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Hypernuclear and Strange Particle Physics

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DISTO data on K^-pp

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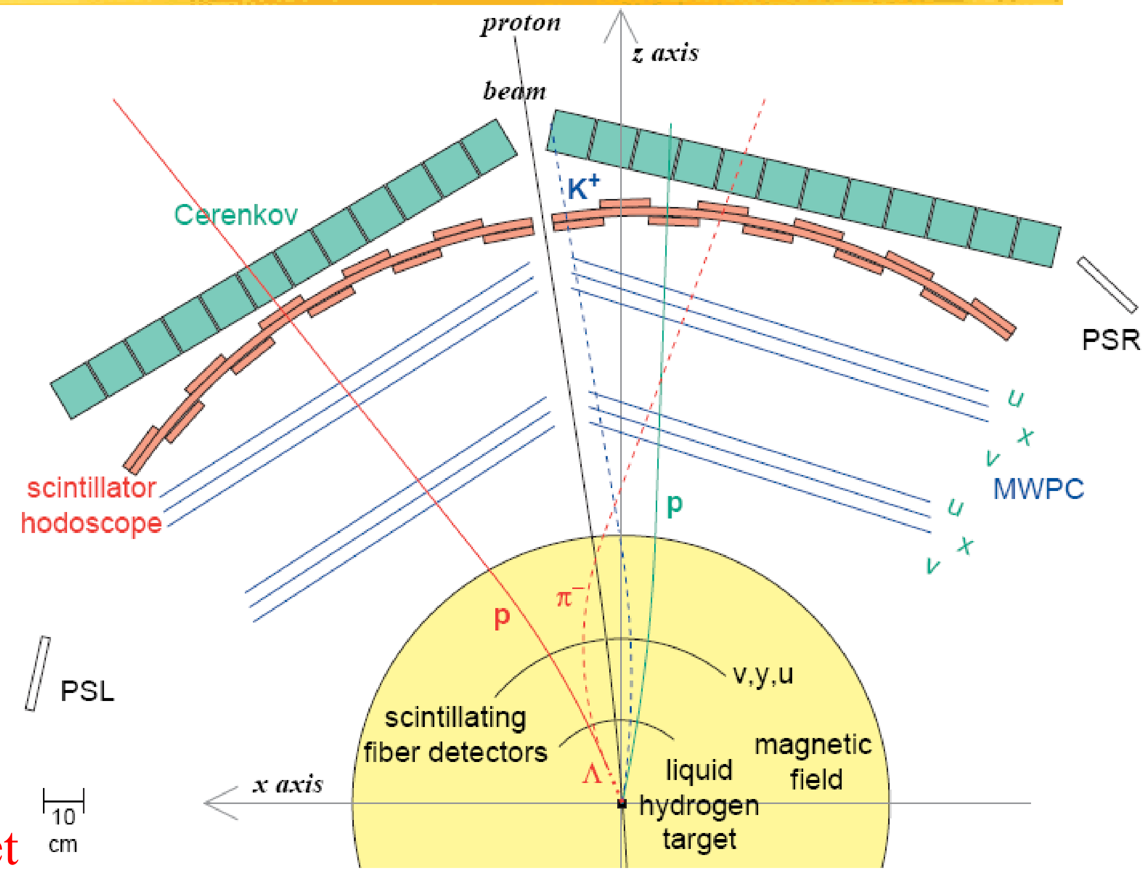
DISTO @ Saturne: polarised proton beam up to T = 2.9 Gev

Acceptance:

$\Delta\varphi = \pm\ 15.5^\circ$

$\Delta\theta = \pm\ 45^\circ$



- 2-cm thick unpolarised LH_2 target
- S170 magnet (< 14.7 KGauss, $\Delta\theta = \pm\ 120^\circ$, $\Delta\varphi = \pm\ 20^\circ$)
- semi-cylindrical 1mm-square scintillating fibers triplets inside magnet
- MWPC planar triplets outside magnet
- scintillator hodoscopes vertically and horizontally segmented
- scintillator hodoscopes as polarimeter slabs
- doped water Cerenkov counters

Hyperon production @ DISTO

Reaction	T_{thr}	Detected Prongs
$\vec{p}\,p \rightarrow p\,K^{+}\vec{\Lambda}$	1.58	$p\,K^{+}(p\,\pi^{-})$
$\vec{p}\,p \rightarrow p\,K^{+}\vec{\Sigma}^{0}$; $\vec{\Sigma}^{0} \rightarrow \vec{\Lambda}\,\gamma$	1.79	$p\,K^{+}(p\,\pi^{-})$

GOAL: first exclusive (kinematically complete) measurements with a polarised beam for

$$\vec{p}p \rightarrow pK^{+}\vec{Y}$$

@ $T_p = 2.85 / 2.5 / 2.145$ GeV

Hyperon production @ DISTO

Reaction	T_{thr}	Detected Prongs
$\vec{p}\,p \rightarrow p\,K^{+}\,\vec{\Lambda}$	1.58	$p\,K^{+}(p\,\pi^{-})$
$\vec{p}\,p \rightarrow p\,K^{+}\,\vec{\Sigma}^{0}$ $\vec{\Sigma}^{0} \rightarrow \vec{\Lambda}\,\gamma$	1.79	$p\,K^{+}(p\,\pi^{-})$
$\vec{p}\,p \rightarrow p\,K^{+}\,\Sigma^{*0}_{(1385)}$	2.34	$p\,K^{+}(p\,\pi^{-})$ from $\Lambda\,\pi^{0}$ or $\Sigma^{0}\,\pi^{0}$ $p\,K^{+}\,\pi^{+}(\pi^{-})$ from $\Sigma^{-}\,\pi^{+}$ $p\,K^{+}\,\pi^{-}(p)$ or (π^{+}) from $\Sigma^{+}\,\pi^{-}$
$\vec{p}\,p \rightarrow p\,K^{+}\,\Lambda^{*}_{(1405)}$	2.40	$p\,K^{+}\,\pi^{+}(\pi^{-})$ from $\Sigma^{-}\,\pi^{+}$ $p\,K^{+}(p\,\pi^{-})$ from $\Sigma^{0}\,\pi^{0}$ $p\,K^{+}\,\pi^{-}(p)$ or (π^{+}) from $\Sigma^{+}\,\pi^{-}$

Hyperon events' topology – Data @ 2.94 , 3.31 and 3.67 GeV

- DECAY VERTEX:
  $\vec{\Lambda} \to p\,\pi^-$
  - 1 positive track
  - 1 negative track
- REACTION VERTEX:
  $p\,K^+$
  - 2 positives tracks

$p\,K^+\Lambda$ → complete reconstruction

$p\,K^+\Sigma^0$ → γ missing

$p\,K^+\Sigma^{*0}_{(1385)}$, $p\,K^+\Lambda_{(1405)}$ → $\pi^0$and/or γ missing

Hyperon production: event selection

Kinematic region restricted to:

$-0.7 \leq x_F \leq 0.9$, $p_T \leq 750$ MeV/c , $|\cos \varphi_\Lambda| < 0.7$

Additional cuts:

- π^+ veto
- $|\theta_{p,\Lambda}| < 0.15$ rad, decay proton momentun in LF
- p ID for positive track from decay vertex
- $\Delta p_{tot} < 1$ GeV/c $\Rightarrow$ missing a π at most
- $|z_{V_R}| < 3.5$ cm $\Rightarrow$ Klegecell veto
- $\overline{V_R V_D} > 4\ cm$

Hyperon production: event selection

Kinematically constrained refit (the most effective cut!)

- $M_{\pi^- p} = M_\Lambda$ $\Rightarrow$ 1 d.o.f
- $\vec{p}_\Lambda \parallel \overrightarrow{V_R V_D}$ $\Rightarrow$ 2 d.o.f
- $\Delta M_{4B} = 0$ or $\Delta M_{4B} = M_\pi$ $\Rightarrow$ 1 d.o.f

$\vec{p}\,p \rightarrow p\,K^+\,\vec{\Lambda}$

$\vec{p}\,p \rightarrow p\,K^+\,\vec{\Sigma}^0$

$\vec{p}\,p \rightarrow p\,K^+\,\Sigma^{*0}_{(1385)}$

$\vec{p}\,p \rightarrow p\,K^+\,\Lambda^{*}_{(1405)}$

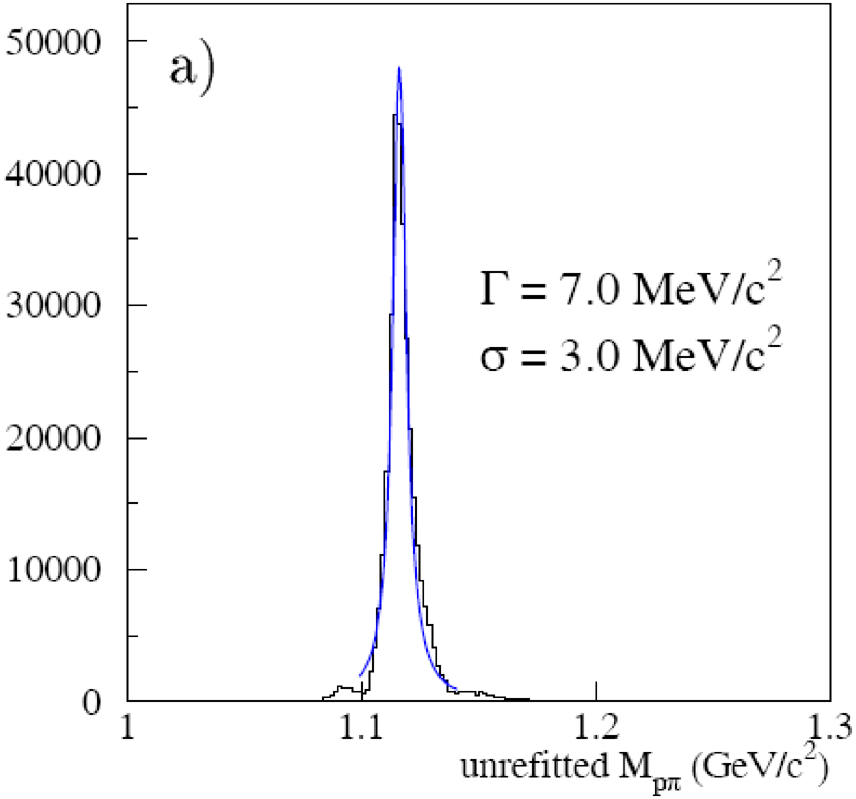
- soft constraint on reaction vertex: $\dfrac{d^2\left(\vec{v}_{reac}, \vec{b}(z_{reac})\right)}{\sigma_d^2} \subset \chi^2_{min}$

