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RIKEN

Search for the "$\bar{K}NN$" bound state produced via in-flight $d(K^-, \Lambda p)\pi^-$ reaction

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For the J-PARC E31 collaboration

Kaonic nuclei "KbarNN"

- Nuclear system with Kbar mesons.
- Based on Strong KbarN (I=0) attraction.

Excited hyperon $\Lambda(1405)$ as KbarN quasi-bound state

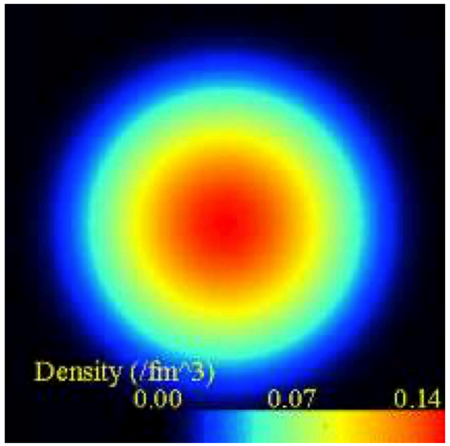
  - Kbar meson should bound in a nucleus with large binding energy.
  - "KbarNN" is the simplest Kaonic nucleus to investigate.

Expected as

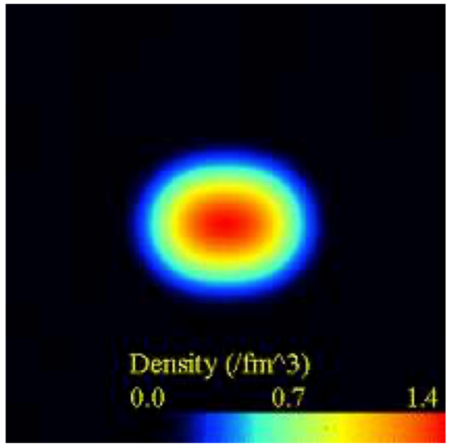
- "Cold and Dense" state.
- Anti-quark in matter.

Good probe for low energy QCD.

Phys. Lett. B 590 (2004) 51

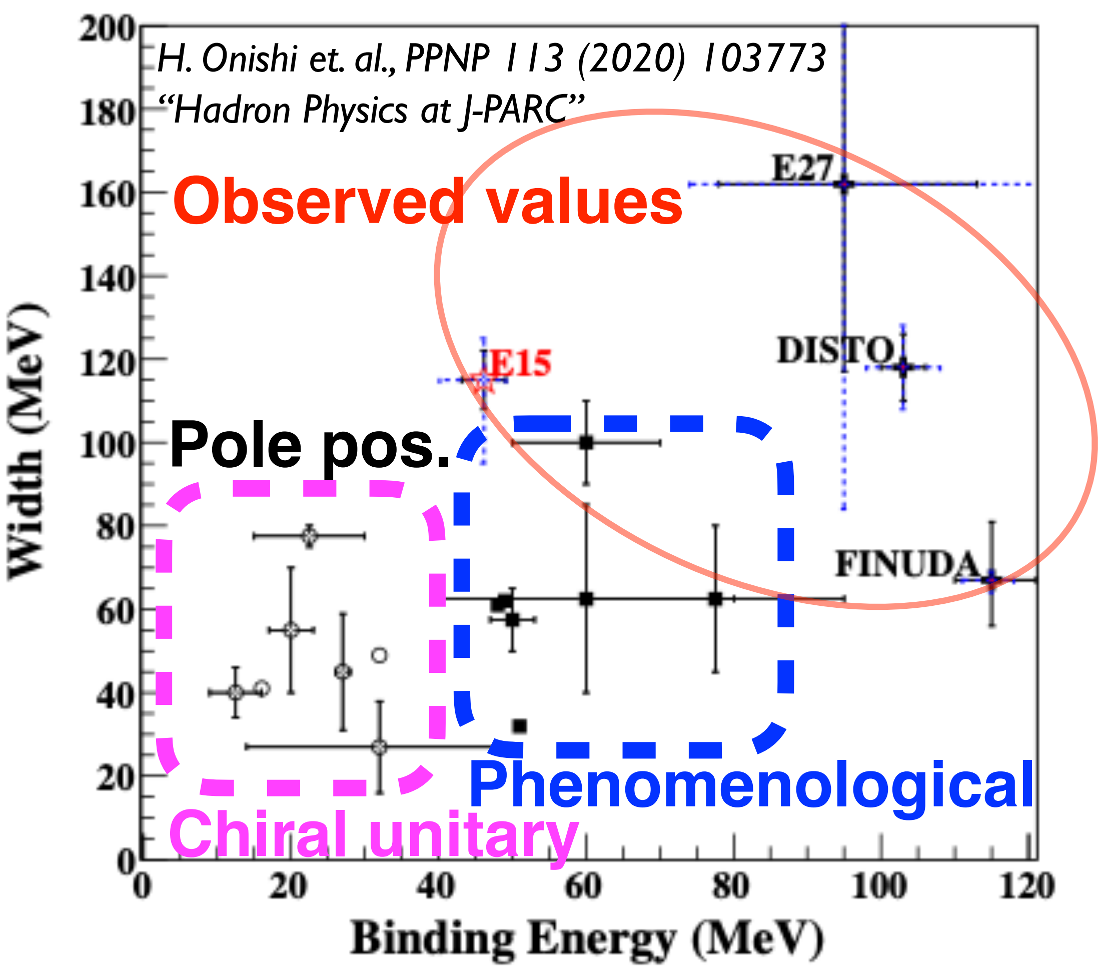


ppn



ppnK

Theories and experiments on “K̄NN”



- E15 at K1.8BR J-PARC

  $^{3}He(K^{-}, \Lambda p)n$

- E27 at K1.8 J-PARC PTEP(2015)021D01.

  $d(\pi^{+}, K^{+})\Lambda p$ / $\Sigma^{0}p$

  Inverse reaction $dK^{-} \rightarrow \Lambda p \pi^{-}$ has be taken at K1.8BR.

- DISTO PRL**104**(2010)132502

  Intermediate $N^{*} \rightarrow pK^{+}$?

  $pp \rightarrow p\Lambda K^{+}$

- FINUDA PRL**94**(2005)212303

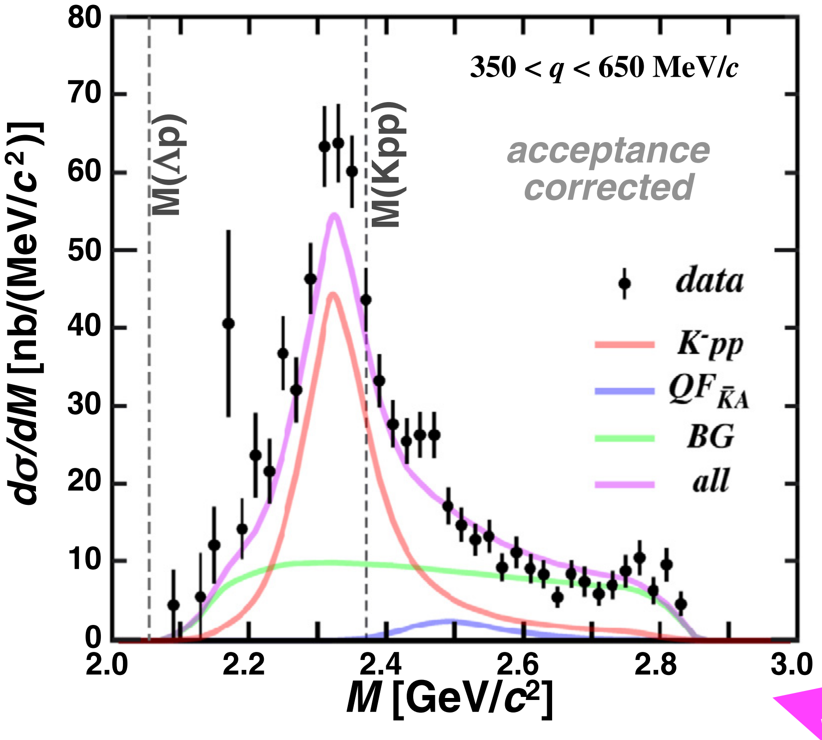
  Multi-NA processes?

