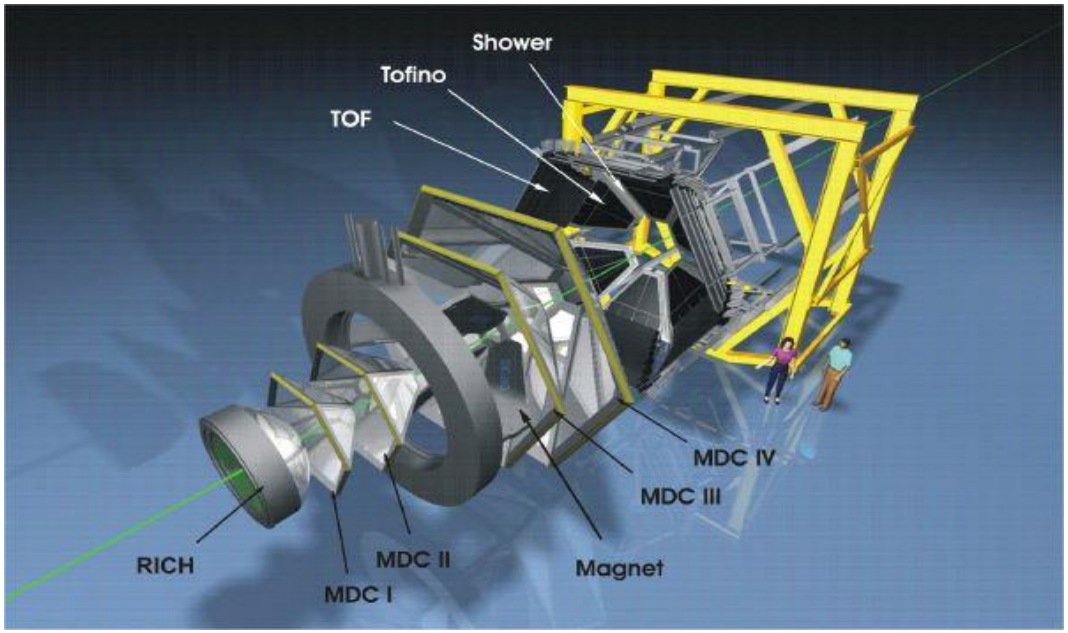
Two- pion production in np reactions with HADES



A.Kurilkin, P.Kurilkin, V.Ladygin, A.Jerusalimov, T.Vasiliev,
LHEP-JINR, Dubna, Russia

For the HADES collaboration

Outline

- Introduction:

  motivation, world data

- HADES experiment and Data analysis
- Results
  - double-pion production, comparison with the models
- Conclusion

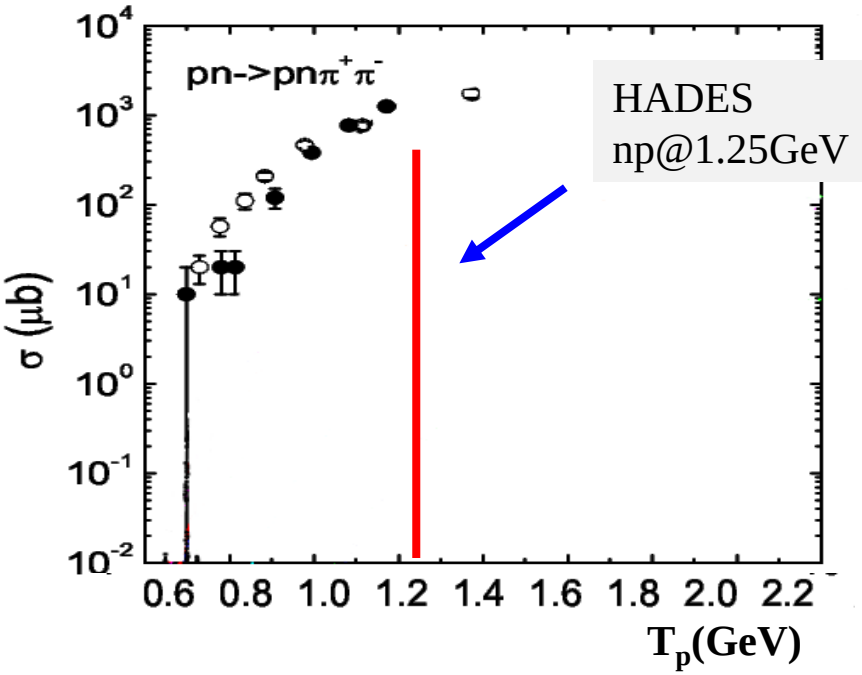
Motivation

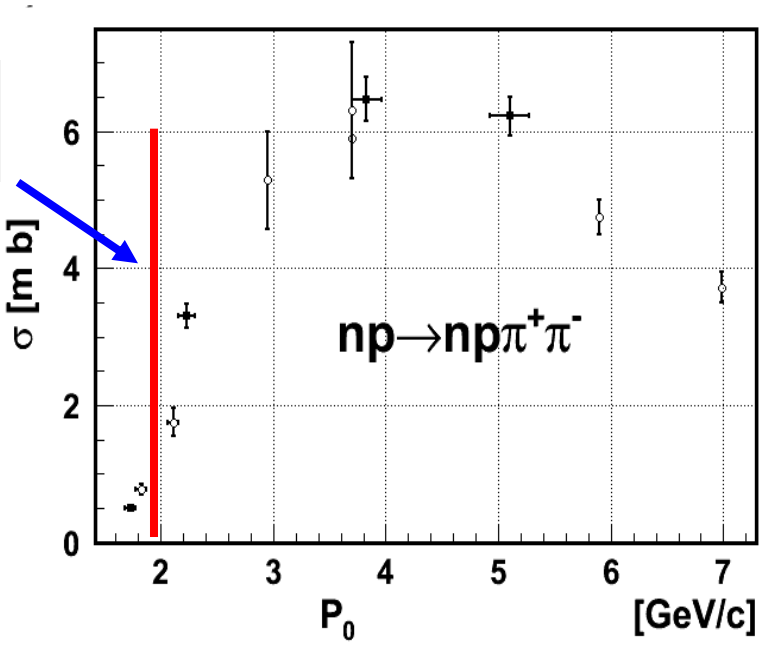
- Double pion production in NN collisions is one way to obtain information about the NN, πN and ππ interactions.

- Specific interest in pp and np collisions at 1.25 GeV is the study of excitation of baryons and their subsequent decays :
  $\Delta(1232) \rightarrow N\pi$, $N^*(1440) \rightarrow \Delta\pi$, $N^*(1440) \rightarrow N\sigma$, $N^*(1440) \rightarrow \rho N$, $\Delta\Delta$ excitation.

- The studies $\pi^+\pi^-$ production in np collision provide the information on the reaction amplitudes with the isospin zero NN initial state necessary for isospin decomposition.

World data on the double pion production in NN collisions





○ data before 1983 (bubble chamber exp)

● T.Tsuboyama et al.,Phys. Rev. C 62, 034001 (2000)

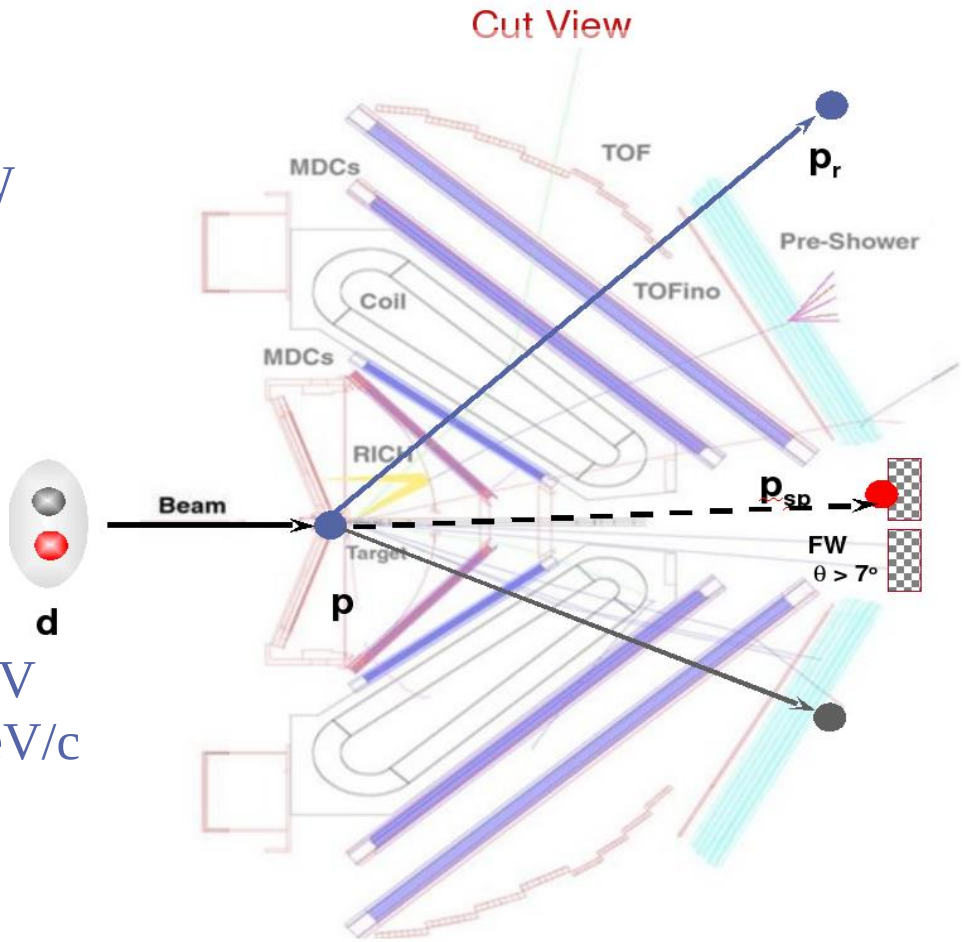
■ C.Besliu et al., YF 43:888-892, 1986

Channel	Collaboration (Tp (MeV))
$pp \to pp\pi^+\pi^-$	CELSIUS(**650, 680, 750, 775, 895, 1100, 1360**), Gatchina(717, 818, 861, 900, 980), COSY(**750, 800**), KEK(698, 780, 814, 908, 995, 1083, 1172)
$pp \to pp\pi^0\pi^0$	CELSIUS(650, 725, 750, **775, 895, 1000, 1100, 1200, 1300**, 1360)
$pp \to nn\pi^+\pi^+$	CELSIUS(800, **1100**)
$pp \to pn\pi^+\pi^0$	CELSIUS(725, 750, 775, 1100)
$pn \to pn\pi^+\pi^-$	KEK(698, 780, 814, 908, 995, 1083, 1172)
$pn \to pp\pi^-\pi^0$	KEK(698, 780, 814, 908, 995, 1083, 1172)