Hyperon production : event reconstruction

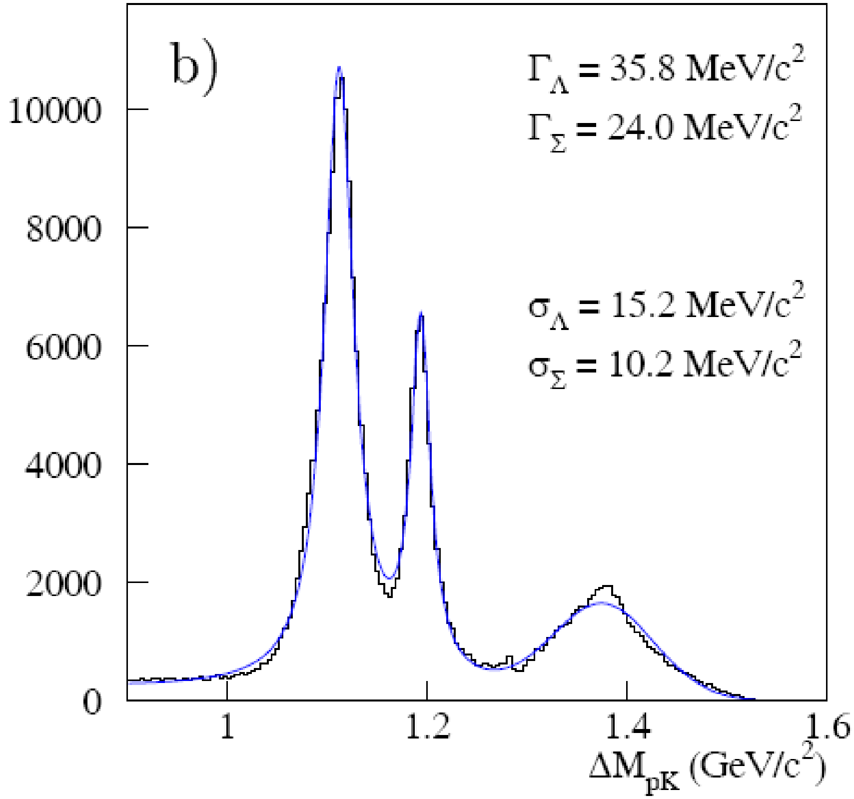
Data set: refitted events with low χ^2

χ^2 requirement on the refit: most effective cut

$M_{\pi p}$ before refit

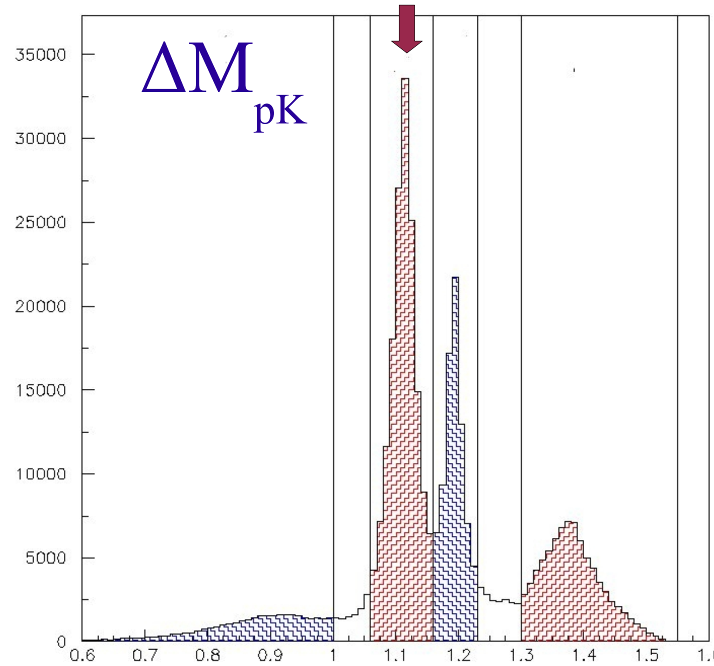


ΔM_{pK} after refit



Hyperon selection: ΔM_{pK} gates

Λ

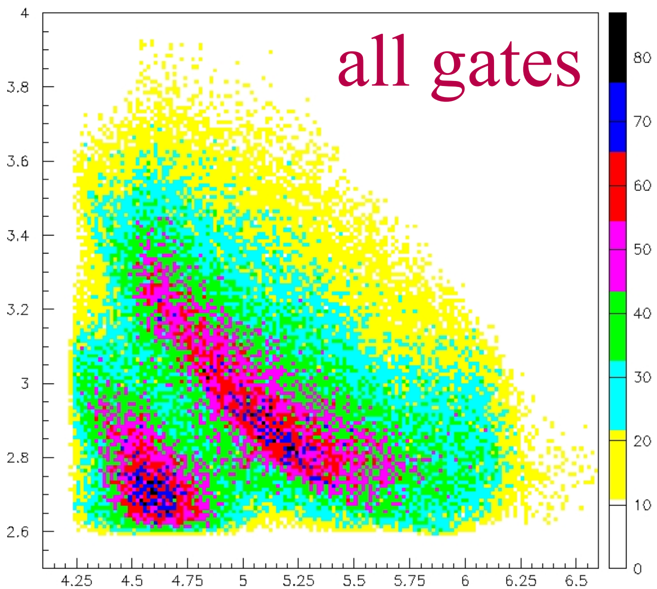


Λ gate: selecting $p\,p \rightarrow p\,K^+\,\Lambda$

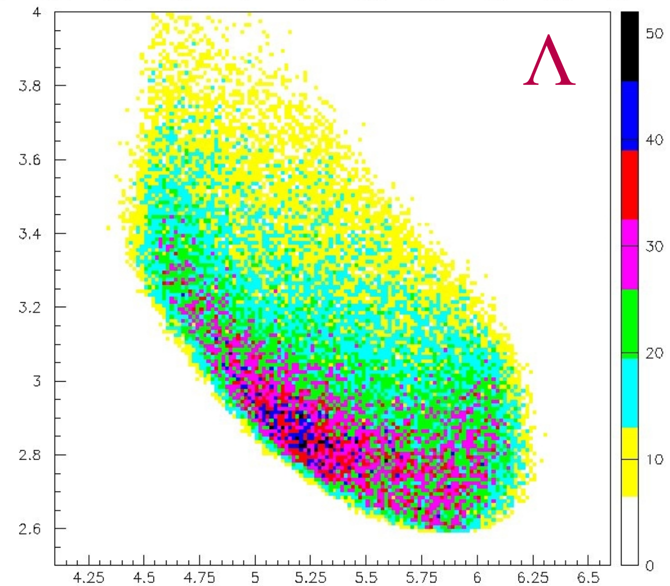
Hunt for $p\,p \rightarrow K^+\,X$

$X \rightarrow p\,\Lambda$

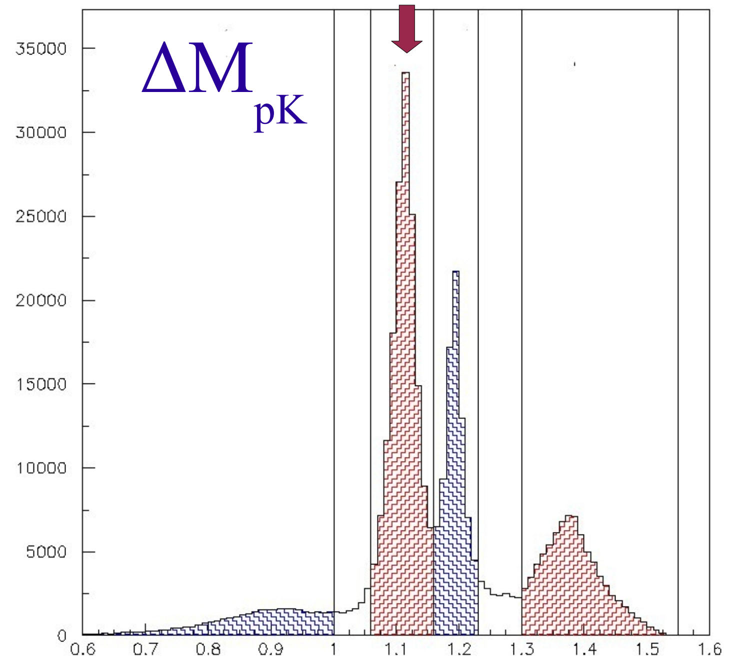
$\Lambda \rightarrow p\,\pi^-$



$M^2_{K\Lambda}$ vs $M^2_{p\Lambda}$



Hyperon selection: ΔM_{pK} gates



Λ gate: selecting $p\,p \rightarrow p\,K^{+}\,\Lambda$

Hunt for $p\,p \rightarrow K^{+}\,X$

$X \rightarrow p\,\Lambda$

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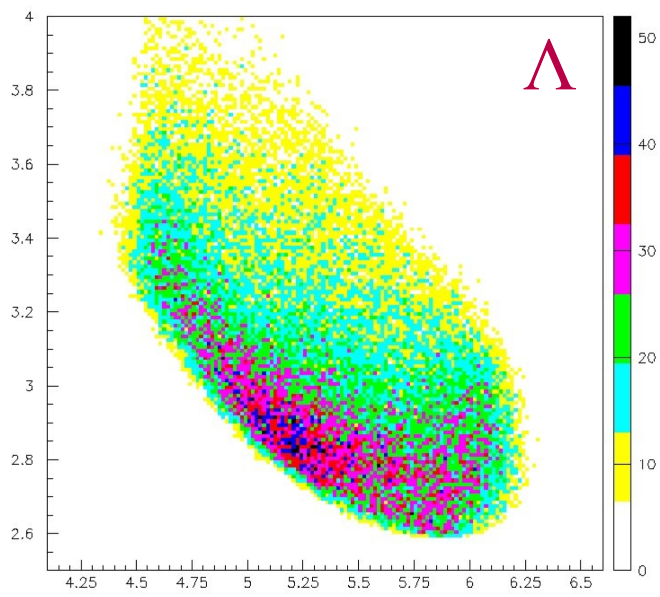
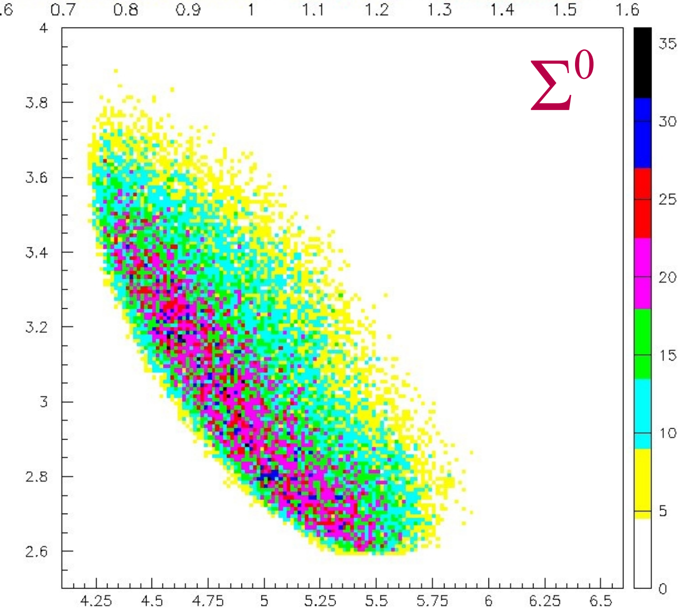