  $(K_{stop}^{+}, \Lambda p)$

Result of J-PARC E15

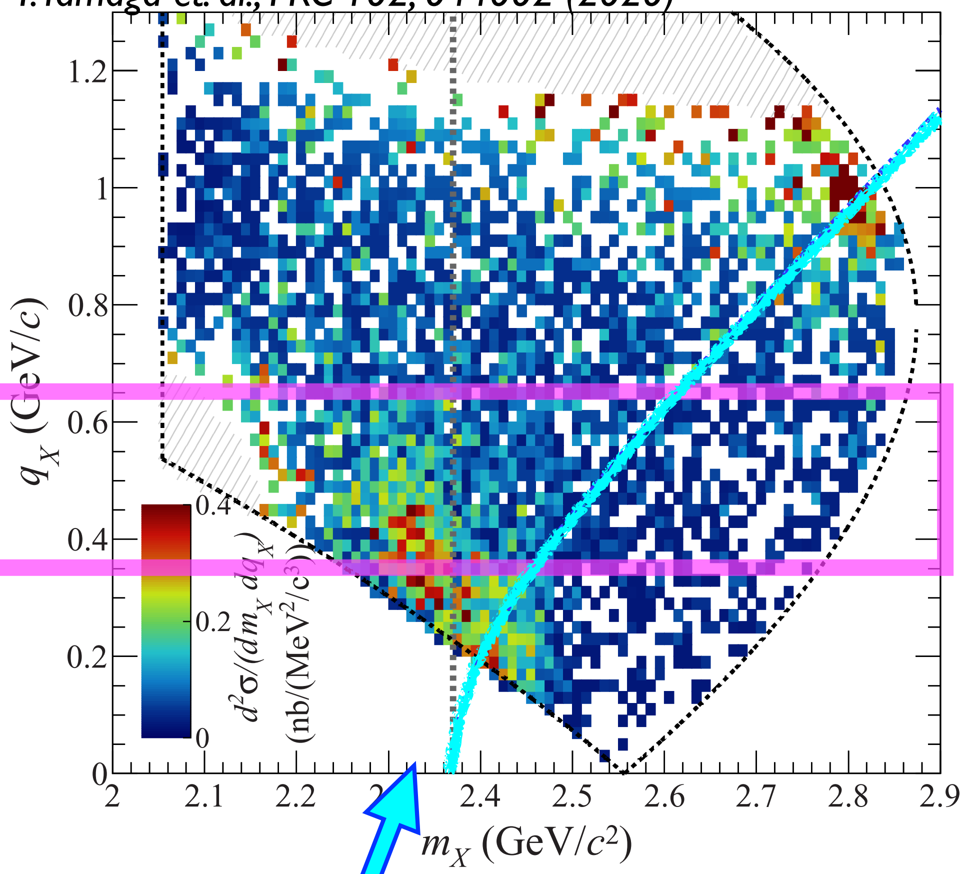
J-PARC E15 exp. $^{3}He(K^{-},\Lambda p)n$

S. Ajimura et. al., PLB 789, 620 (2019)



J-PARC E15 exp. $^{3}He(K^{-},\Lambda p)n$

T. Yamaga et. al., PRC 102, 044002 (2020)



$0.35<q_x<0.65$

Projection

Quasi-free KN→Kn, KNN→Λp

$$M_F(q) = \sqrt{4m_N^2 + m_K^2 + 4m_N\sqrt{m_K^2+q^2}},$$

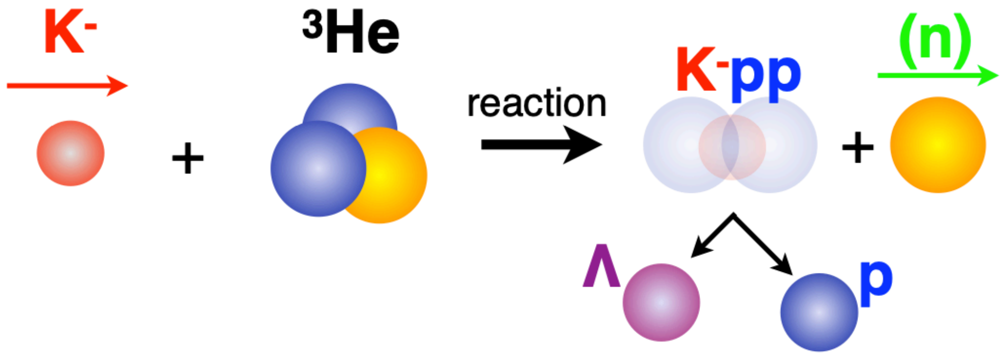
- Momentum transfer q

  $q(\Lambda p) = p_k - p_n$

The advantage is the q dependence to understand background processes.

