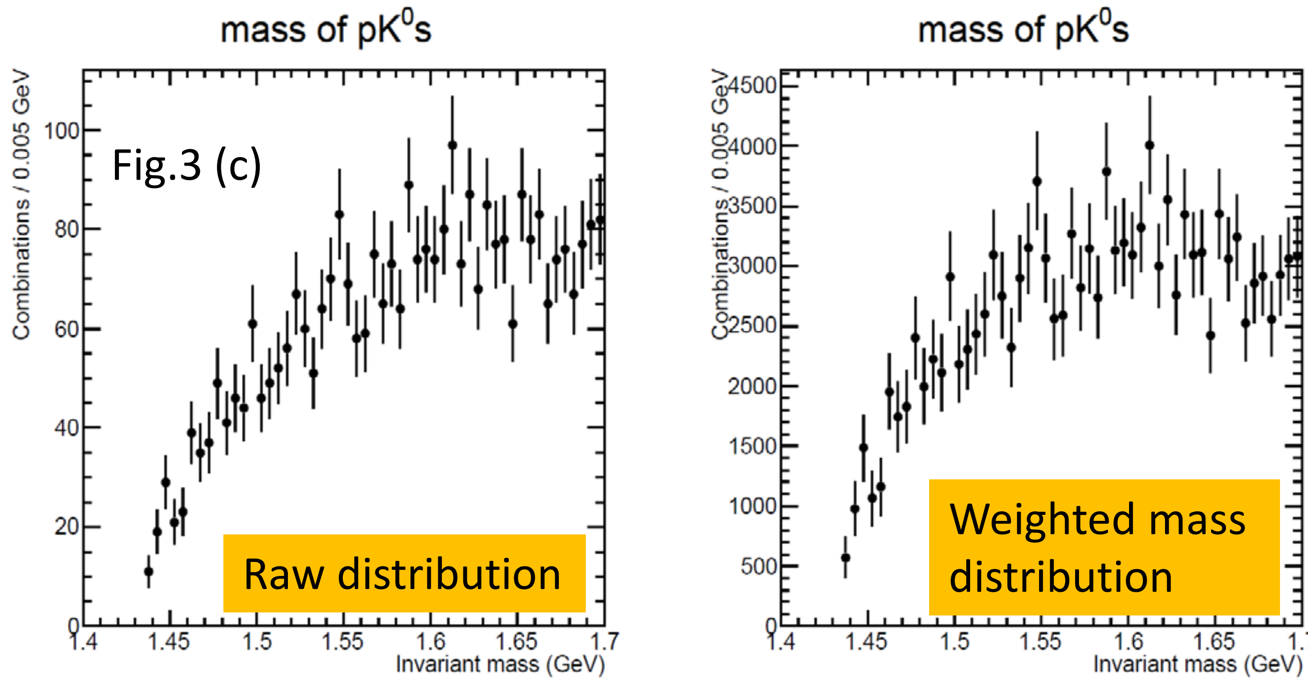
  = # event pass Box15x15cm/ # event pass Spp02taken
- In Q^2 > 20 GeV² TLT trigger efficiency ~ 1.

  => can ignore trigger pre-scale factor (introduced in higher Q^2 from 2006)

  => can use full luminosity 364.20pb⁻¹

Setting of PQ cross section limit calculation and mass distribution

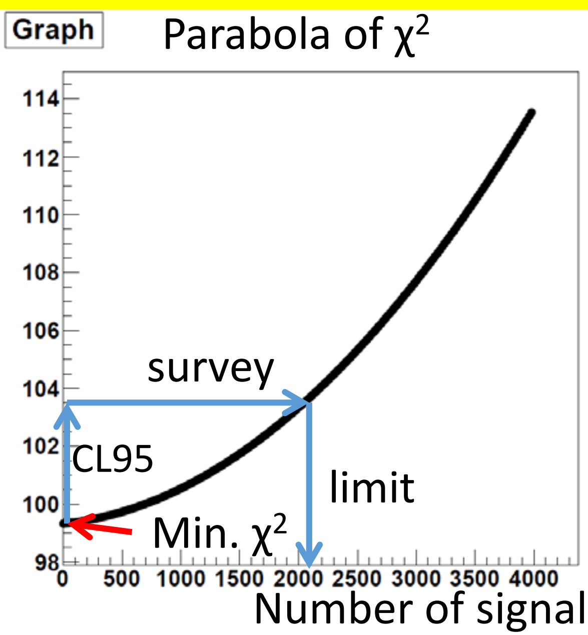
- Limit setting with the well identified phase space.
  - (DIS 20 < Q^2 < 100 GeV², p_T of pK_S^0 : 0.5-3.0 GeV , η of pK_S^0: -1.5 – +1.5)
  - Acceptance correction ASSUMING the p_T/η spectrum of pentaquark is similar to Σ^+(1189). : Some systematics with different p_T slopes.
  - With some sets of Gaussian mass width (6.1MeV as seen in HERA I and else)

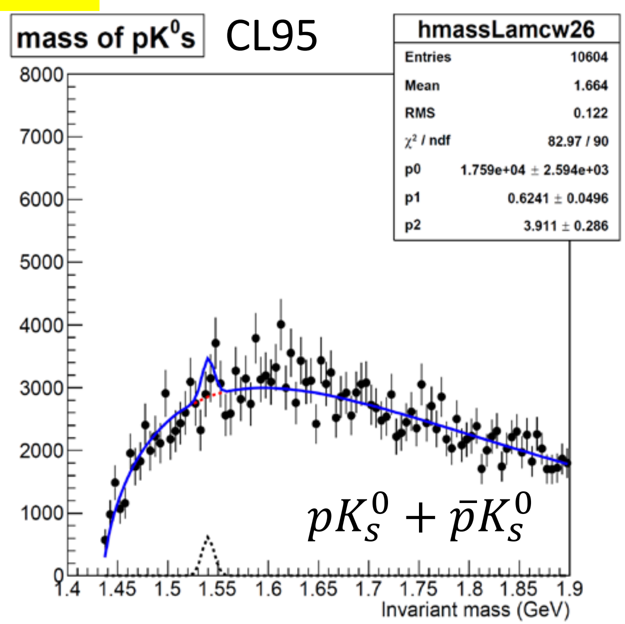


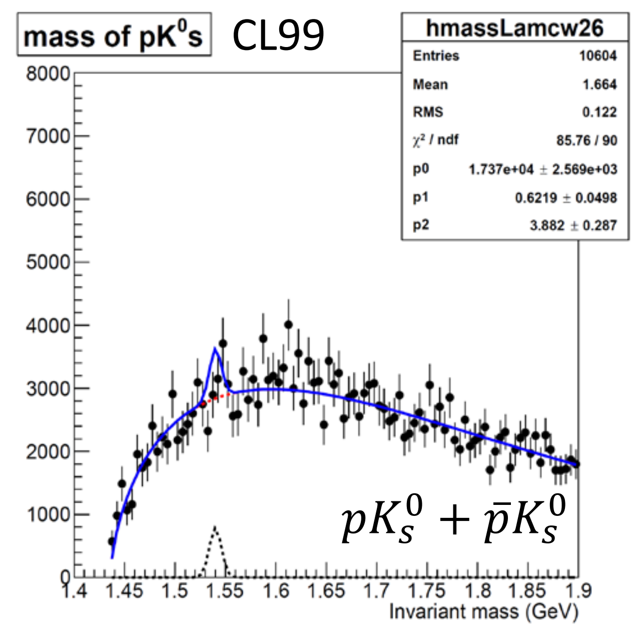
The cross section calculation method

- Signal: Gauss function (σ is parameter, see next page)
- B.G.: $p0*(M_{pk0}-M_p-M_{K0})^{p1}*e^{\{-P2*(Mpk0-Mp-MK0)\}}$
- Blue: fixed signal function + B.G..
- $CL90 = \chi^2_{min} + 2.71$, $CL95 = \chi^2_{min} + 3.84$, $CL99 = \chi^2_{min} + 6.63$

Ex. mass 1540 MeV with σ=6.1MeV







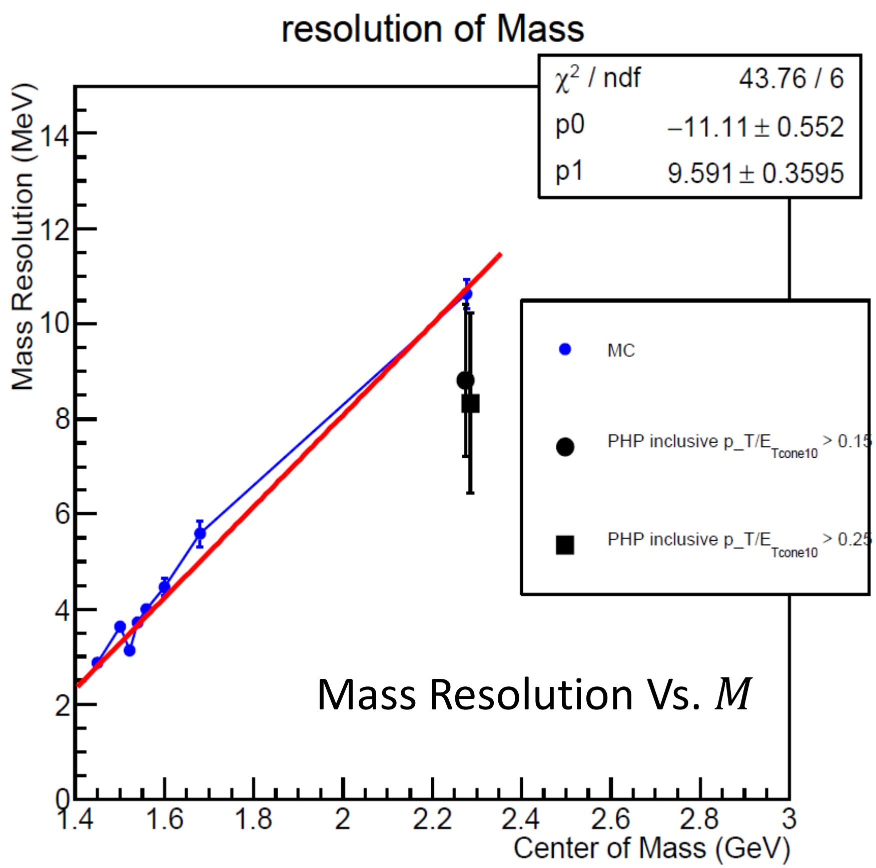
Gaussian widths in Cross section limit calculation

- 6.1 MeV in the draft was the measured width in the HERA I results.
- Cross section limits are calculated with considering the detector resolution.
  - Mass resolutions are estimated by MC (next page)
  - In the measured mass range, the resolution σ is parametrized as a linear function of pK_S^0 mass.
- As at low mass (M(PQ) < 1.45 GeV) the Gaussian area below pK_S^0 mass threshold are included, the limit is worse at smaller masses.
  - We put a sharp cut at the Gaussian at threshold;

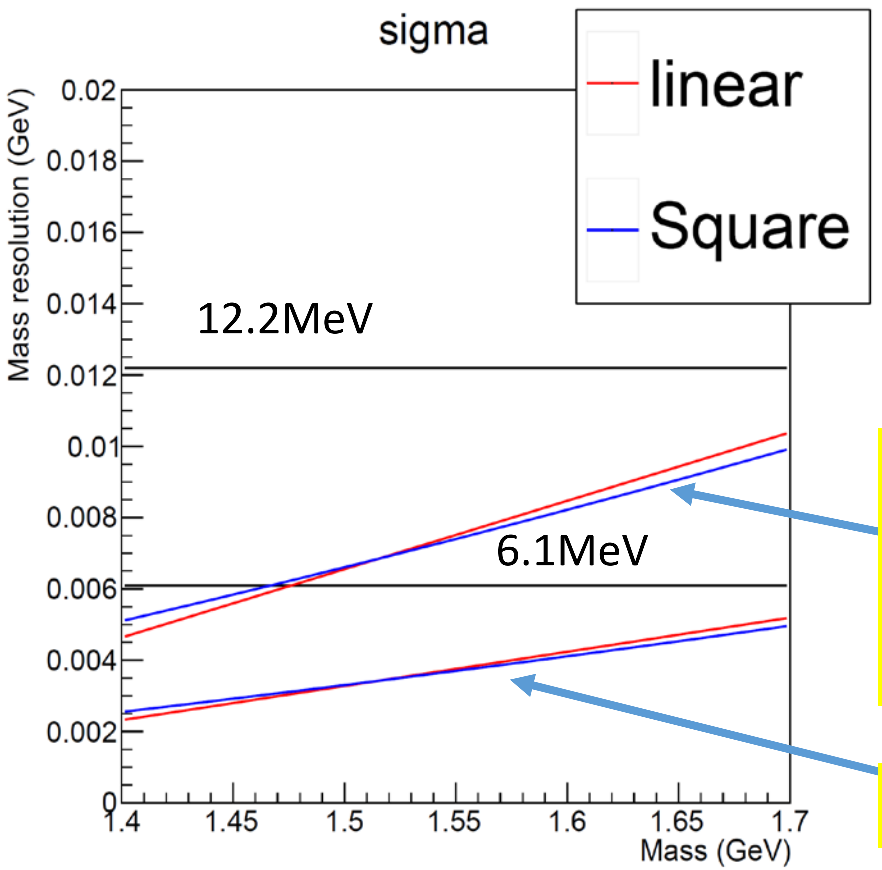
Limits are shown only above M(PQ) > 1.45 GeV.

Signal width determined by mass resolution;

- Mass resolutions (blue) are calculated with MCs.
- They are fitted by linear function (red).
- Black points are come from PHP data (circle; $\frac{p_T}{E_{Tcone10}} > 0.15$, square; $\frac{p_T}{E_{Tcone10}} > 0.25$)



Signal width determined by mass resolution; width calculation



- Linear: $0.009591M$ - 0.01111 GeV
- Square: $0.002601M^2$ - 0.002529 GeV
- The difference is very small

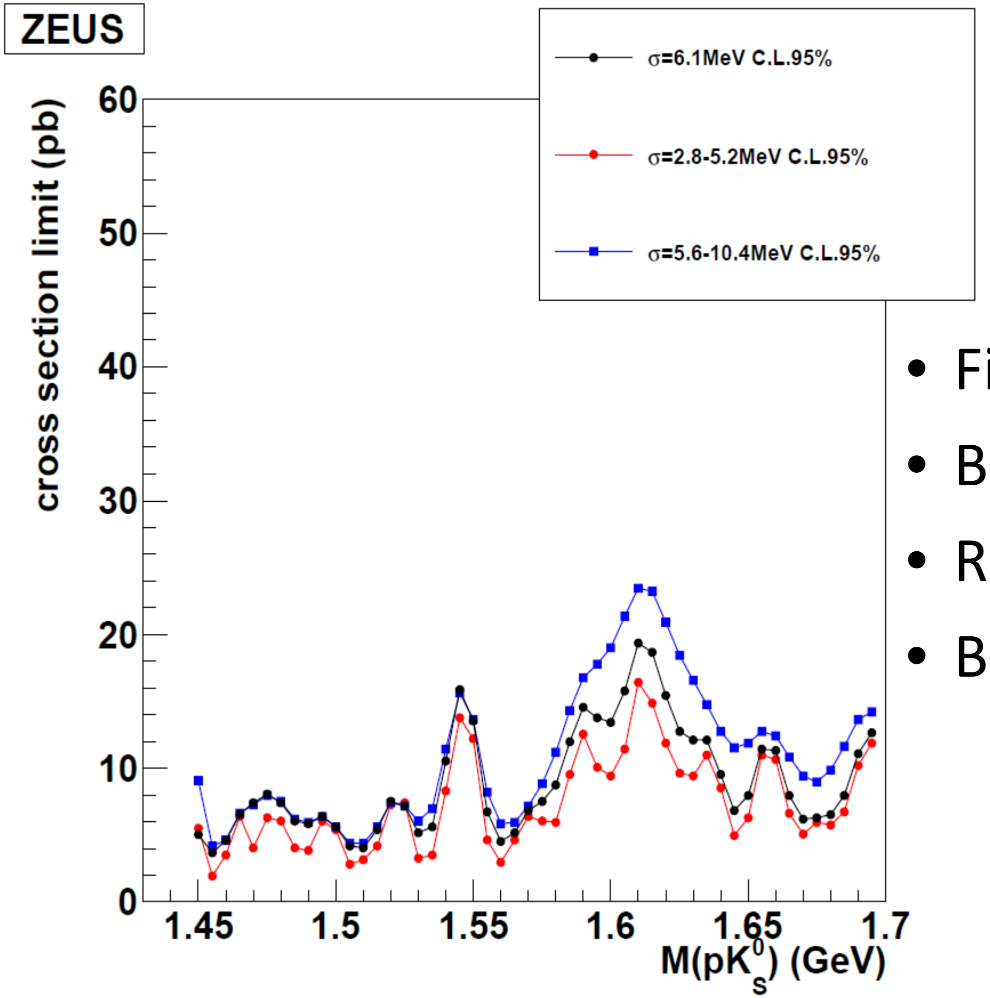
-> the Linear function (red) is used.

Mass resolution (5.6-10.4MeV):

- No physical motivation, but this resolution range is similar with H1 analysis (4.8-11.3MeV).

Mass resolution (2.8-5.2MeV)

Signal width determined by mass resolution (σ_{Θ}->$p + K^0$); cross section comparison



- Fit range 1.435 < M < 1.900 GeV
- Black; constant mass width 6.1 MeV.
- Red; variable width 2.8-5.2 MeV.
- Blue; variable width5.6-10.4 MeV.

Systematic error estimation (σ_{Θ}->$p + K_S^0$)

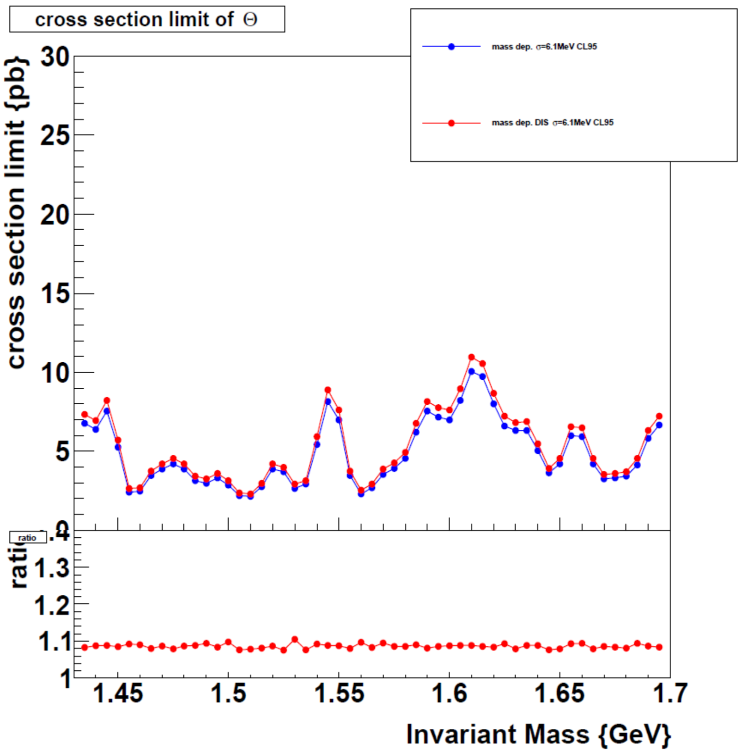
- Systematic uncertainties wew evaluated for the following 5 components.

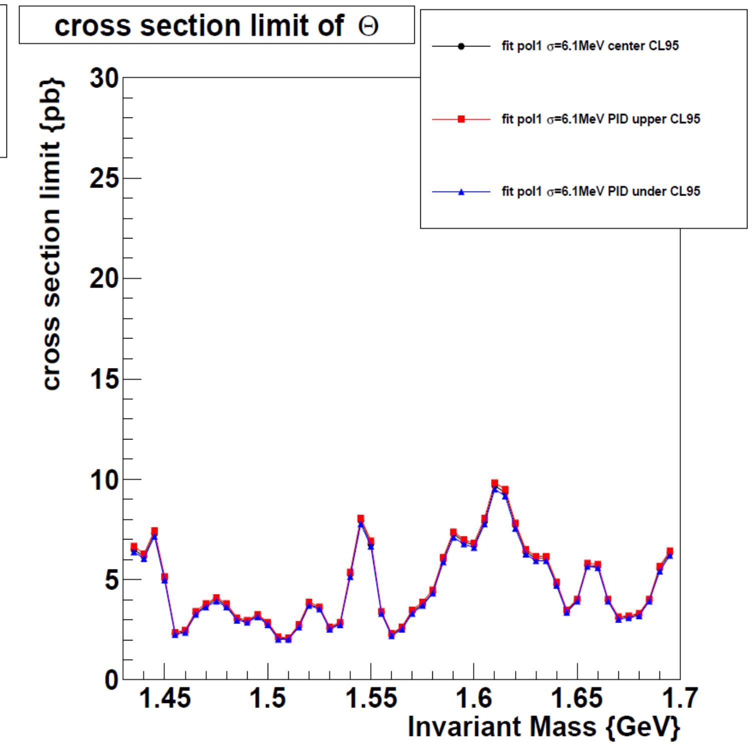
  - DIS electron finding;
  - Proton identification (PID);
  - accept. different (p_T, η) binning;
  - accept. mass dependency;
  - p_T distribution re-weighting.

- Luminosity uncertainty ~ 3%.

Systematic error estimation (σ_{Θ}->$p + K_S^0$): DIS and PID

- DIS efficiency (Left; default and ~10% error of DIS efficiency)
- PID (Right; default and PID efficiency error)

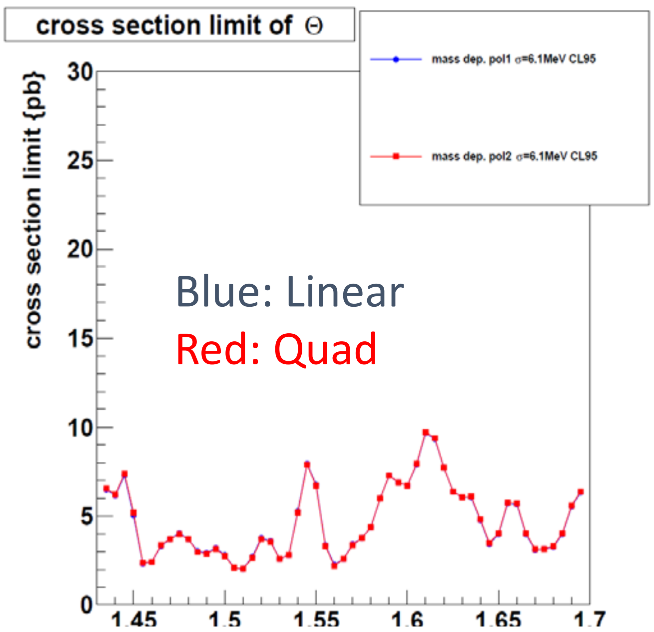




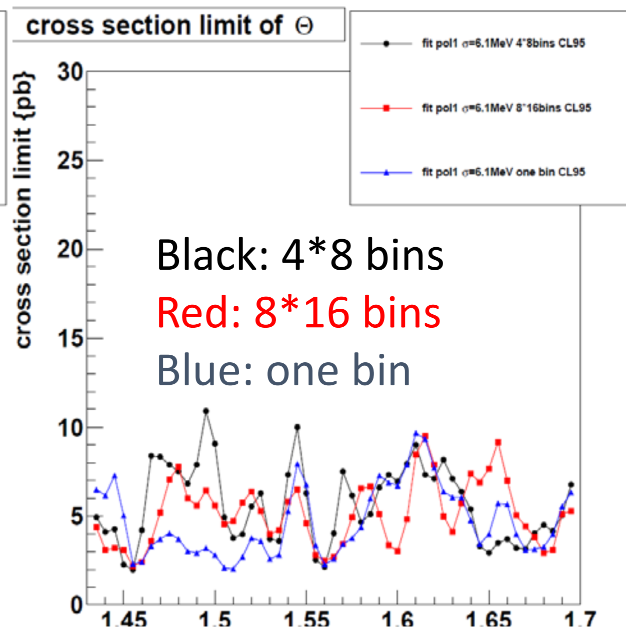
- Uncertainty in the DIS event selection was ~10%.
- PID efficiency error was modified by $\pm 1\sigma$. The effect is a few %.