$M^2_{K\Lambda}$ vs $M^2_{p\Lambda}$



Hyperon selection: ΔM_{pK} gates

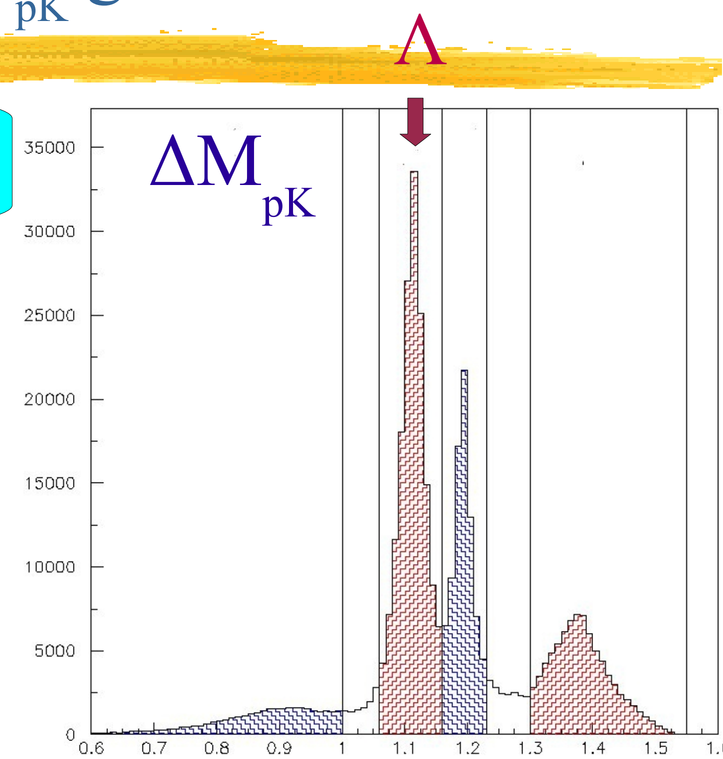
background

Λ gate: selecting $p\,p \rightarrow p\,K^{+}\Lambda$

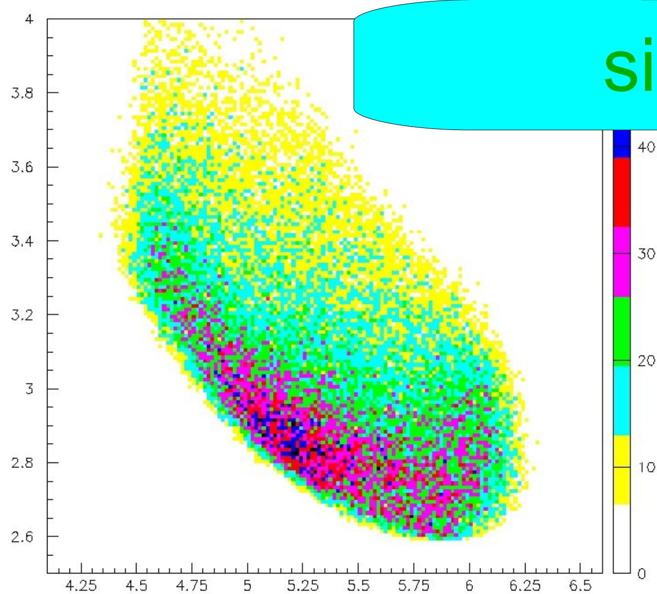
Hunt for $p\,p \rightarrow K^{+} X$

$X \rightarrow p\,\Lambda$

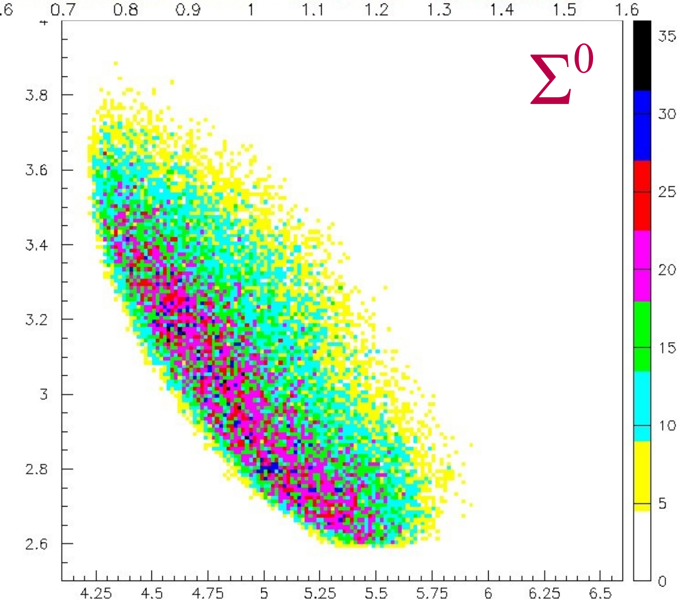
$\Lambda \rightarrow p\,\pi^{-}$



signal



$M^2_{K\Lambda}$ vs $M^2_{p\Lambda}$

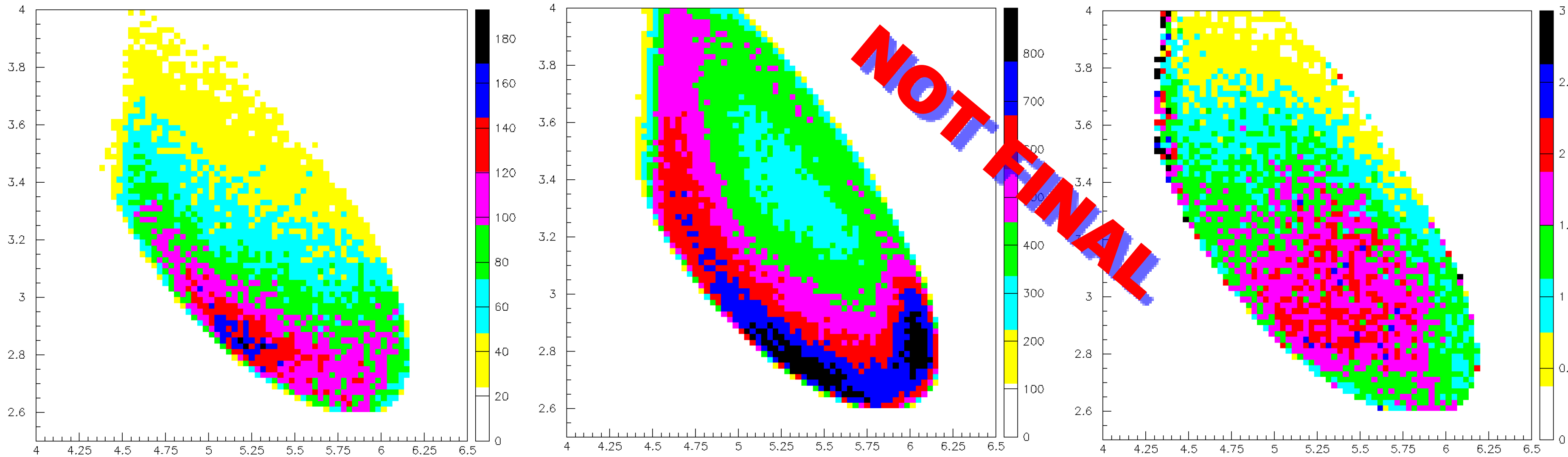


Deviation distributions: raw data vs phase space simulations

raw data

simulated data (uniform PS distribution)

deviation plot (raw/simulated)



$M^2_{K\Lambda}$ vs $M^2_{\Lambda p}$ $[(GeV/c^2)^2]$ $M^2_{K\Lambda}$ vs $M^2_{\Lambda p}$ $[(GeV/c^2)^2]$ $M^2_{K\Lambda}$ vs $M^2_{\Lambda p}$ $[(GeV/c^2)^2]$

Deviation plot: raw data / simulated data

→ looking for deviation from uniform phase-space distribution

Angular distributions for the $pK^+\Lambda$ sample in the Λ gate

DISTO acceptance:

- higher for forward Λ

Hunt for X:

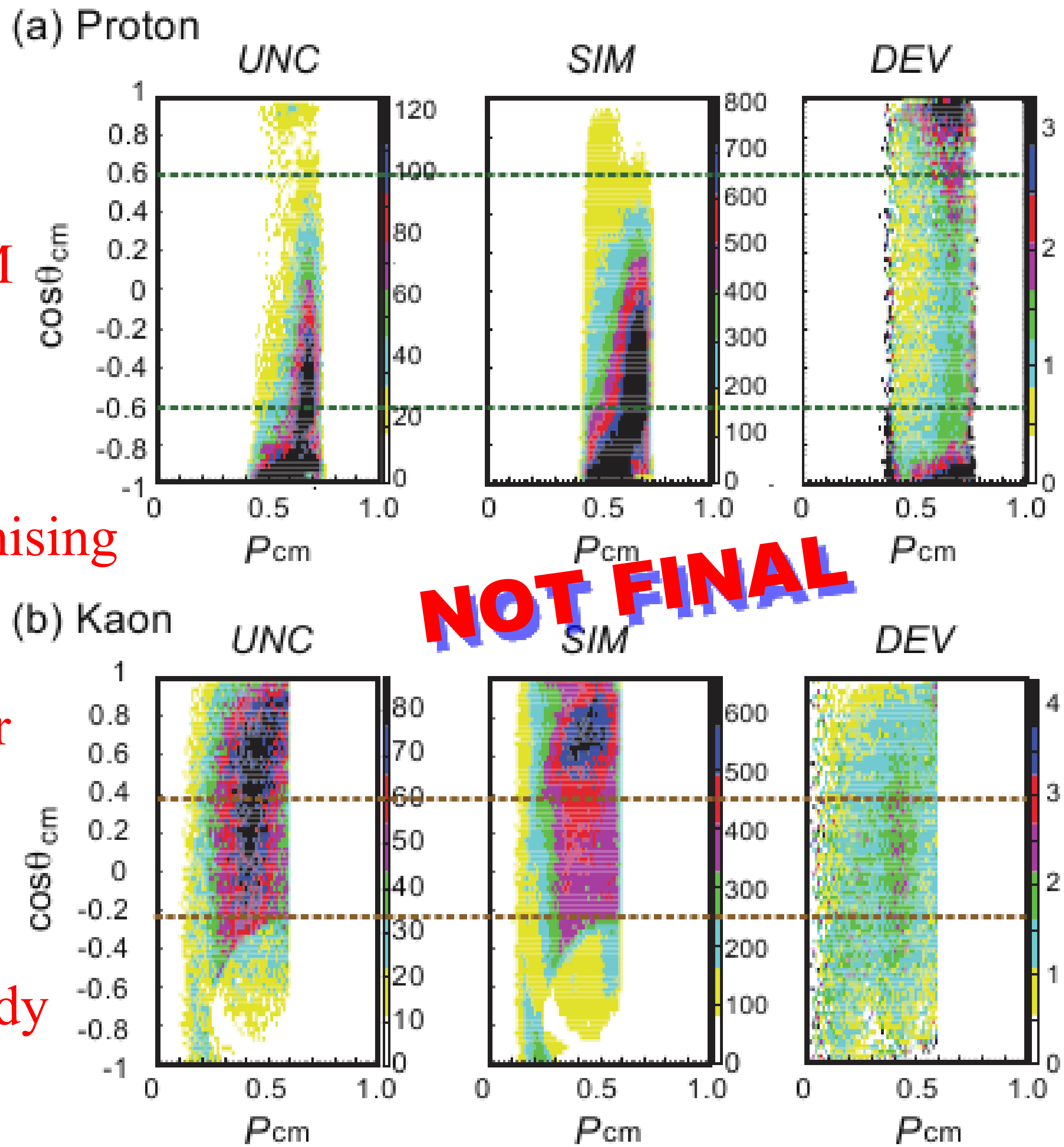
- symmetric pp scattering in CM
- $pK^+\Lambda$ "background" dominant at low q_T
- large-angle protons most promising

$|\cos \theta_{CM}(p)| < 0.6$

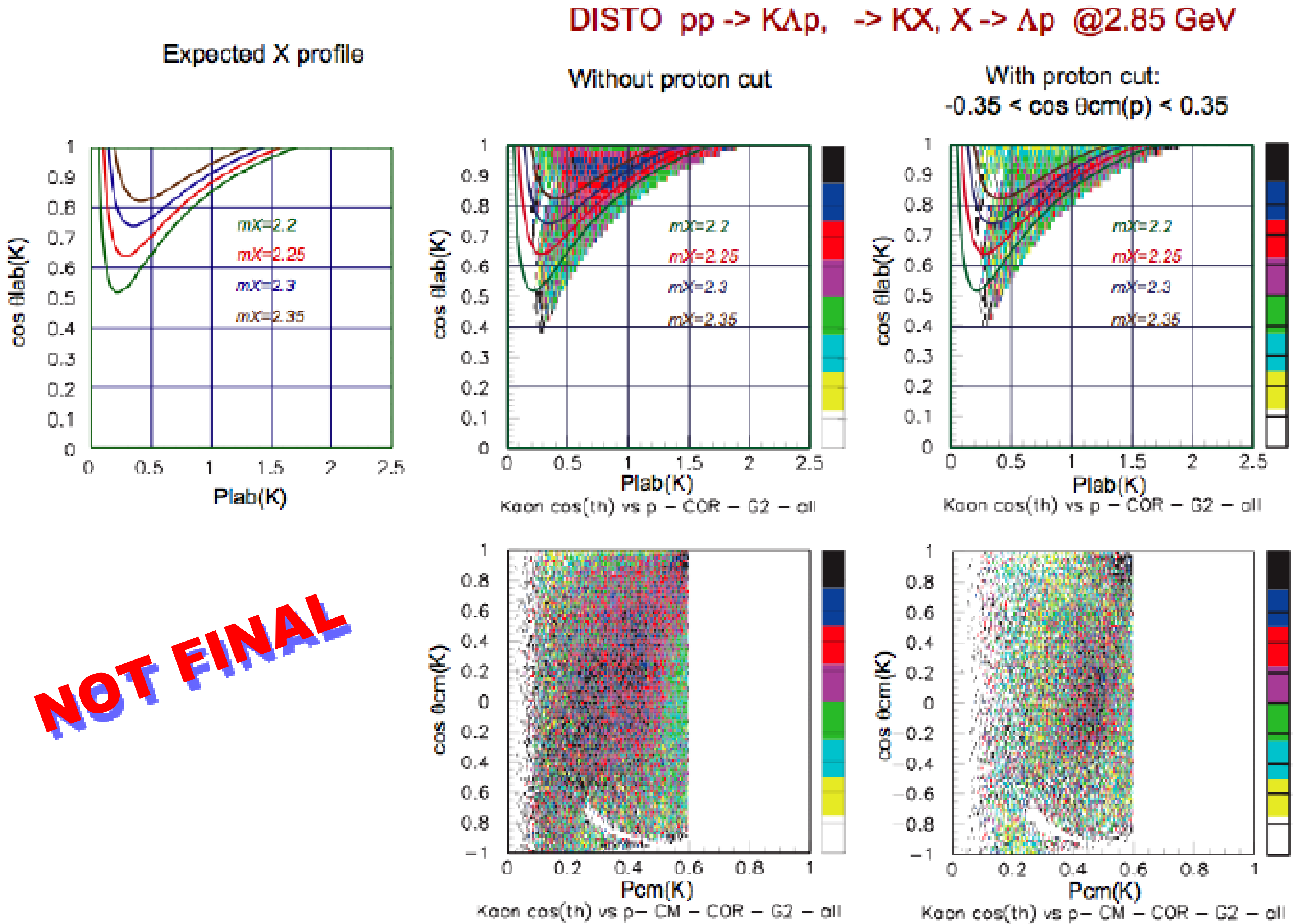
- mono-energetic component for $p_{CM}(K) \sim 0.4$ GeV/c

$0.2 < \cos \theta_{CM}(K) < 0.4$

possible signature of a two-body process K^+X?