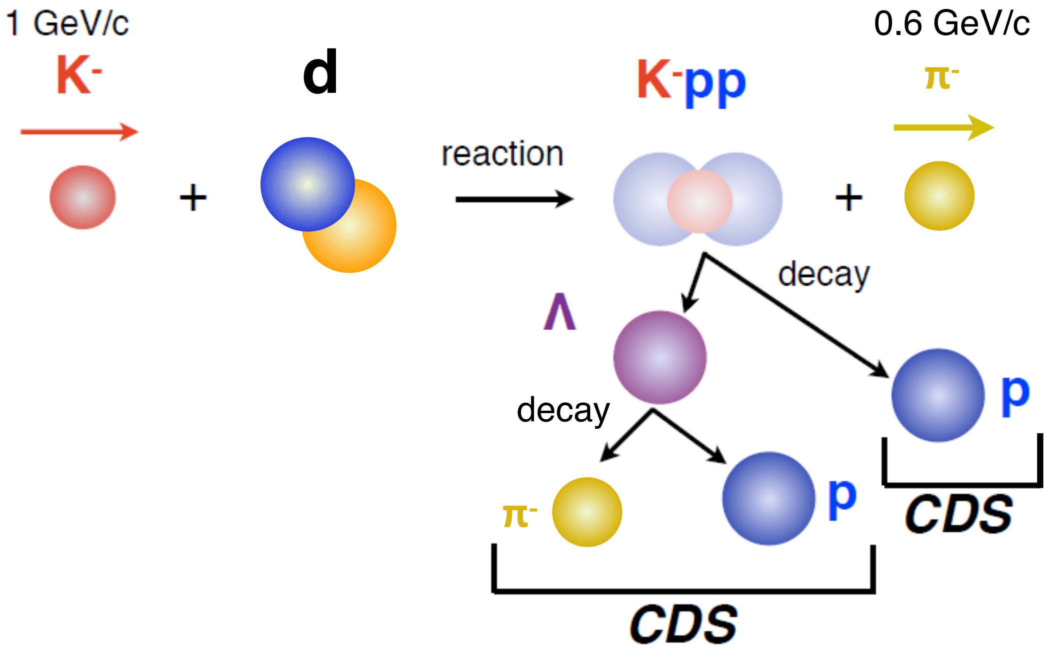
$d(K^-, \Lambda p)\pi^-$ reaction

J-PARC E15



J-PARC E31

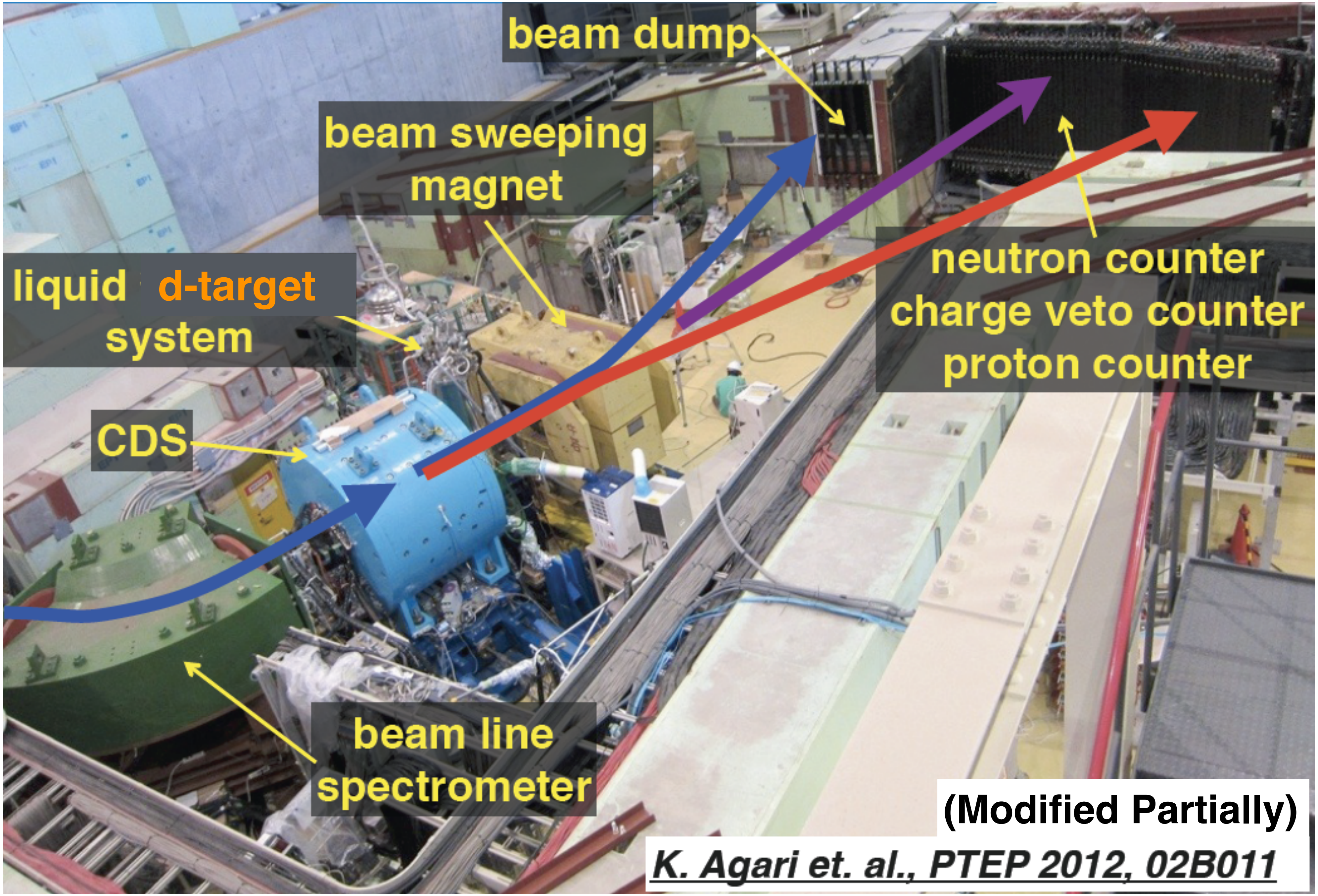
This talk.



Missing.

Tracking and time-of-flight.

Experimental Setup at K1.8BR



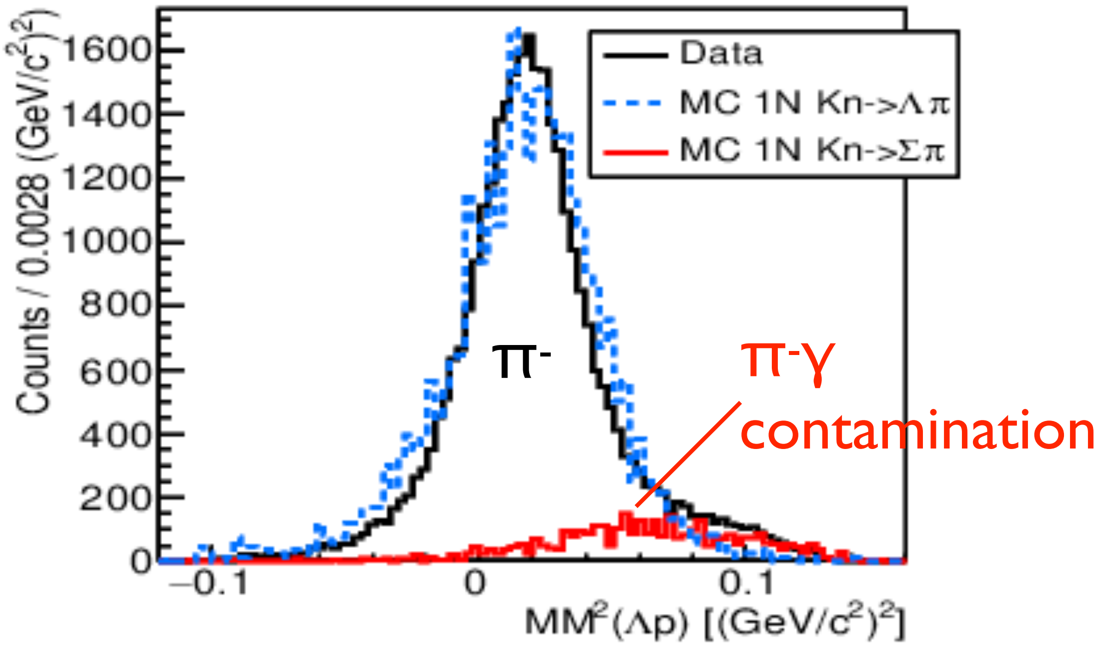
Event selections

- $pp\pi$ event selection in CDS.

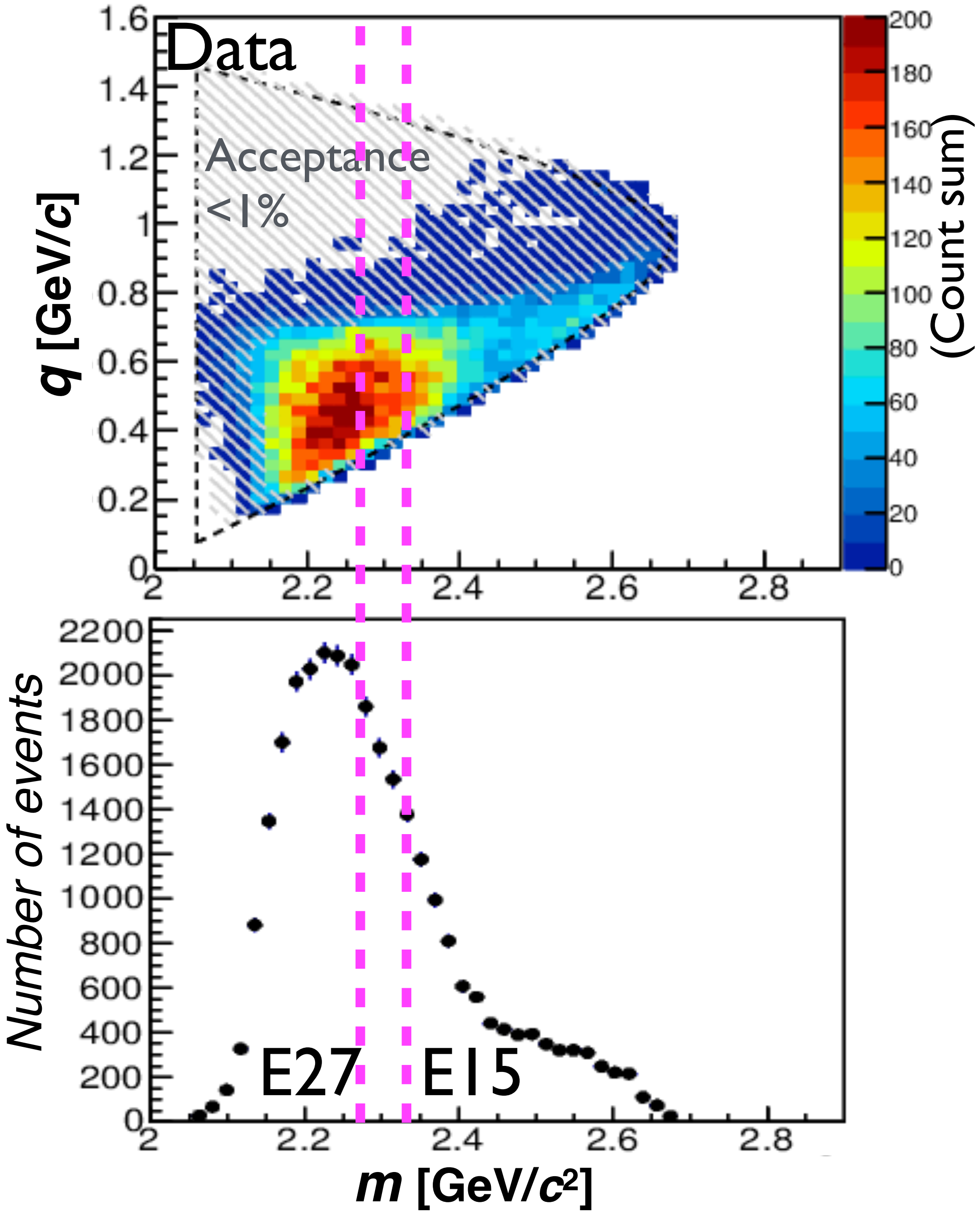
- $\Lambda \rightarrow p\pi^-$ pairs selection: Likelihood method on closest distance approach.