HADES experiment at SIS18, GSI

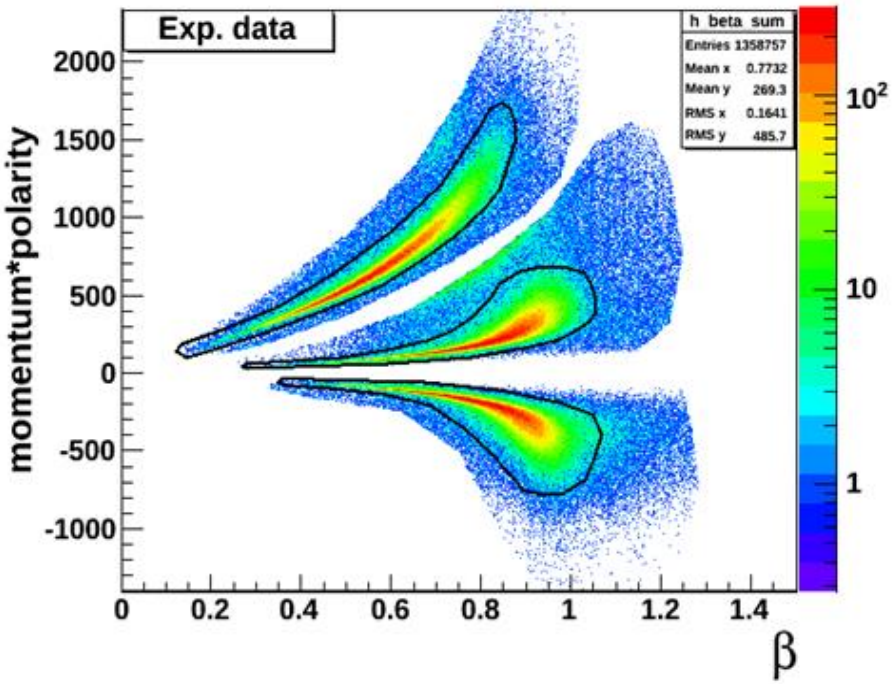
- d+p reactions, May 2007:
  - LVL1 (MULT >2) && FW
- Detector set-up:
  - LH2 target
  - 24 MDC
  - No Start detector
  - Forward Wall
- Kinematics for np:
  - Kinetic Energy = 1.25 GeV
  - Momentum = 1.97 GeV/c
  - np selection by detecting Proton-spectator in FW

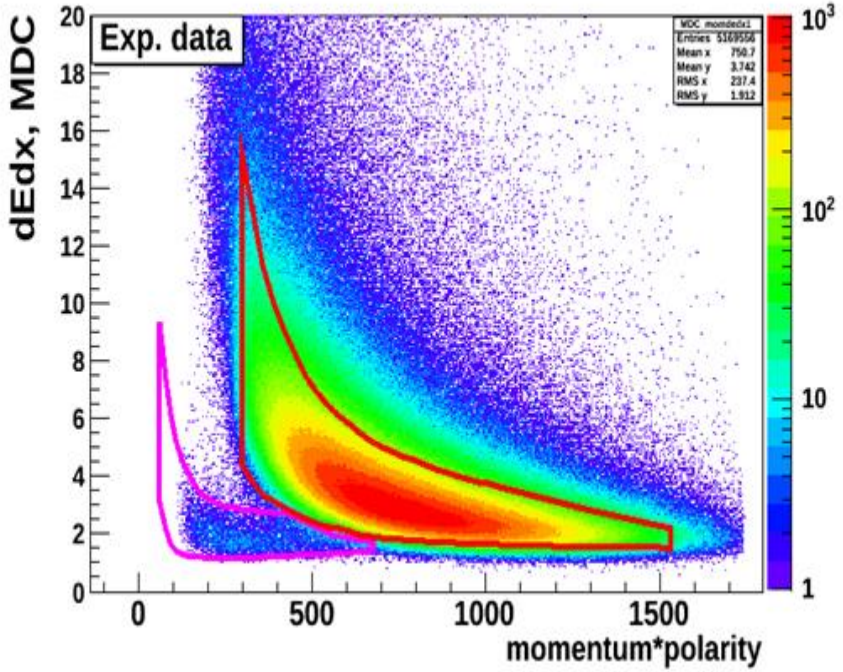
1.6GeV/c<Psp<2.6GeV/c



PID and selection of the reaction channels

Time of flight is relative (no START detector). Time of flight reconstruction was based on tracking information + hypothesis. Each combination must fit into PID cuts. The best combination (the lowest $\chi 2$) wins.





Correction of the experimental data

$$Eff_{total} = Eff.\ \pi^{+} * Eff.\ \pi^{-} * Eff.\ p * Eff._{PID} * 0.84$$

Normalization: $$\frac{d\sigma}{dM_{inv}} = Scaling * \frac{dN}{dM} * \frac{\sigma_{pp}}{N_{pp}}$$

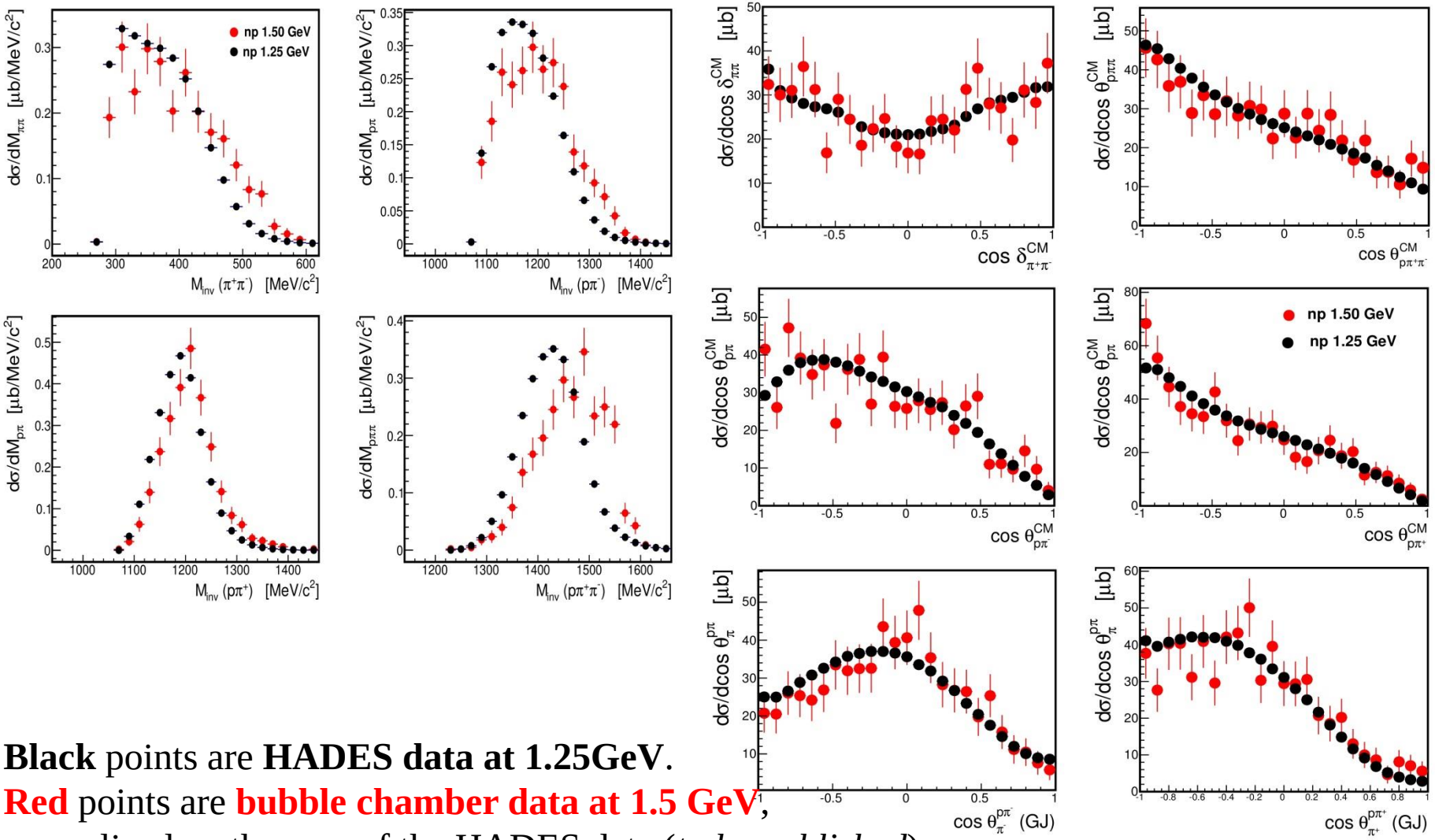
Scaling = 4 (LVL1) ;

0.84 – FWall correction factor, (K.Lapidus - PhD)

$$\frac{\sigma_{pp}}{N_{pp}} = (3.85 \pm 0.25) * 10^{-9}\ mb/events$$

http://hades-wiki.gsi.de/pub/SimAna/NormalizationForPpAndDp/pp_elastic260109.pdf

Comparison $\pi^+\pi^-$ production in np collisions at 1.25 and 1.5 GeV



Black points are **HADES data at 1.25GeV**.
Red points are **bubble chamber data at 1.5 GeV**, normalized on the area of the HADES data (*to be published*)
Comparison in HADES acceptance.