Interpreting[1] DISTO data on K^-pp



The $pK^+\Lambda$ sample in the Λ gate: large-q_T protons

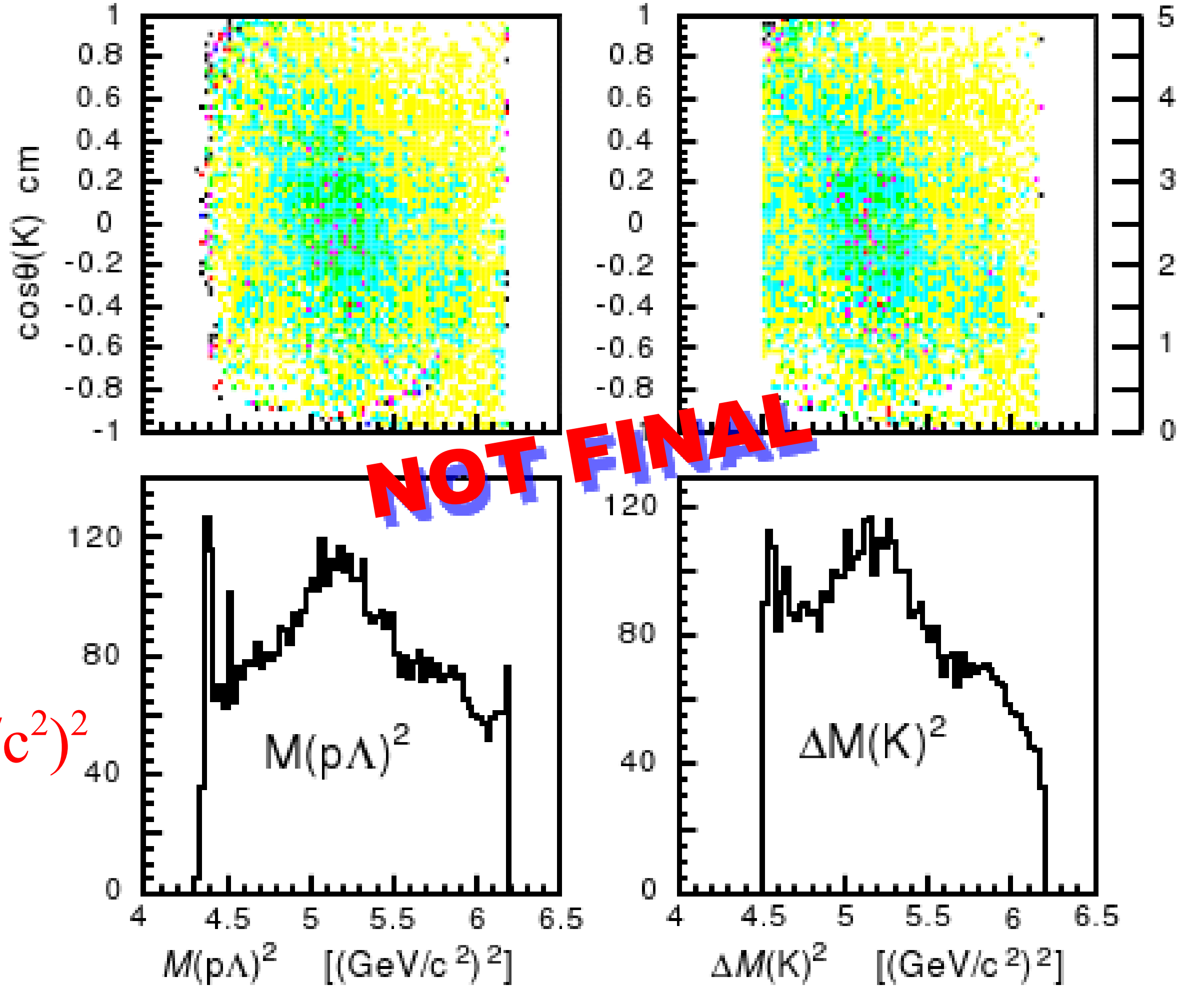
Selecting large-q_T protons: $|\cos\theta_{CM}(p)| < 0.6$

- Enhancing statistics @ $p_{CM}(K) \sim 0.4$ GeV/c

Possible indication of X formation
(monoenergetic K^+ emission)

- Structure appears @ $M^2_{p\Lambda} \sim \Delta M^2_K \sim 5.15\ (GeV/c^2)^2$

$M_X \sim 2.27\ GeV/c^2$



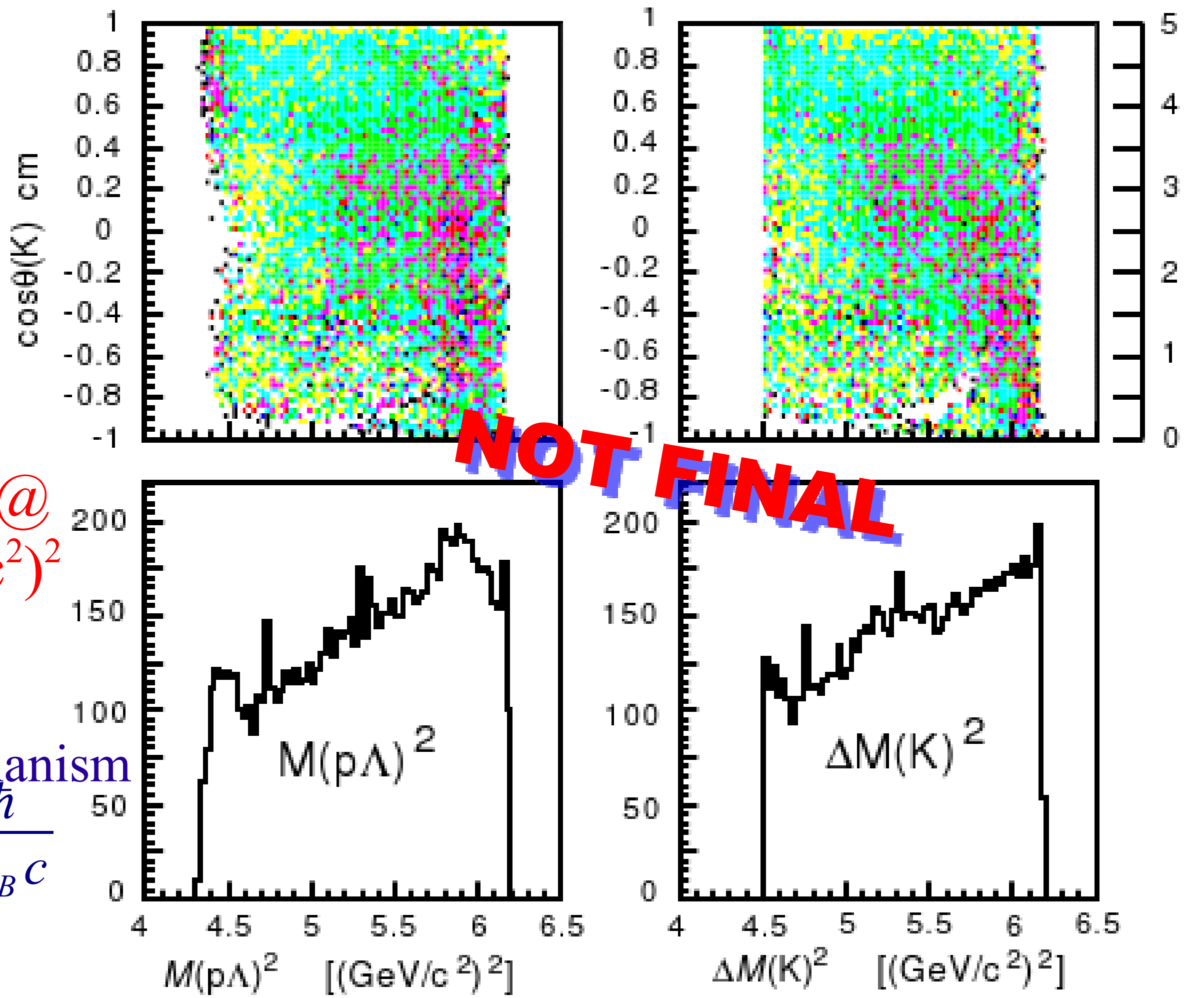
The $pK^+\Lambda$ sample in the Λ gate: small-angle protons

Selecting small-angle protons: $|\cos\theta_{CM}(p)| > 0.6$

- missing structure @ $p_{CM}(K)$ 0.4 ~ GeV/c
- almost vanishing structure @ $M^2_{p\Lambda} \sim \Delta M^2_K \sim 5.15\ (GeV/c^2)^2$

well accounted[1] by a $pK^+\Lambda$ mechanism with collision lenght $\sim \dfrac{\hbar}{m_B c}$

$m_B \sim 0.2\ GeV/c^2$



[1] T. Yamazaki and Y. Akaishi, private communications.

$pK^+\Lambda$ deviation from uniform phase space distribution

Deviation from PS uniform distribution

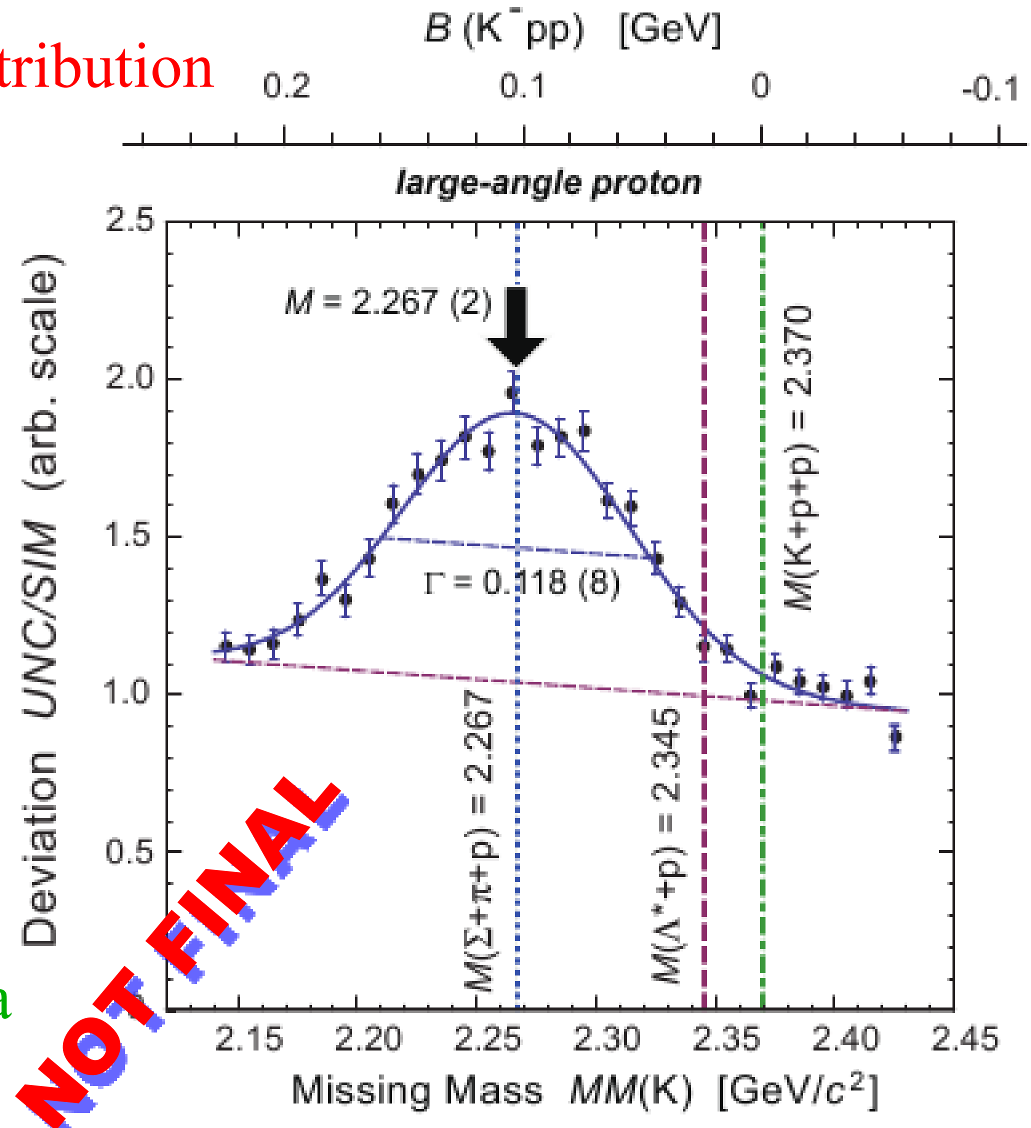
Peak properties:

- $M = 2.267 \pm 0.002$ GeV/c^2
- $\Gamma = 0.118 \pm 0.008$ GeV/c^2
- SYMMETRIC!

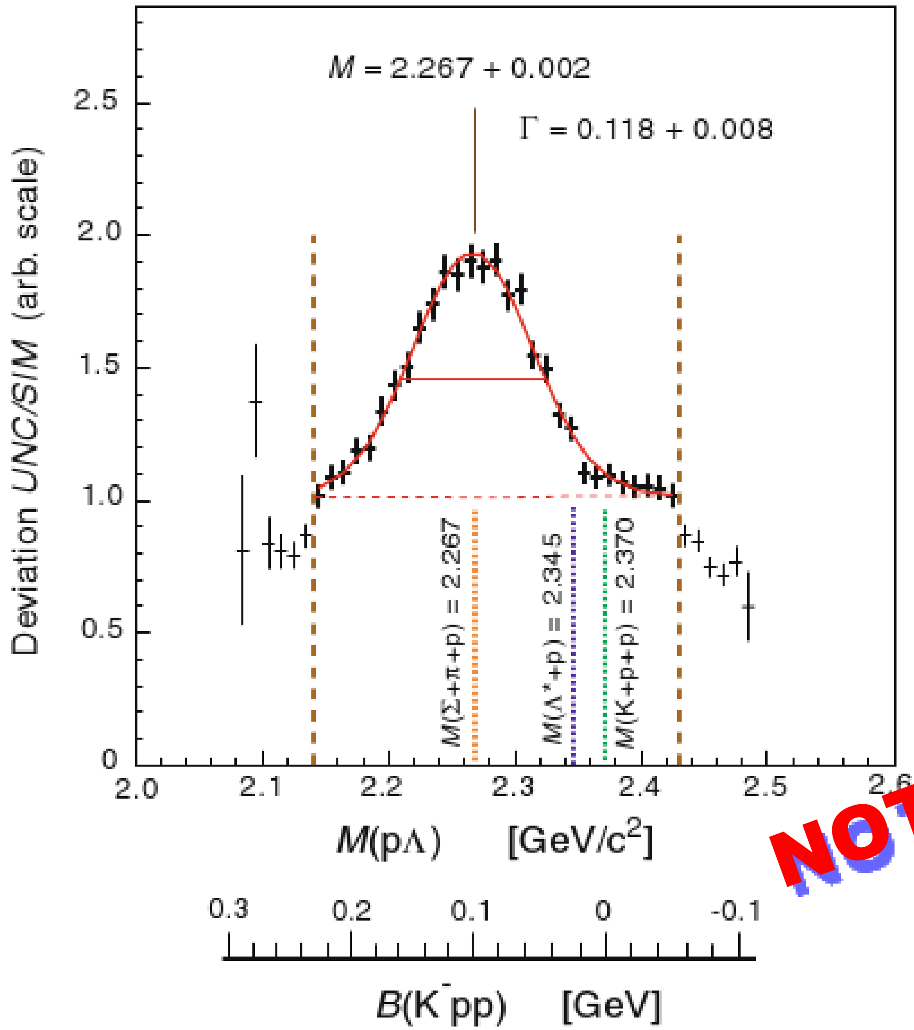
Fit properties:

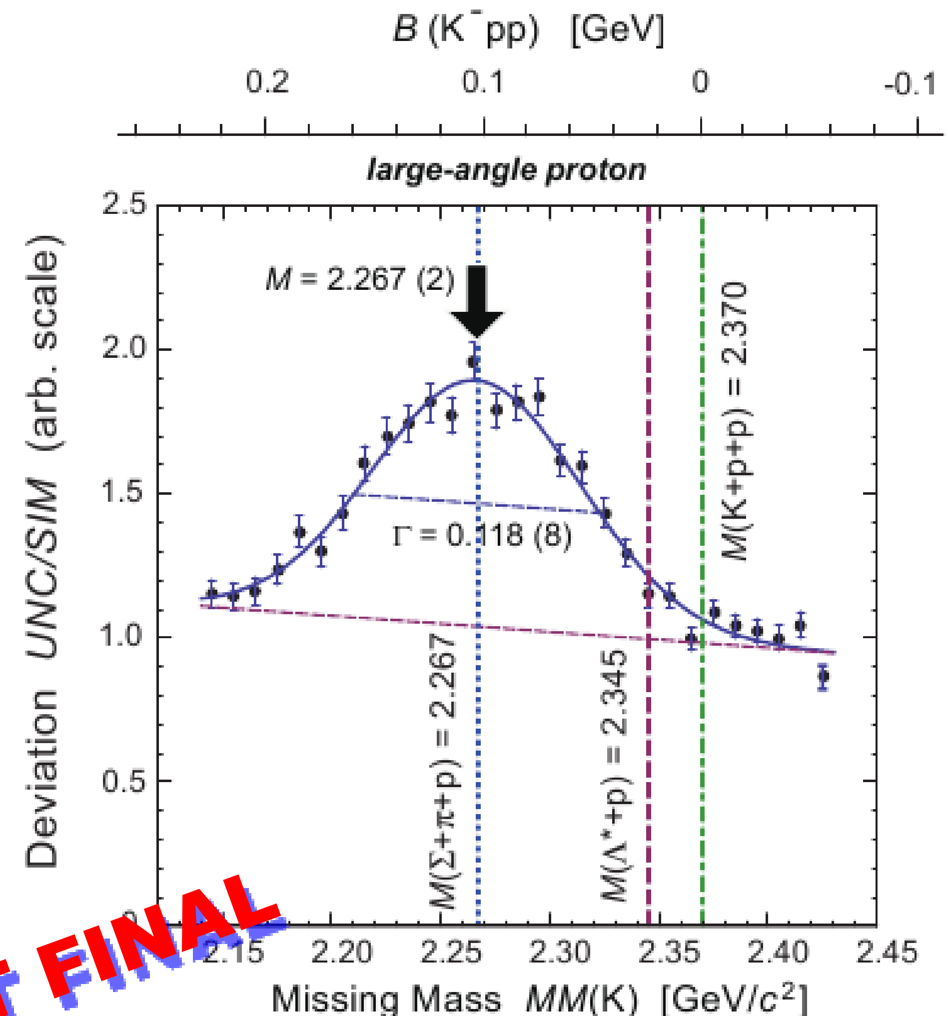
- gaussian + linear
  χ^2 /ndf = 34/24 = 1.4
- Linear only
  χ^2 /ndf = 947/25 = 35

Is this a possible indication of a K^-pp ($\rightarrow\Lambda p$) bound state ?!?



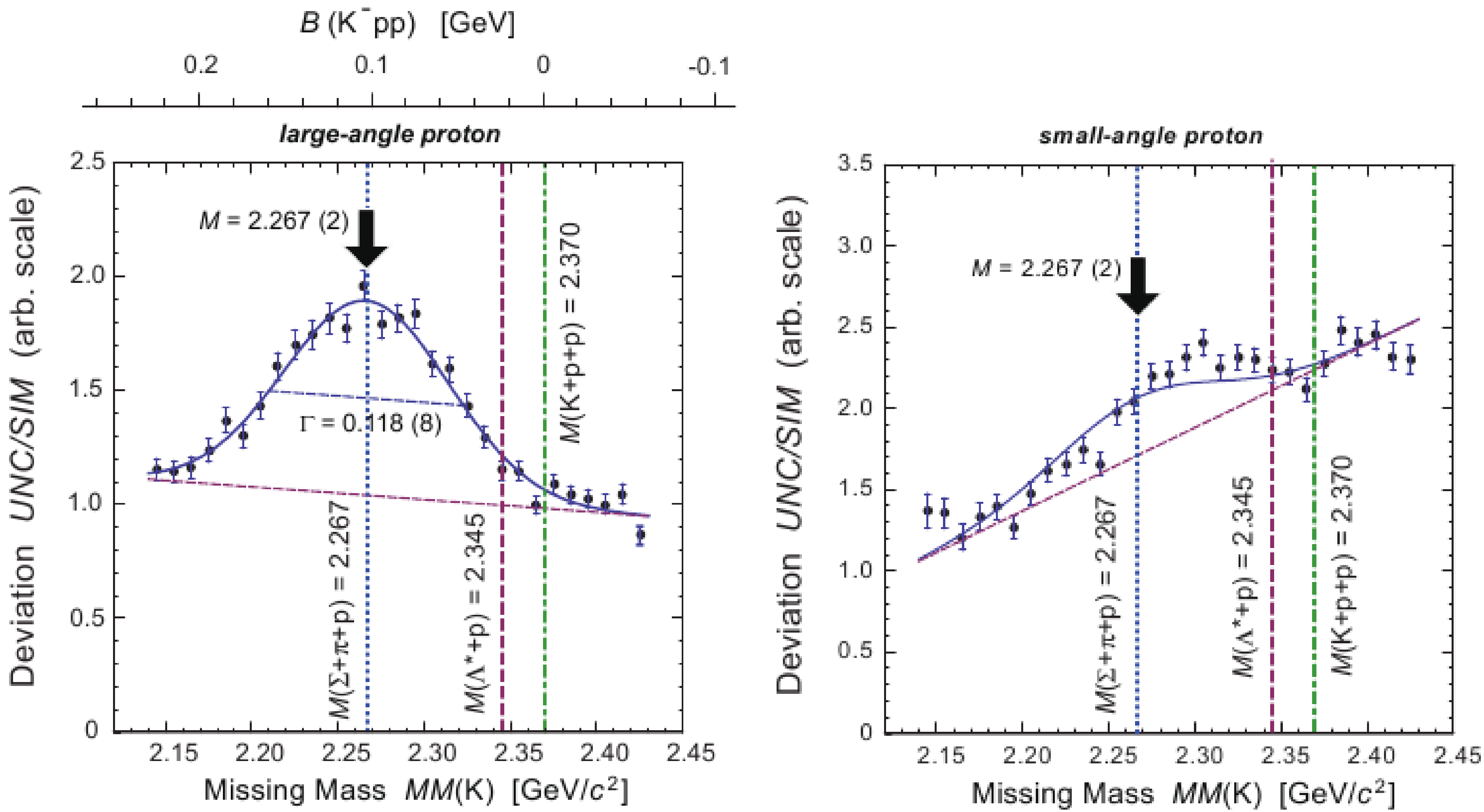
pK$^+\Lambda$ deviation from uniform phase space distribution