Systematic error estimation (σ_{Θ}->$p + K_S^0$) : Binning

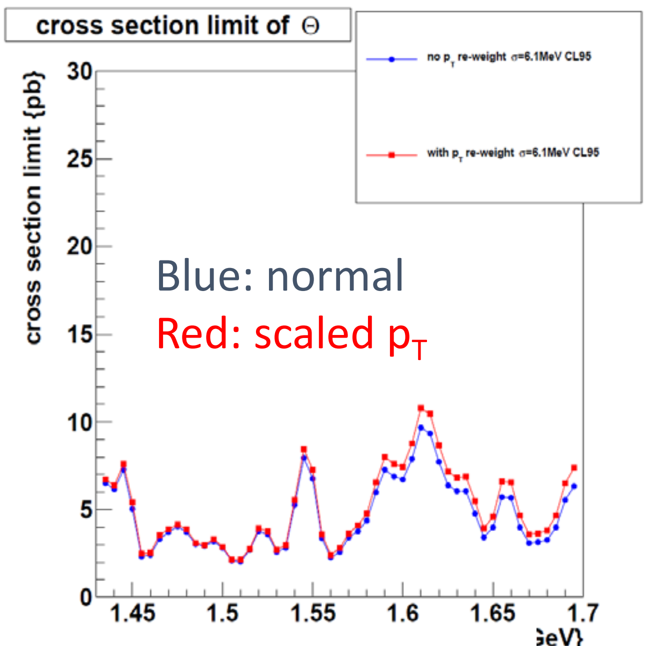
- Acceptance mass dependency (linear(default) or quadratic function)
- Different (p_T, η) binning : 3 patterns (1X1(default), 4X8, 8X16)
- p_T Spectrum correction (default, scaled with Mass)



Acceptance/ mass dependency



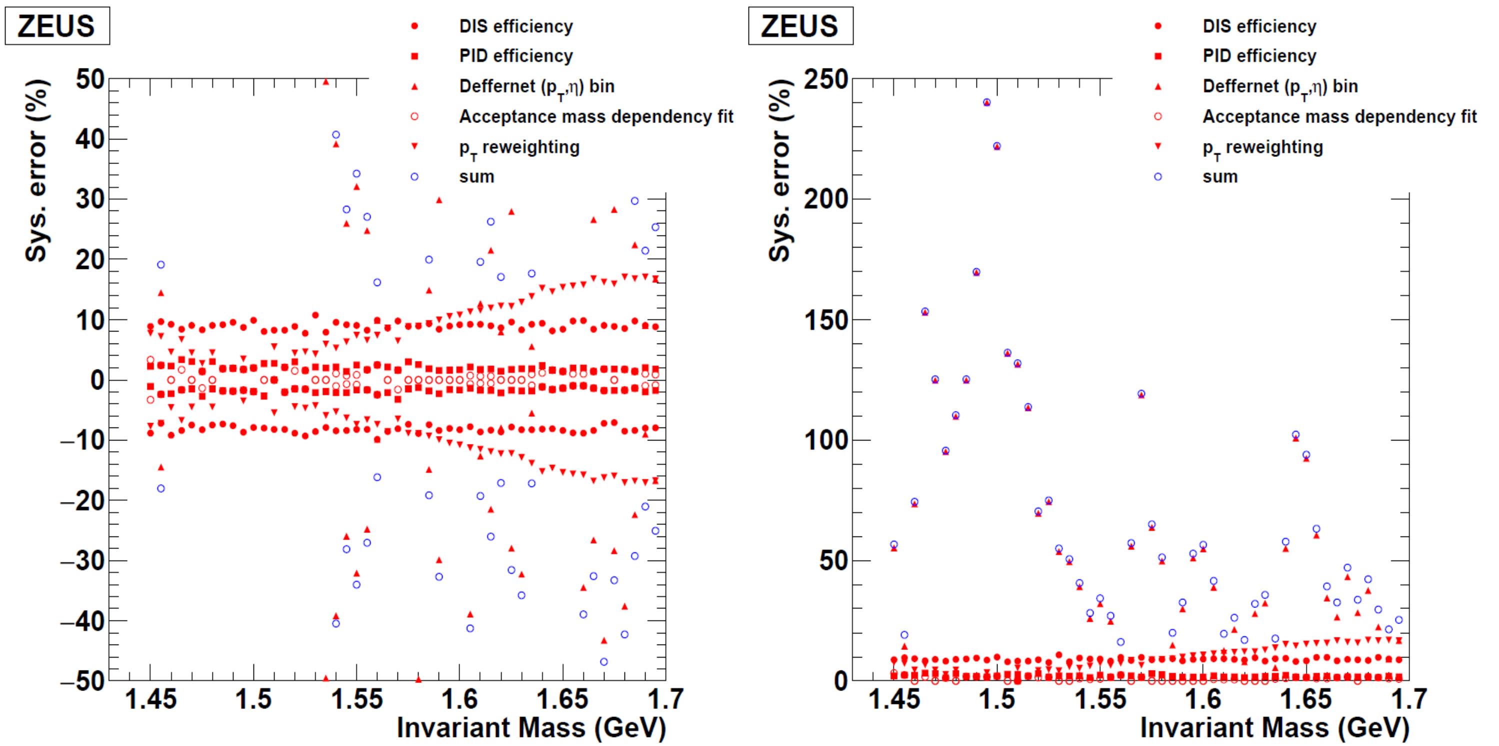
Acceptance / different Bin



p_T reweighting

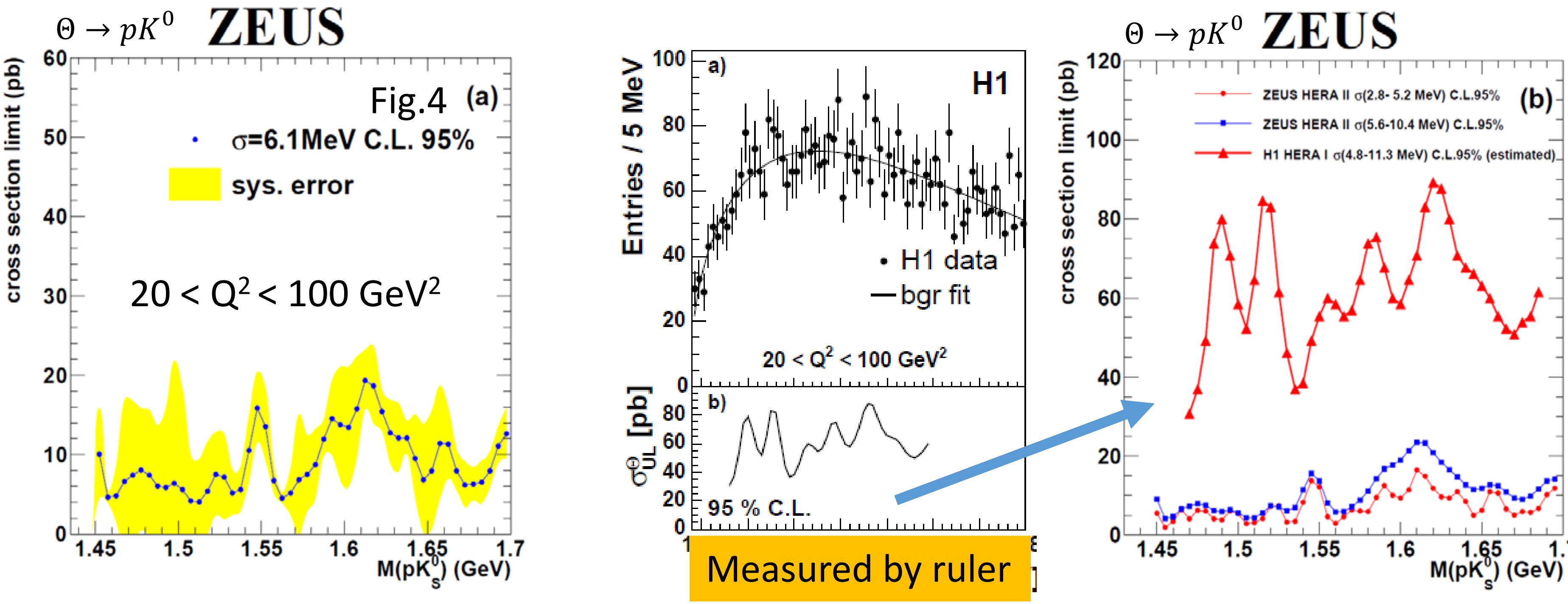
- Acceptance mass-dependency uncertainty is so small as negligible.
- Binning error is the largest, particularly, in smaller mass region (M~1.5GeV). Error uses the maximum difference from default calculation.
- p_T distribution error effect is ~20% (at high mass).

Sum of systematics Error (σ_Θ->$p + K_S^0$)



- Systematic error from Binning in pT-η plane is the largest.
- Other errors are not so large (also luminosity uncertainty).

Results; Cross section upper limit (σ_Θ->$p + K^0$)



- Cross section of $\Theta \rightarrow pK^0$ is 2 times $\Theta \rightarrow pK_S^0$.
- HERA I ZEUS result of production cross section is 125±27(stat.)$^{+36}_{-28}$ (sys.)pb^{-1} Cf. the ICHEP conference paper in Beijing(2004), with mass resolution σ=6.1 MeV. Fig.4 (a) shows the result of 95% CL upper limit with this width.
- H1 reported the C.S. limit (used σ = 4.8-11.3 MeV). The H1 HERA I result is measured by ruler and plotted in fig. 4(b). (Achim's request, but I don't access to H1 accurate values.)
- Fig. 4(b) shows the comparison between the H1 results and the width determined by the mass resolution plots (σ = 2.8-5.2 MeV and 5.6-10.4MeV) in HERA II.
- The obtained HERA II ZEUS upper limit is significantly lower than HERA I results.

Summary

- A resonance in the $pK_S^0(\bar{p}K_S^0)$system was searched for with the HERA II data collected by the ZEUS detector.
  - An improved proton PID capability made possible by the newly installed MVD detector.
  - The peak structure for which evidence has been observed in the previous ZEUS analysis with HERA ,I data was not confirmed.
- The upper limits on the production cross section have been set as a function of the pK^0 mass.
  - Assumed a hadronic production model with an isotropic decay.
  - Kinematic region: 0.5 < $p_T(pK^0)$ < 3.0 GeV, | η (pK^0)| < 1.5 and 20 < Q^2 < 100 GeV^2

Paper plots

Figure1

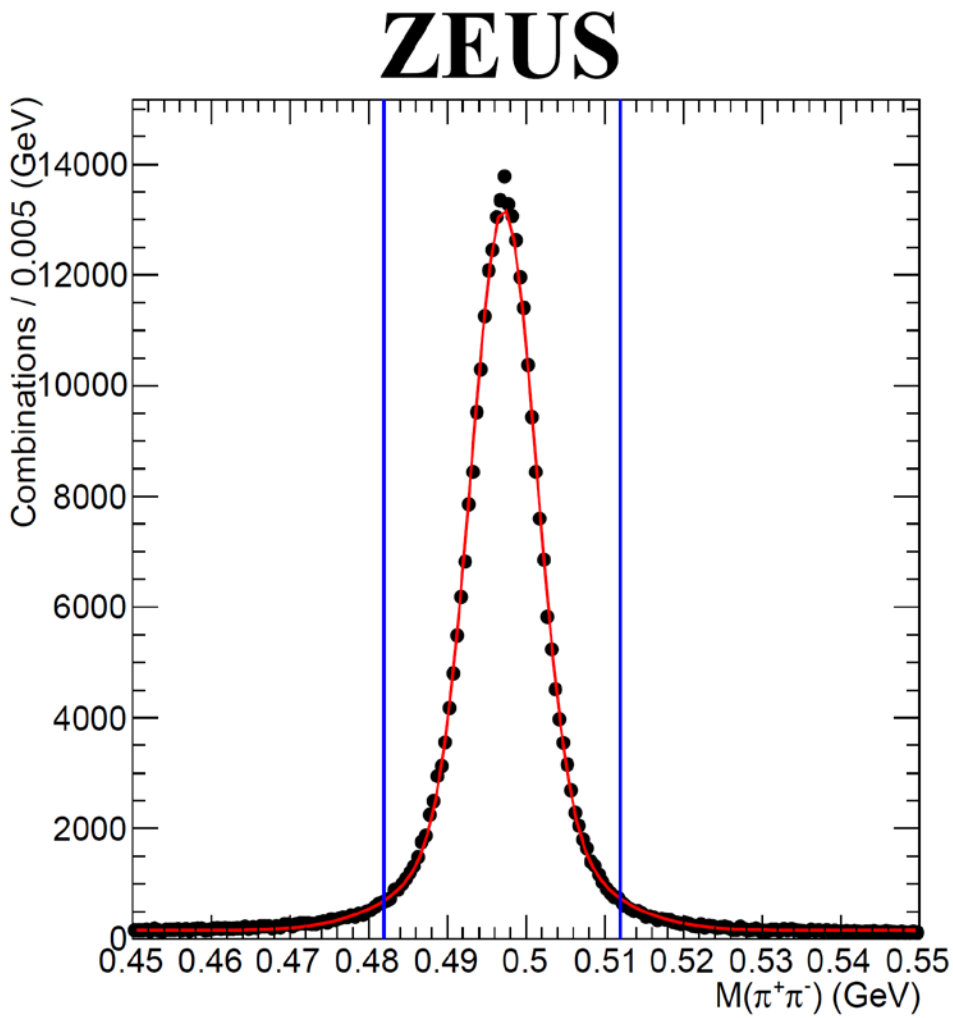

ZEUS
Combinations / 0.005 (GeV)
14000
12000
10000
8000
6000
4000
2000
0
0.45 0.46 0.47 0.48 0.49 0.5 0.51 0.52 0.53 0.54 0.55
M(π⁺π⁻) (GeV)

Figure2

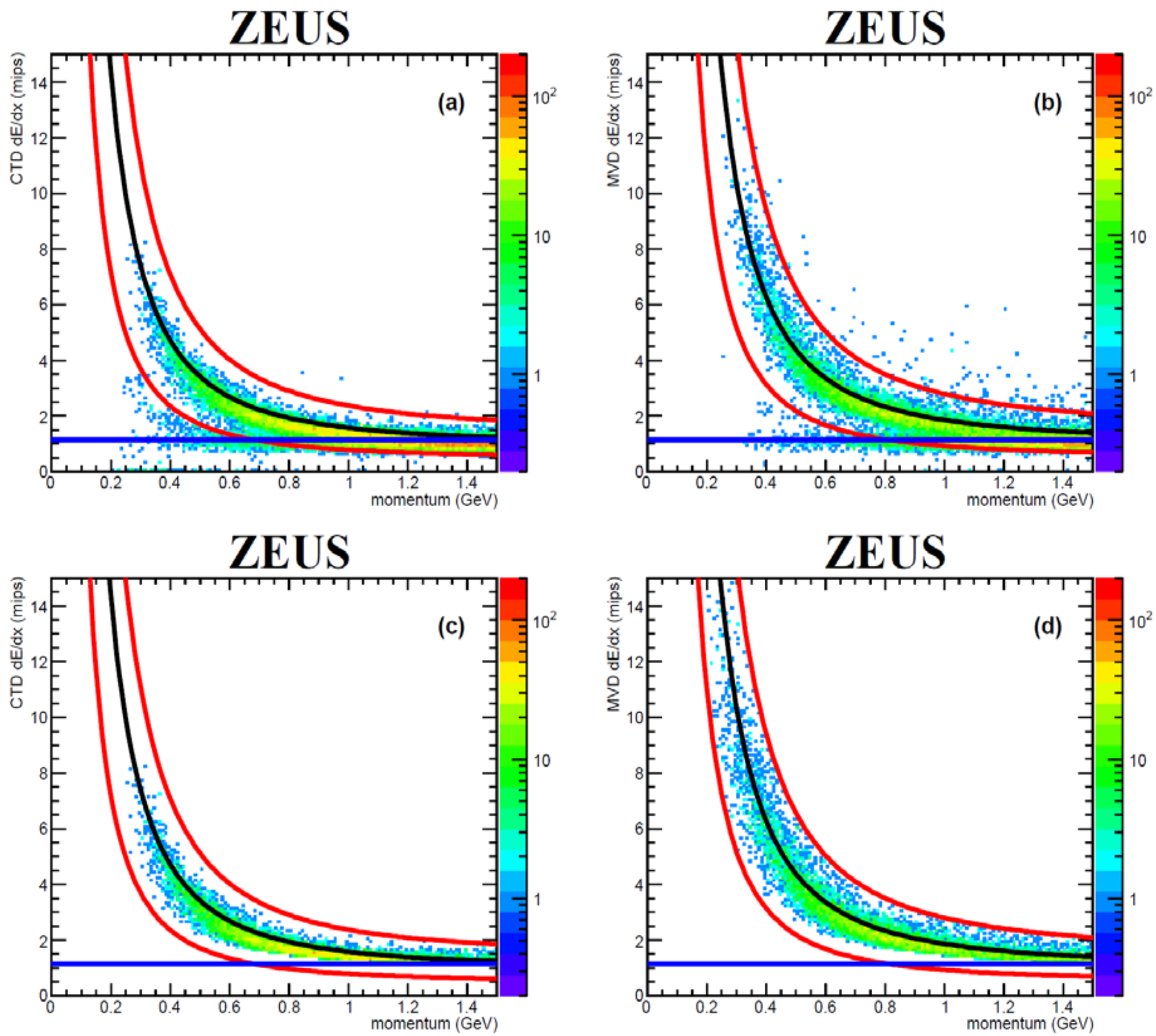

ZEUS
(a)
CTD dE/dx (mips)
momentum (GeV)
ZEUS
(b)
MVD dE/dx (mips)
momentum (GeV)
ZEUS
(c)
CTD dE/dx (mips)
momentum (GeV)
ZEUS
(d)
MVD dE/dx (mips)
momentum (GeV)

Figure3

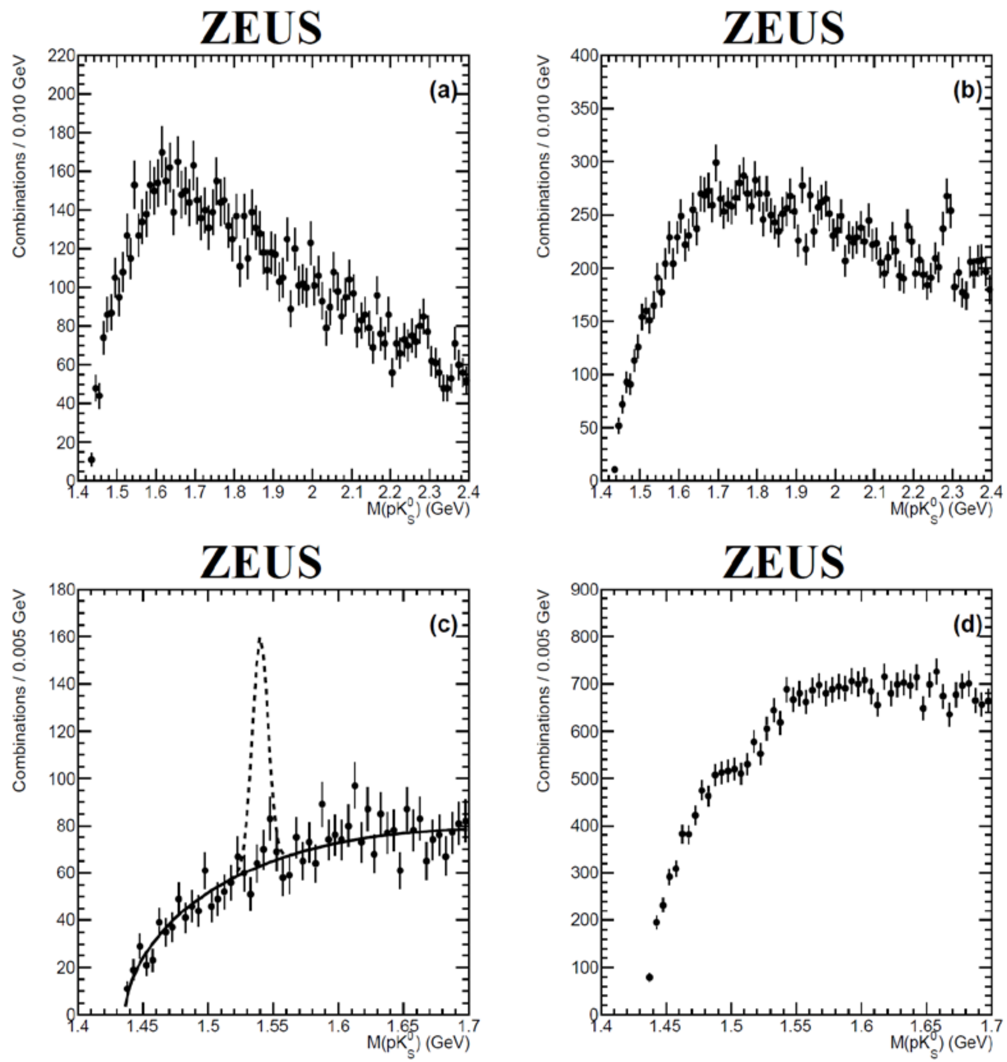
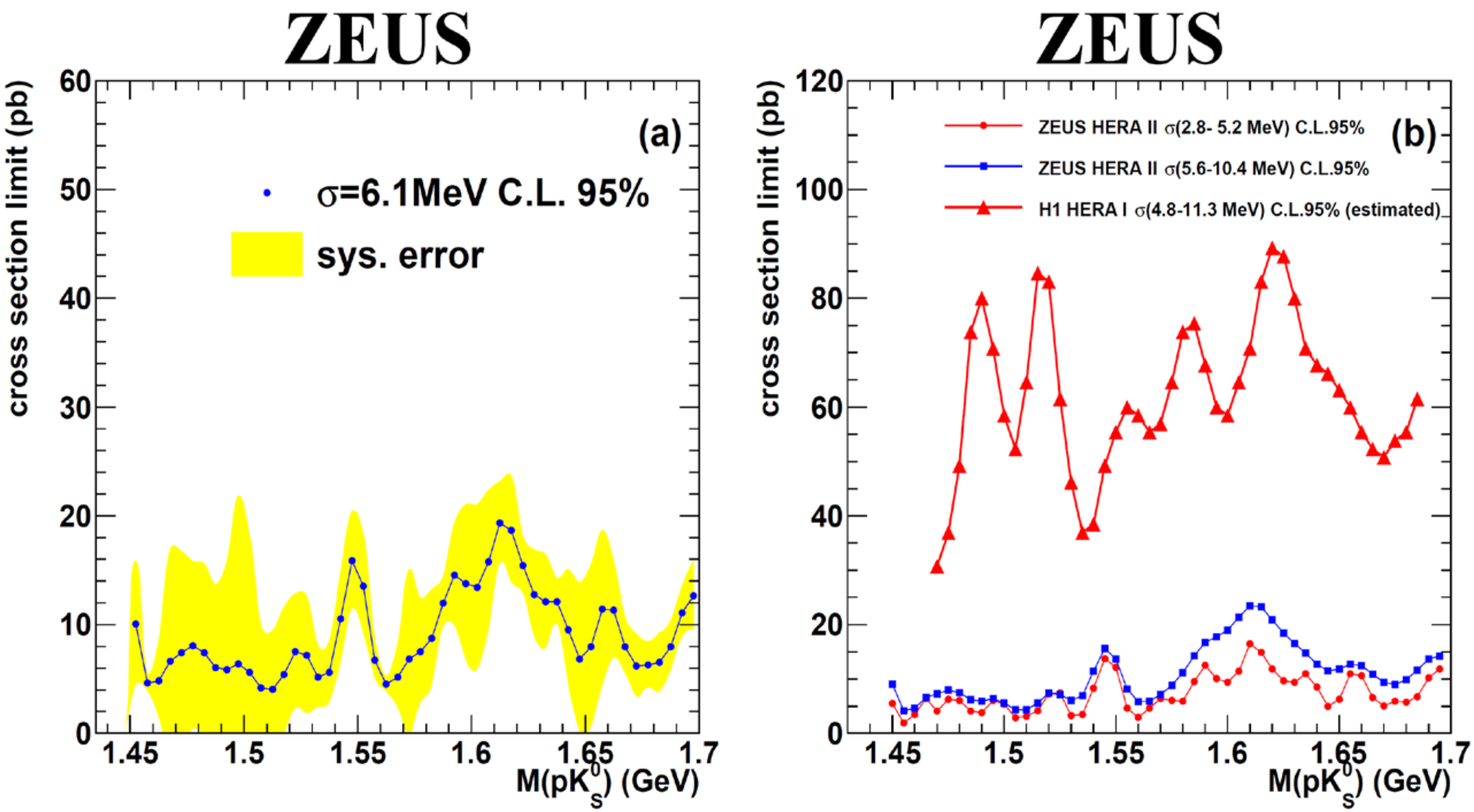
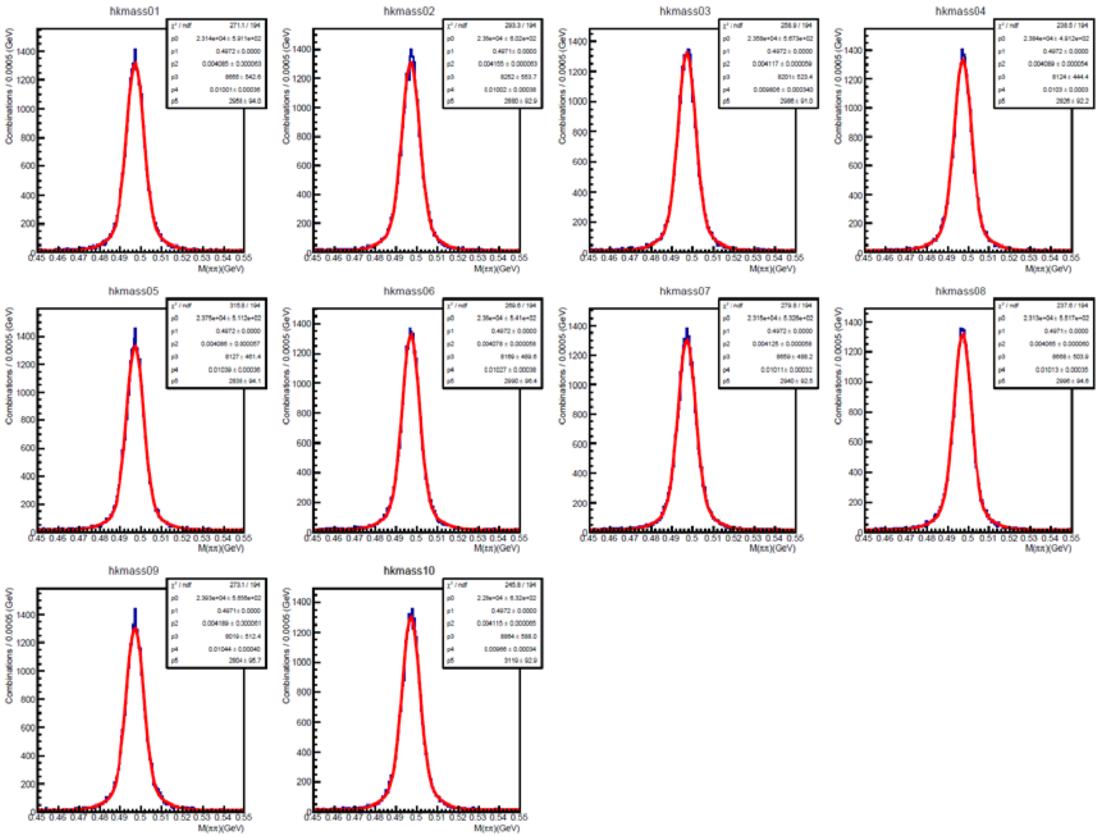