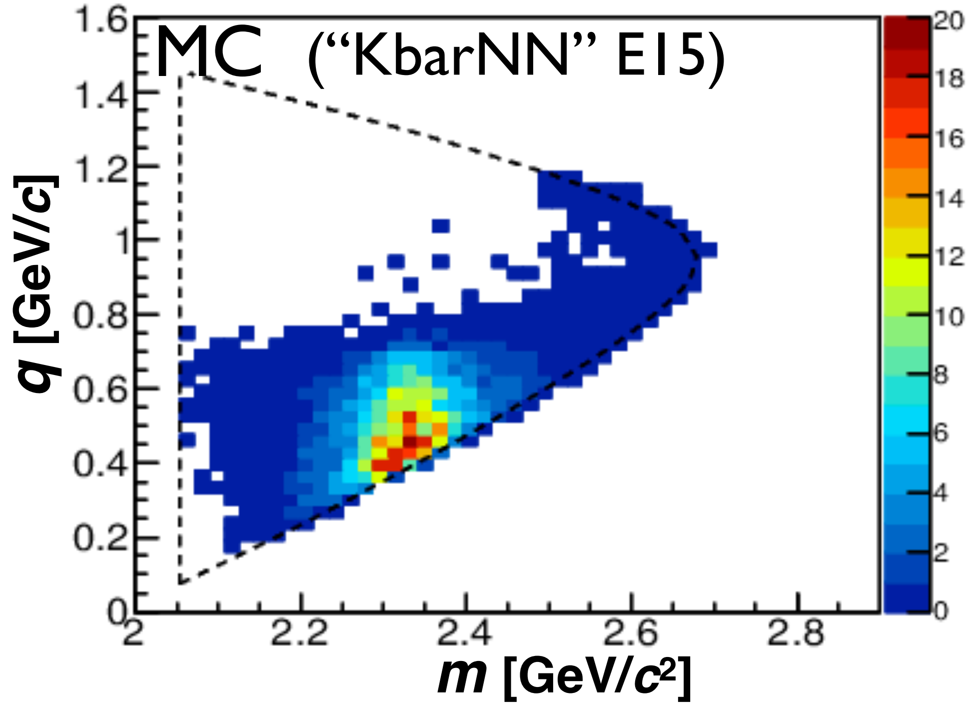
- Missing pion selection: χ^2 method on kinematical refit to conserve energy-momentum.

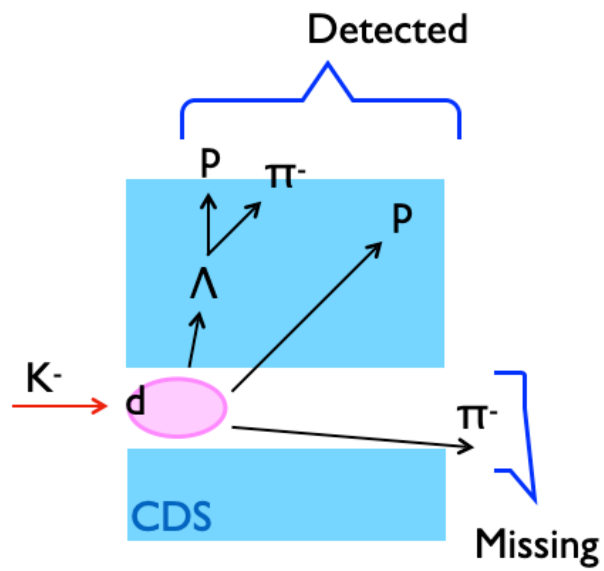
Square of Λp missing mass after applying all the event selections



Λp distribution







Event distribution of Λ pπ^- final state

kinematical Degree-of-Freedom = 5

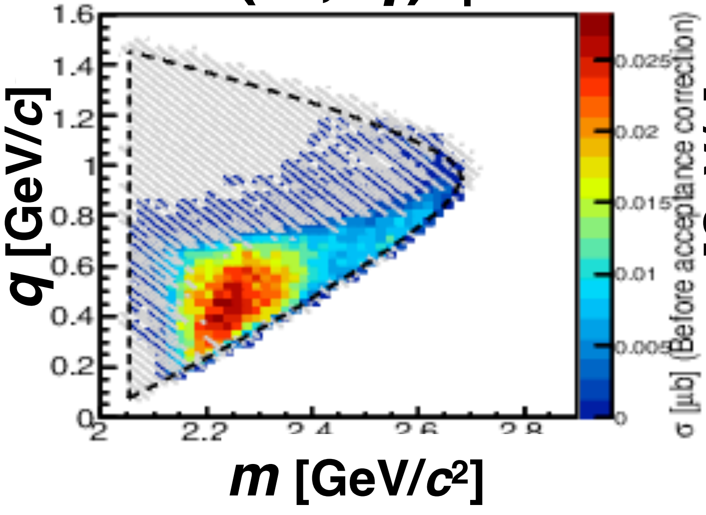
9 (3 on-shell particles) - 4 (energy-momentum conservation and ϕ symmetry)

3 (*m*, *q*)-plots are ***more than sufficient*** to identify the event kinematics

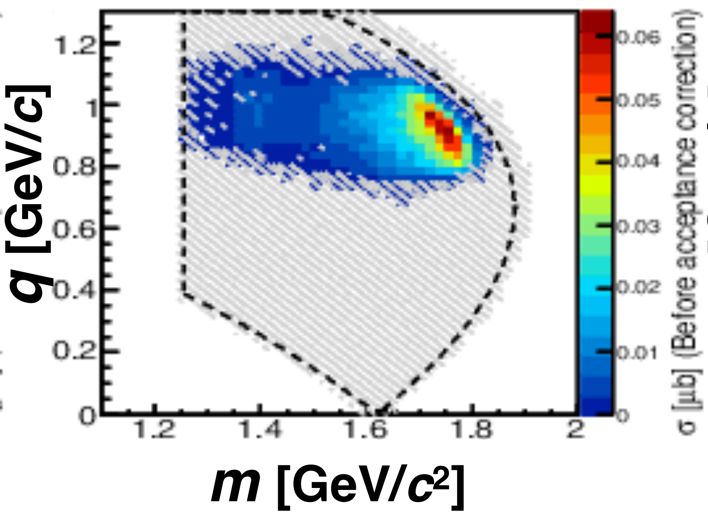
➡ We can specify reaction dynamics by these 3 plots