Comparison of the HADES data with theoretical models

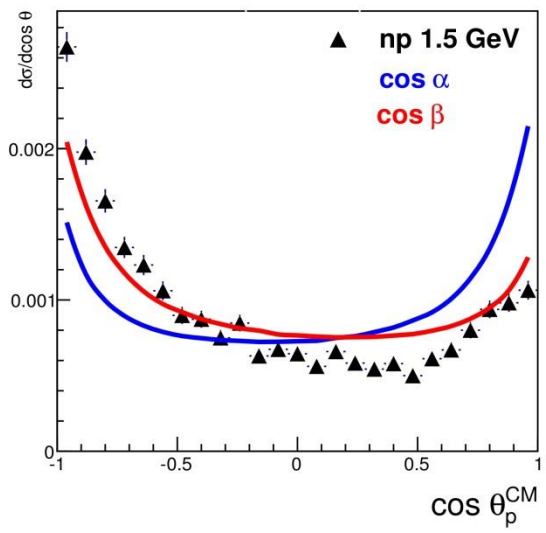
- **OPER-2 model :** *A. Jerusalimov, arXiv:1203.3330 [nucl-th] arXiv:1208.3982[nucl-ex]*

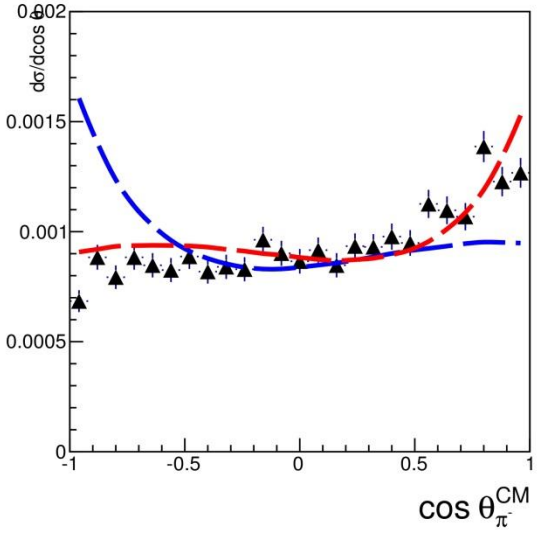
- **Xu Cao model :** *Xu Cao et al. Phys Rev C81, 065201 (2010)*

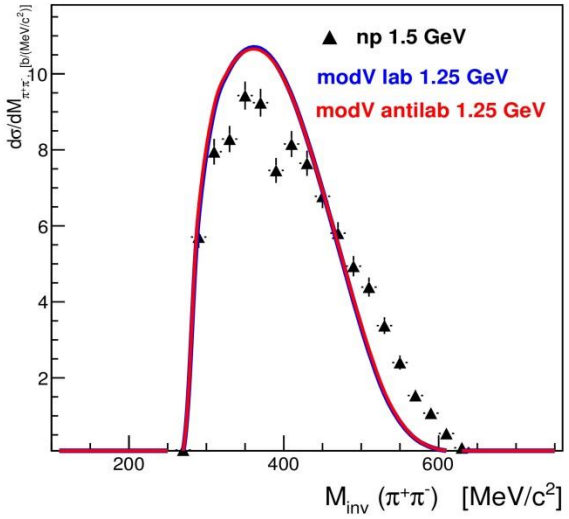
- **modified Valencia model :** *T. Skorodko*, et al., *Physics Letters B 679 (2009)30, Phys.Lett.B695:115-123,(2011)*

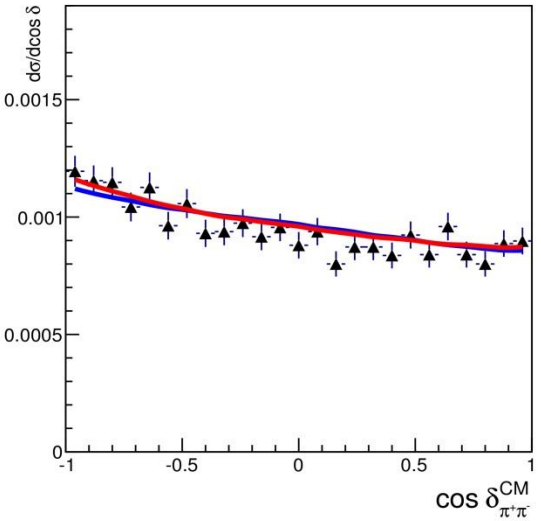
- Data corrected for the tracking and PID efficiency.
  - only statistical errors presented
  - systematical errors on the order of 10 % (normalization, eff. correction)
- Models filtered by the acceptance, normalized to the areas of experimental data.

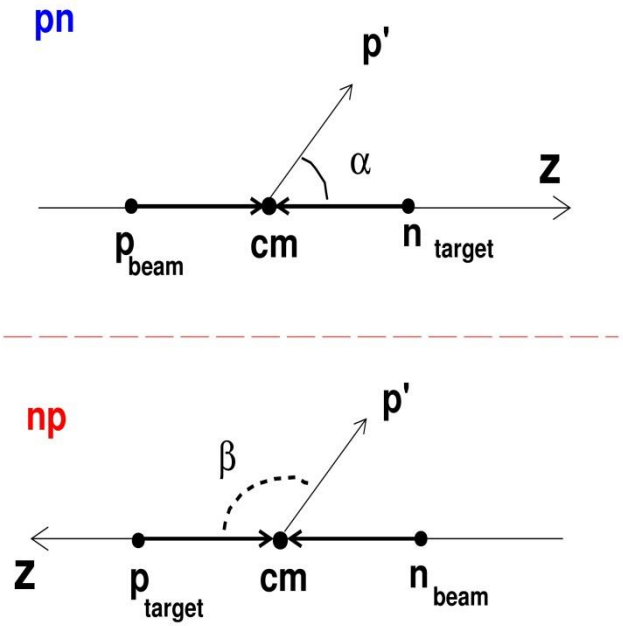
Comparison of 4π experimental data with theoretical models