ZEUS
(a)
Combinations / 0.010 GeV
M(pK^0_S) (GeV)
ZEUS
(b)
Combinations / 0.010 GeV
M(pK^0_S) (GeV)
ZEUS
(c)
Combinations / 0.005 GeV
M(pK^0_S) (GeV)
ZEUS
(d)
Combinations / 0.005 GeV
M(pK^0_S) (GeV)

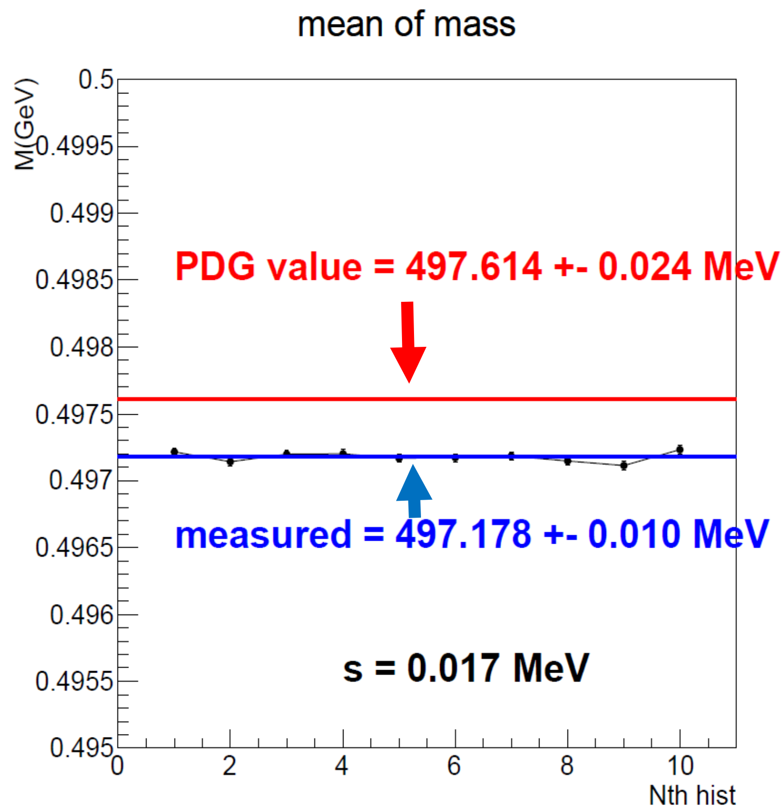
Figure4


ZEUS
cross section limit (pb)
(a)
σ=6.1MeV C.L. 95%
sys. error
M(pK^0_S) (GeV)
ZEUS
cross section limit (pb)
ZEUS HERA II σ(2.8- 5.2 MeV) C.L.95%
ZEUS HERA II σ(5.6-10.4 MeV) C.L.95%
H1 HERA I σ(4.8-11.3 MeV) C.L.95% (estimated)
(b)
M(pK^0_S) (GeV)

Back up slide

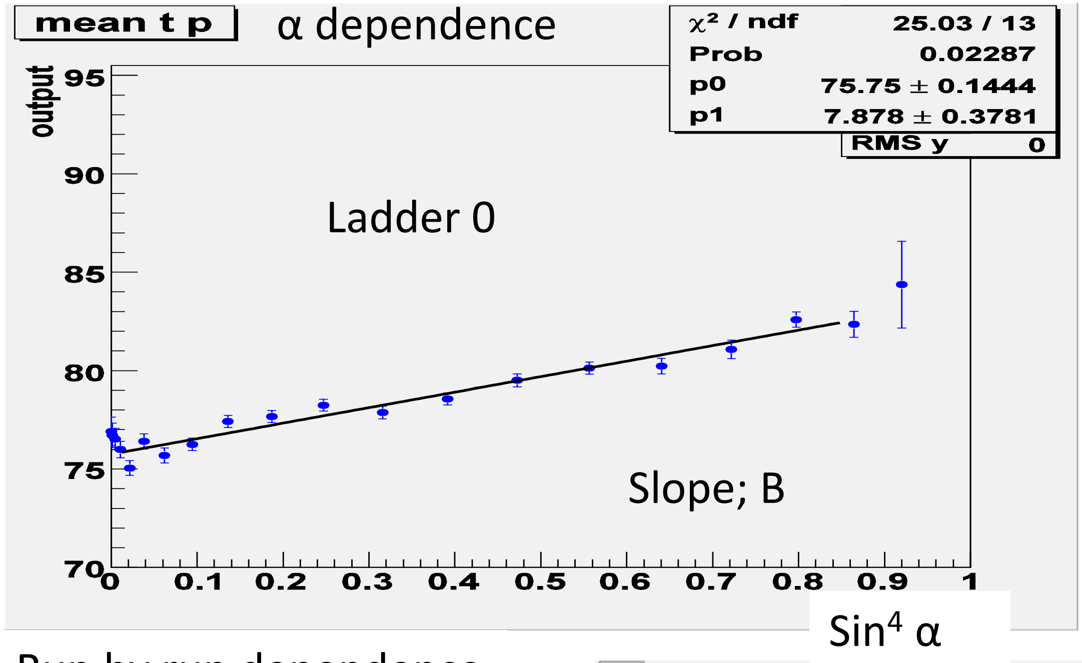
Mass error check

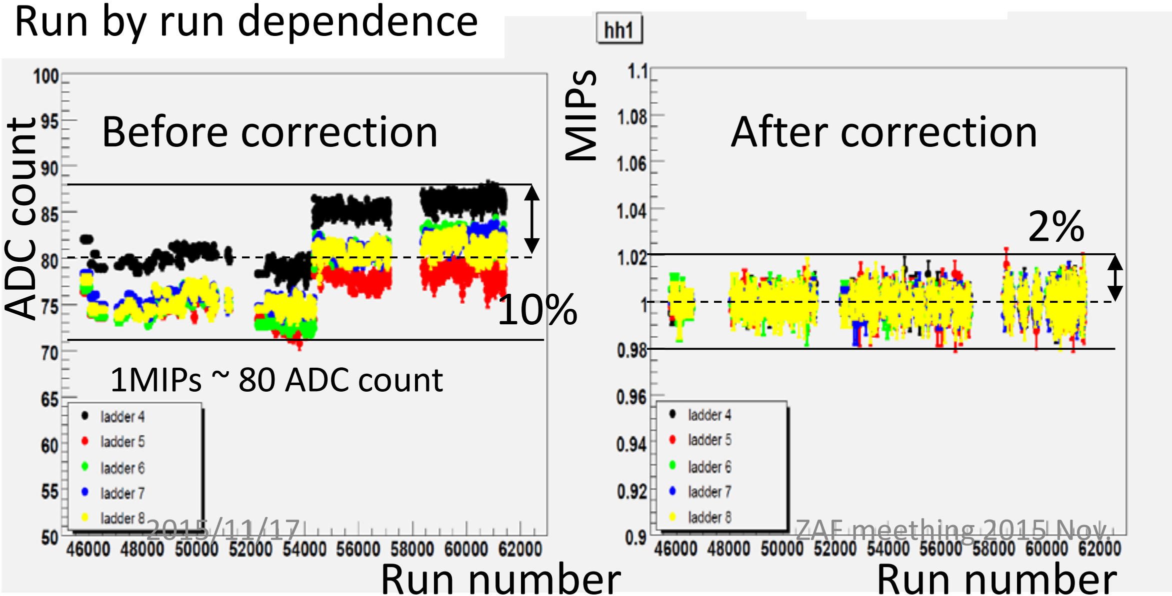




- K_S^0 mass distribution is divided to 10 histograms (same mass bin). The standard deviation s is checked for the means for measured value.
- Total mean error of K0s fit is 9.65*10E-6 GeV. This is 0.01 in MeV unit (plot in page 9).
- In the case of K0s distribution dividing to 10 histograms, each mean error is also 0.0000GeV,（bin=0.5MeV）. The Standard deviation is 0.017MeV (right figure).

MVD dE/dx; ladder and run-by-run correction (reminder)





At first, I checked remaining MVD angle dependence and run-by-run variation.

α is incident angle to the MVD module.

From the left histogram, I adopted the following function.

$$dE/dx_{hit}=A(1-B\sin^4\alpha)*ADC_{raw}$$

where,

is a function of ladder.

is a function of ladder and run umber.

ter the correction run variation is thin ±2%.

MVD dE/dx; Likelihood (reminder)

Fig.1

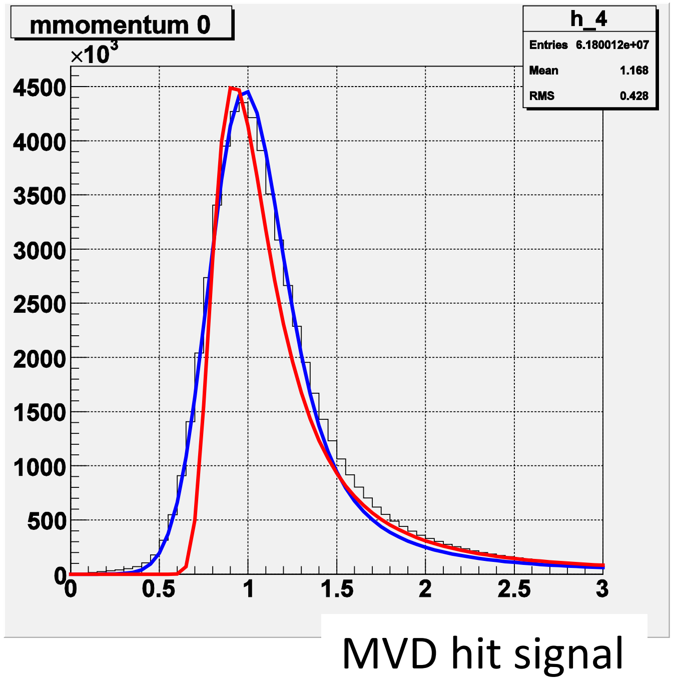


Fig. 1 dE/dx for each MVD hit point.

(π 0.5~0.6GeV)

Red: Landau function Fit

Blue: Landau function Fit convoluted with gaussian (gLandau)

(http://root.cern.ch/root/html/examples/langaus.C.html)

Better description with gLandau. For example the left shape.

σ of gaussian => 0.168 MIP fixed.

Fig.2

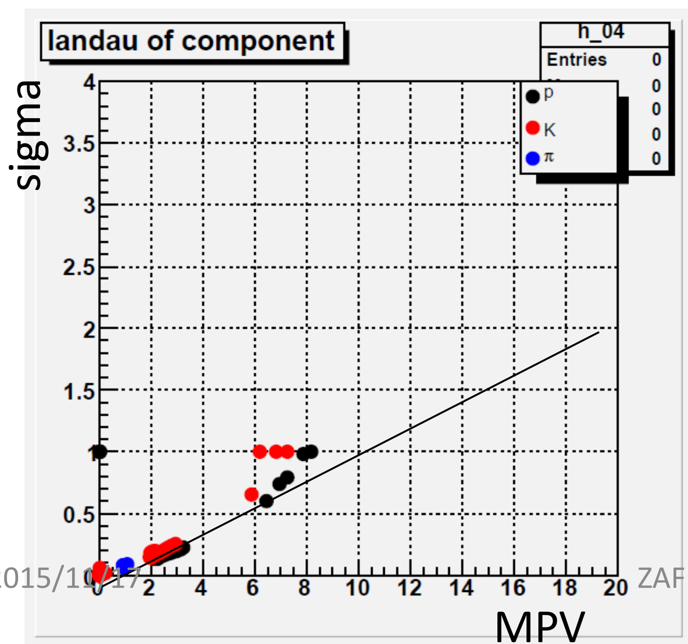


Fig. 2 determination of PDF function。

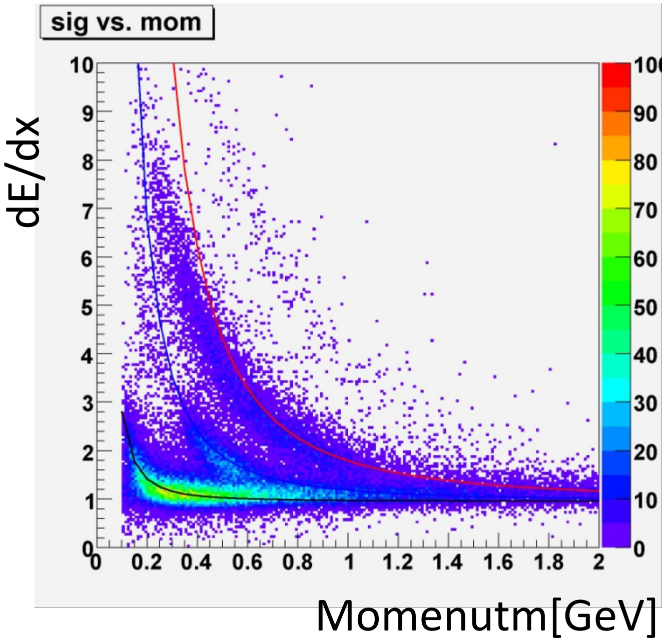
Hit distribution is fitted with gLandau with Landau MPV point and sigma variable.

Almost linear relation between MPV and sigma.

↓

PDF(x;μ) = gaus(σ=0.17)⊗ Landau(x,MPV=μ,sigma=0.086*μ)

MVD dE/dx; gain correction (reminder)



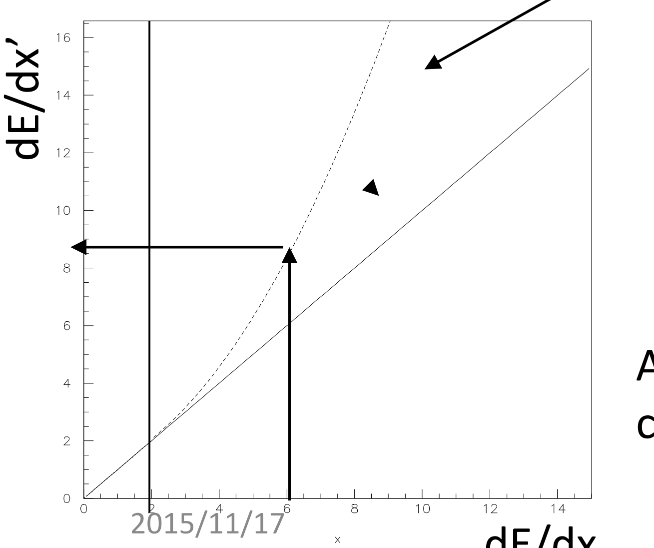
Bethe-Bloch fit can not fit well.
->try to introduce non-linear gain-correction.

Empirical formula:

$$dE/dx' = dE/dx + 0.1517(dE/dx-2)^2 \qquad (dE/dx \geqq 2)$$

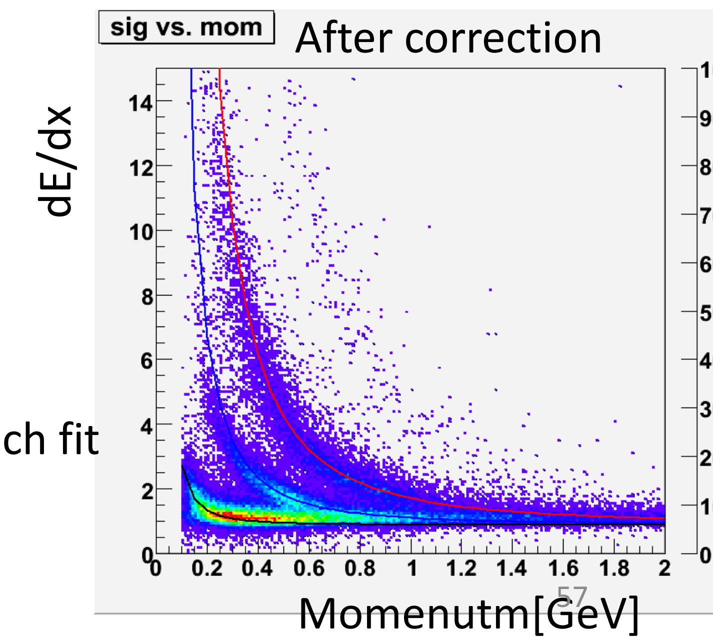
$$dE/dx' = dE/dx \qquad (dE/dx < 2)$$

dE/dx – dE/dx' (corrected dE/dx)



After correction, Bethe-Bloch fit can better describe data.

After correction

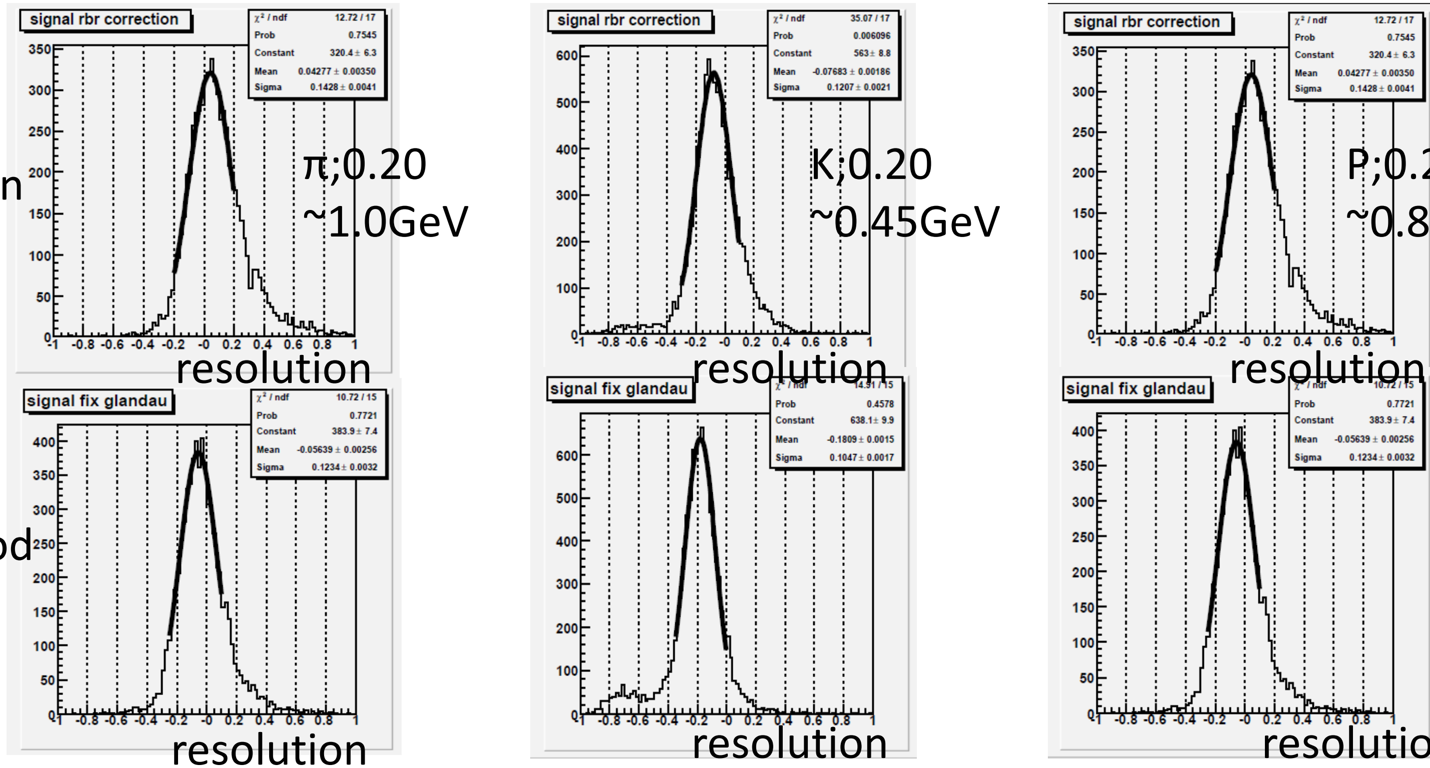


Comparison with the standard truncation method

* Angle and run-by-run corrections are applied to the both methods..