m : invariant mass of a pair ***q*** : momentum transfer to the pair

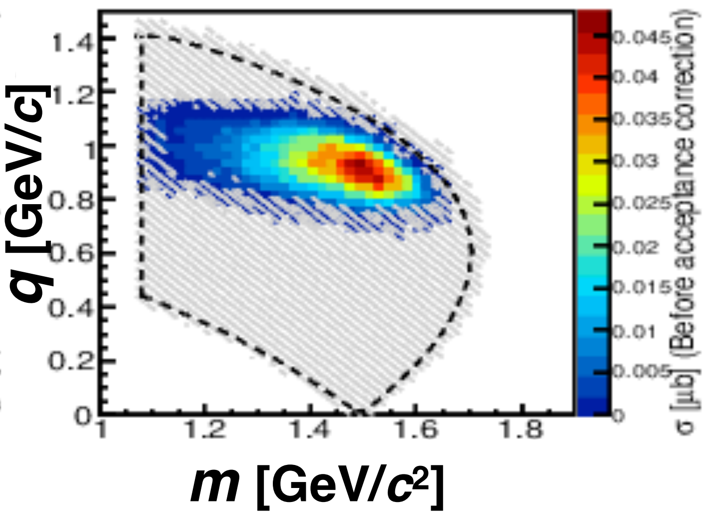
$(m, q)_{\Lambda p}$



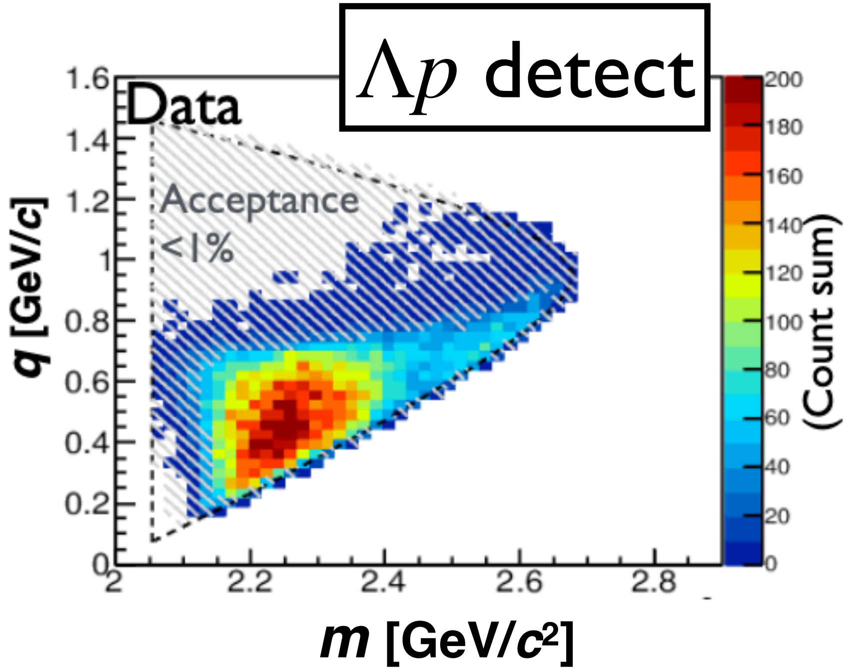
$(m, q)_{\Lambda\pi^-}$



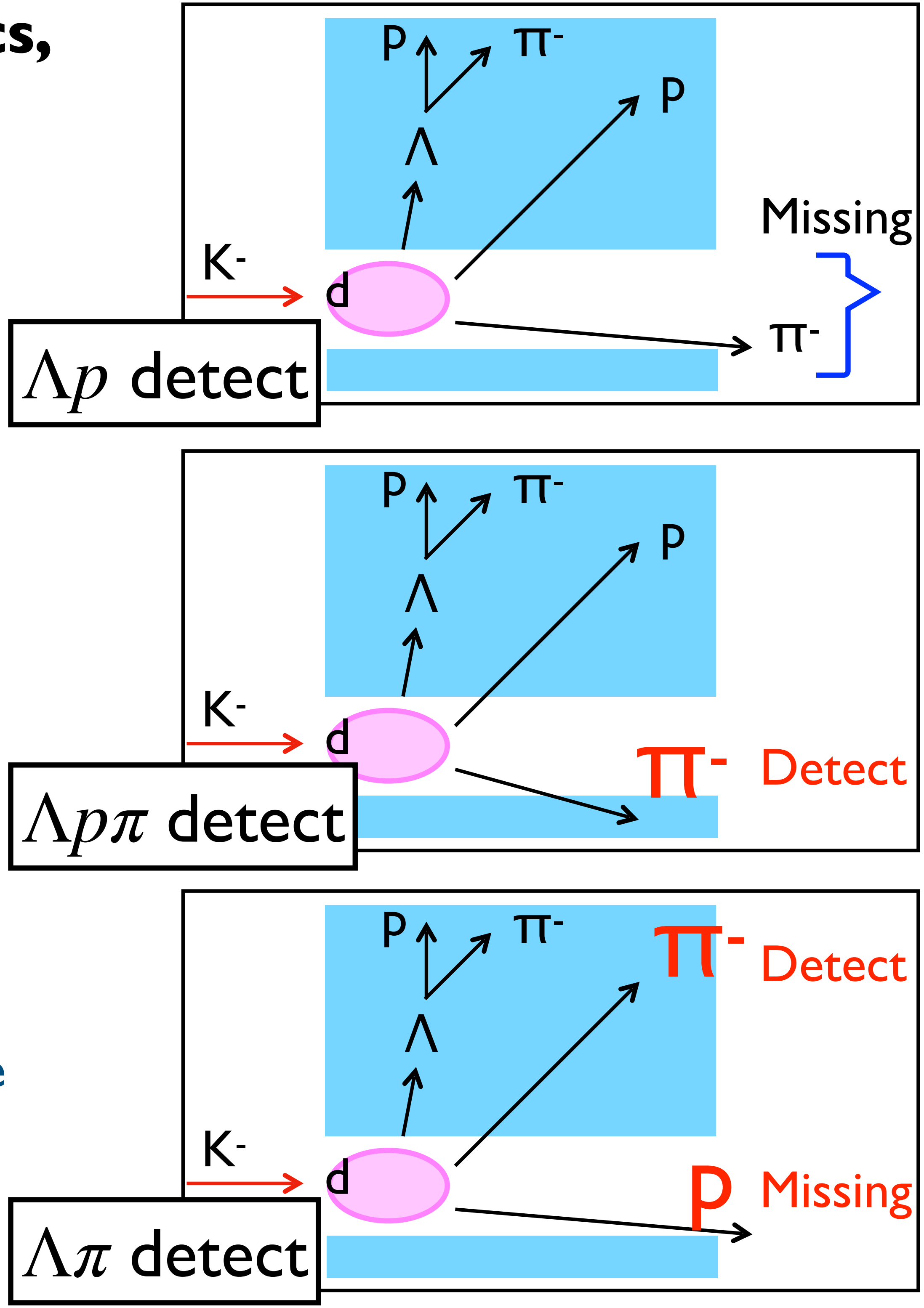
$(m, q)_{p\pi^-}$



To know reaction dynamics, we need to expand the acceptance on (m, q).



When we require Λ detection, there are three possible event geometries to identify $\Lambda p \pi^-$ final state.