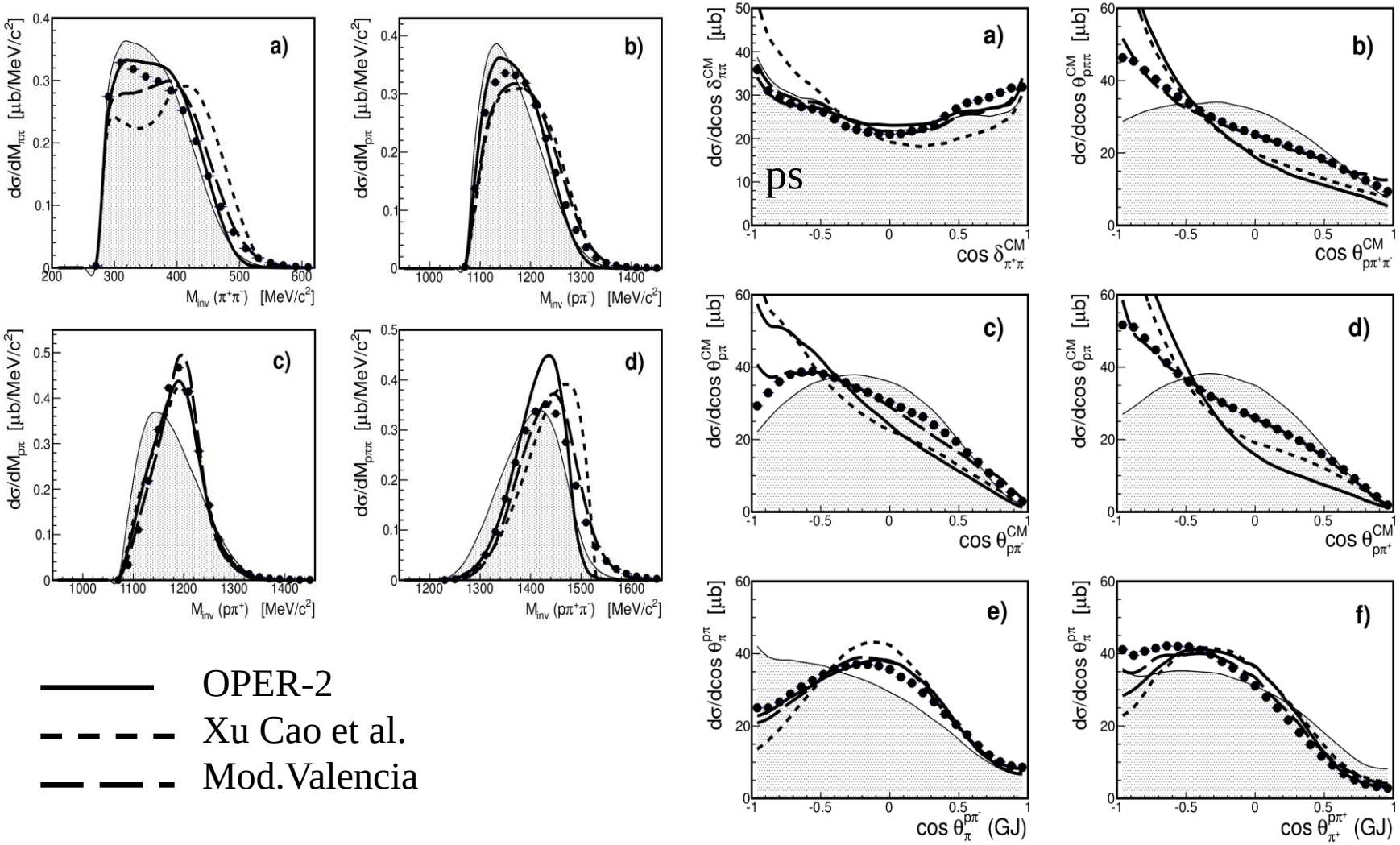




pn – Z axis is along proton,
np – Z axis is along neutron,

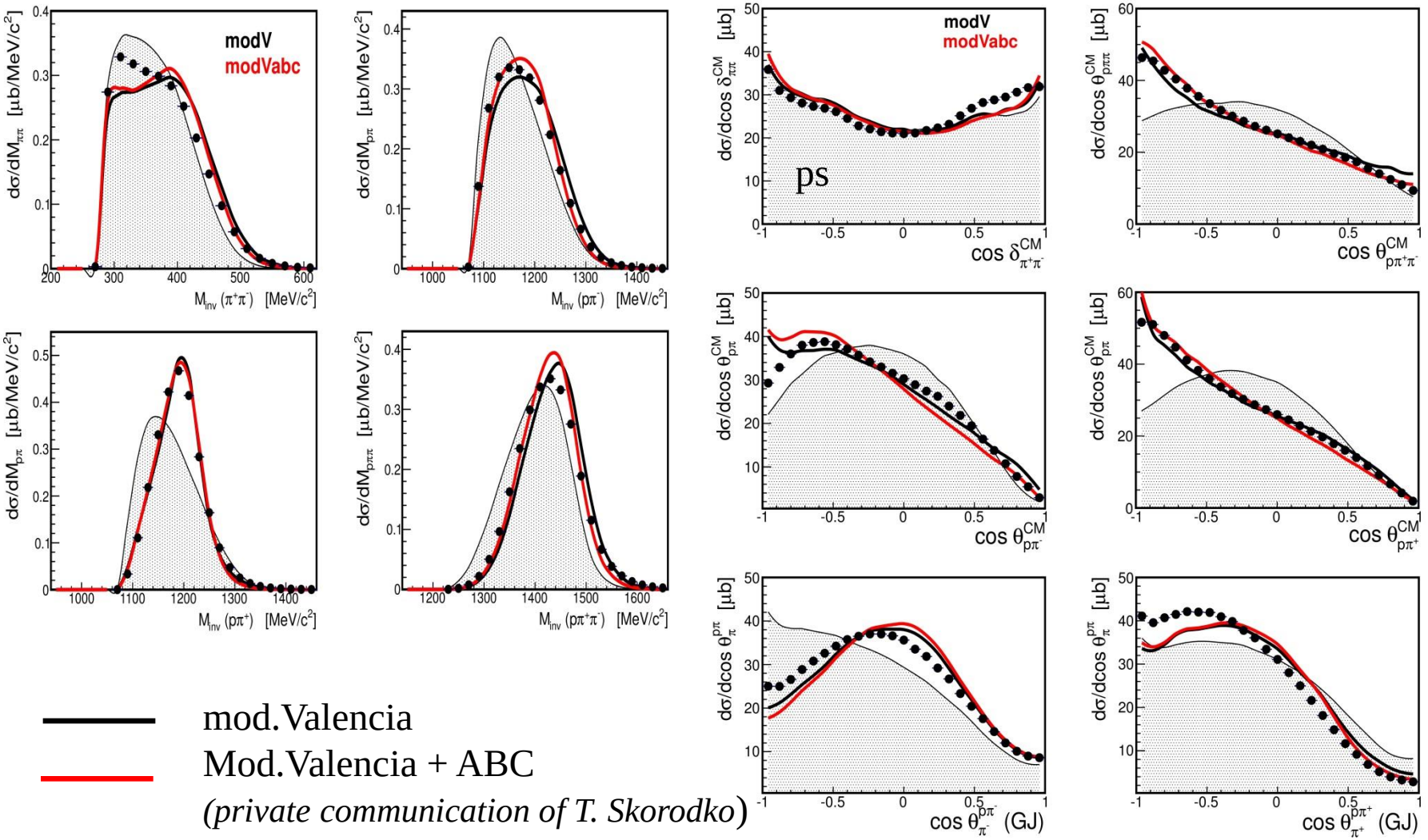
Difference in angular distribution between pn and np in c.m. is due to the opposite orientation of Z axis.

Results: double pion production in np @1.25 GeV



Black points are HADES data. *Comparison in HADES acceptance*.

Results: double pion production in np @1.25 GeV



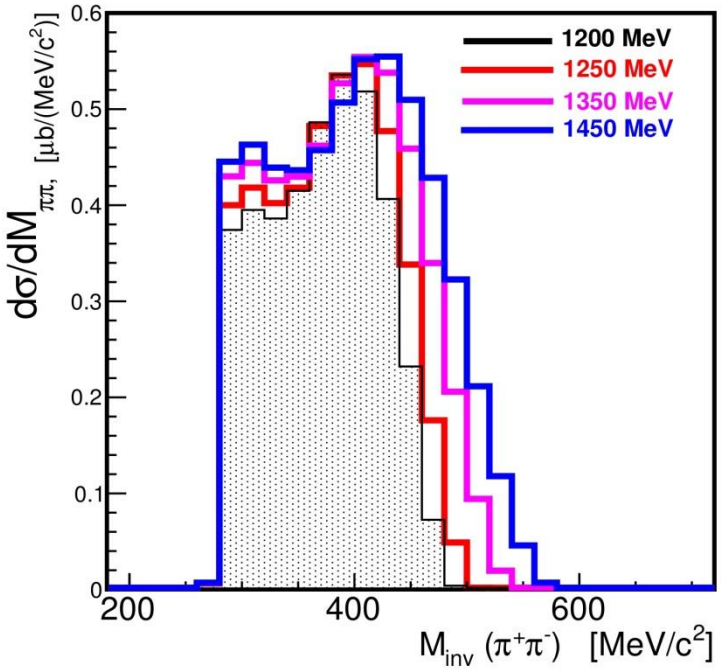
mod.Valencia

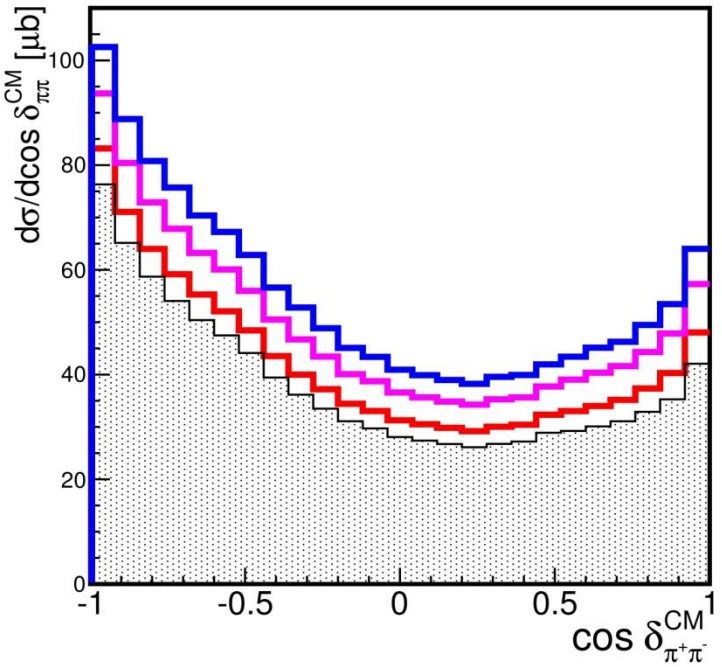
Mod.Valencia + ABC

(private communication of T. Skorodko)

Black points are HADES data. *Comparison in HADES acceptance*.

Predictions of Xu Cao et al., models at different energies.





Summary

- HADES provides high statistics data for double pion production in np @ 1.25 GeV

- The comparison of two-pion production in np @ 1.25 GeV with the theoretical models has been performed :
  - ✓ modified Valencia model (*better agreement with data*)
  - ✓ Xu Cao et al. model
  - ✓ OPER-2 model

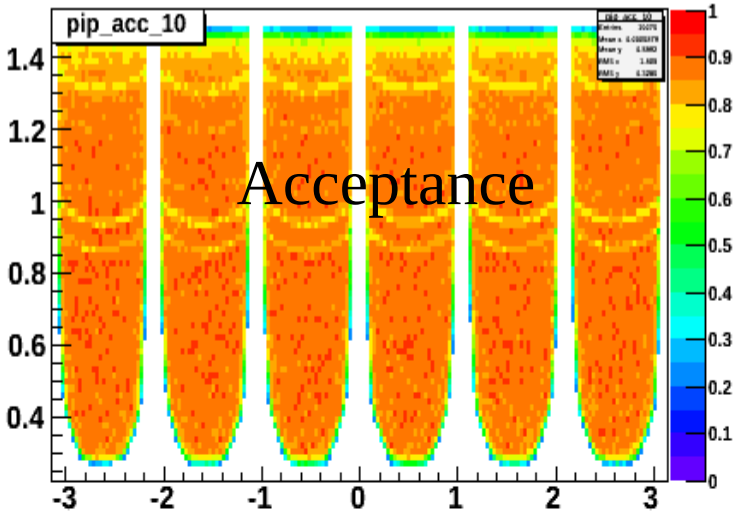
- The present models can not reproduce the observed enhancement in $\pi^+\pi^-$ spectra in low mass region.