Truncation

Likelihood



	π	K	p
Truncation	14.3%	12.1%	13.4%
Likelihood	12.3%	10.5%	11.7%

- In the analysis with Common ntuple, only global run-by-run correction (i.e. not ladder-by-ladder) is made, so the resolution is worse than this plot.

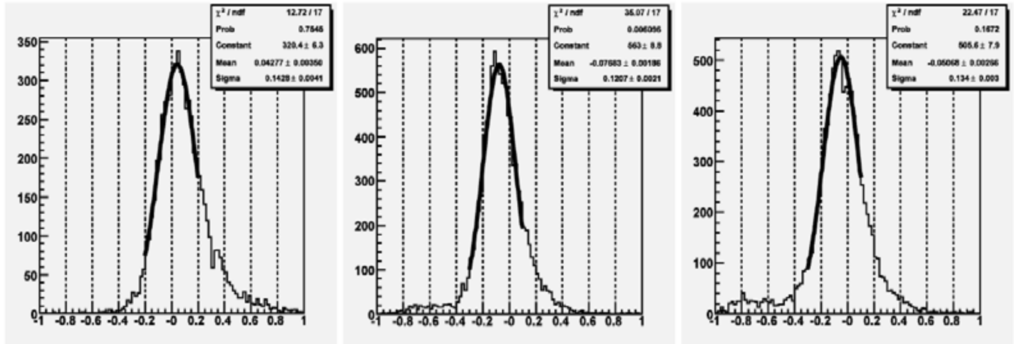


Figure 4.14: typical MVD dE/dx resolutions of the truncation method. Left: π, Center: K, Right: p

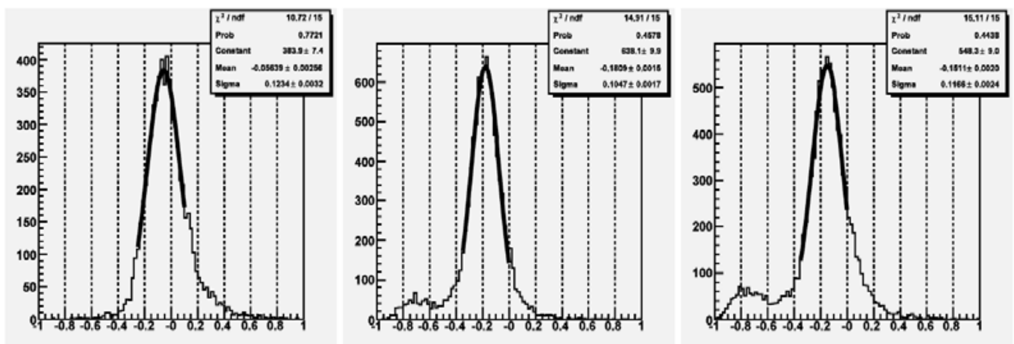
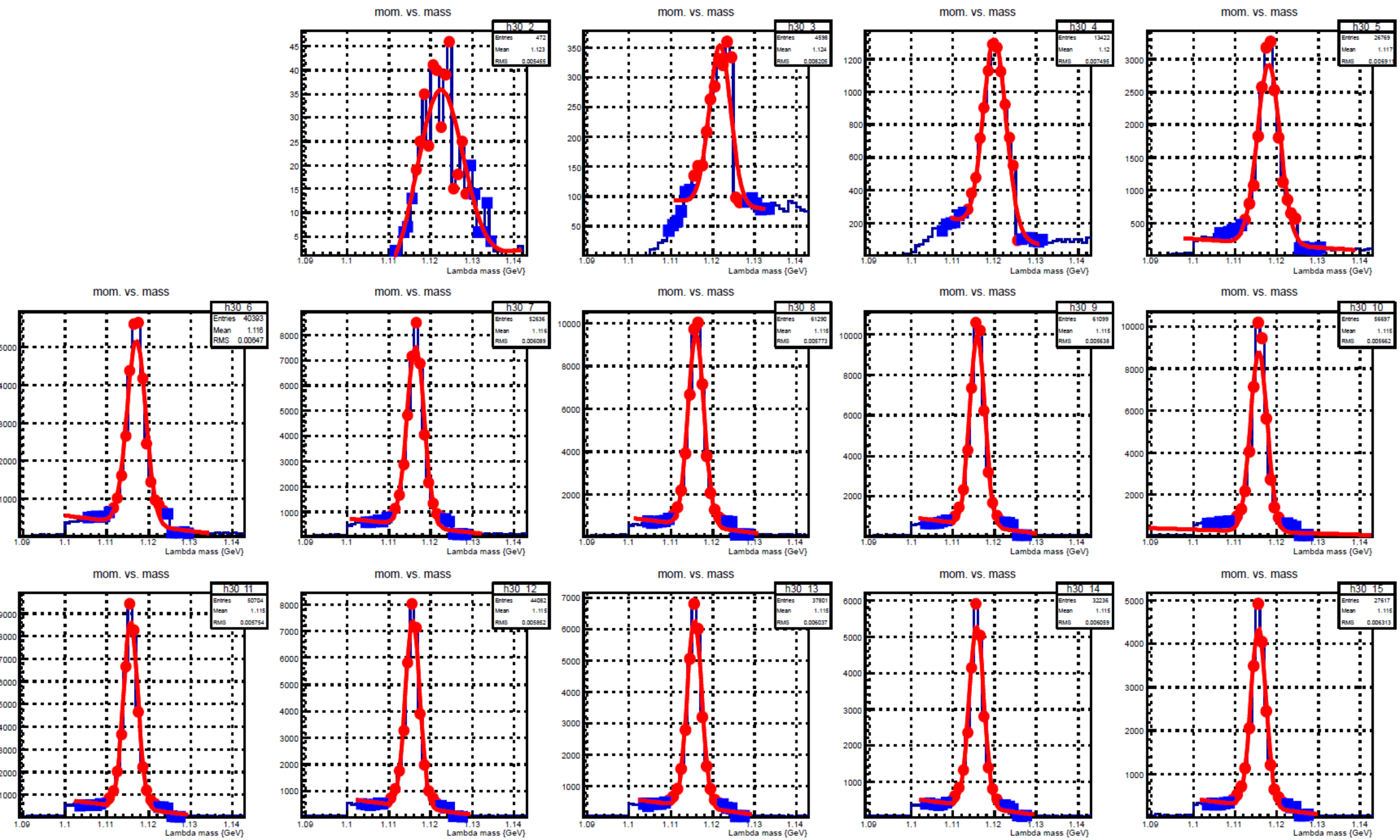


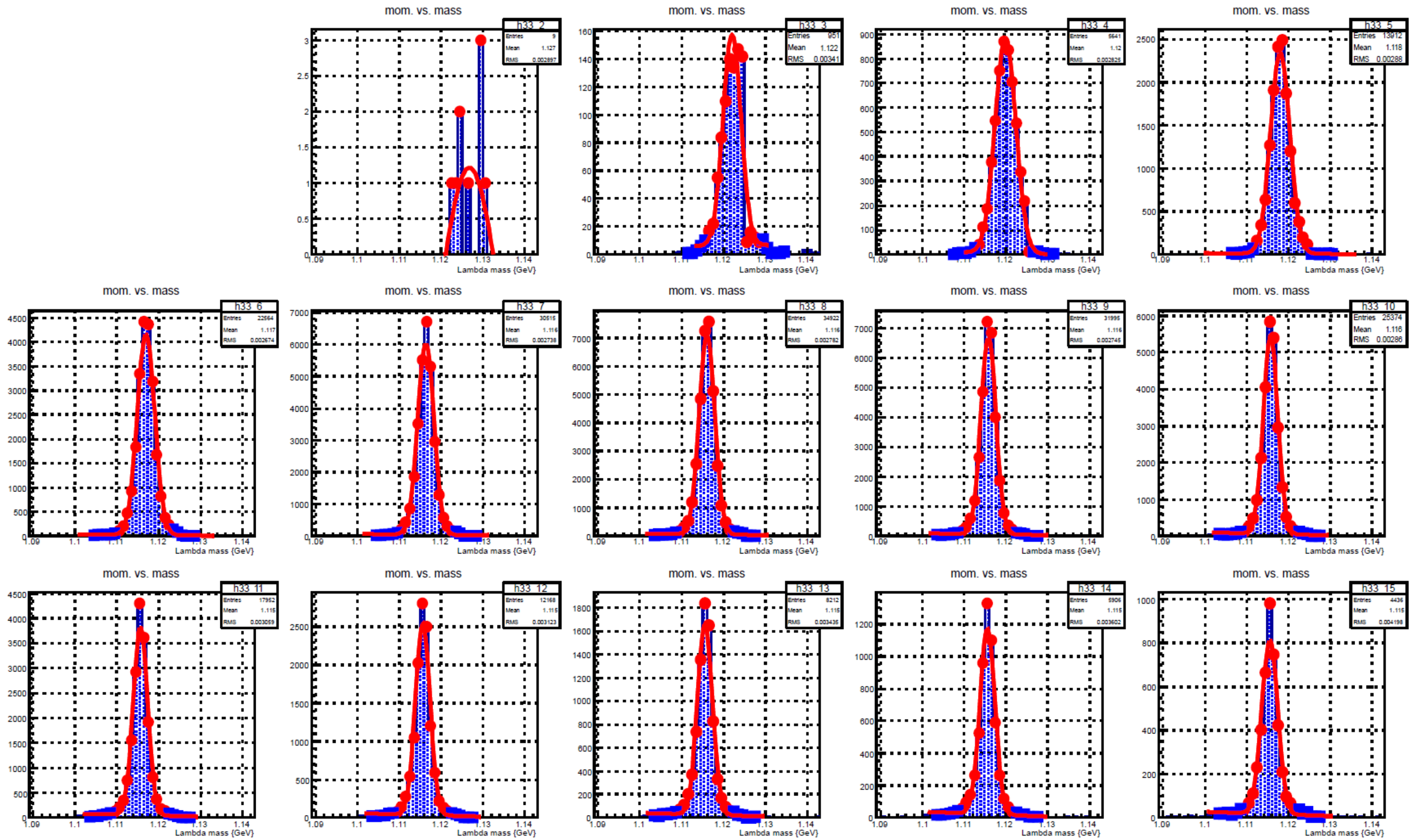
Figure 4.15: typical MVD dE/dx resolutions of the likelihood method. Left: π, Center: K, Right: p

	The dE/dx resolutions		
	MVD		CTD
particle	one hit Truncated mean (%)	Maximum likelihood (%)	30 % Truncated mean (%)
π	14.3	12.3	10.5
K	12.1	10.5	10.0
p	13.4	11.7	9.4

Λ sample; 0.1 < p(p) < 1.5 Ge, V0lite selected (sliced proton momentum 0.1 GeV)

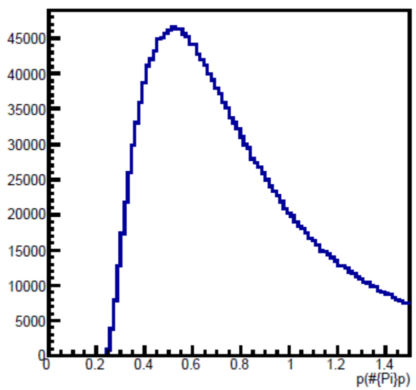


PID selected Λ; 0.1 < p(p) < 1.5 GeV

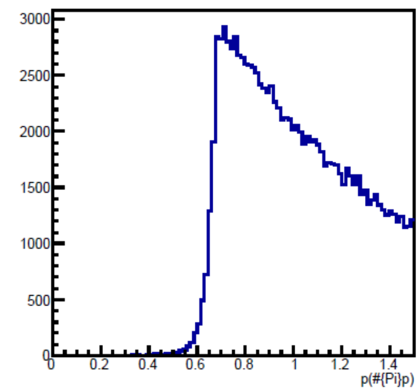


Momentum distributions w/wo PIDs

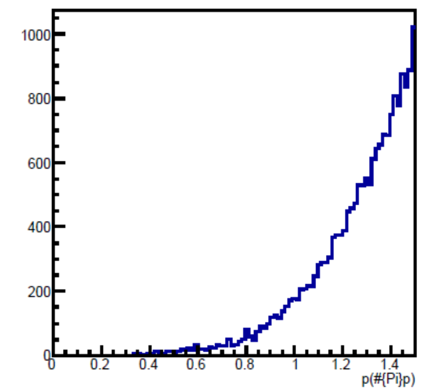
1.15<M(pπ)<1.35 GeV (pπ event in K0s sample)



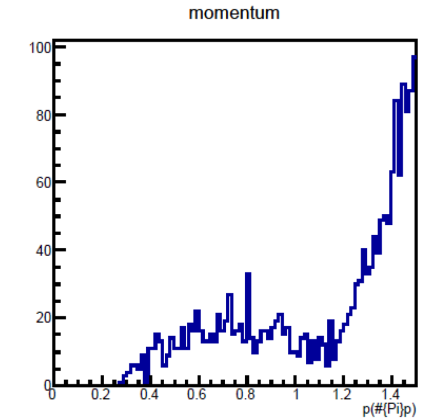
No PID



CTD PID(MIP and band)

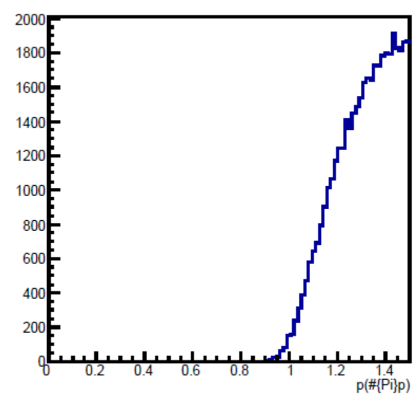


CTD PID(MIP, band
and likelihood)

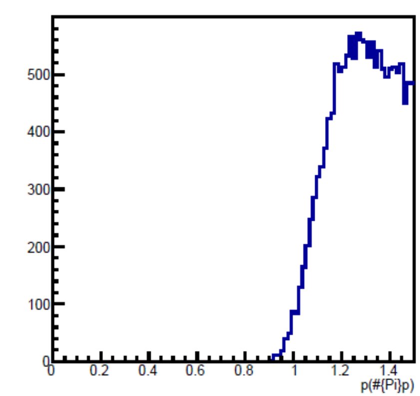


My PID

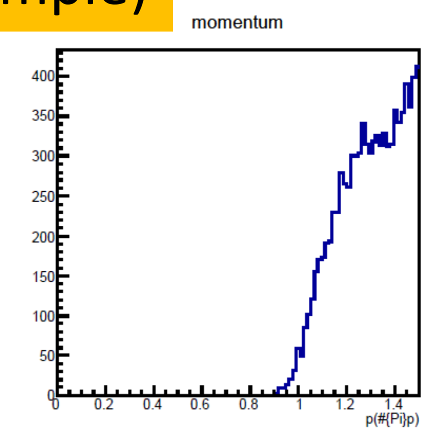
M(pπ)<1.121 GeV (Lambda in K0s sample)



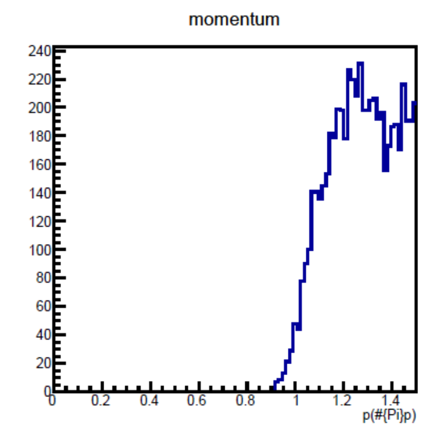
No PID



CTD PID(MIP and band)

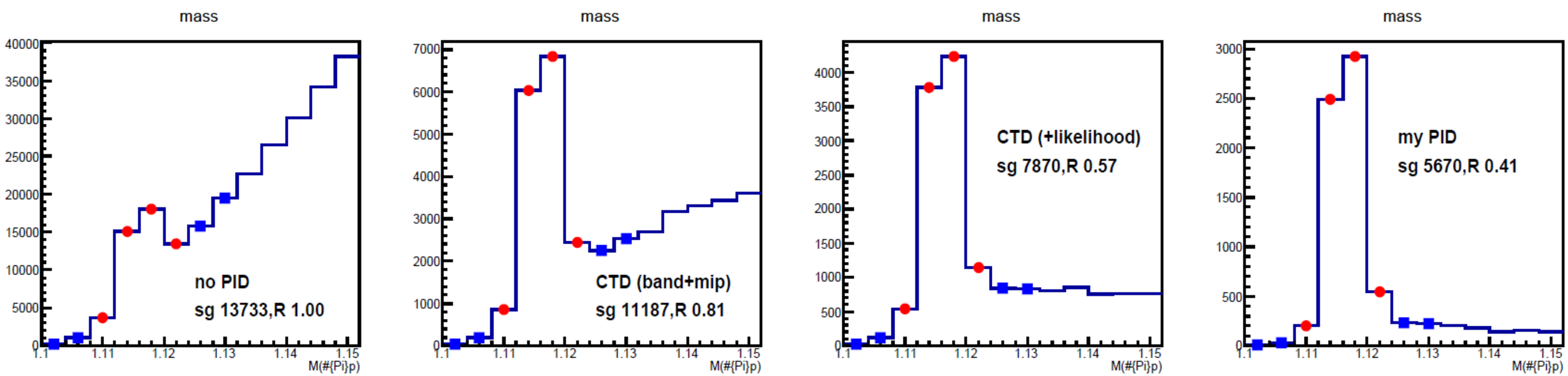


CTD PID(MIP, band
and likelihood)



My PID

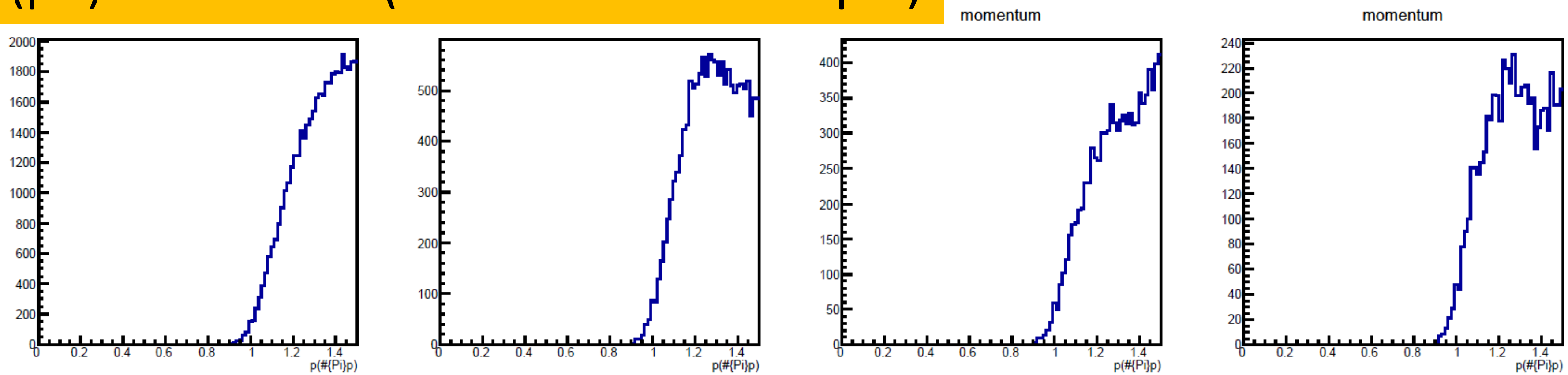
Ration of PIDs (Lambda event in K0s sample)



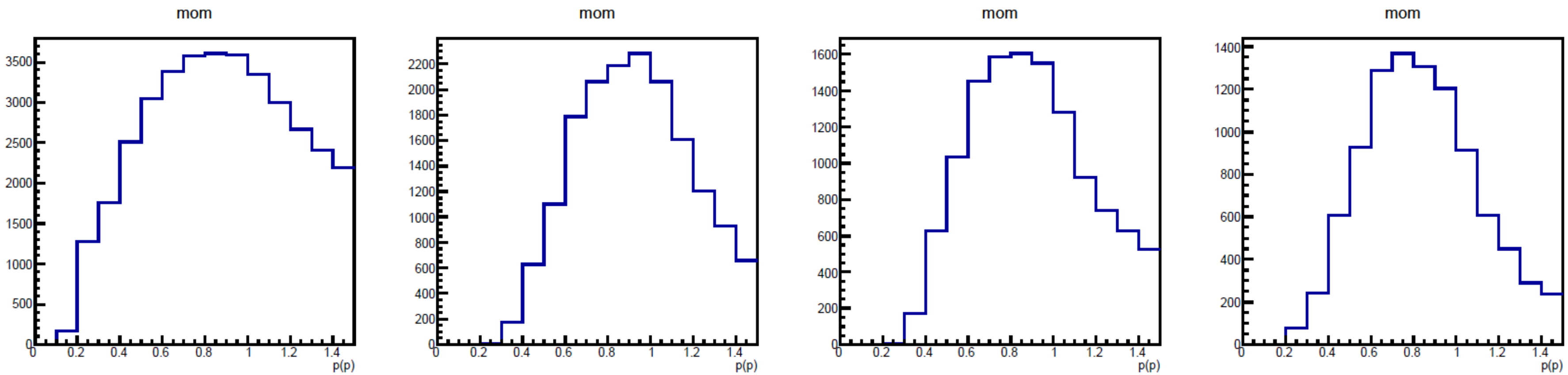
- Ratio = Signal bin (red) – B.G estimated from both sideband bin (blue)
- CTD (band+mip): 81%
- CTD (+likelihood): 57%
- My PID (based on CTD and MVD): 41%
- These values seem to correspond to proton PID efficiency

Momentum comparison

M(pπ)<1.121 GeV (Lambda in K0s sample)



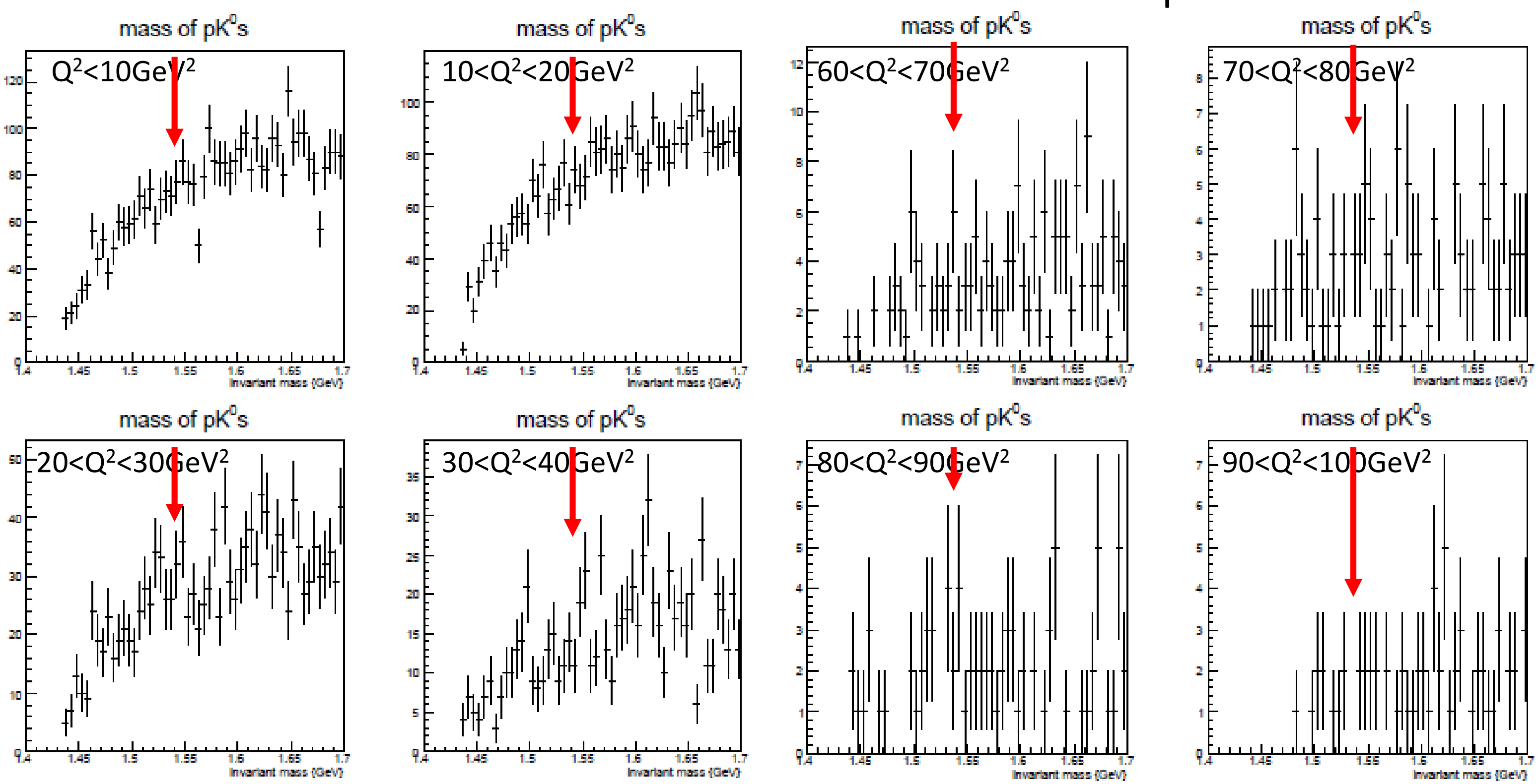
M(pπ)<1.144 GeV (Lambda in lambda sample)