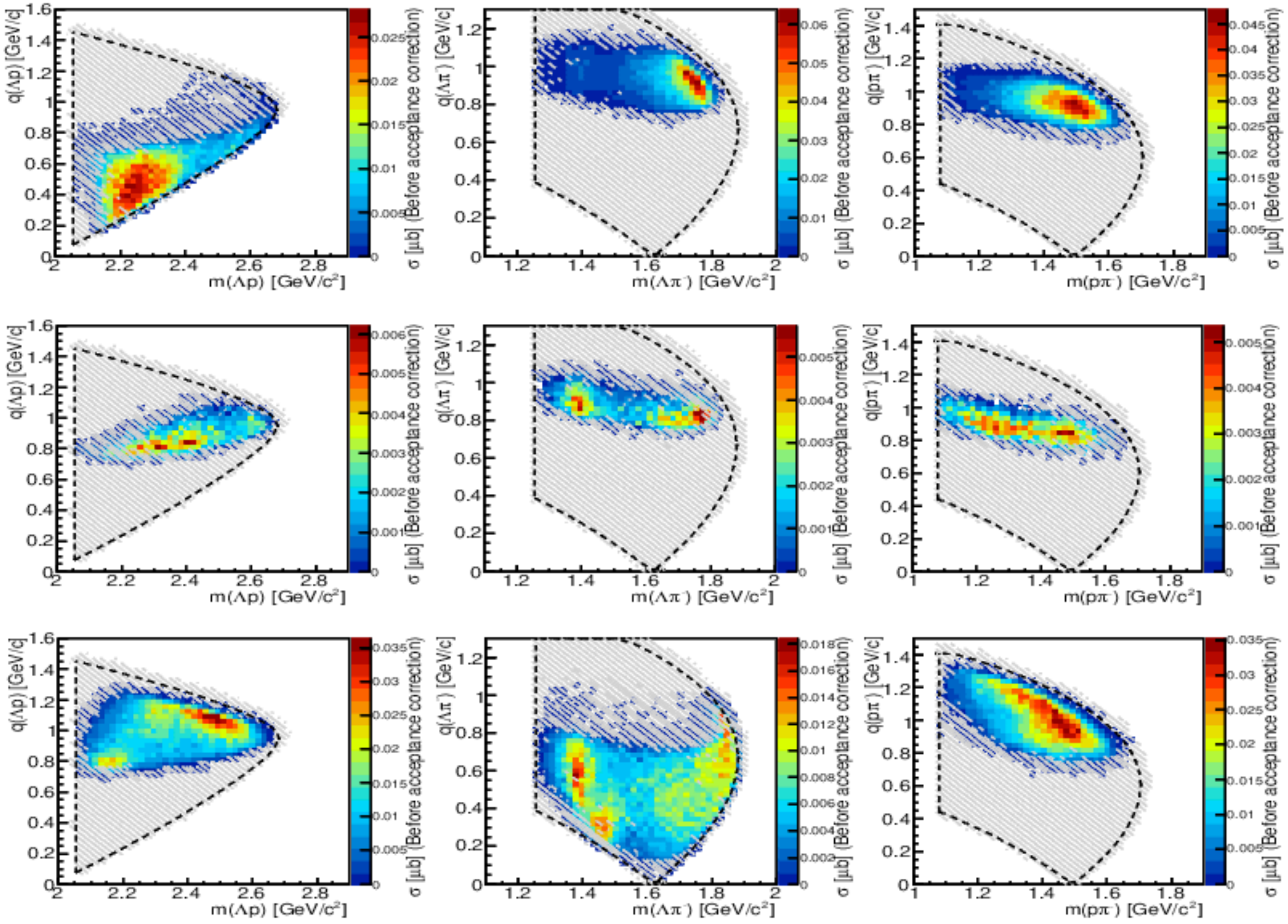


	$(m, q)_{\Lambda p}$	$(m, q)_{\Lambda\pi}$	$(m, q)_{p\pi}$

Λp detect

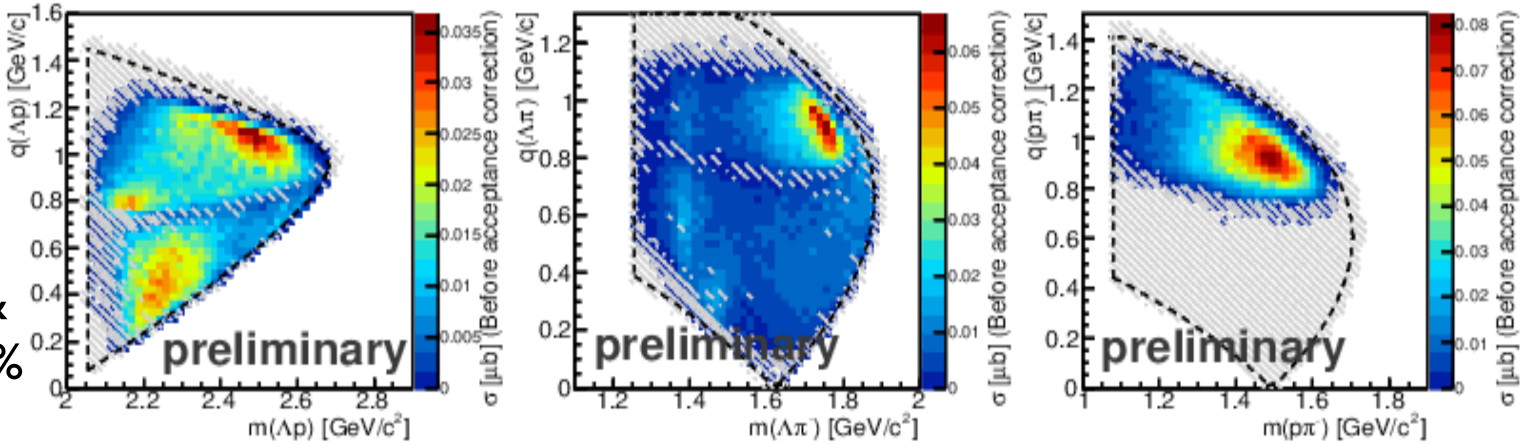
$\Lambda p \pi$ detect

$\Lambda \pi$ detect



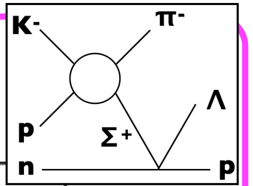
Sum

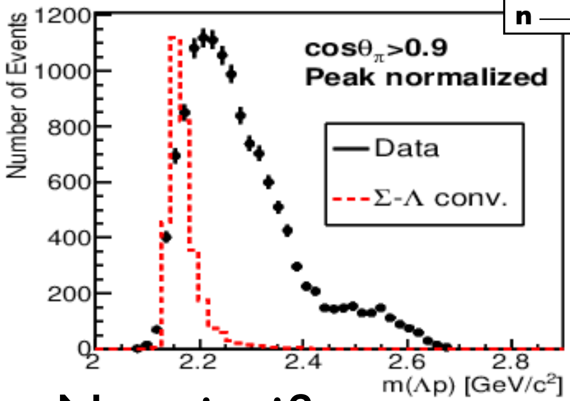
Shaded Systematical & statistical Error > 30 %



Knowledge from reaction dynamics (m, q)

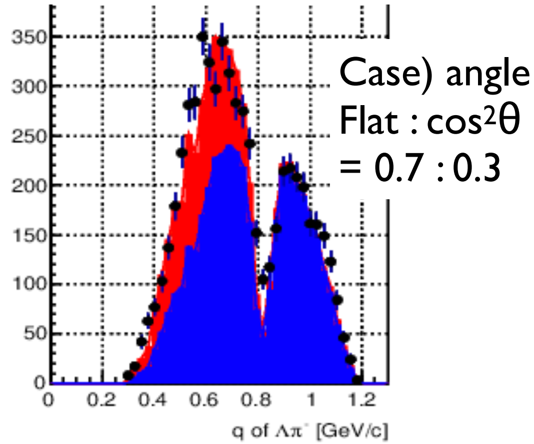
Σ-Λ conversion



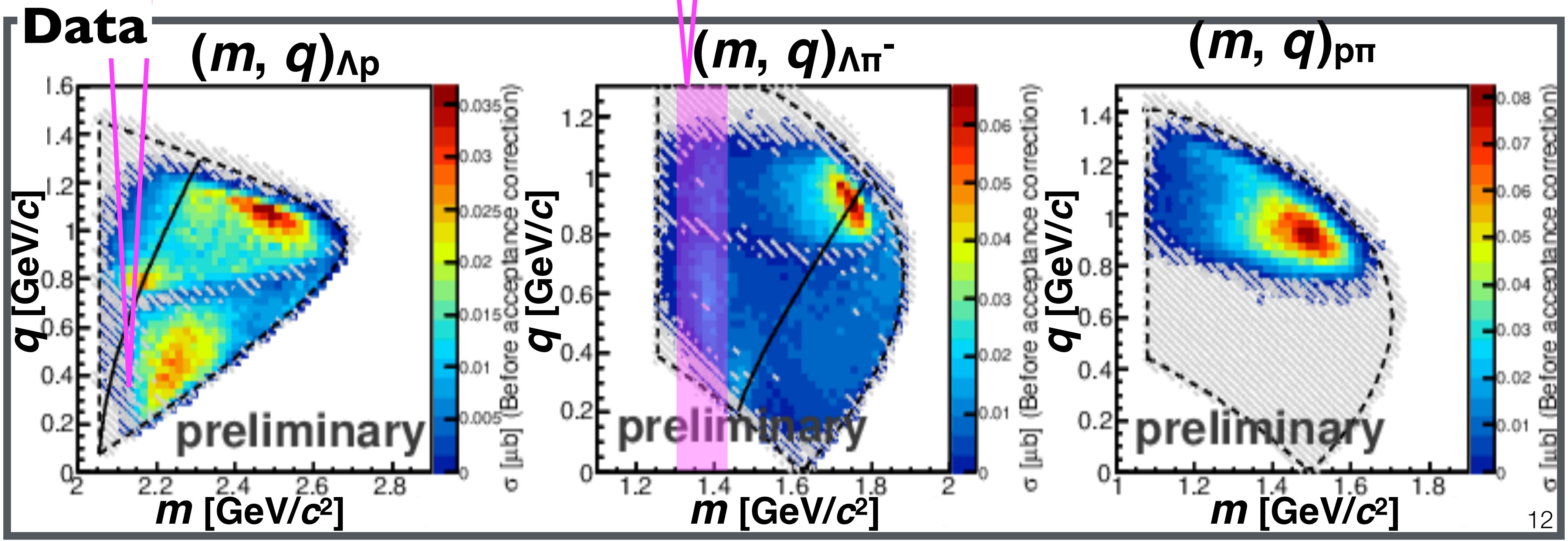


- Not significant.