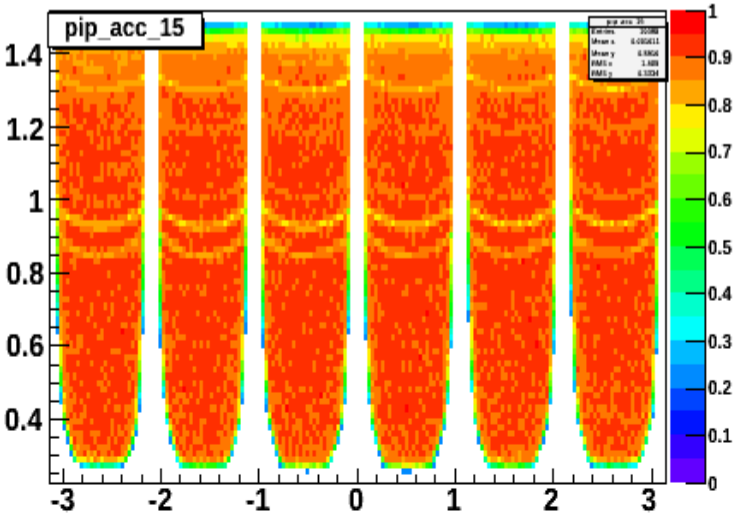
- The deviation for some differential distributions shapes still leave an opportunity for further optimization of existing model.

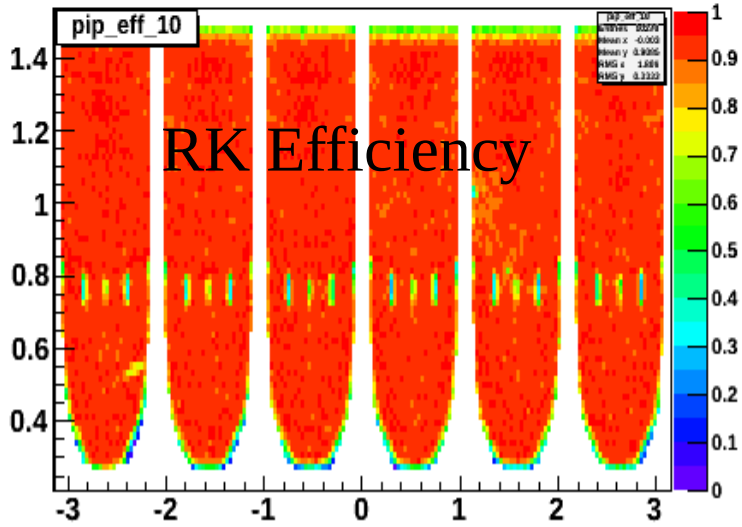
Thank you for your attention!

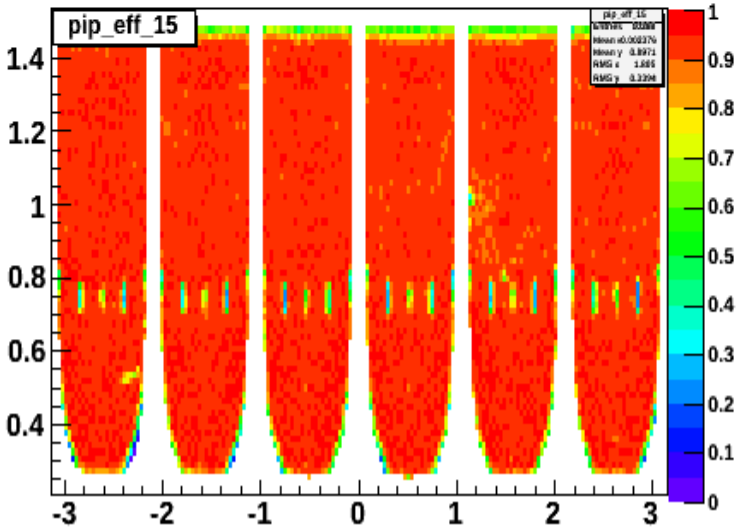
- Catania (INFN - LNS), Italy
- Cracow (Univ.), Poland
- Darmstadt (GSI, EMMI), Germany
- München (TUM, Excellence Cluster Universe), Germany
- Dresden (FZD), Germany
- Frankfurt (Univ., EMMI, HIC for FAIR), Germany
- Giessen (Univ., HIC for FAIR), Germany
- Darmstadt (TUD, EMMI), Germany
- Dubna (JINR), Russia
- Moscow (ITEP,RAS), Russia
- Nicosia (Univ.), Cyprus
- Orsay (IPN), France
- Rez (CAS, NPI), Czech Rep.
- Santiago de C. (Univ.), Spain
- Coimbra (Univ.), LIP, Portugal

Part III: Acceptance and Efficiency matrices of π^+ (Slice - 50 MeV)