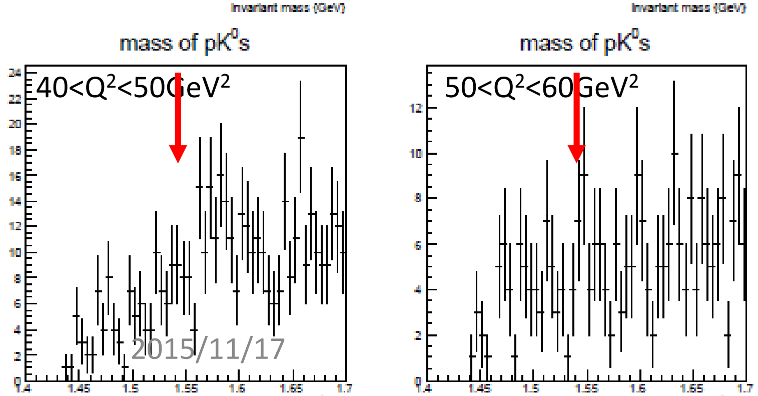


- Momentum distribution is different

Mass distribution (sliced by Q^2)

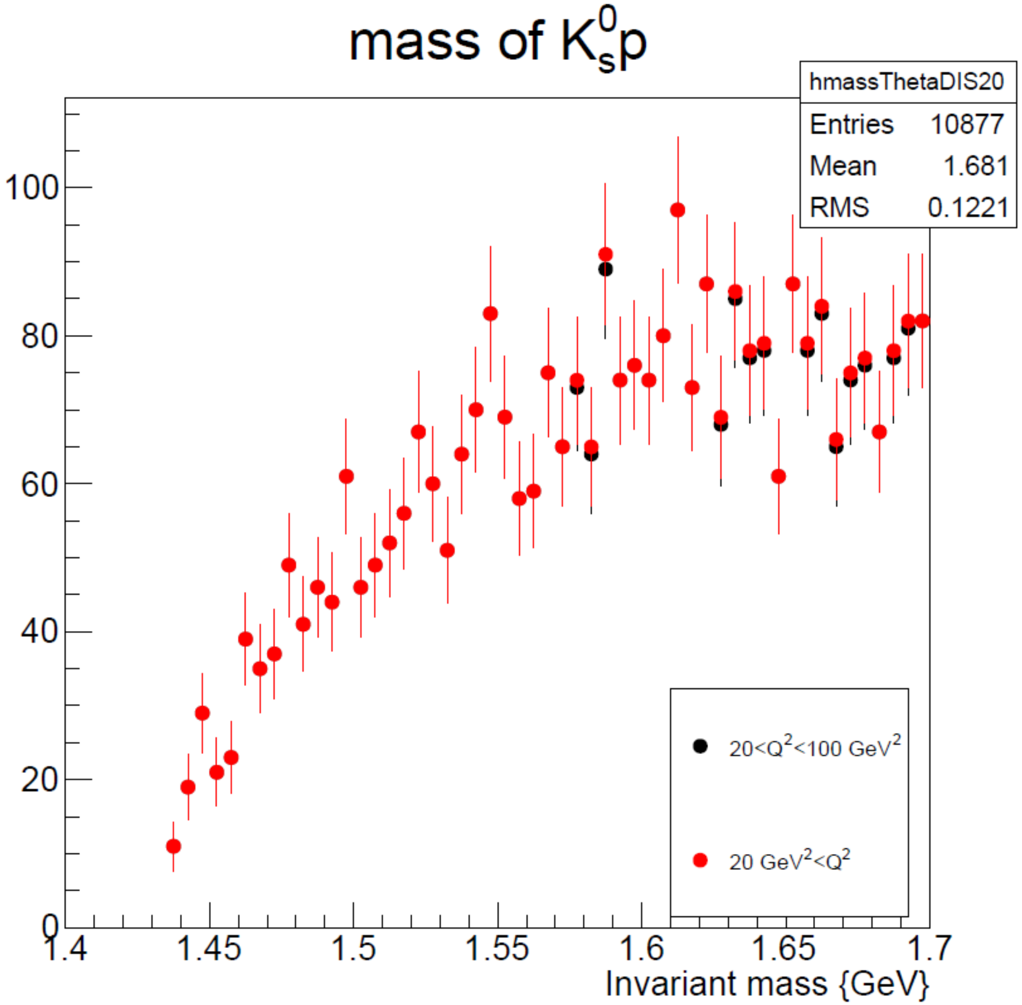
Red arrows point to ~1.54 GeV





- Events are check with Q^2 slice 10 GeV^2 step from 0 to 100 GeV^2
- Any peak is not seen.

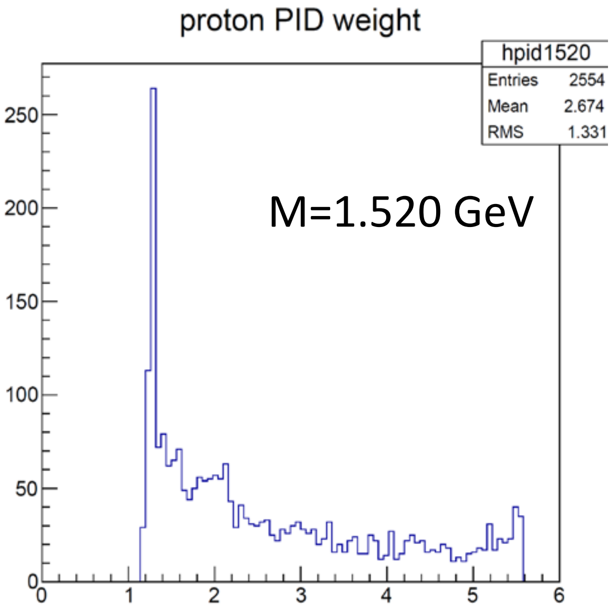
Remove Q^2 maximum selection

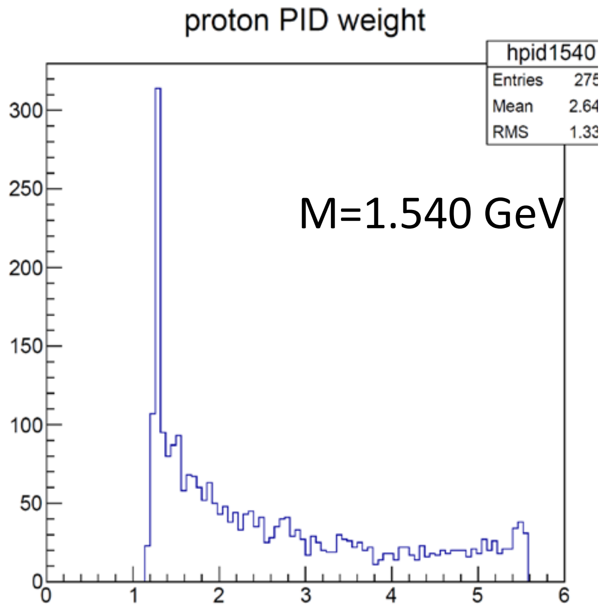


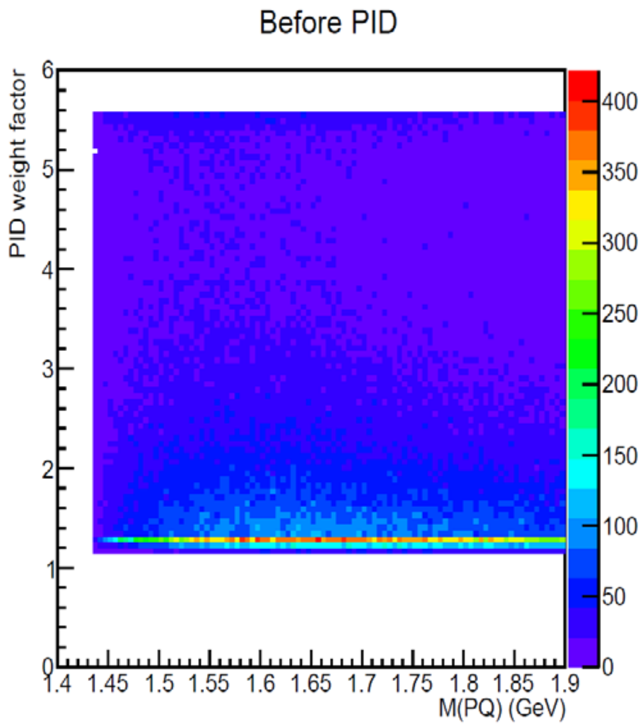
- Q^2 > 20 GeV^2 sample
- Red: no cut Q^2 maximum limit
- Black: maximum Q^2 less than 100 GeV^2

- The number difference is negligible.

Event-by-event PID weight distributions for each pK_S^0 mass (before PID selection)

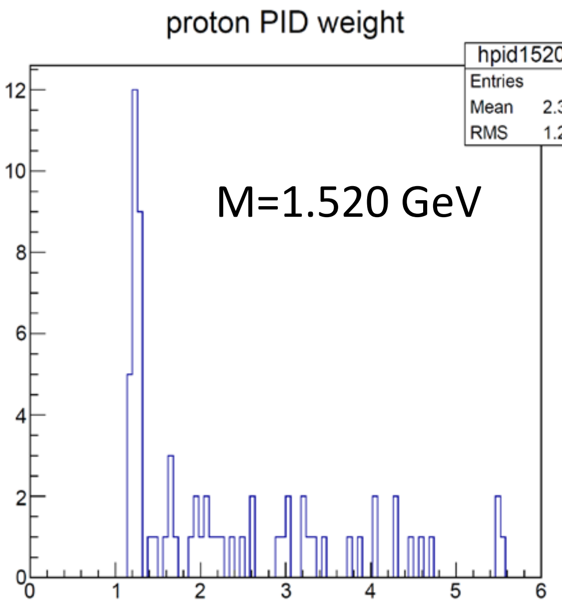


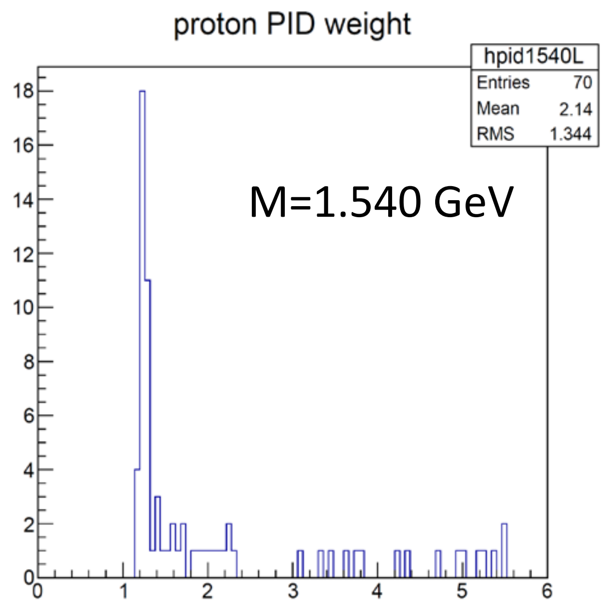


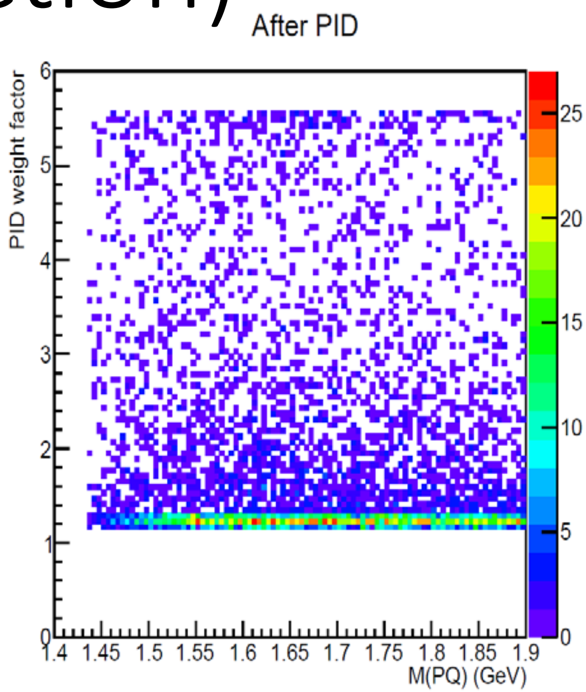


- The peak corresponds to the low momentum proton (<0.8 GeV).

PID weight distributions (after the PID selection)



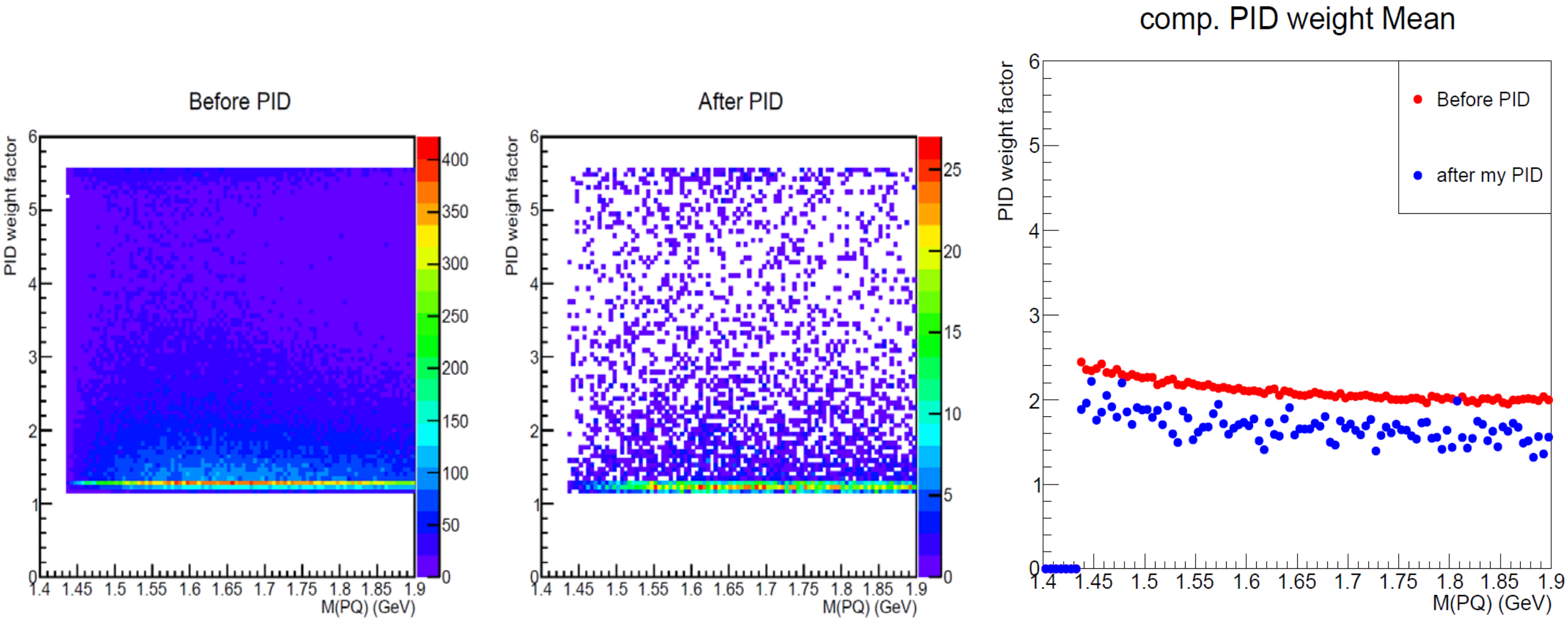




- After PID selection, low statistics -> weight fluctuations become large.

PID weight distributions (Mean)

- After PID, the mean of weight factor looks like scattering than the one before PID.
  -> This gives the fluctuation in the mass plots after the correction.
- => global proton PID correction with PQ MC is tried.



Global PID efficiency correction.

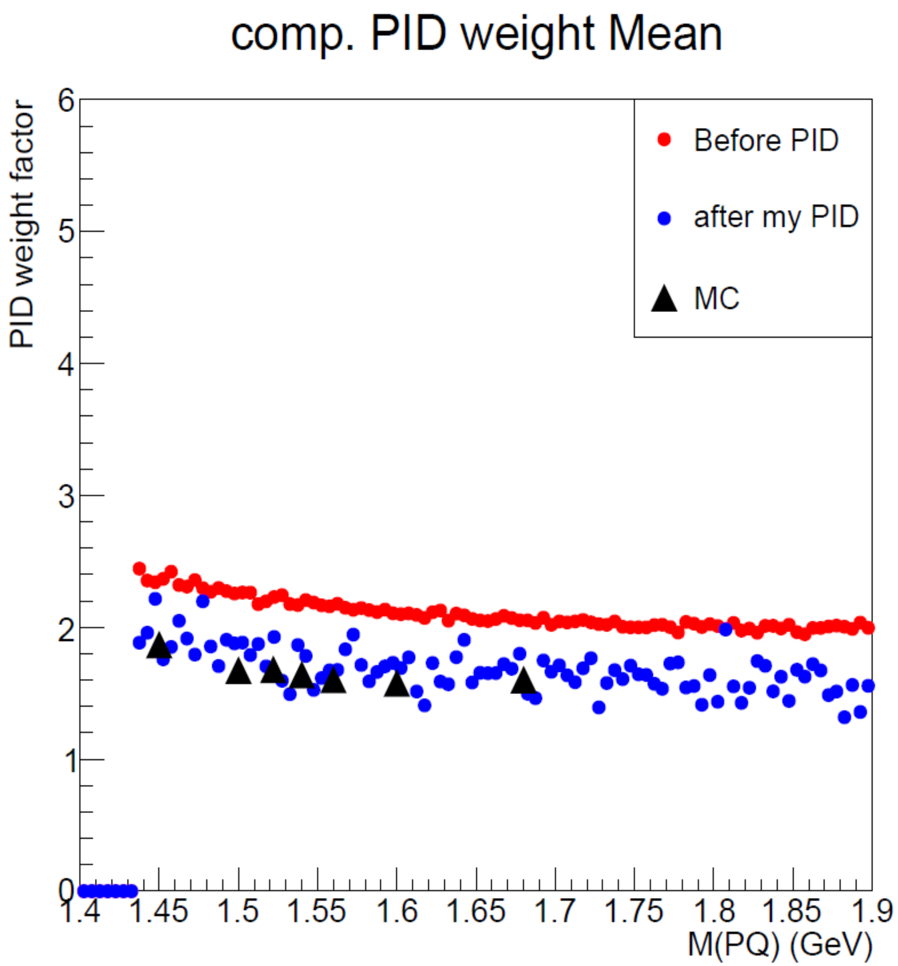
- Why event-by-event weight ? Better with the global correction? (Robert Klanner)

  We used event-by-event correction because we have 2 different correction (PID and eta-pt acceptance) for each events. For the main analysis we decided to choose a global correction to the $p_T - \eta$, now proton PID efficiency is the only event-by-event weight. In this situation, it is also thinkable to have the global correction for proton PID as well.

  -- We tried this option. (page 21)

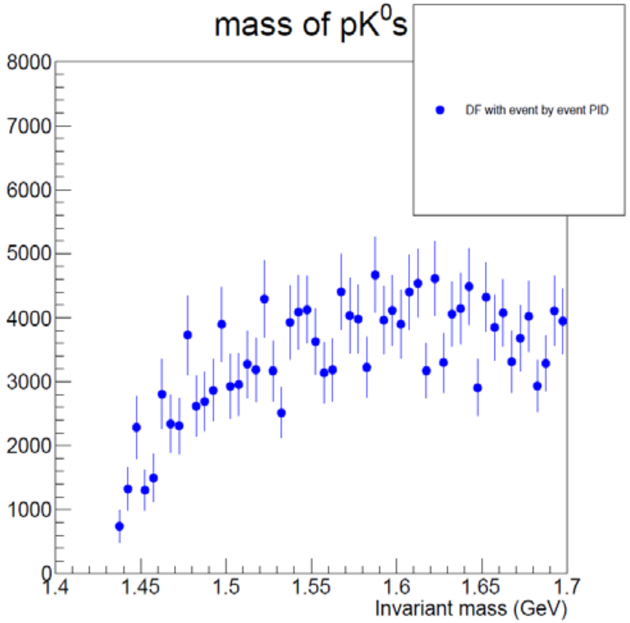
- Test an alternative method of proton PID efficiency correction.
  - Weight factor is calculated from PQ MC samples.
  - Include PID efficiency weight into acceptance correction.