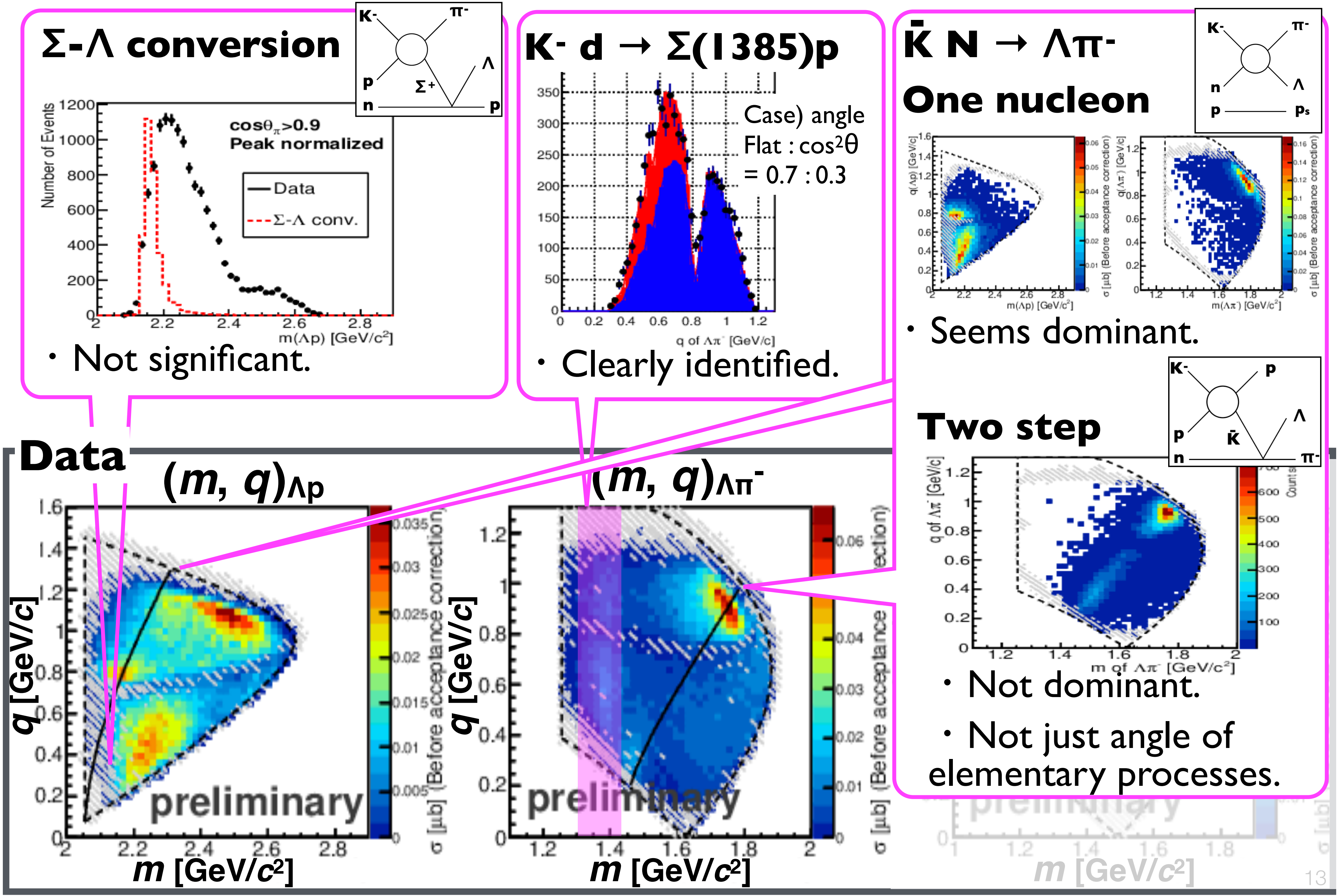
K⁻ d → Σ(1385)p



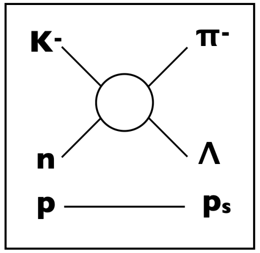
- Clearly identified.



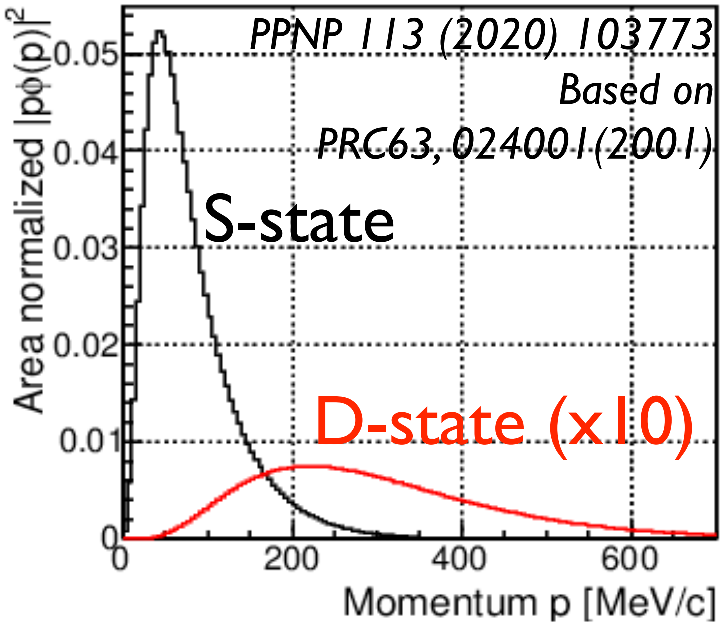
Knowledge from reaction dynamics (m, q)



One nucleon reaction: K⁻ n → Λ π⁻ (1/2)



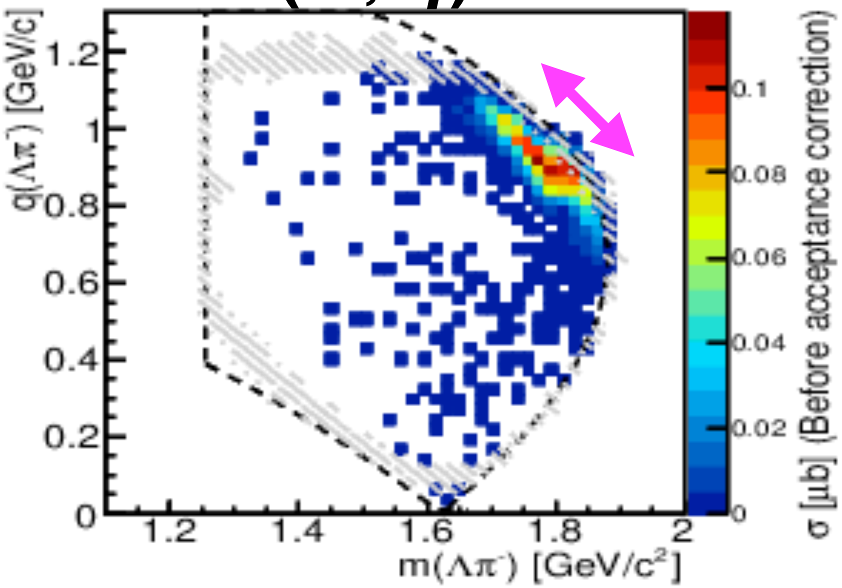
- Spectator-proton w/ large ***p*** fires trigger. Tail component of Fermi-motion affect the distribution.