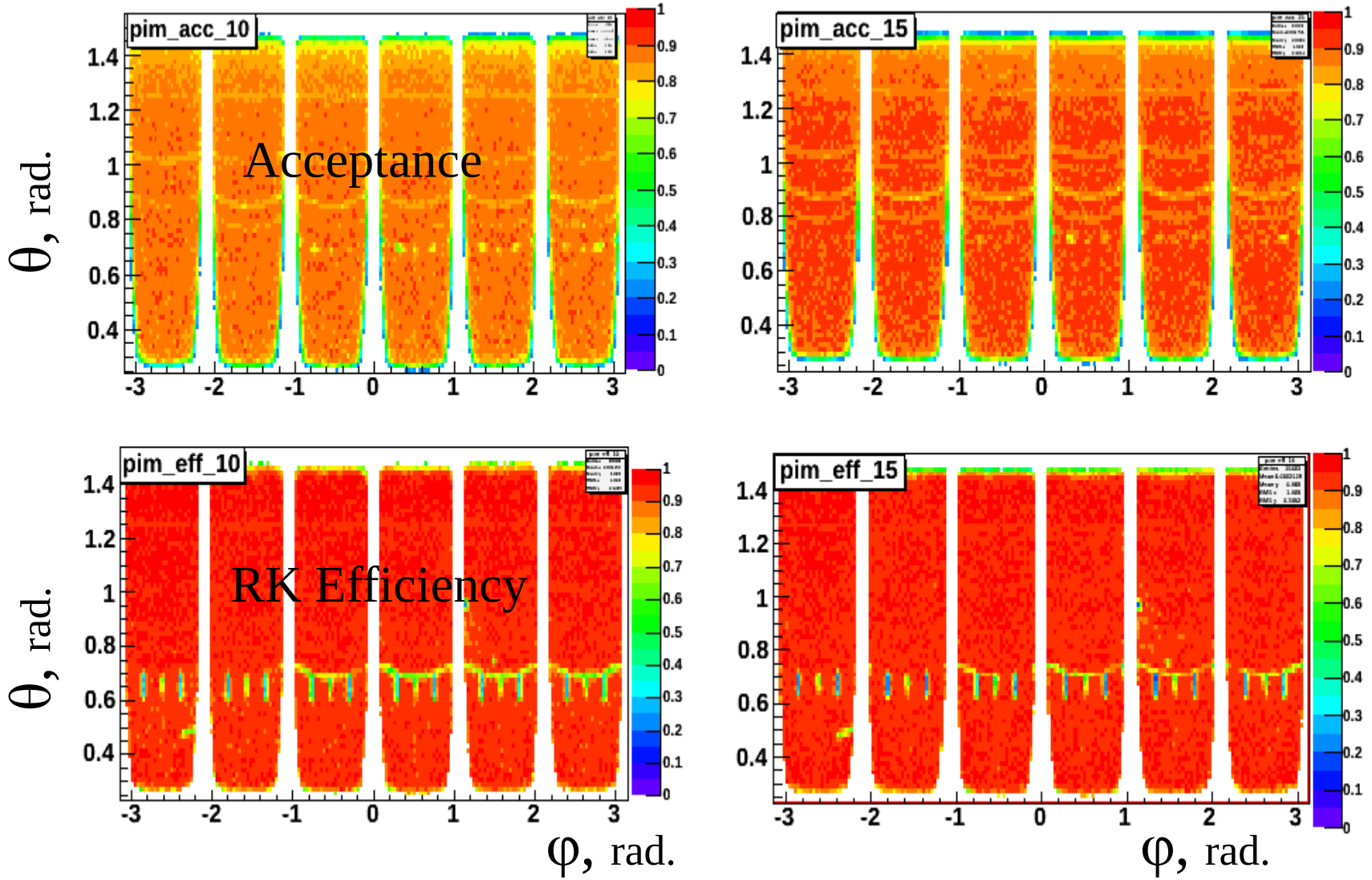




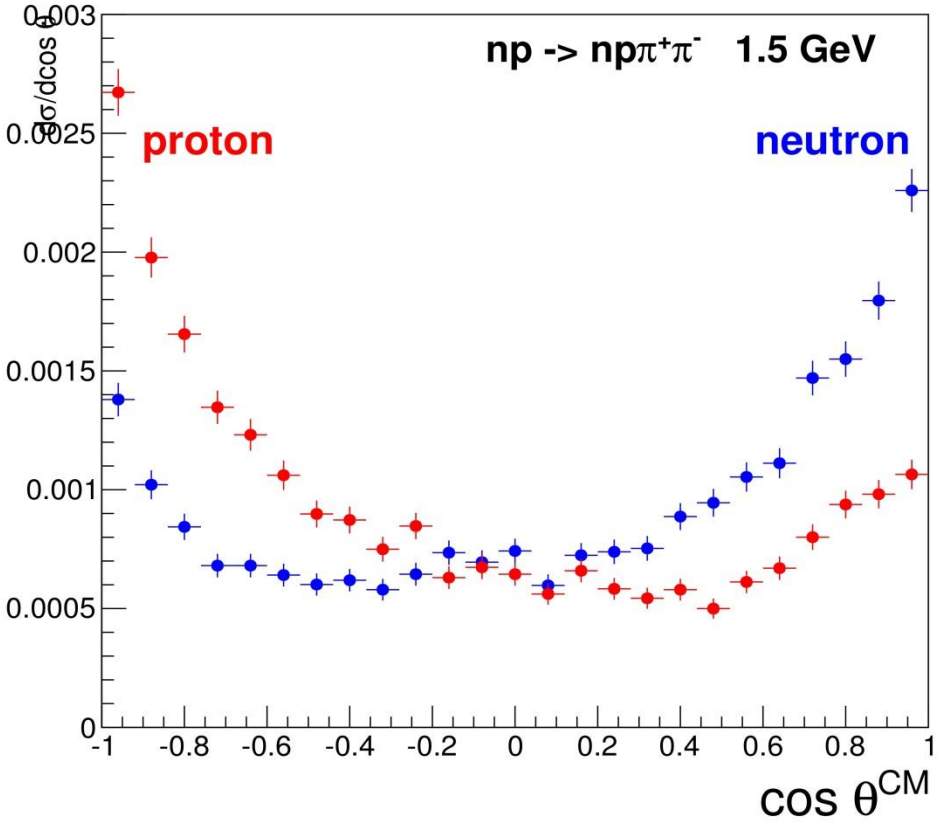




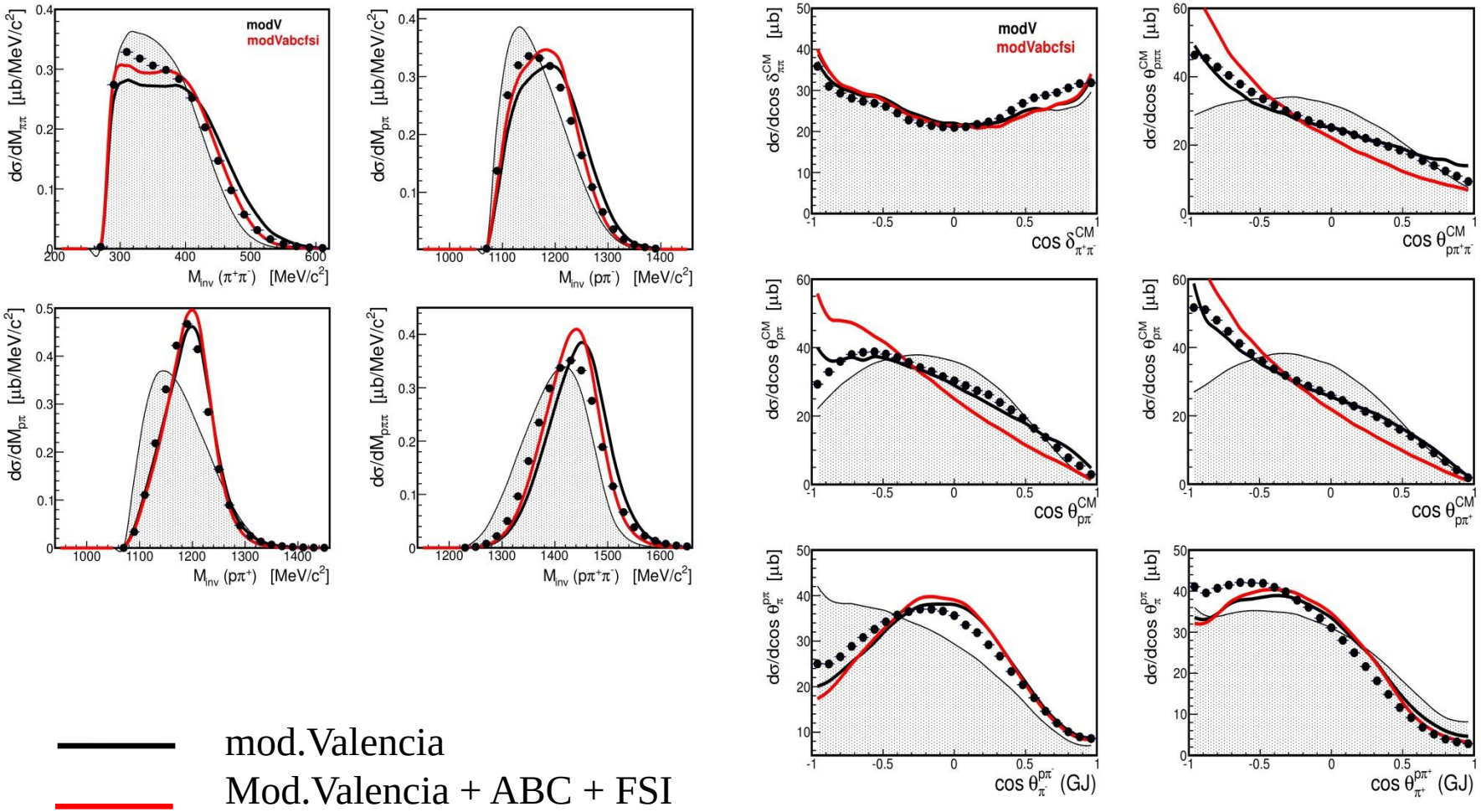
Part II: Acceptance and Efficiency matrices of π^- (Slice - 50 MeV)



Results: angular distribution for np @1.5 GeV



Results: double pion production in np @1.25 GeV



mod.Valencia

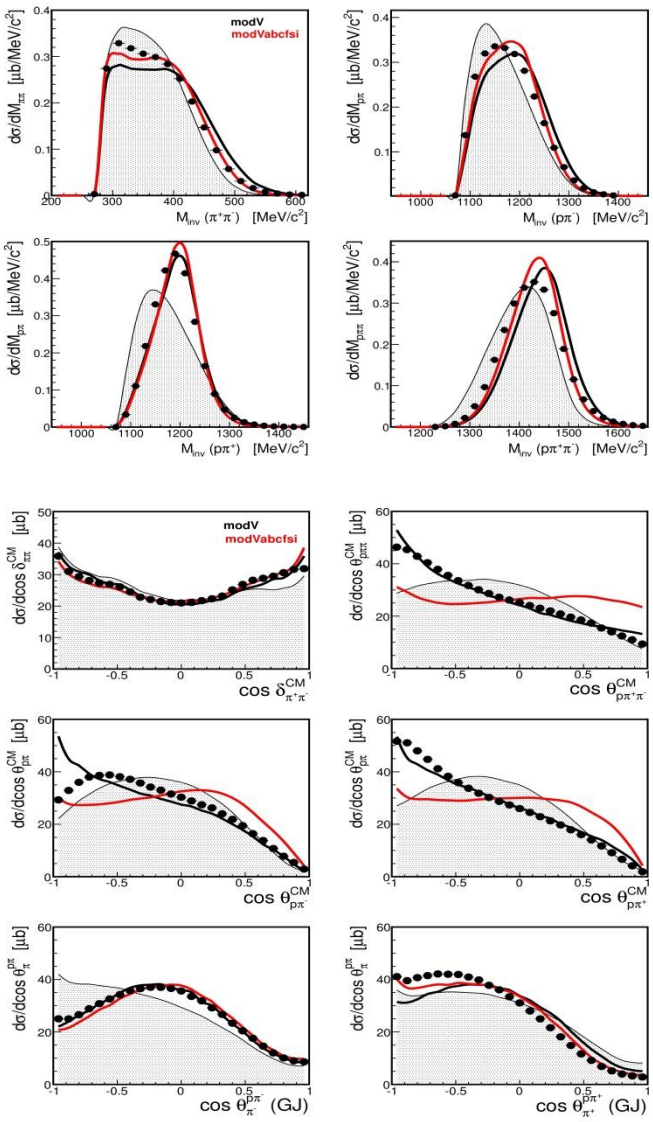
Mod.Valencia + ABC + FSI

(private communication of T.Skorodko)

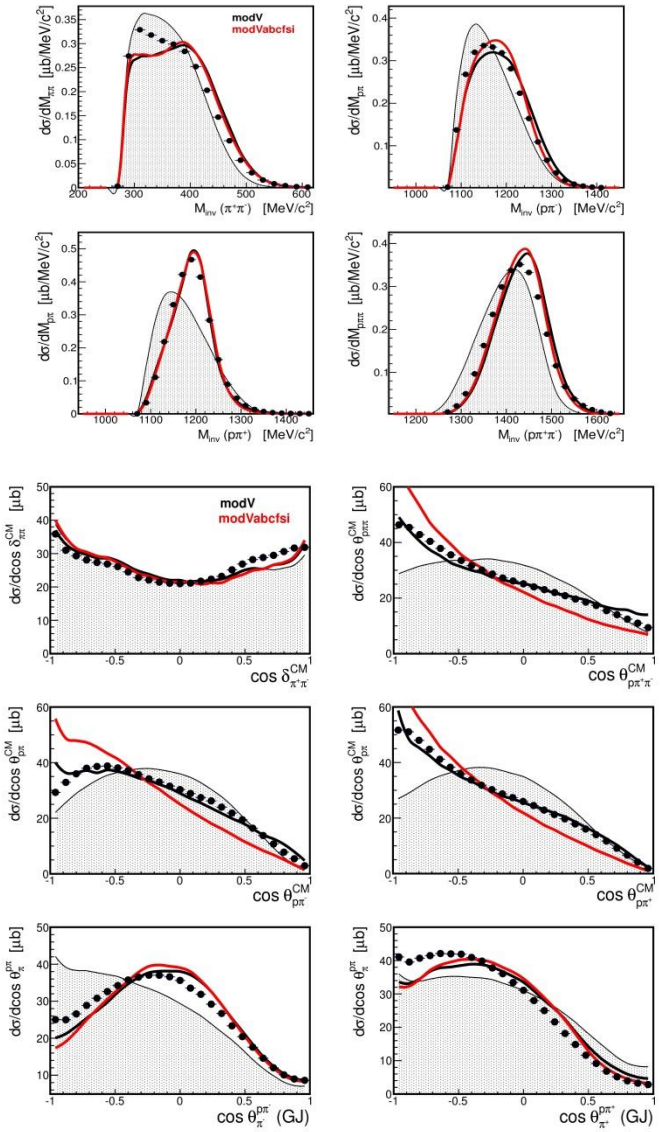
Black points are HADES data. *Comparison in HADES acceptance*.