NOT FINAL

$pK^+\Lambda$ deviation from uniform phase space distribution



NOT FINAL

Modelisation[1] of a K^-pp bound state

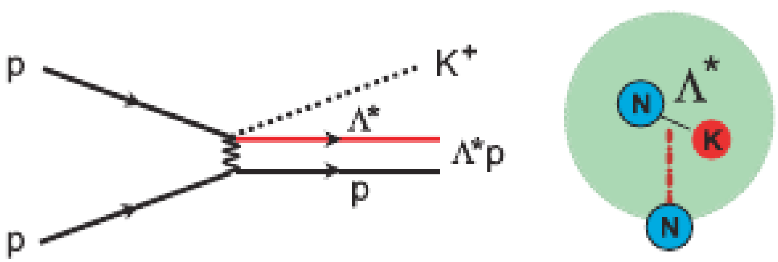
- short pp collision lenght
- K^-pp: a very compact state
- large momentum transfer
- based on the $\Lambda^*(1405)$ Ansatz

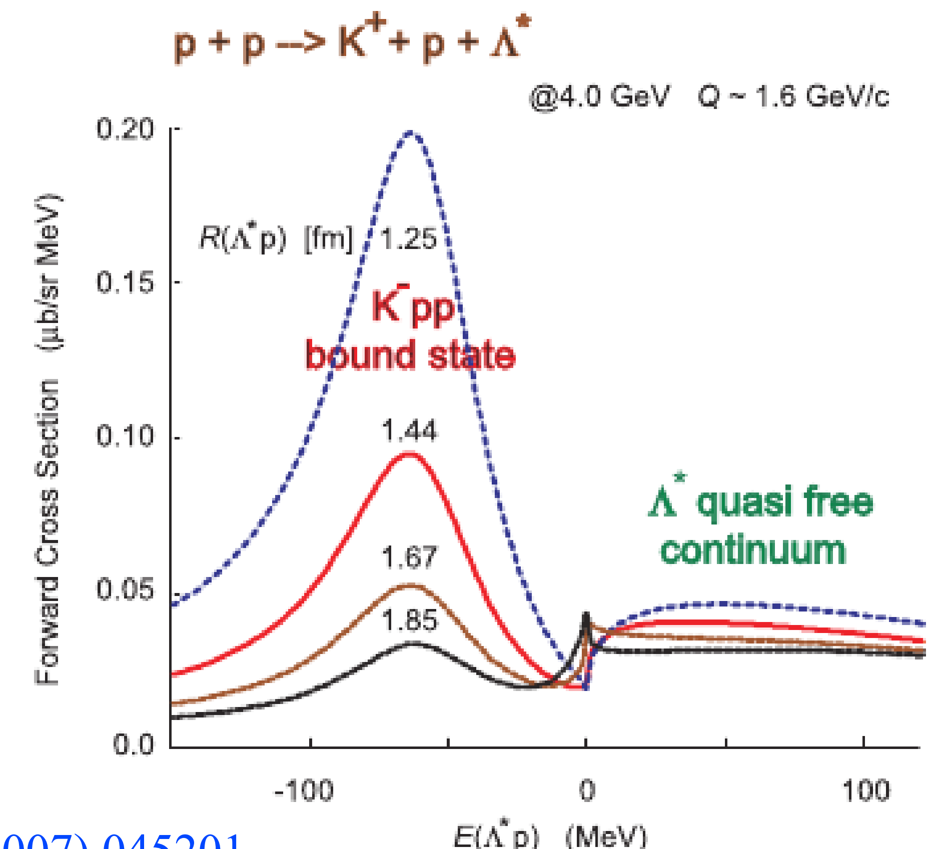
strongly coupled Λ^*p doorway

pp --> K^+ + Λ^*p

bare Λ^*p --> bound K^-pp *dominant*

--> quasi-free Λ^*





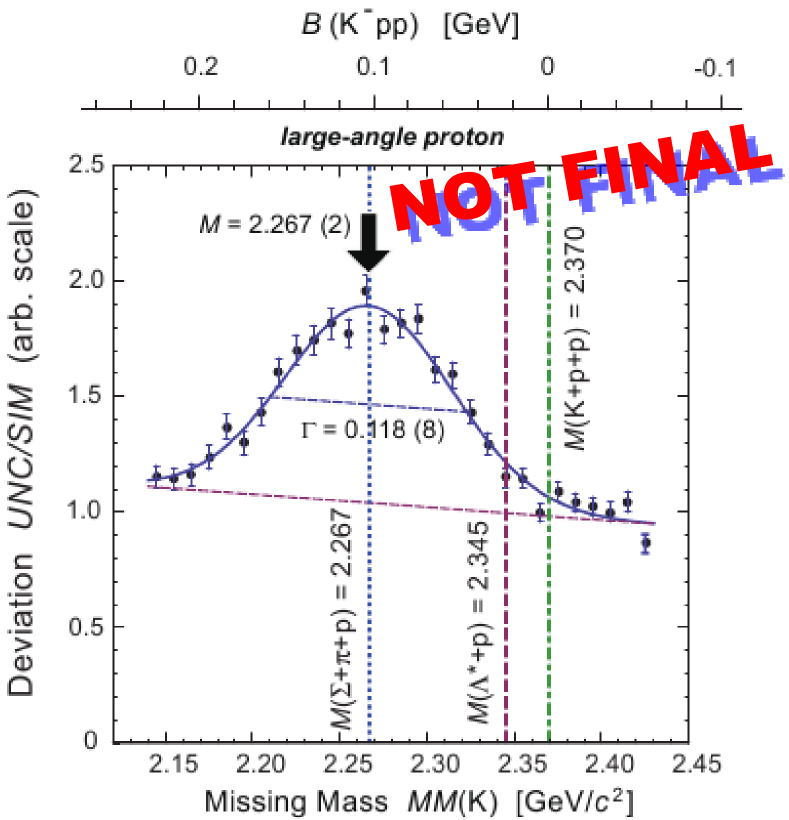
[1] T. Yamazaki and Y. Akaishi, Phys Rev C76 (2007) 045201

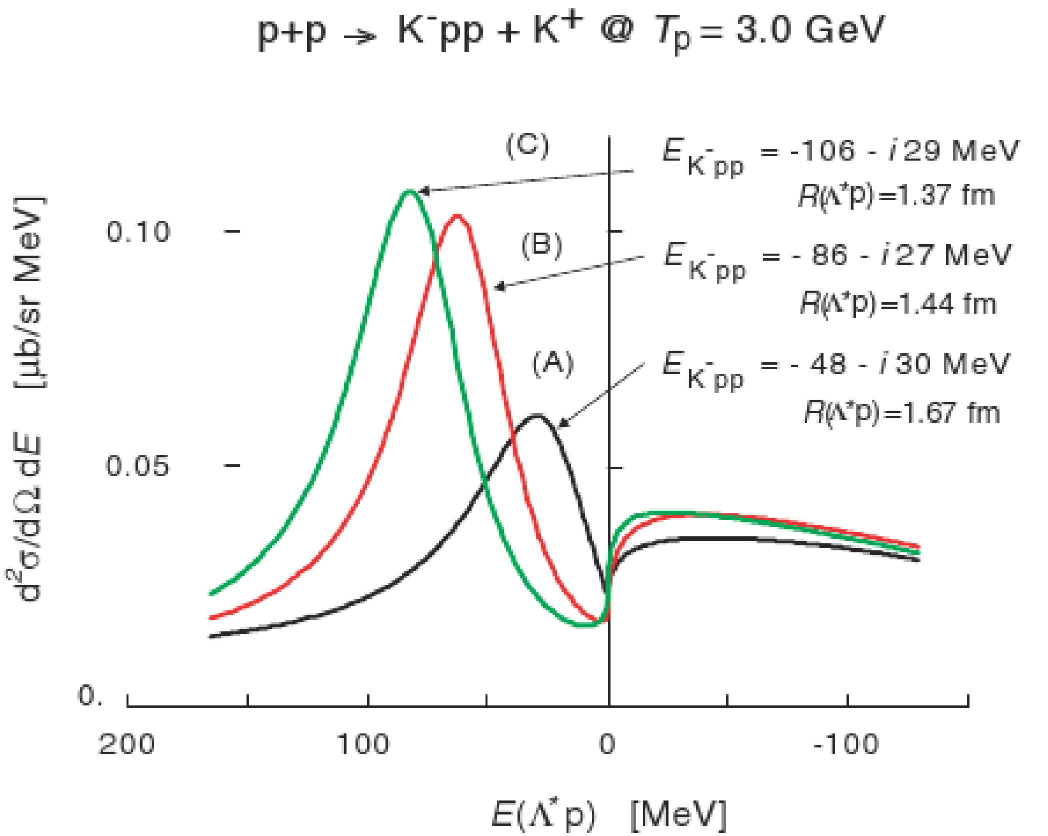
Interpreting[1] DISTO data on K^-pp

Peak properties:

- $M = 2.267 \pm 0.002$ GeV/c^2
- $\Gamma = 0.118 \pm 0.008$ GeV/c^2
- SYMMETRIC!

- $B_K = 105 \pm 2$ MeV/c^2





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Conclusions

DISTO **preliminary** experimental data: $\vec{p}\,p \rightarrow p\,K^{+}\vec{\Lambda}$ @ T_p = 2.85 GeV

- deviation from uniformity in both $M_{p\Lambda}$ and ΔM_K spectra
- acceptance corrections in progress
- clean sample: low contamination from $\Sigma^0 \rightarrow \Lambda\gamma$ or pp → π-background
- full-efficiency corrections in progress: preliminarily **the peak is confirmed!**

Possible interpretation: is that a K^-pp bound state?!?

- BK = 105 ± 2 MeV
- Γ = 118 ± 5 MeV
- deeper than predicted
- interpreted[1] as strongly bound, dense system

NOT FINAL

[1] T. Yamazaki and Y. Akaishi, Phys Rev C76 (2007) 045201

Question time

QUESTION TIME

ありがとうございます。

4body event reconstruction @ DISTO

pattern reconstruction and track fitting iteration:

pattern recognition provides candidate for the fitting stage; input is the 12D coordinates vector $\vec{x}$

track fitting: 5D parameter vector $\vec{p}$

(x,y): coordinates of the intersection point with z = 0

a: inclination of track at z = 0

φ: starting angle in (x-z) plane

$p_{xz} = \frac{1}{\sqrt{p_x^2 + p_z^2}}$: inverse momentum perpendicolar to B

detector coordinates depend smootly on all parameters

4body event reconstruction @ DISTO

track fitting by lookup table:

goal is inverting $\vec{x} = F(\vec{p})$ in $\vec{p} = G(\vec{x})$

look-up table:

5D lattice that provide for tracks $\vec{x}$ track coordinates $F(\vec{p})$ consist in linear interpolation of the lattice to obtain $\vec{p}$

χ^2minimisation:

F inversion is performed minimizing:

$$\chi^2_{min} = \left[\sum_{j \in \{valid\ coords\}} \left(\frac{x_j^m - x_j(\vec{p})}{\sigma_j} \right)^2 \right]_{min}$$

iteration stops if $\Delta \vec{p}$ do not change $\vec{x}$ to nearest grid point

4body event reconstruction @ DISTO

kinematically constrained refit:

- global 4 tracks – 2 vertices refit
- same approach, inversion of $\vec{x} = F(\vec{p})$
- More complex parameter 18 D $\vec{p}$
    - 3 (x_{12}, y_{12}, z_{12}) for reaction vertex
    - six (φ_1, a_1, $p_{xz,1}$, φ_2, a_2, $p_{xz,2}$ to describe momenta of the two track emerging from the reaction vertex
    - 3 (x_{12}, y_{12}, z_{12}) for decay vertex
    - six (φ_3, a_3, $p_{xz,3}$, φ_4, a_4, $p_{xz,4}$ to describe momenta of the two track emerging from the decay vertex
- 4 degrees of freedom are constrained kinematically

Hyperon production: reconstruction @ DISTO

kinematic constrains:

- reconstructed Λ momentun parallel to the joiner of the reaction and decay verteces ⇒ 2 parameters
- reconstructed $M_{\pi^- p}$ at decay vertex is M_Λ = 1.115 GeV/c^2 ⇒ 1 parameter
- $\Delta M_{4B} = 0$ ($\vec{p}\,p \rightarrow p\,K^+\,\vec{\Lambda}$ or $\vec{p}\,p \rightarrow p\,K^+\,\vec{\Sigma}^0$) or $\Delta M_{4B} = M_\pi$ ($\vec{p}\,p \rightarrow p\,K^+\,\vec{\Sigma}^*$) ⇒ 1 parameter

14D $\vec{p}$

$$\chi^2_{min} = \left[\frac{d^2\left(\vec{v}_{reac}, \vec{b}(z_{reac})\right)}{\sigma_d^2} + \sum_{j\in\{valid\ coords\}} \left| \frac{x_j^m - x_j(\vec{p})}{\sigma_j} \right|^2 \right]_{min}$$

“soft” constraint on reaction vertex along the beam

Hyperon production: event selection

One of the most effective cuts in event selection is the kinematically constrained refit itself!