Effect of large Fermi-momentum tail on Λπ distribution

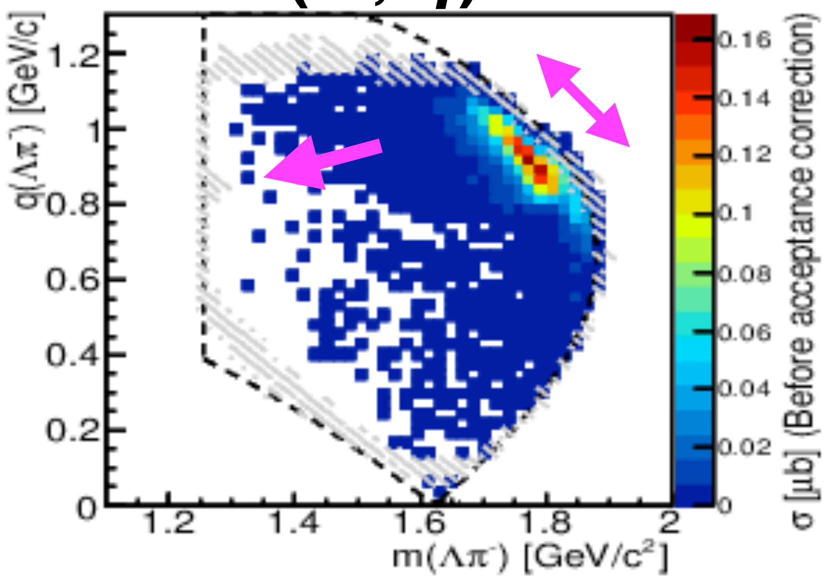
MC **w/o** D-state

(*m*, *q*)$_{\Lambda\pi}$



MC **w/** D-state

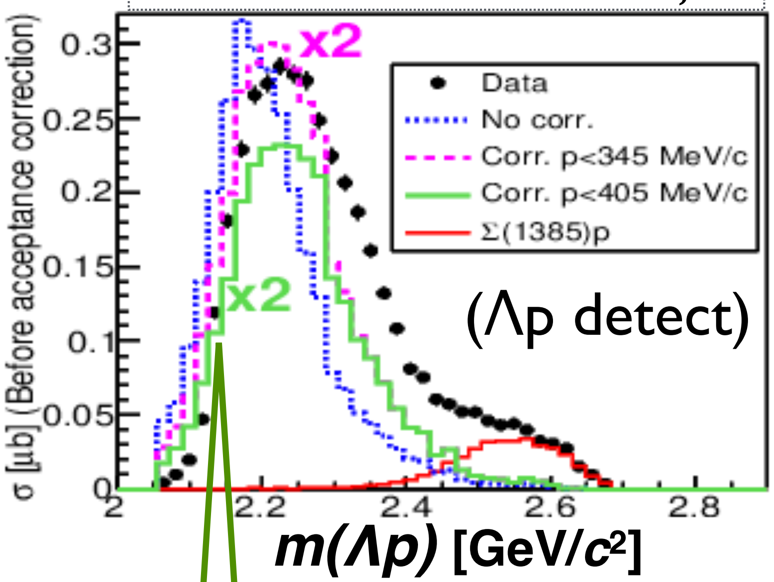
(*m*, *q*)$_{\Lambda\pi}$

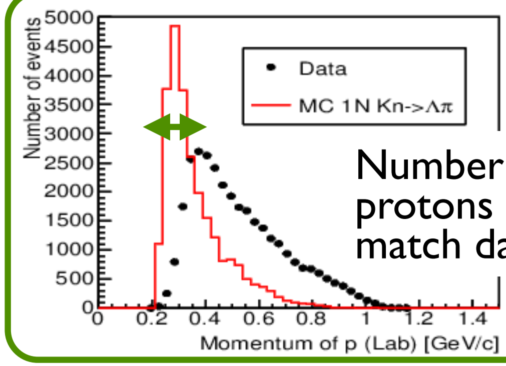


One nucleon reaction: $K^- n \to \Lambda \pi^-$ (2/2)

IM of "$\bar{K}NN$" region

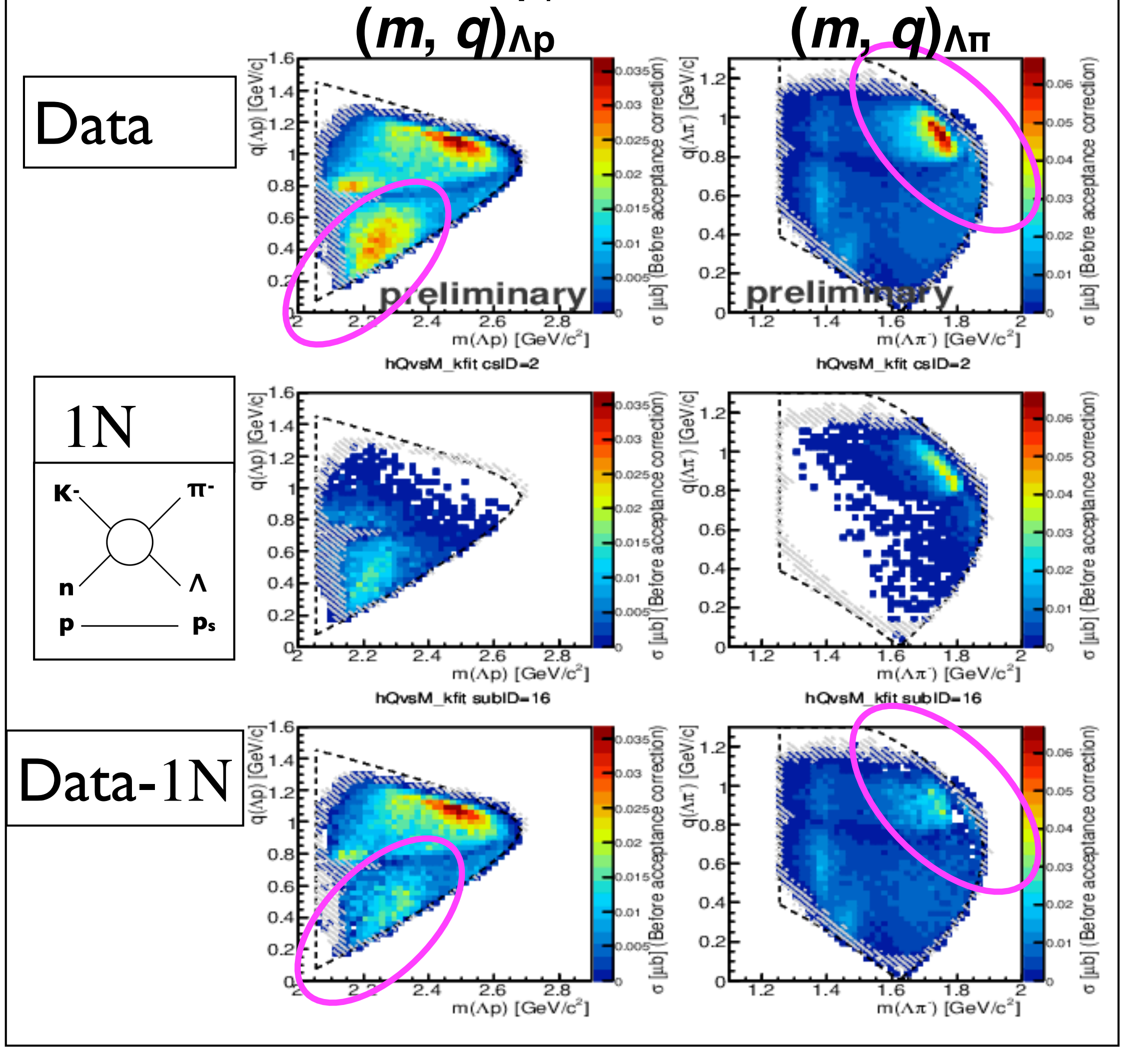
· MC Cross-section: (4.8±0.34)μb *NPB129,253*





Number of low-momentum protons are corrected to match data, currently.

Subtraction 1N corr. p_p<345 MeV/c



- W/ Correction of spectator-proton momentum, data of interested region is mostly explained w/ 1N reaction.
- Difference of proton momentum is under investigation.

Summary

- E31 collaboration is investigating "KbarNN" bound state using d(K^-, Λp)π^- reaction with the confirmation of all the kinematical freedoms.

- Reaction dynamics are determined by the momentum transfer and invariant mass of Λp, $\Lambda\pi^-$ and $p\pi^-$ systems. The reaction processes, one nucleon reaction $Kn \rightarrow \Lambda\pi^-$, two nucleon reaction $Kp \rightarrow Kp$, $Kn \rightarrow \Lambda\pi^-$, none-mesonic Y* production $Kd \rightarrow \Sigma(1385)p$, are clearly identified.

- "KbarNN" interested region is mostly explained with one nucleon reaction $Kn \rightarrow \Lambda\pi^-$ including large momentum Fermi-motion tail and correction of spectator-proton momentum distribution. Difference of proton momentum is under investigation.