Influence of Acceptance filter on shapes of distributions in pn and np at 1.25 GeV

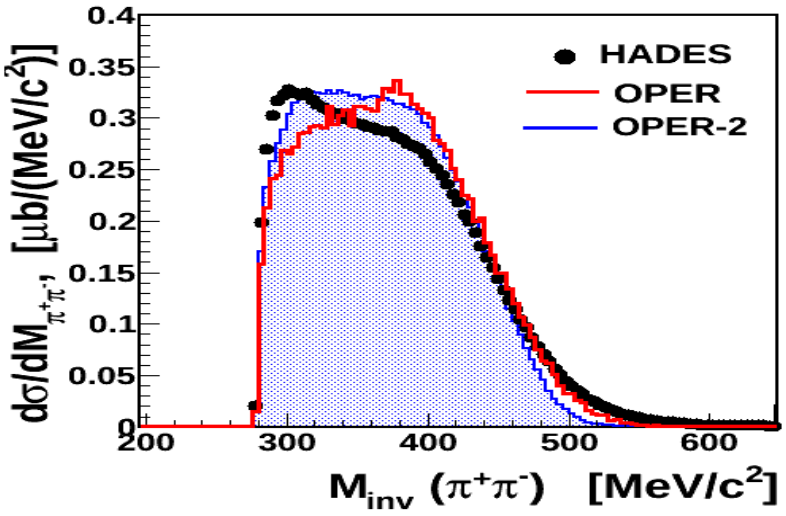
pn

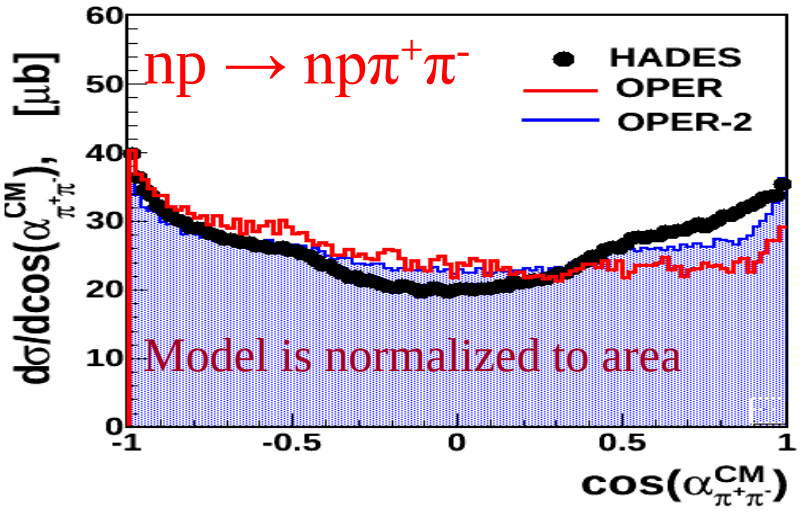


np

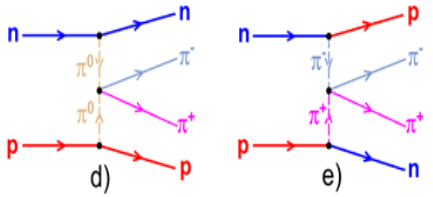


Comparison HADES data with OPER model





$M_{\pi^+\pi^-}$ and angular distributions for np → np $\pi^+\pi^-$ and pp → pp $\pi^+\pi^-$.
Black points are HADES data. *Comparison in HADES acceptance*.
OPER-2 takes into account 'hanged' diagrams (π and P exchange).
A.P.Jerusalimov arXiv:1208.3982[nucl-ex]



Modifications introduced to the Valencia model

in collaboration with Tatiana Skorodko

Following modifications have been done to the Valencia code. These changes are based on WASA analysis of channel pp -> pp$\pi^0\pi^0$. Events including modifications have been provided by T. Skorodko.

1. Modification of the partial decay width between the decay N* -> Nσ via Δ and direct

$$\frac{\Gamma(N^* \to \Delta\pi)}{\Gamma(N^* \to N\sigma)} = 1.$$

PDG	Bonn-Gatchina PWA	WASA analysis
4	0.9(1)	1.0(1)

(1): T. Skorotko et al. EPJA35,317 (2008)

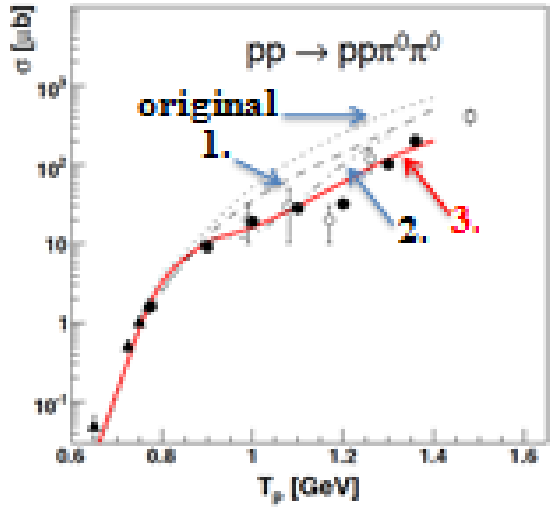
2. Strength of N*(1440)

After 'modification' the Roper behaves as s-channel resonance: rises in beginning and decreases later

3. ρ exchange in double Δ excitation

Amplitude for the Double-Δ excitation, consists of two parts: one for π-exchange and second for ρ. The ρ part hasbeen suppress by fact of 12.

(ρ-exchange is not as wel fixed by exp. observables as π-exchange.)

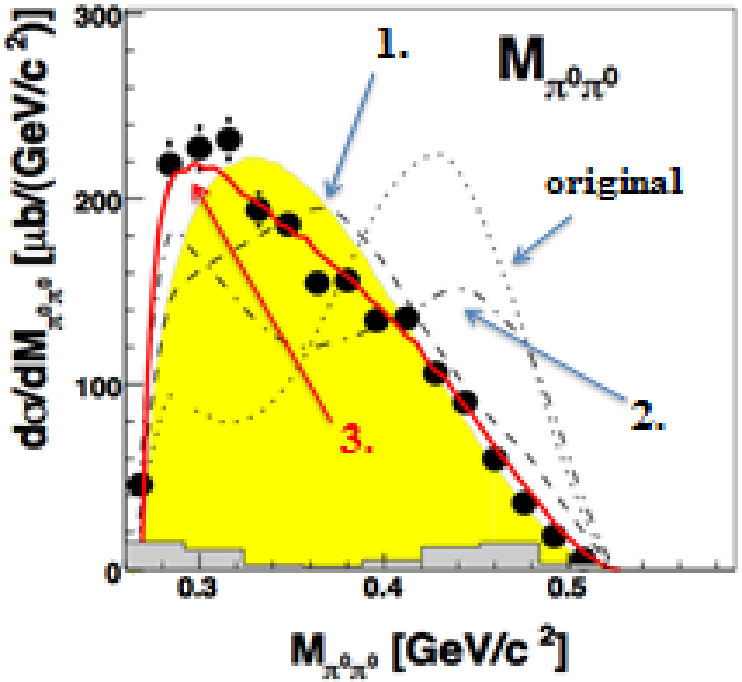


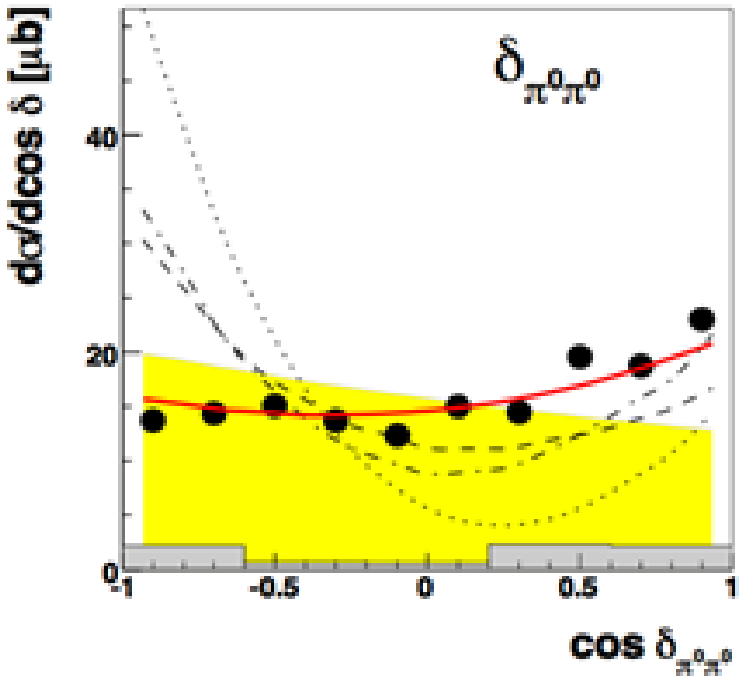
More details about the changes to the model can be found here:
Physics Letters B 679 (2009)30, Phys.Lett.B695: 115-123,2011