- $M_{\pi^- p} = M_\Lambda$
- $\vec{p}_\Lambda \parallel \overrightarrow{V_R V_D}$
- $\Delta M_{4B} = 0$ or $\Delta M_{4B} = M_\pi$

Kinematic region restricted to:

$-0.7 \leq x_F \leq 0.9$

$p_T \leq 750$ MeV/c

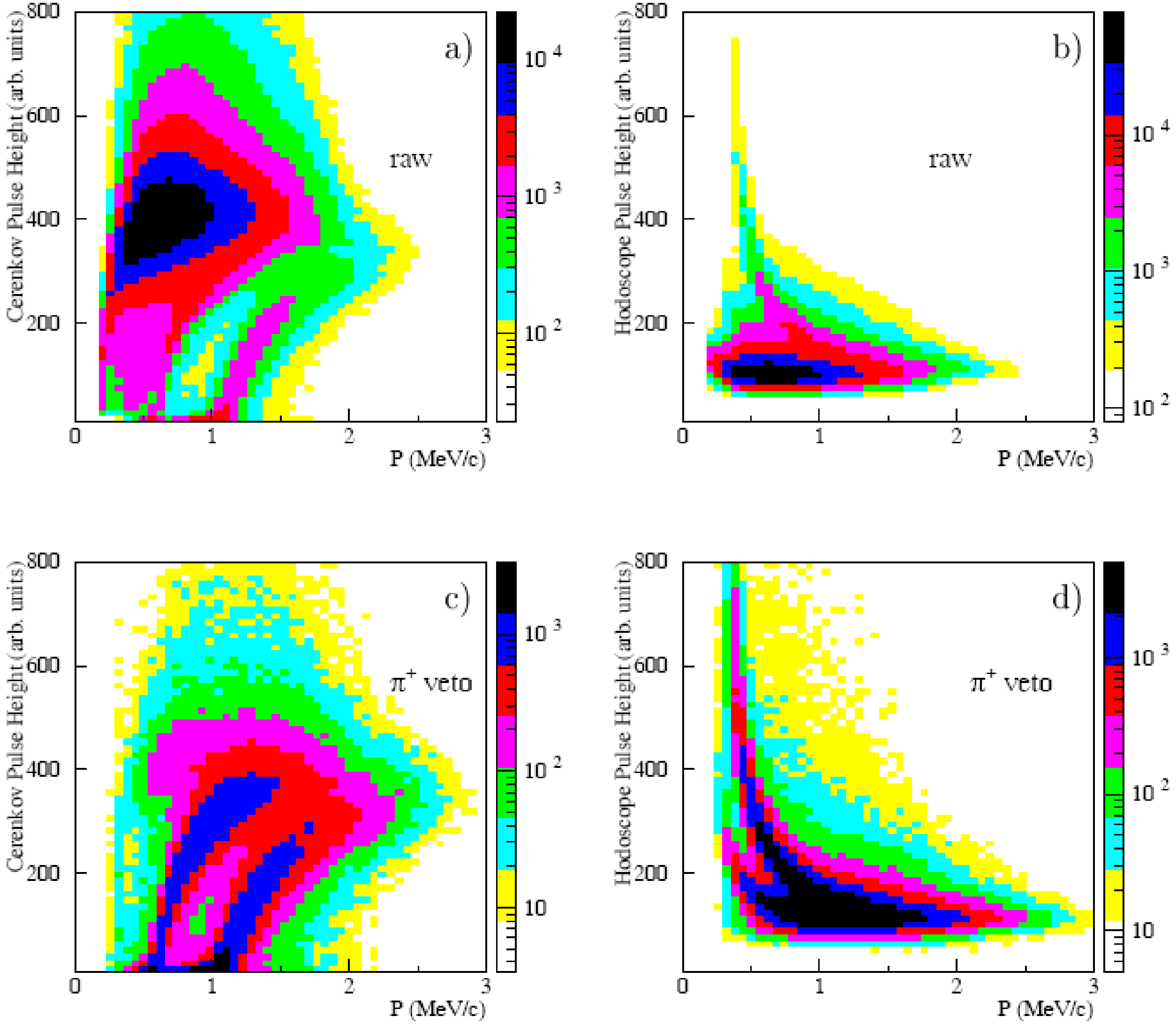
$|\cos \varphi_\Lambda| < 0.7$

Additional cuts:

- π^+ veto
- $|\theta_{\pi,\Lambda}| < 0.15$ rad, decay proton momentun in LF
- p ID for positive track from decay vertex
- $\Delta p_{tot} < 1$ GeV/c $\Rightarrow$ missing a π at most
- $|v_z| < 3.5$ cm $\Rightarrow$ Klegecell veto

Particle identification @ DISTO

particle identication: iterative process for tagging candidates



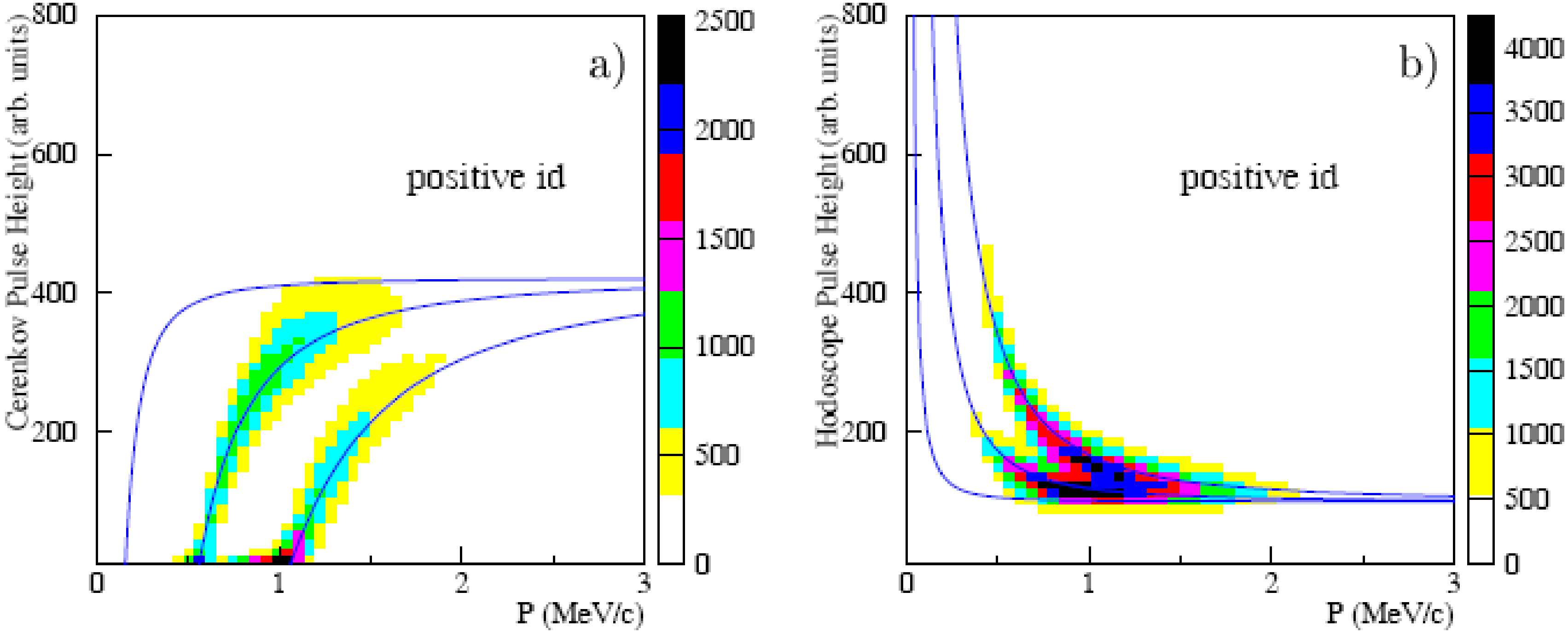
π^+veto:
$pp\pi^+\pi^-$ is
major background

Particle identification @ DISTO

particle identication:

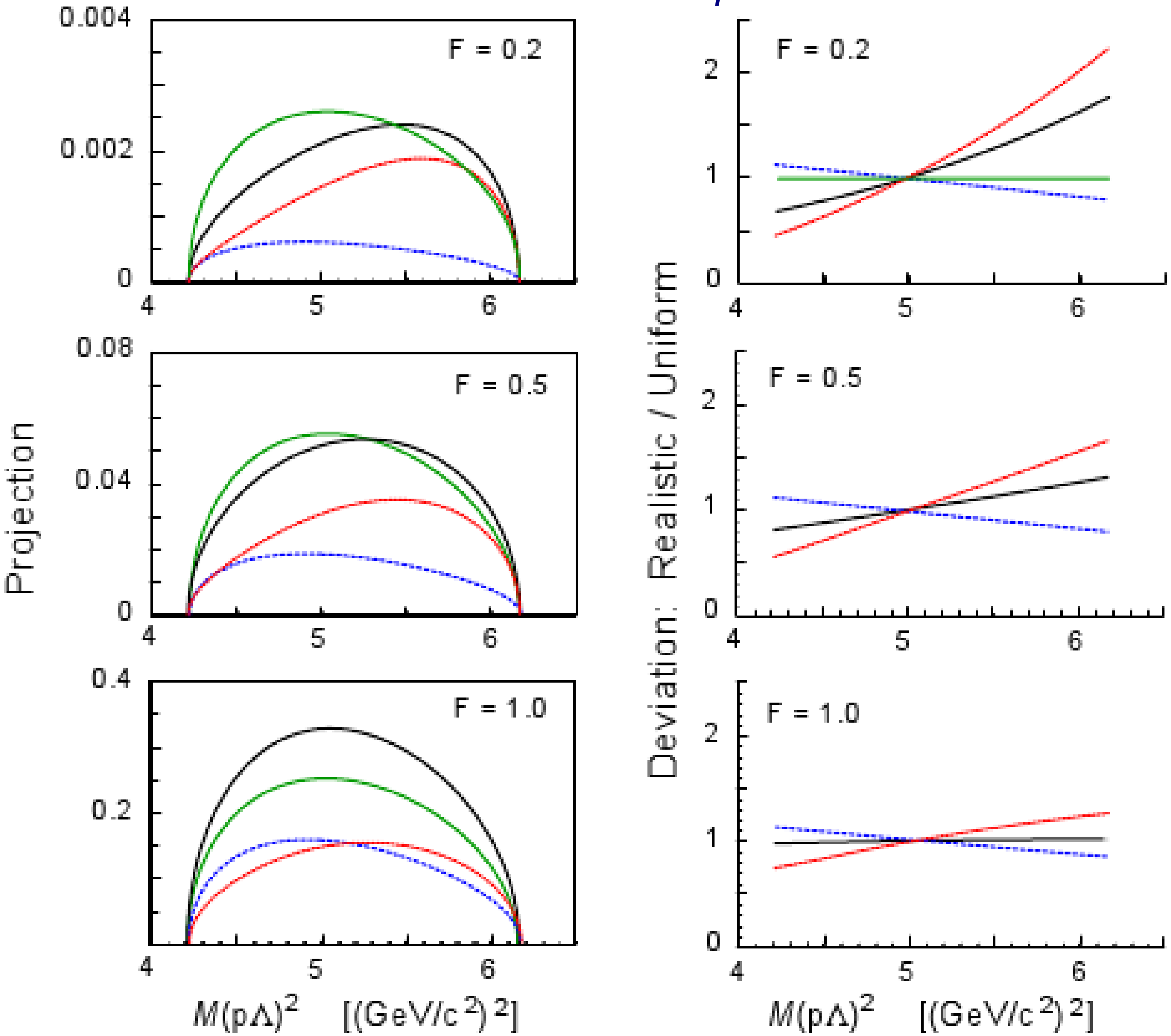
combined Cerenkon and hodoscopes tagging