PID efficiency comparison (DATA and MC)

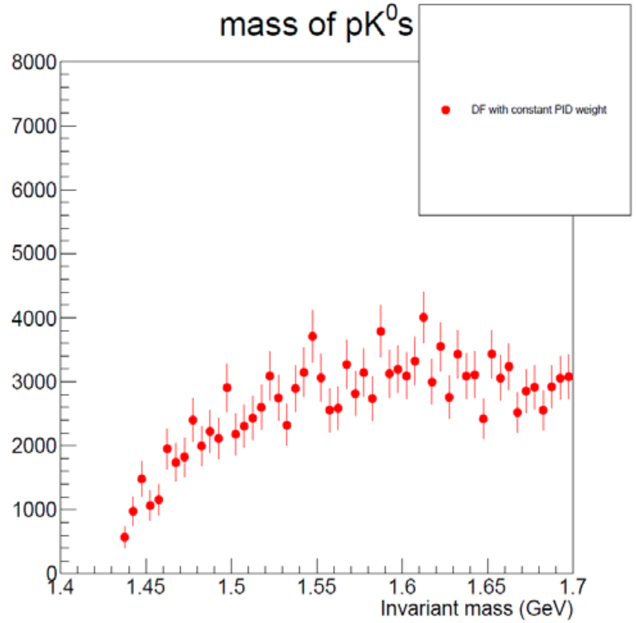


- The correction factor determined by the PQ MC follows the average event-by-event factor from the data (but less fluctuation)

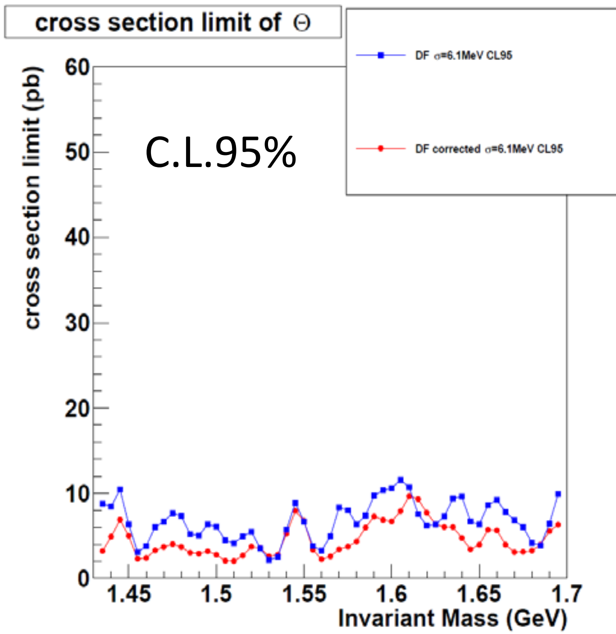
Comparison



Event-by-Event PID weight (default)



Global PID weight



comparison

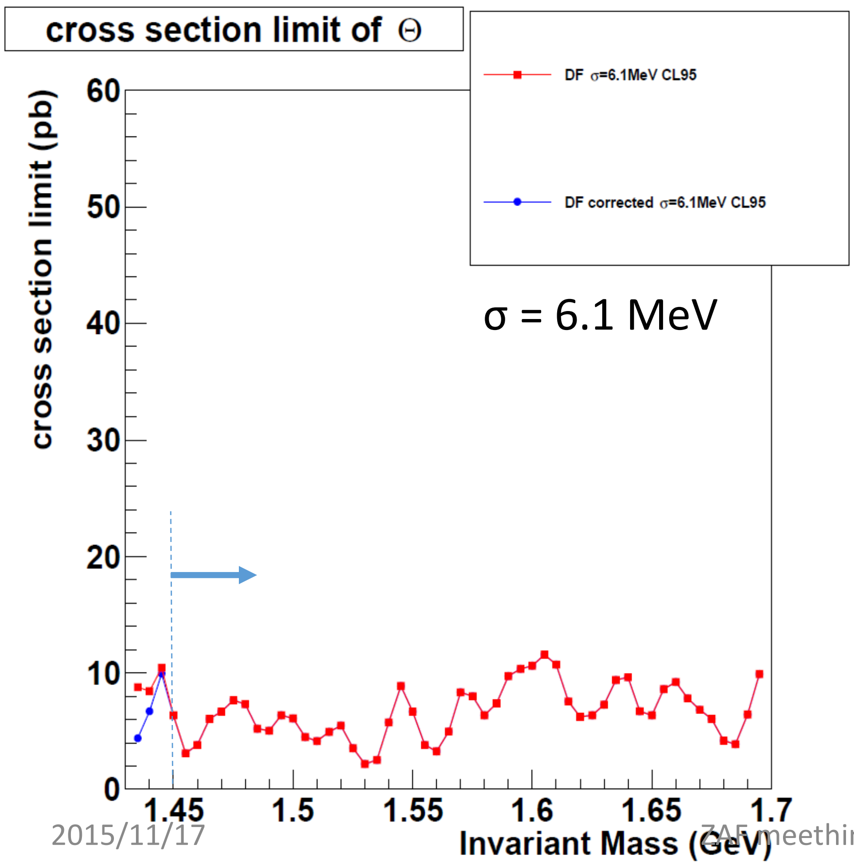
- Lower fluctuation with the global correction.
- The cross section limit is ~20% smaller.

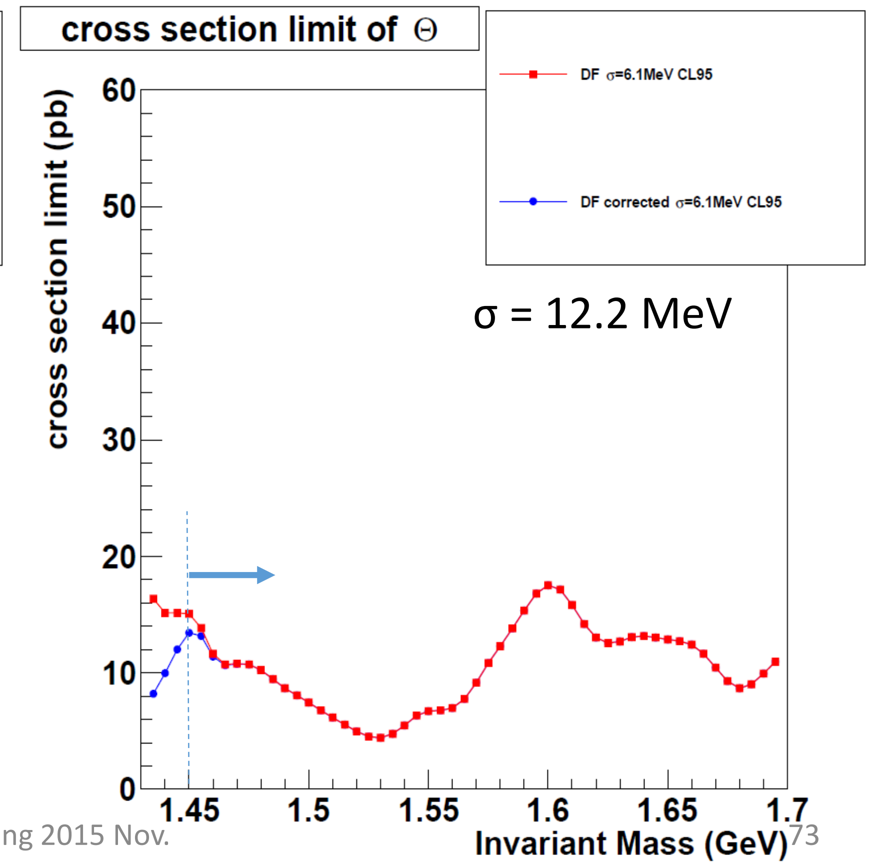
Gaussian correction

- Simple Test to correct an effect of signal Gaussian（after correction：blue）.
  - Exclude the Gaussian area below pK_S^0 mass kinematic limit:

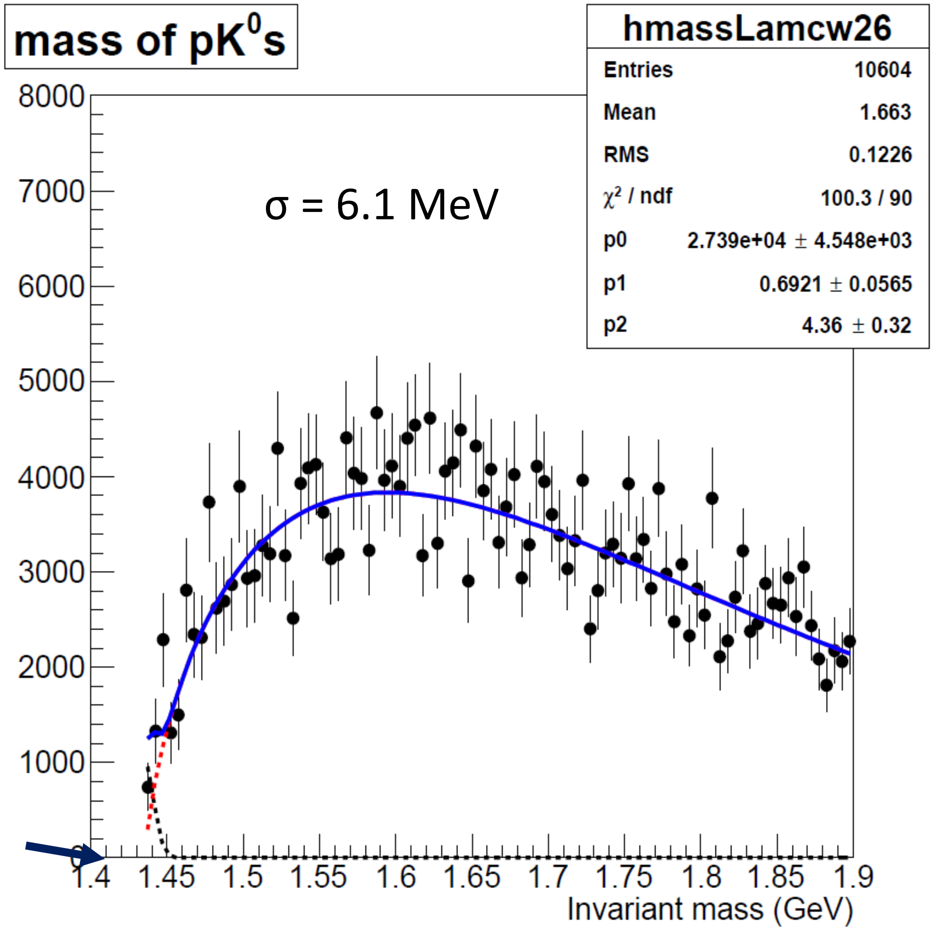
    We don’t like to consider the more complicated threshold effect

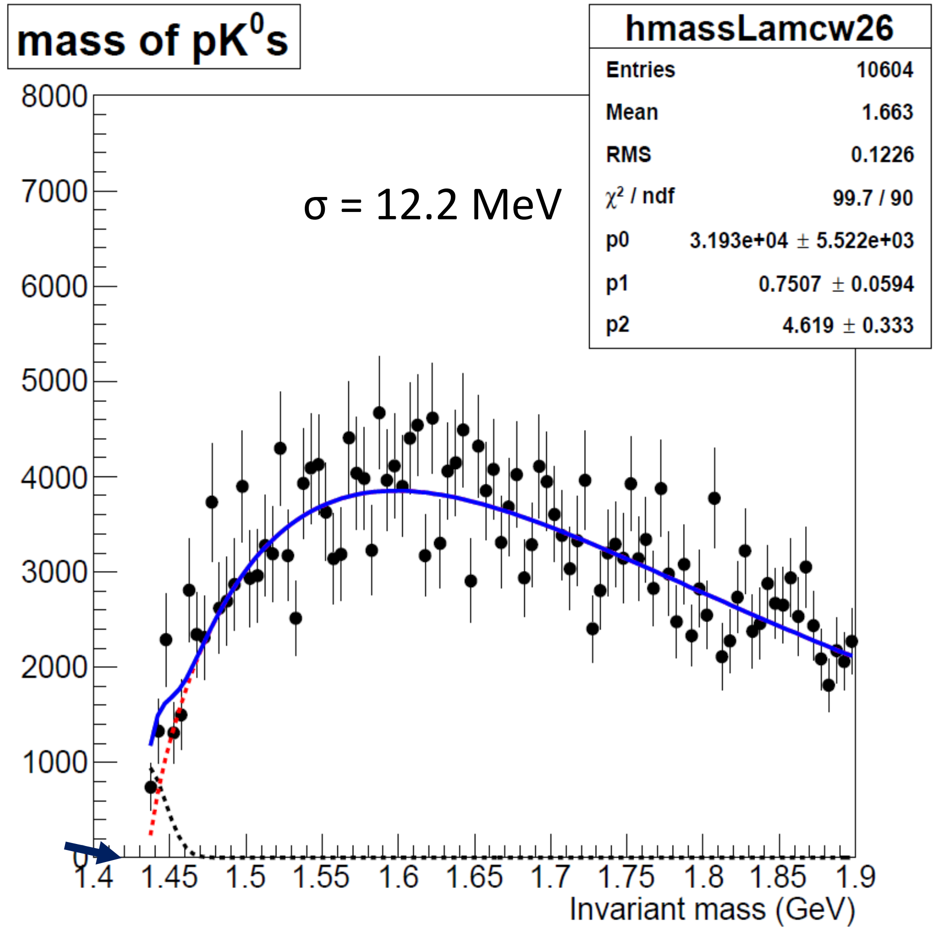
    → Proposal： show the limits above 1.45 GeV





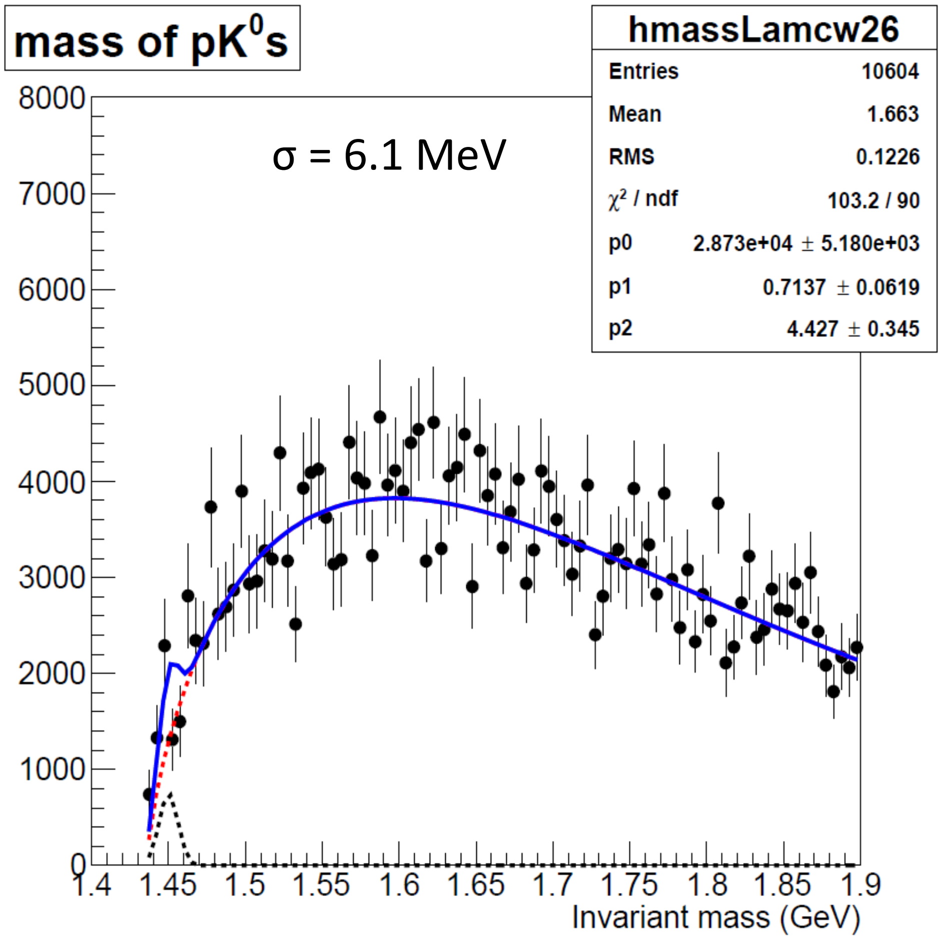
Fit figure. (M=1.435GeV)

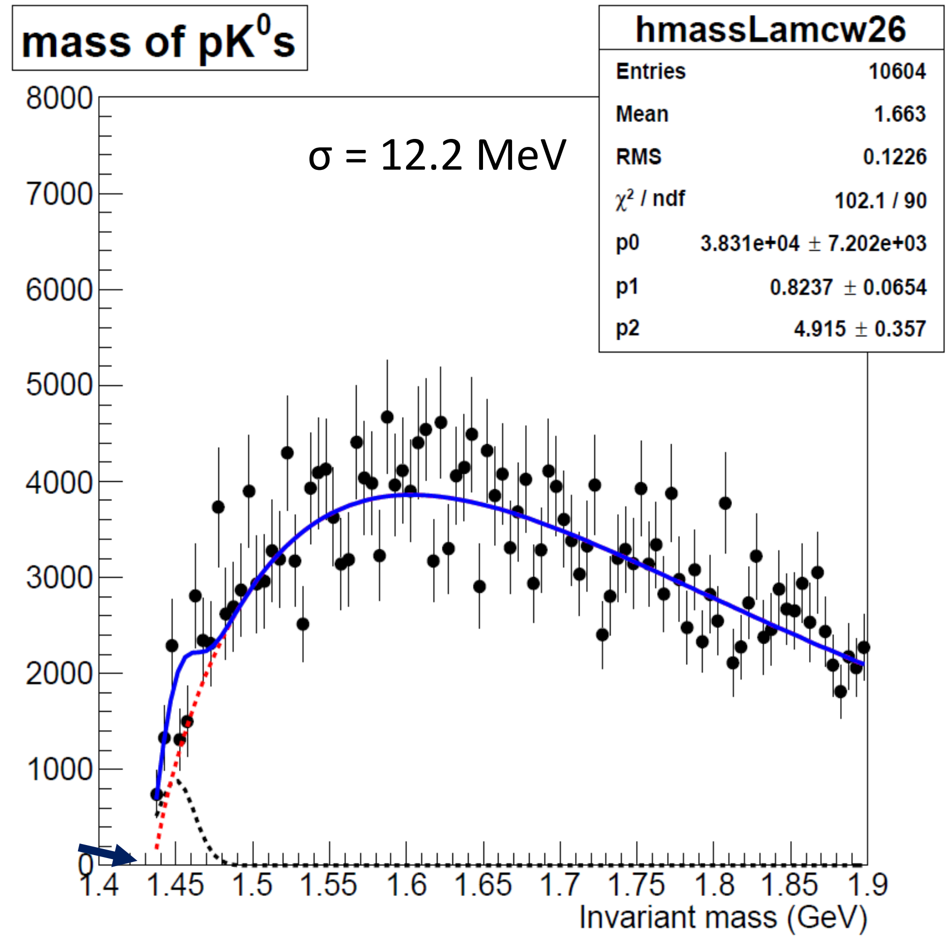




- Cross section is overestimated because of the edge of fitting Gaussian is out of fit range.

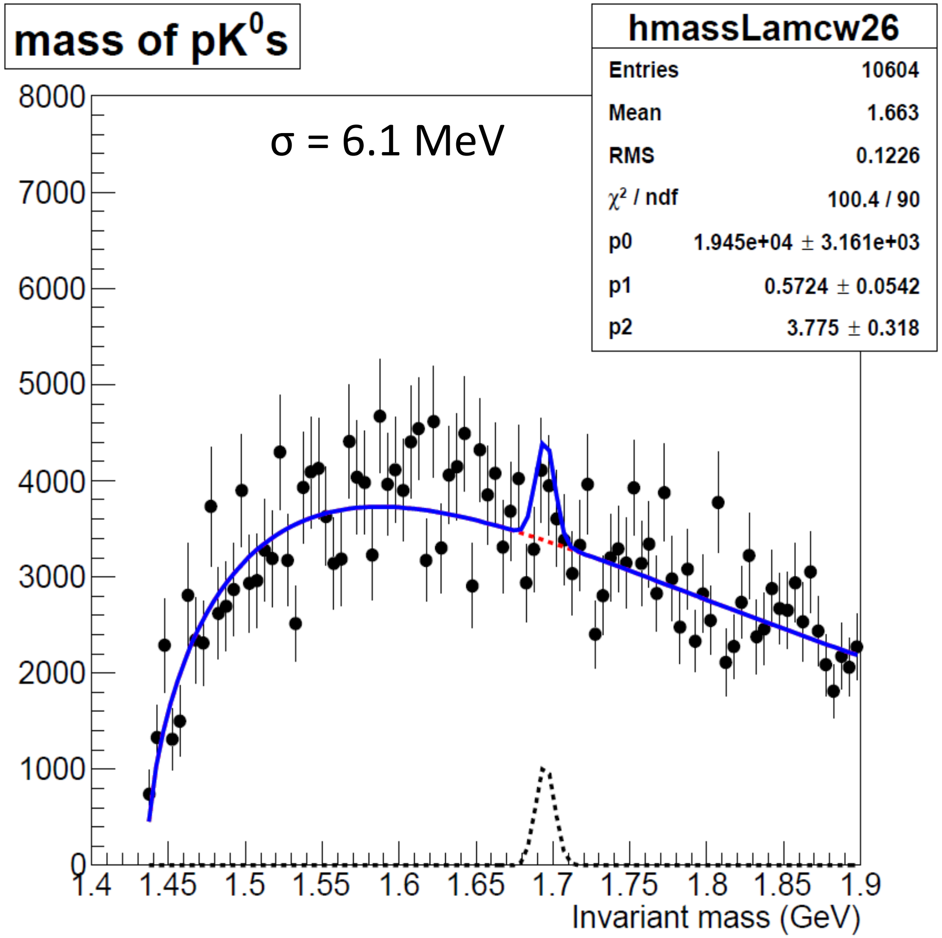
Fit figure. (M=1.450GeV)

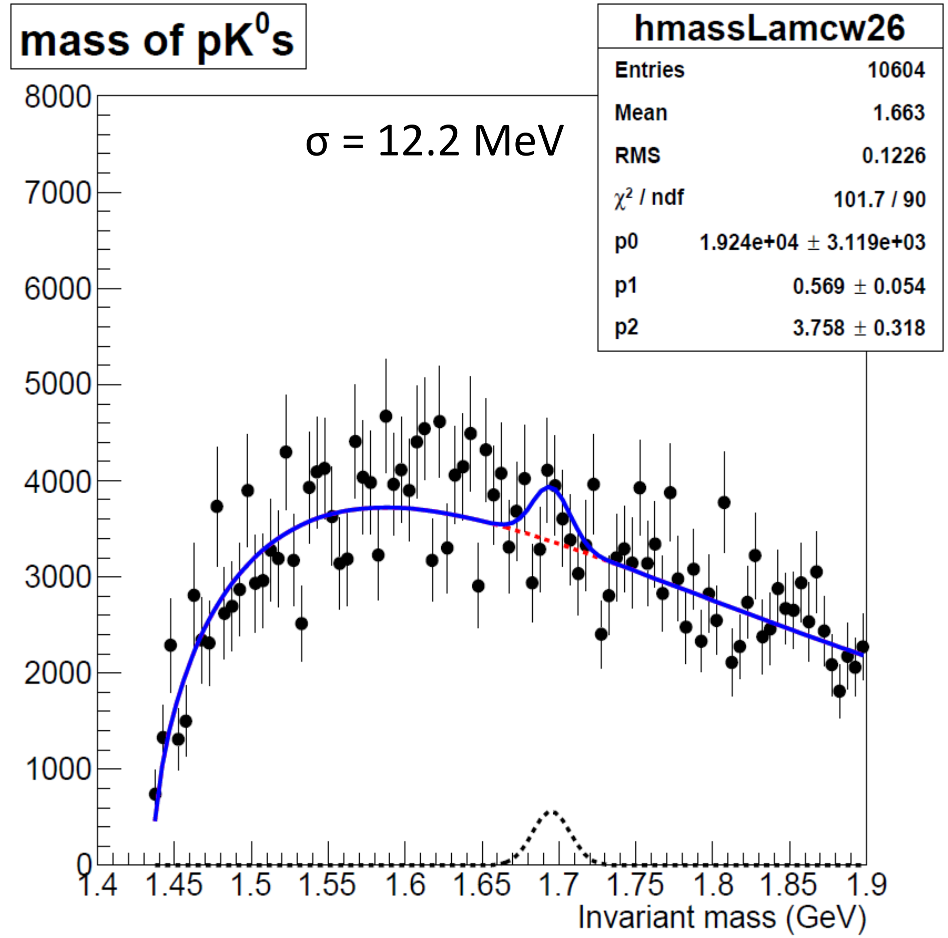




- Fitting Gaussian of larger σ shape also out of the range.

Fit figure. (M=1.695GeV)





- Since mass range is enough to fit, there is no problem.

Comparison with CN and my private ntuple (DF)

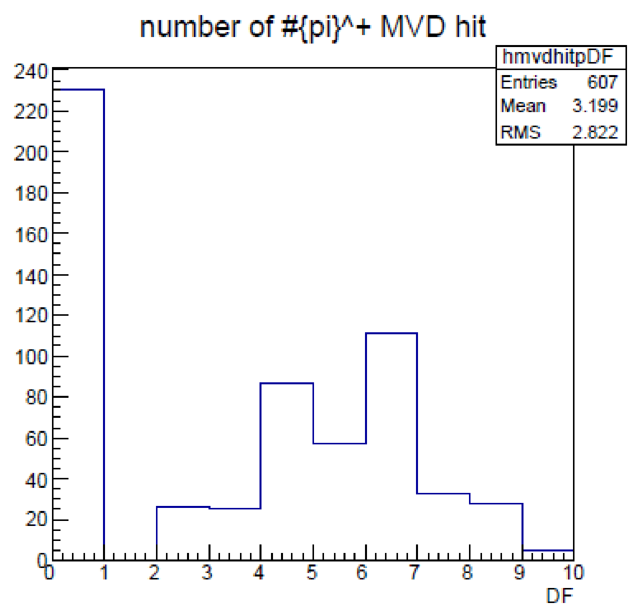
- In summer 2014, I reported there are no big overlap in the events selected by my nutple and common ntuple. After some differences (in track selections) are corrected, the agreement is better and the main difference is in the PID selection.
- Comparison of numbers of events between after CTD PID and my PID are shown below tables.
  - events in CN are ~10% more than my ntuple but now 80% of events are common after CTD-PID selection
  - Difference become larger after the CTD&MVD PID but this is because the calibration of MVD PID is better in my ntuple.