15

Influence of the modifications of the model

$pp \rightarrow pp\pi^0\pi^0$ at $T_p = 1.2$ GeV WASA





dotted : original model

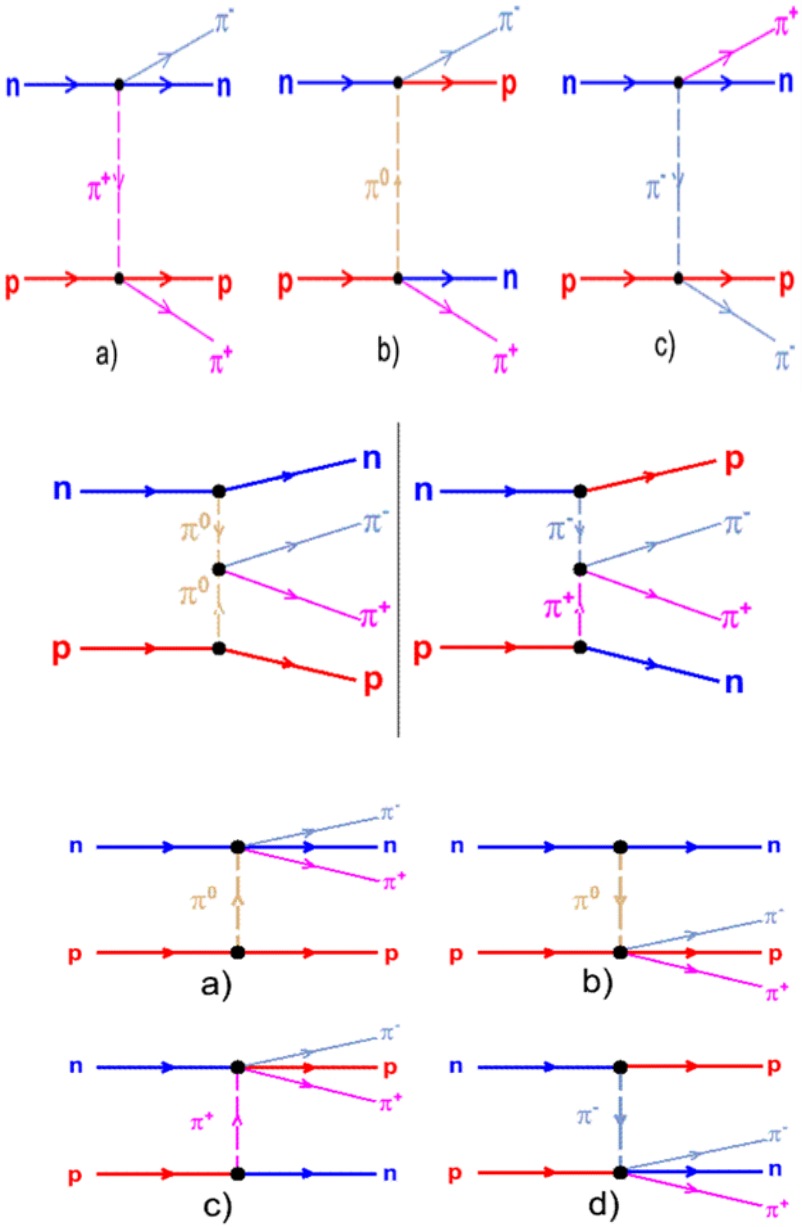
dashed: (1) N* -> Δπ and N* -> Nσ branching ratio

dashed-dotted : (2) readjustment of strength of the N*(1440)

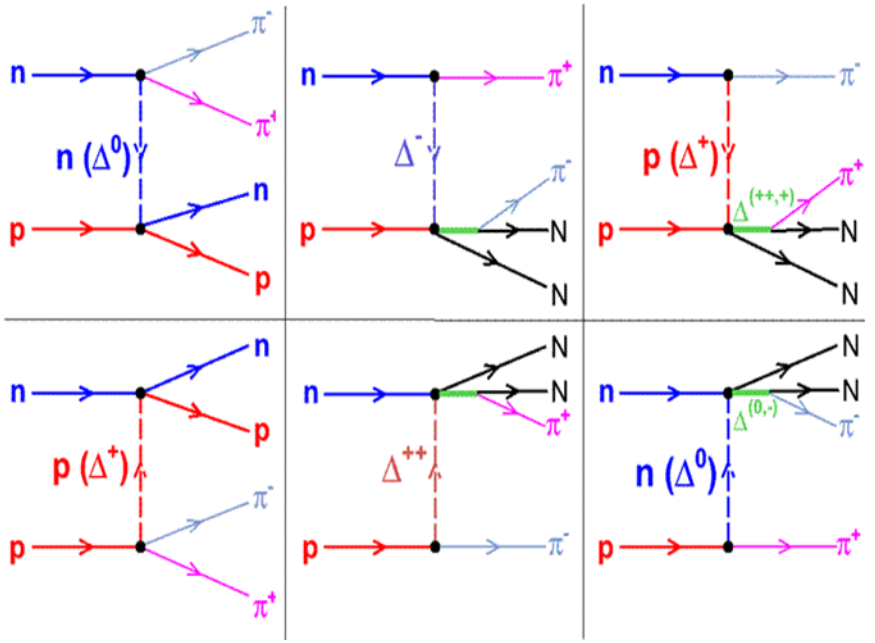
red: (3) ρ exchange in double Δ excitation

16

Model : OPER (A.P.Jerusalimov)

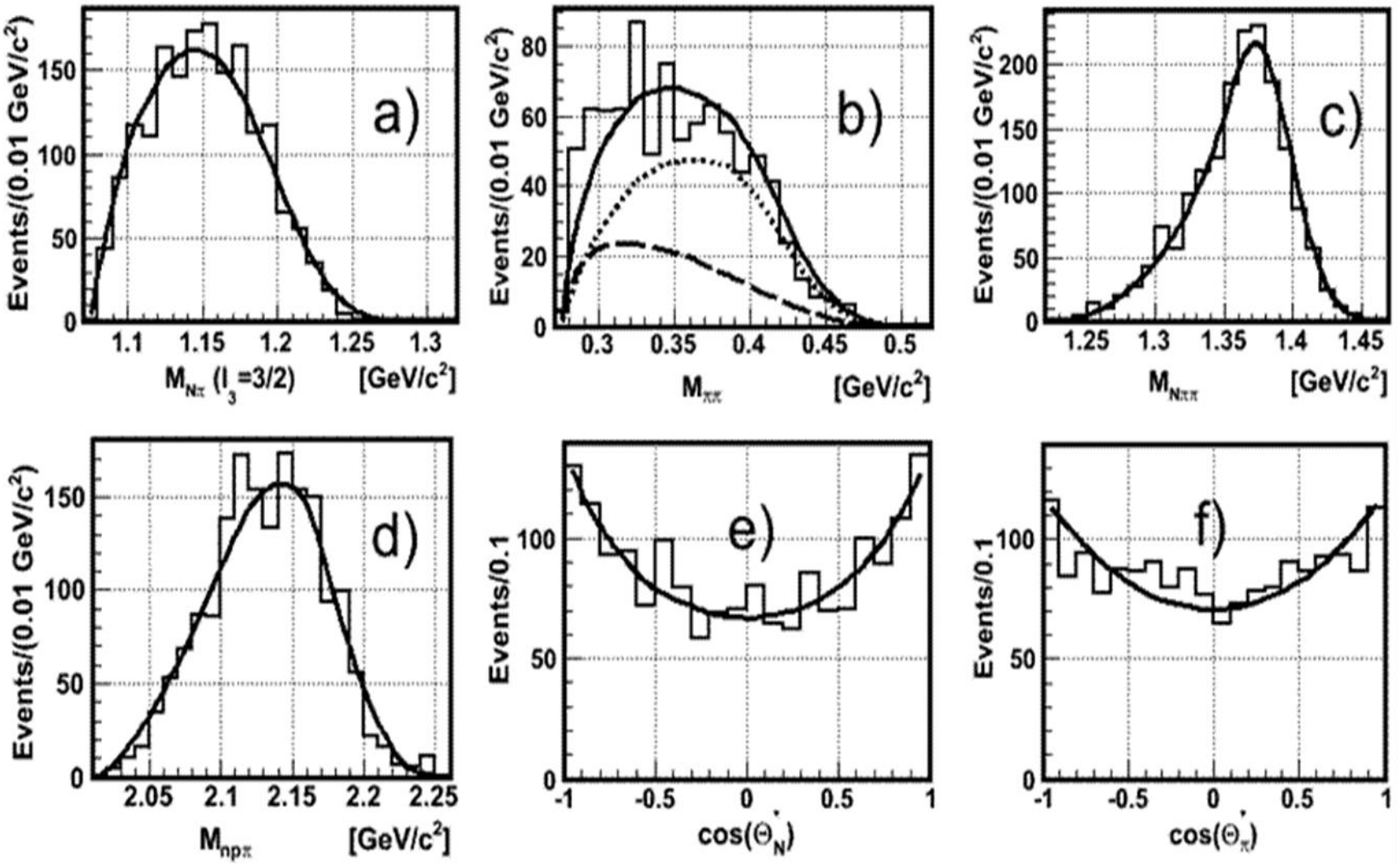


diagrams OPE



diagrams OBE

Experimental distributions for np→npπ+π- at p 1.73 GeV/c



The dEdx PID cuts for Sim. to Exp. data