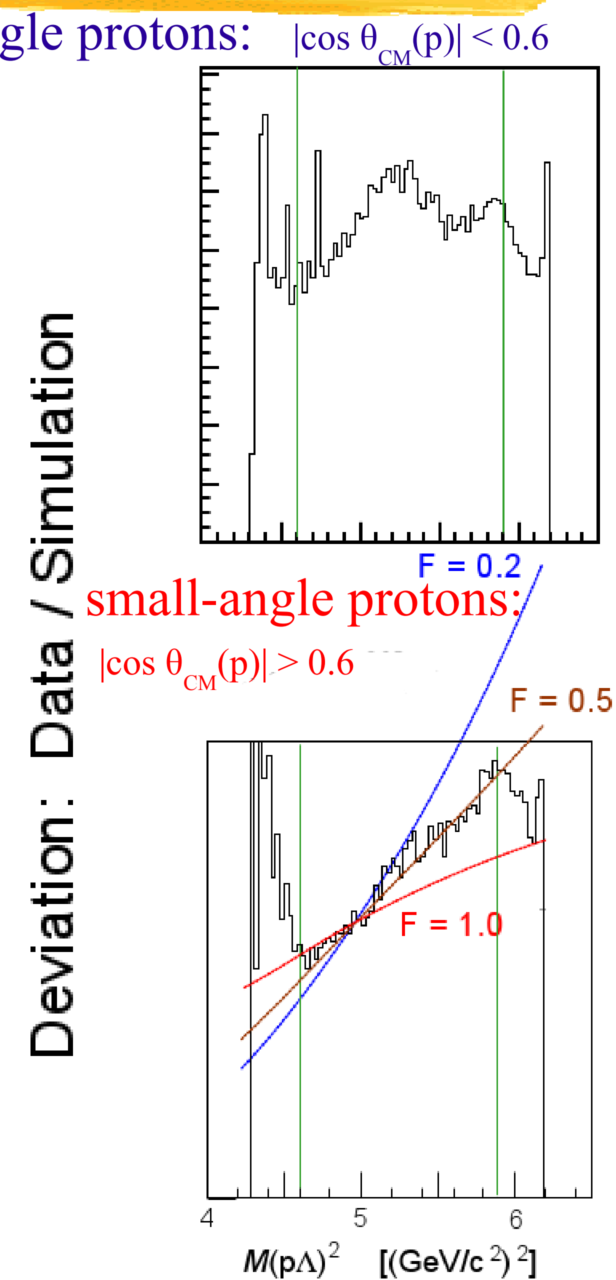
very small π^+ contamination
in hyperon sample



$pK^+\Lambda$ “background” distributions [1] (low q_T)

$$m_B = F \times m_\rho$$





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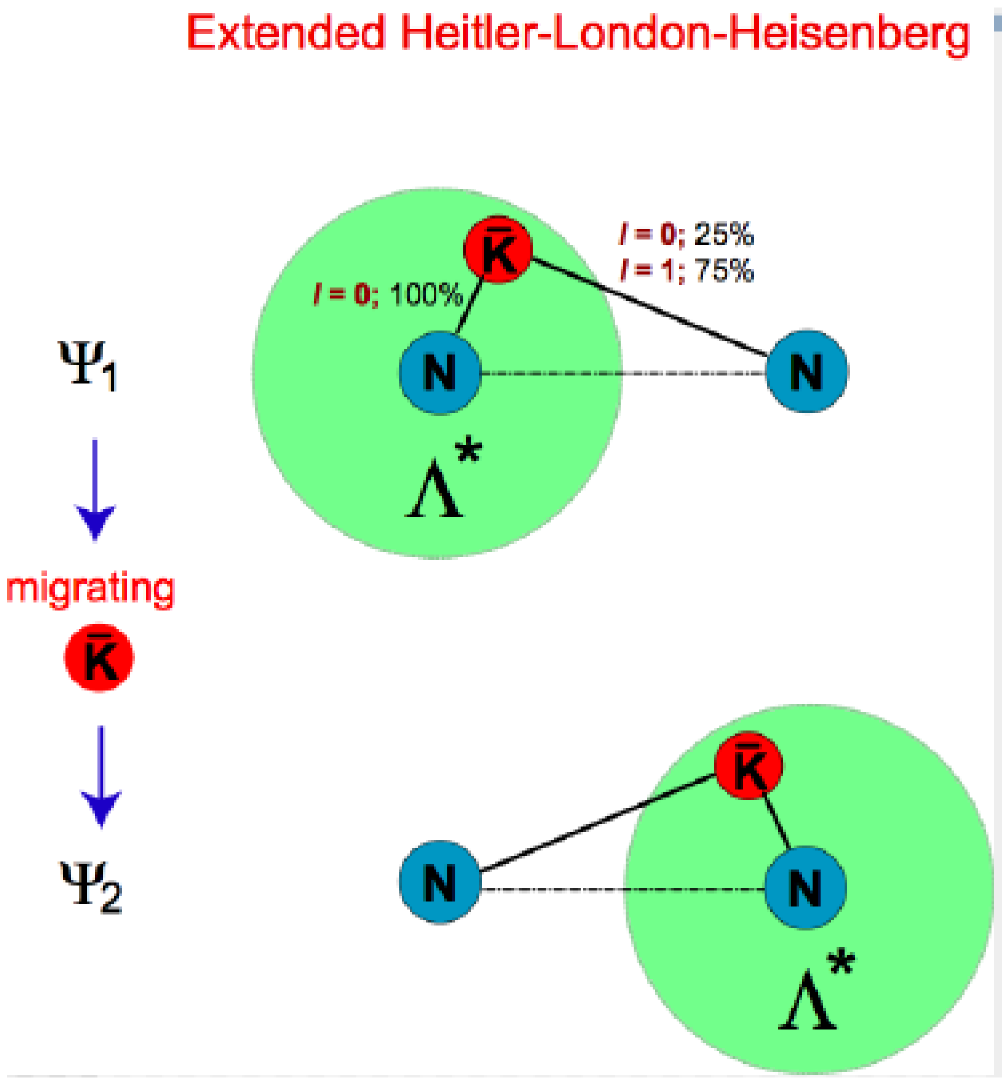
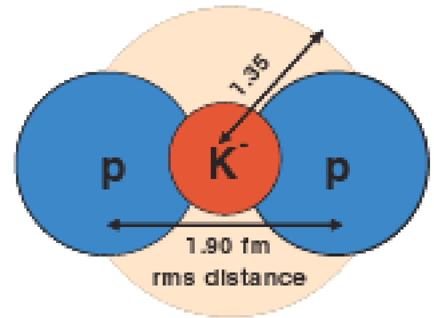
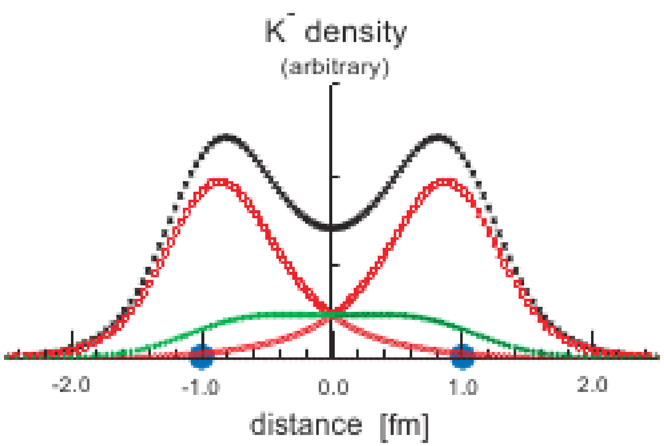
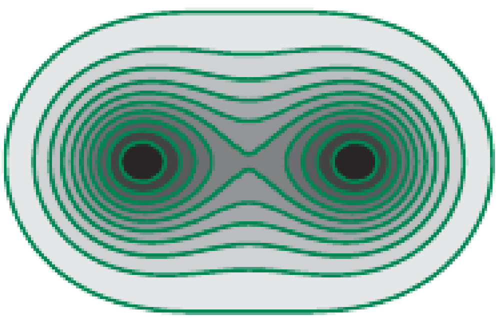
Modelisation[1] of a K⁻pp bound state



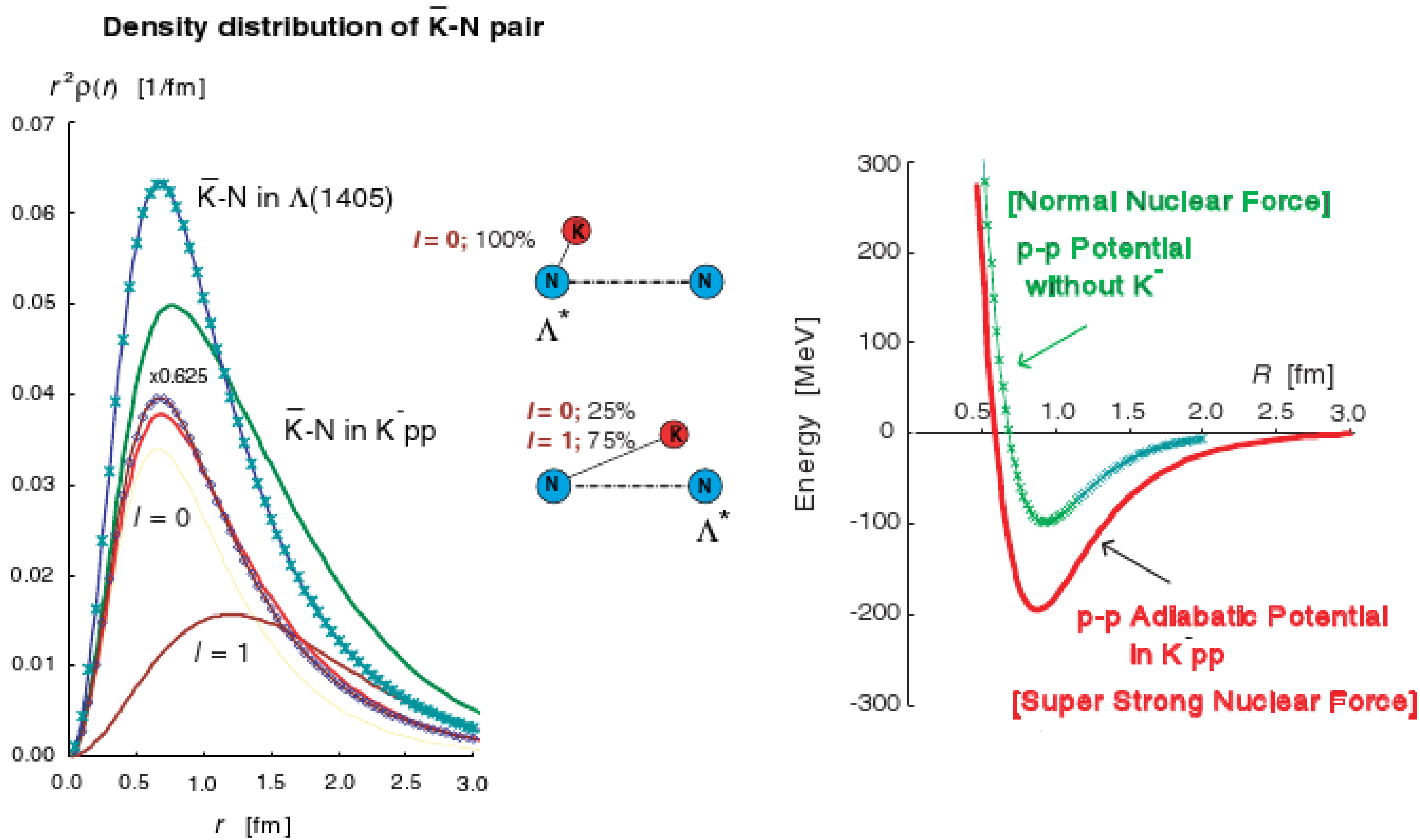






[1] T. Yamazaki and Y. Akaishi, Phys Rev C76 (2007) 045201

Modelisation[1] of a $K^{-}pp$ bound state



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