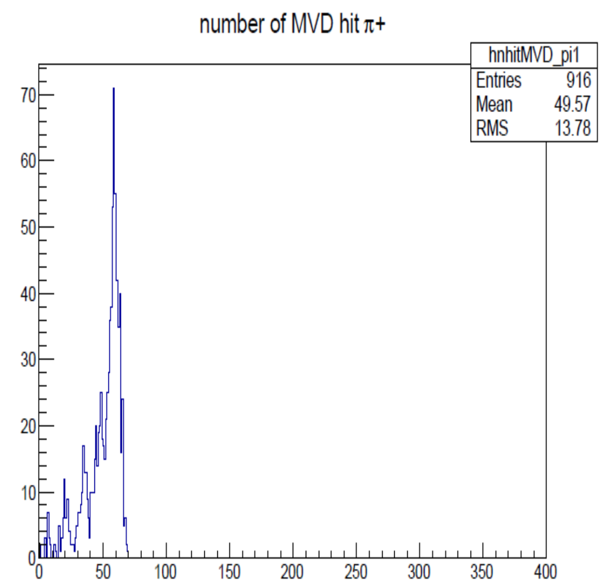
2004-5CTD	**Total**	**Common**	**Ryuma Only**	**CN only**
Ryuma	7459	6720	739	
CN	8207	6720		1487

2005myPID	**Total**	**Common**	**Ryuma Only**	**CN only**
Ryuma	2866	2458	408	
CN	3476	2458		1017

1) trk_ndof2 miss match

- MVD dEdx hit distributions are different
  - Analysis uses trk_ndof2 orange variable as number of MVD hit.
  - When I created my private ntuple, trk_ndof2 contains the number of MVD hit.
  - But, in the CN, trk_ndof2 seems to have the number of CTD hit
  - > Modified to use the sum of trk_br, trk_bz, trk_wv and trk_wu



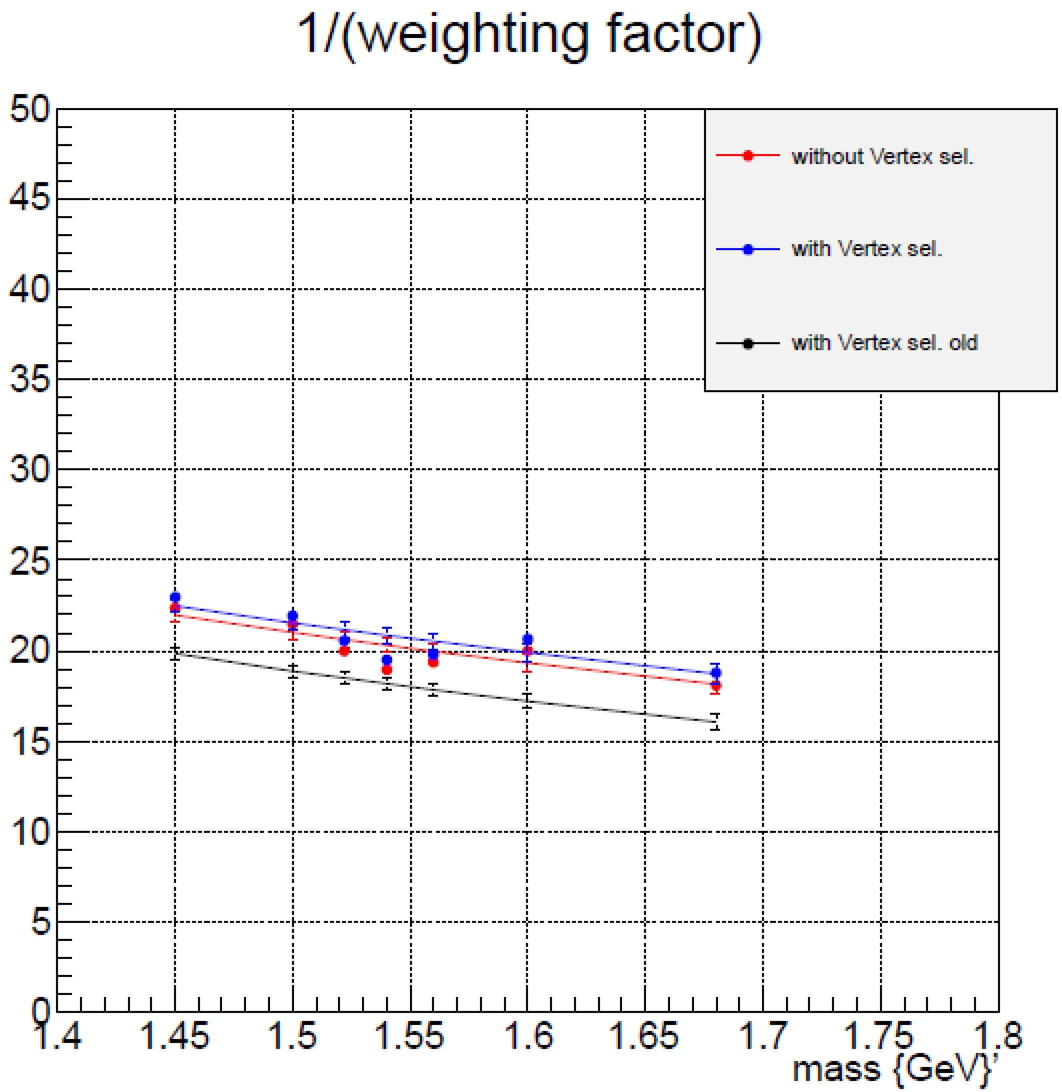


2) Primary vertex condition

- In my analysis, K^0s are reconstructed with the tracks not associated to the primary vertex, as it is the case for the HERA-1 analysis.
- 62 events (out of 94 mismatched events) are not selected in the common-ntuple sample because one of the pion track of K^0s belongs to the primary vertex, tested with the orange variable (trk_prim_vtx).
- Still checking the reason of the difference.

-> probably we modify to remove the non-primary-vertex requirement.

Check efficiency comparison



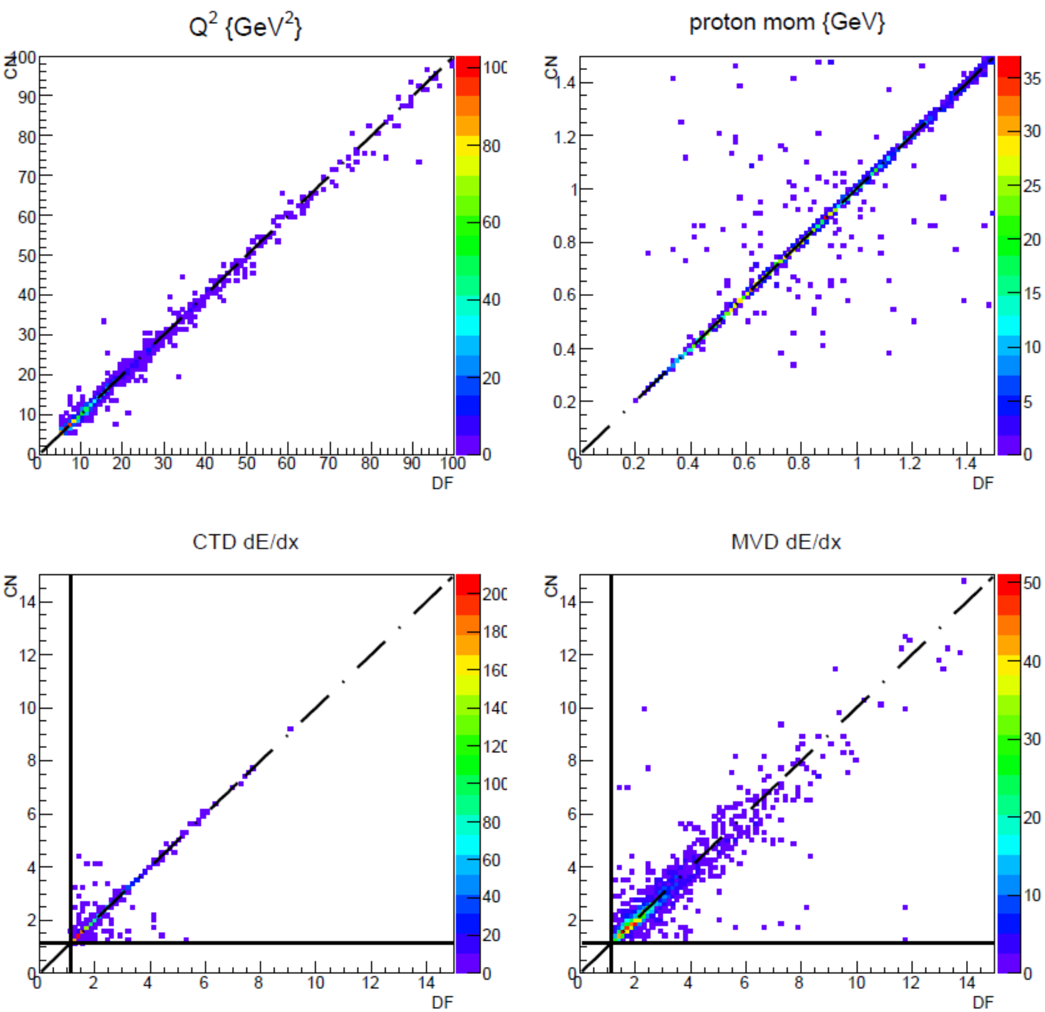
- Re-calculate efficiency.
- Comparison w/o 2ndary Vtx requirement to K0s.
  - Blue: with vtx. Req.
  - RED : without vtx. Req.
  - Black: older calc. with vtx. Req.
- The difference between newer eff.s is not large than before.

MVD dE/dx calculation difference

- Difference of MVD dE/dx calculation method between my private ntuple and CN
  - My ntuple
    - Calculate dE/dx by using Probability Density Function (my routine)
      - Gaussian convoluted Landau function used as PDF
    - Correct 2ndary angle effect
      - $dE/dx_{hit}=A(1-B\sin^4\alpha)*ADC_{raw}$
    - run-by-run dE/dx correction for each ladder
    - Gain correction
  - CN
    - Calculate dE/dx by truncated mean (orange default)
    - global run-by-run dE/dx correction (i.e. not ladder-by-ladder) : (my routine)
    - Gain correction

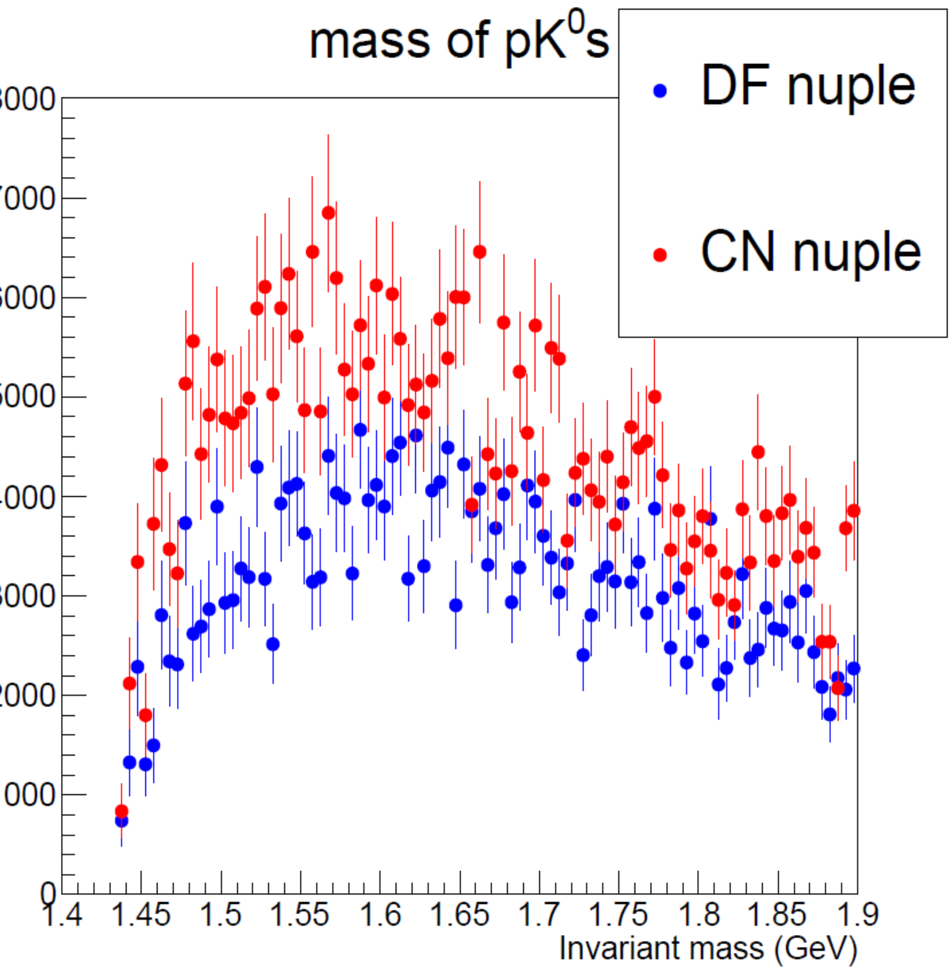
=> dE/dx resolution of the two method is shown in the next slide

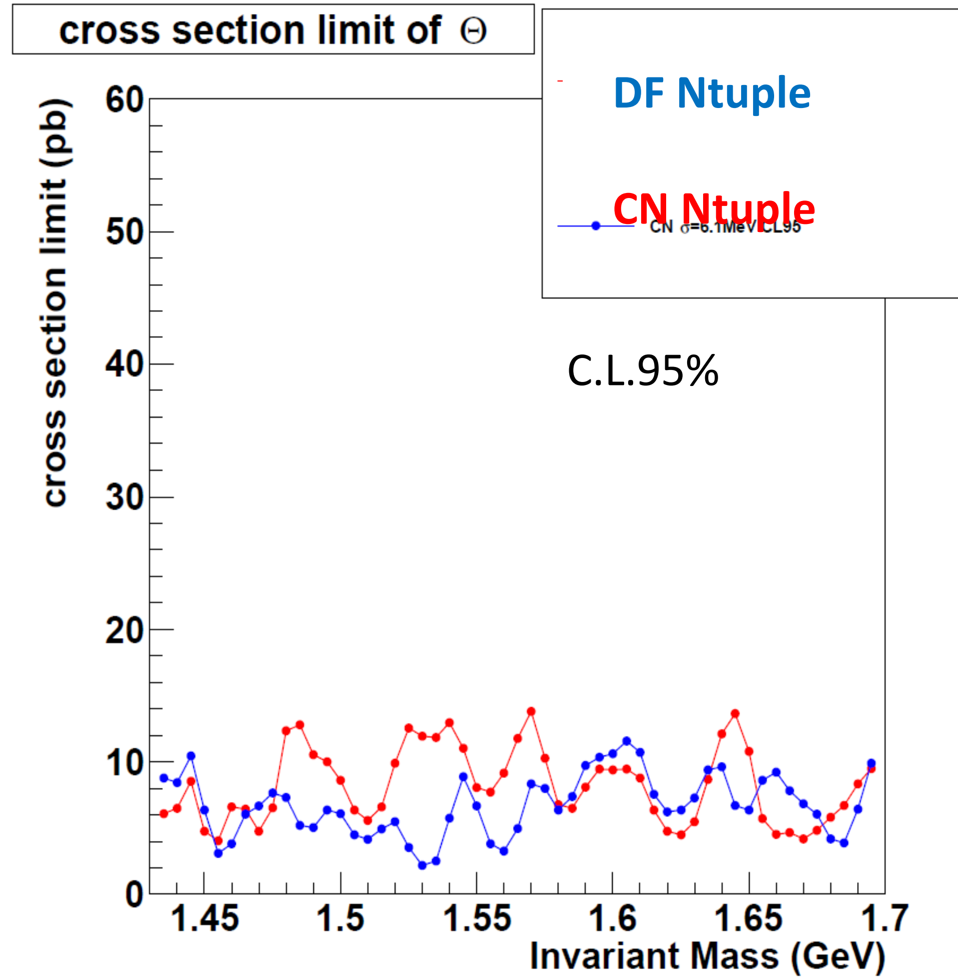
variables comparison between the 2 ntuples



- Compared variables (Q^2, pr(p), CTD dE/dx and MVD dE/dx) between DF(m private) ntuple vs. CN.
- p(p) and CTD dE/dx has small differences.
- Q^2 distribution is broader a little. (Siq2da)
- MVD dE/dx is the broadest variable than others.
  - This is because I cannot make sophisticated corrections for common ntuples as there are missing MVD hit information.

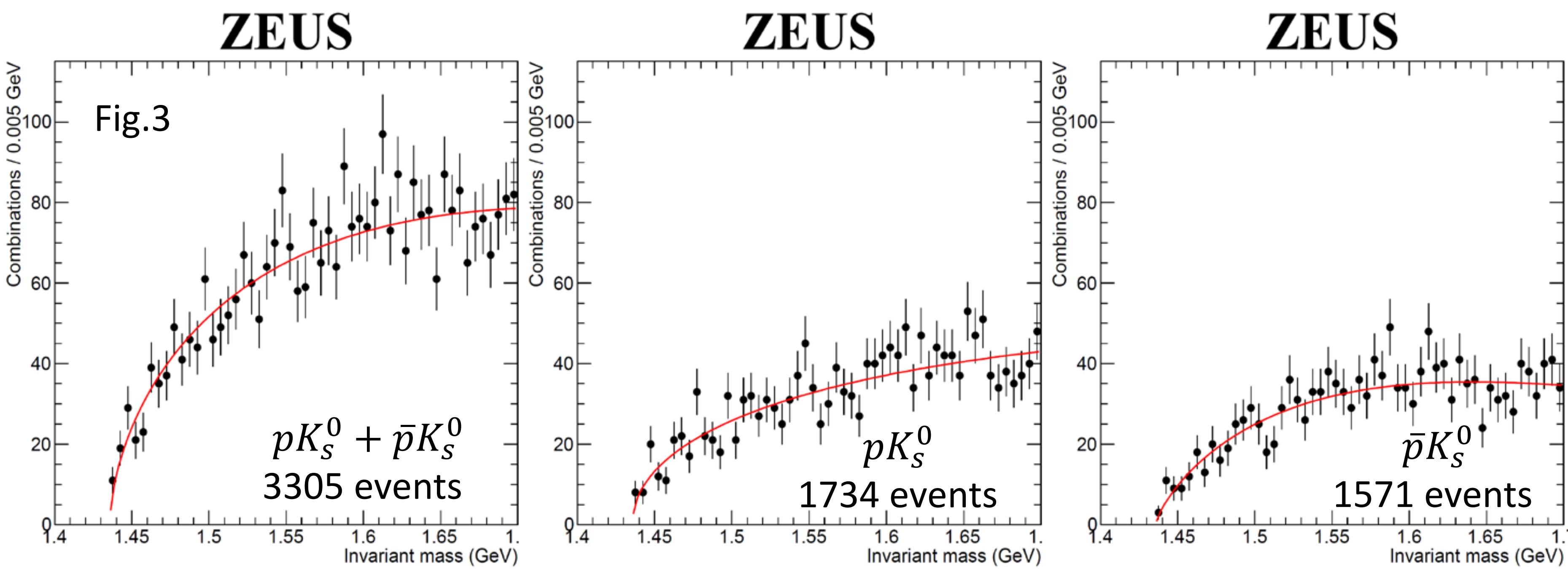
arison weighted mass distribution and cross section limit





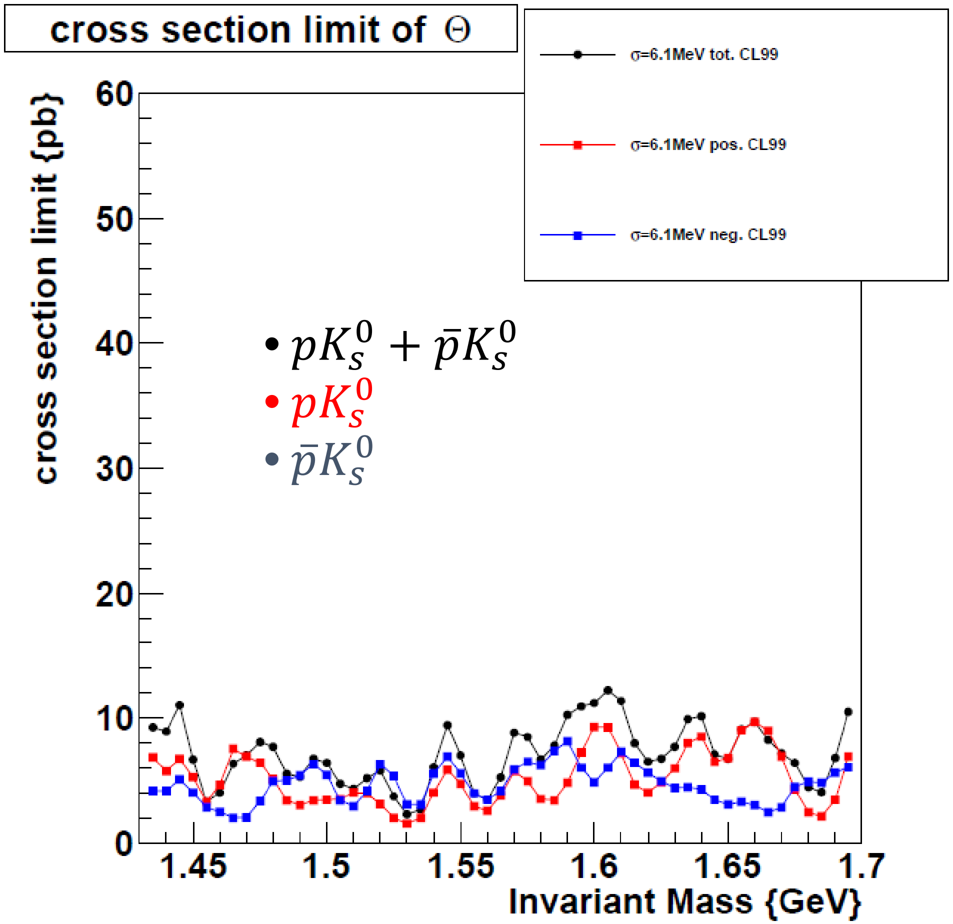
N ntuple is higher than DF. But the differences between cross section limit re not so large.

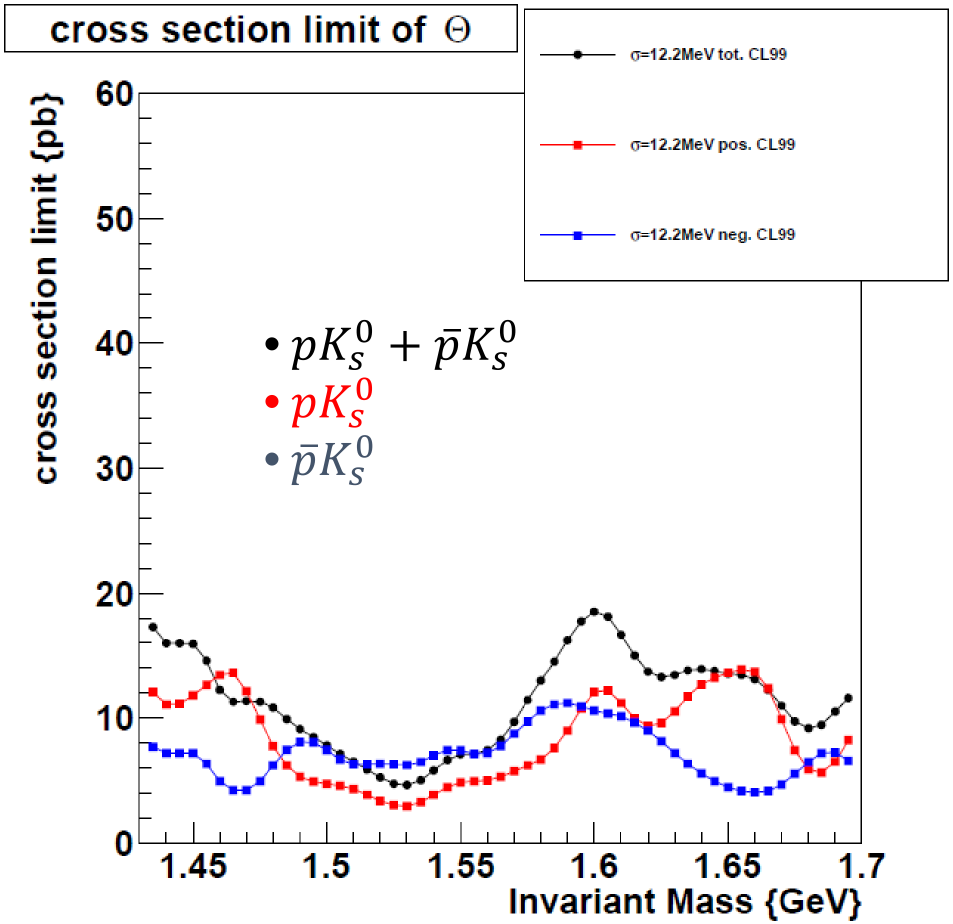
Mass distribution with charge separation (reminder)



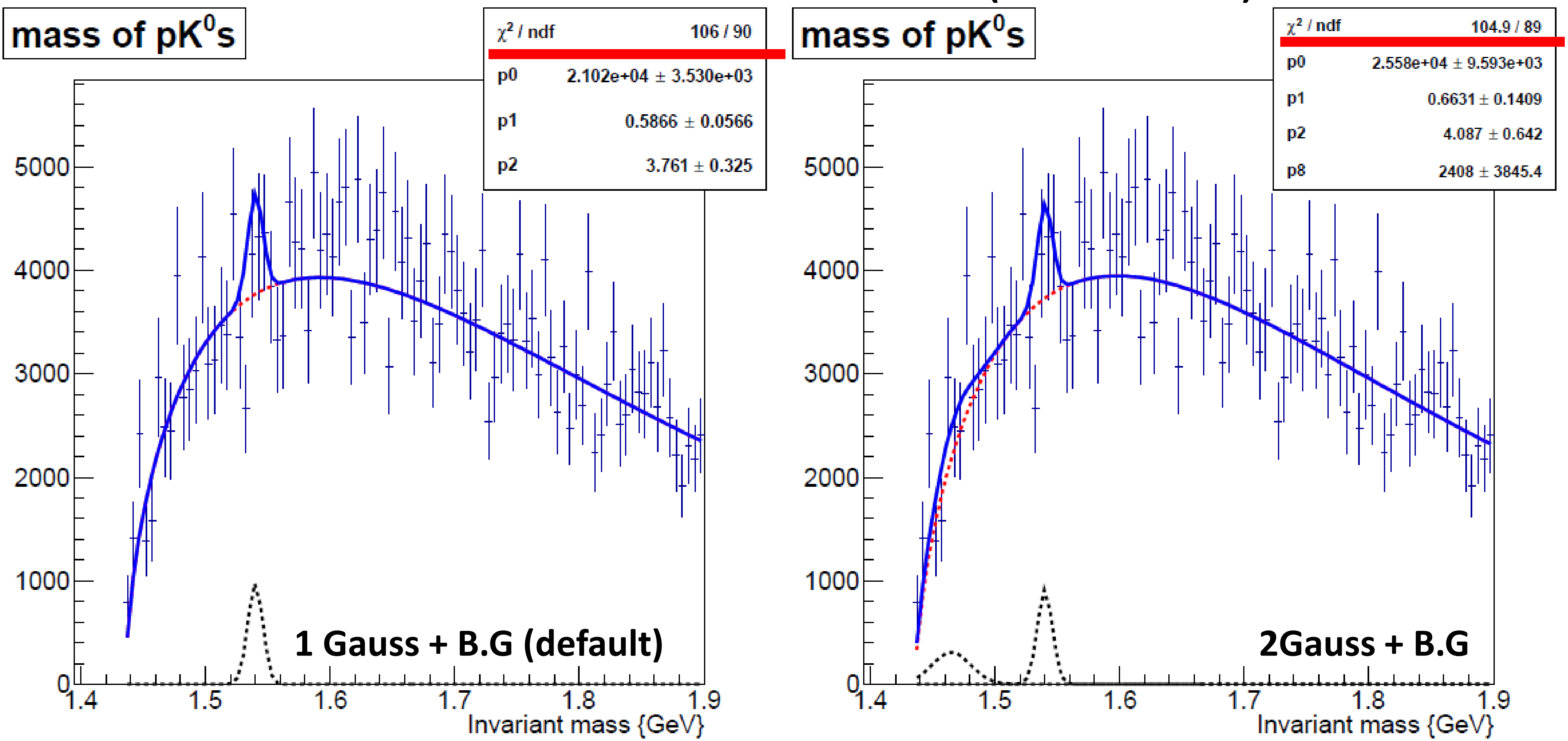
- Charge separation;
  - Fitted by the same function as shown in p.25.

C.S. limit with charge separation CL95 (old calculation)



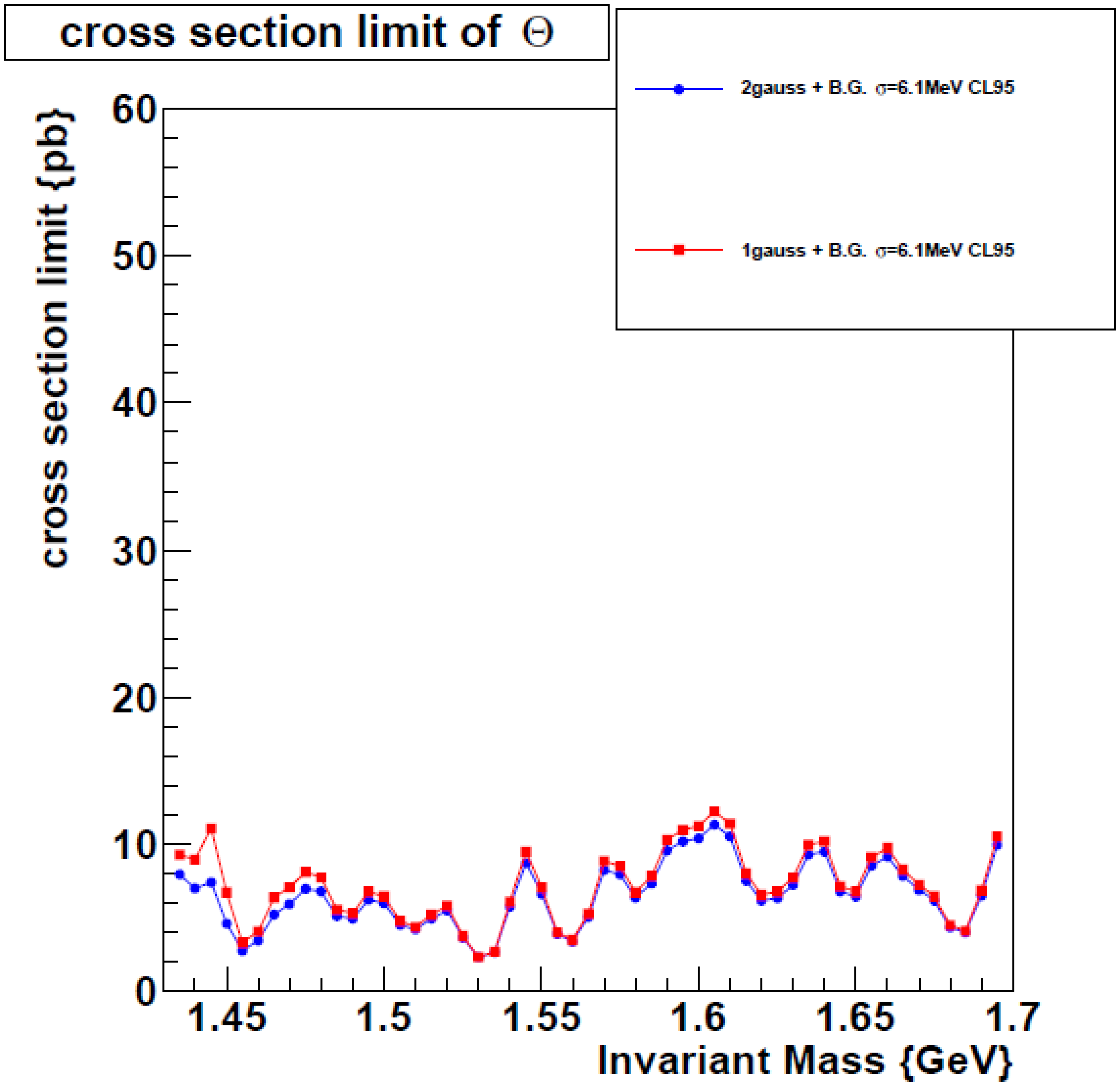


Comparison of fitting function on mass distribution @1540 MeV (C.L. 99)



- Added 2ndary Gauss function (σ=15.5MeV μ=1.465 GeV, these values come from HERA-I analysis.) to fitting function.
- The value of the added function becomes slightly better.

Comparison of C.S. limit

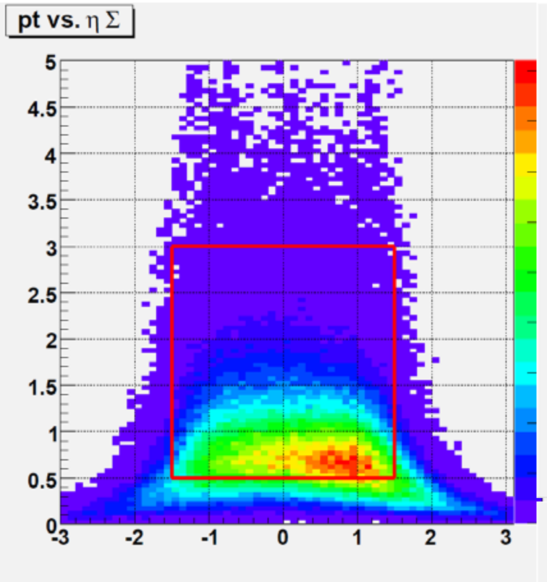


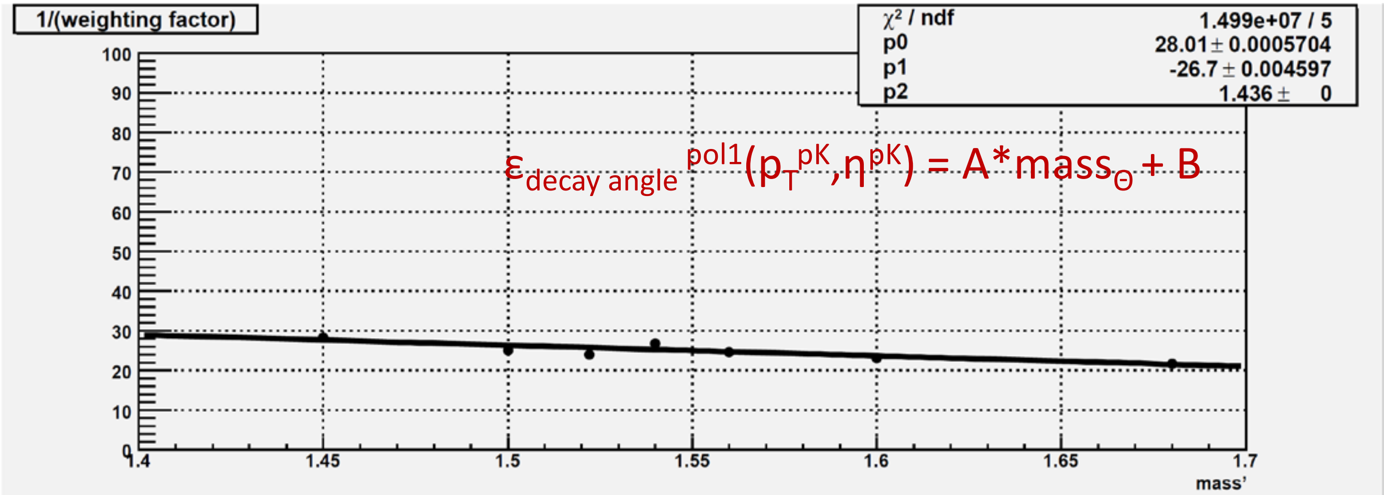
lue: 2 Gauss + B.G fitting

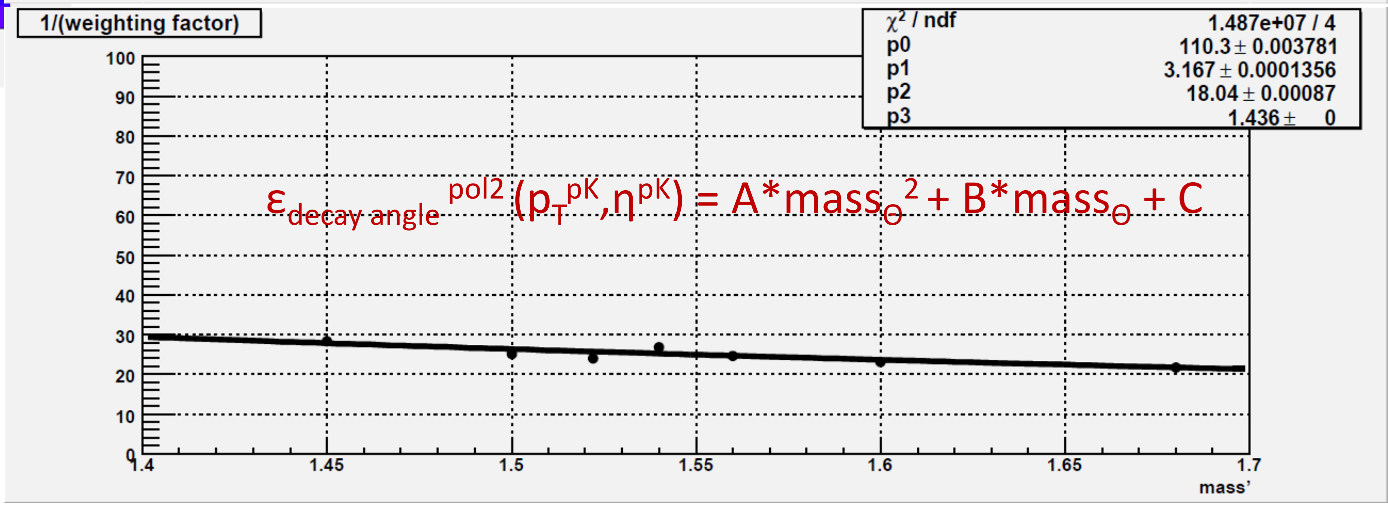
ed: 1 Gauss + B.G fitting

ference is negligible

Example: Acceptance mass dependency (Binning 3)

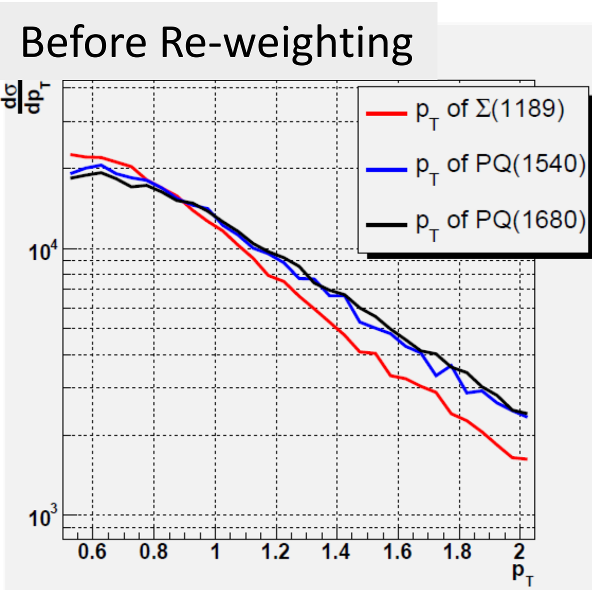


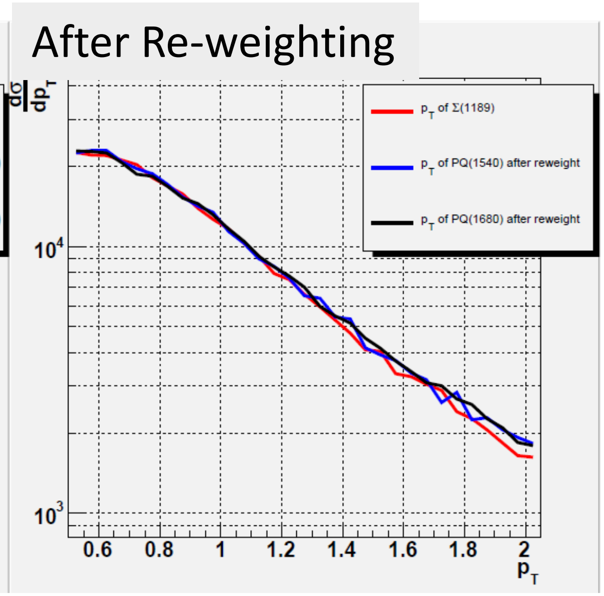




- For each (p_T, η) bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic, the factor is fitted with a linear function and a quadratic function.

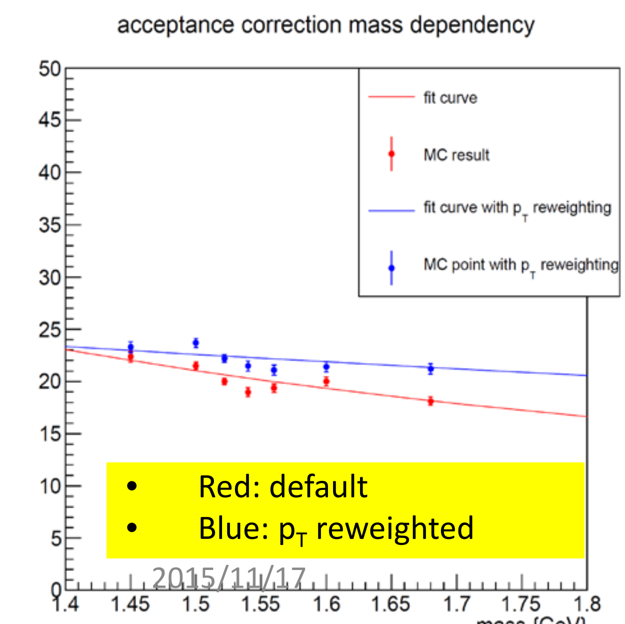
Systematic Estimation: p_T spectrum





- The detector acceptance depends on the p_T-distribution of the penta-quarks (PQ). Two different p_T models were tested.
  - 1. (default) as generated by RAPGAP 3.10 by replacing the Σ(1189) to PQ(X). (upper figure)

    $d\sigma/dp_T$ slopes changes as a function of the PQ mass. (The lighter, the steeper).
  - 2. A constant p_T-slope independent to the PQ mass. (uniformed by reweighting the RAPGAP MCs. $\Sigma^+(1189)$'s slope was used as standard.)



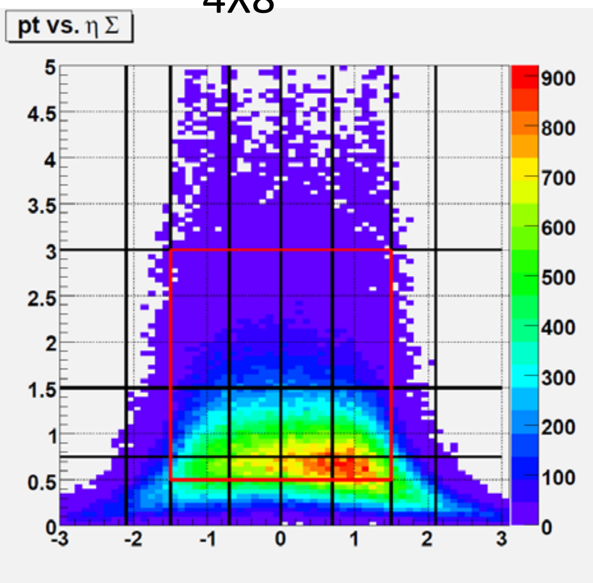
- For each (p_T, η) bin, a correction factor is calculated as a function of the Θ mass.

$$\varepsilon_{\text{decay angle}}^{\text{pol1}}(p_T^{pK},\eta^{pK}) = A*M_\Theta + B$$

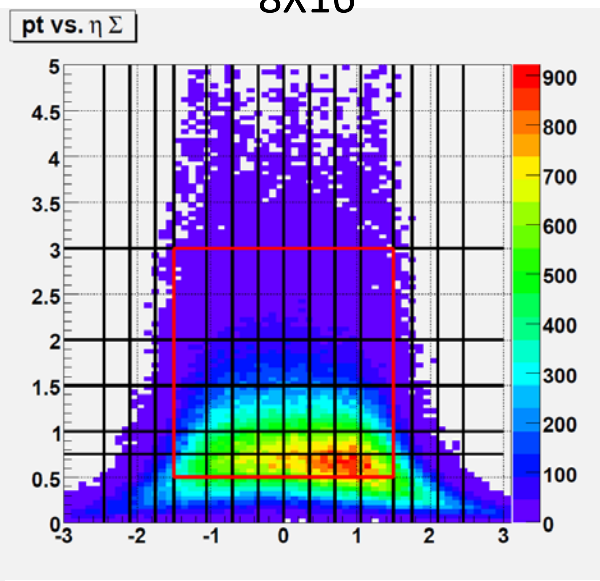
- p_T reweighting performed to estimate systematic error coming from PQ momentum changing.

Systematic Estimation: Binning

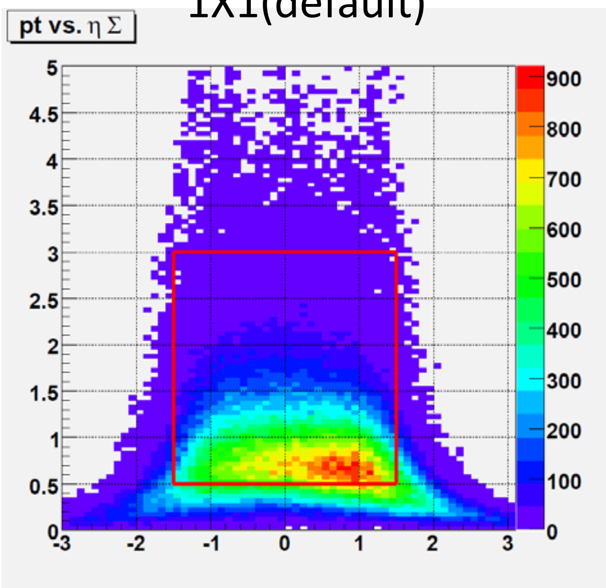
4X8



8X16



1X1(default)



- For each (p_T, η) bin, a correction factor is calculated as a function of the Θ mass. In order to check systematic, the factor is fitted with a linear function (above) and a quadratic function (shown backup). The difference is uses as systematic errors.

i.e. $\varepsilon_{\text{decay angle}}^{\text{pol1}}(p_T^{pK}, \eta^{pK}) = A*\text{mass}_{\Theta} + B$

in this figures.