Hadrons from Quarks and Gluons

Hirschegg 2014

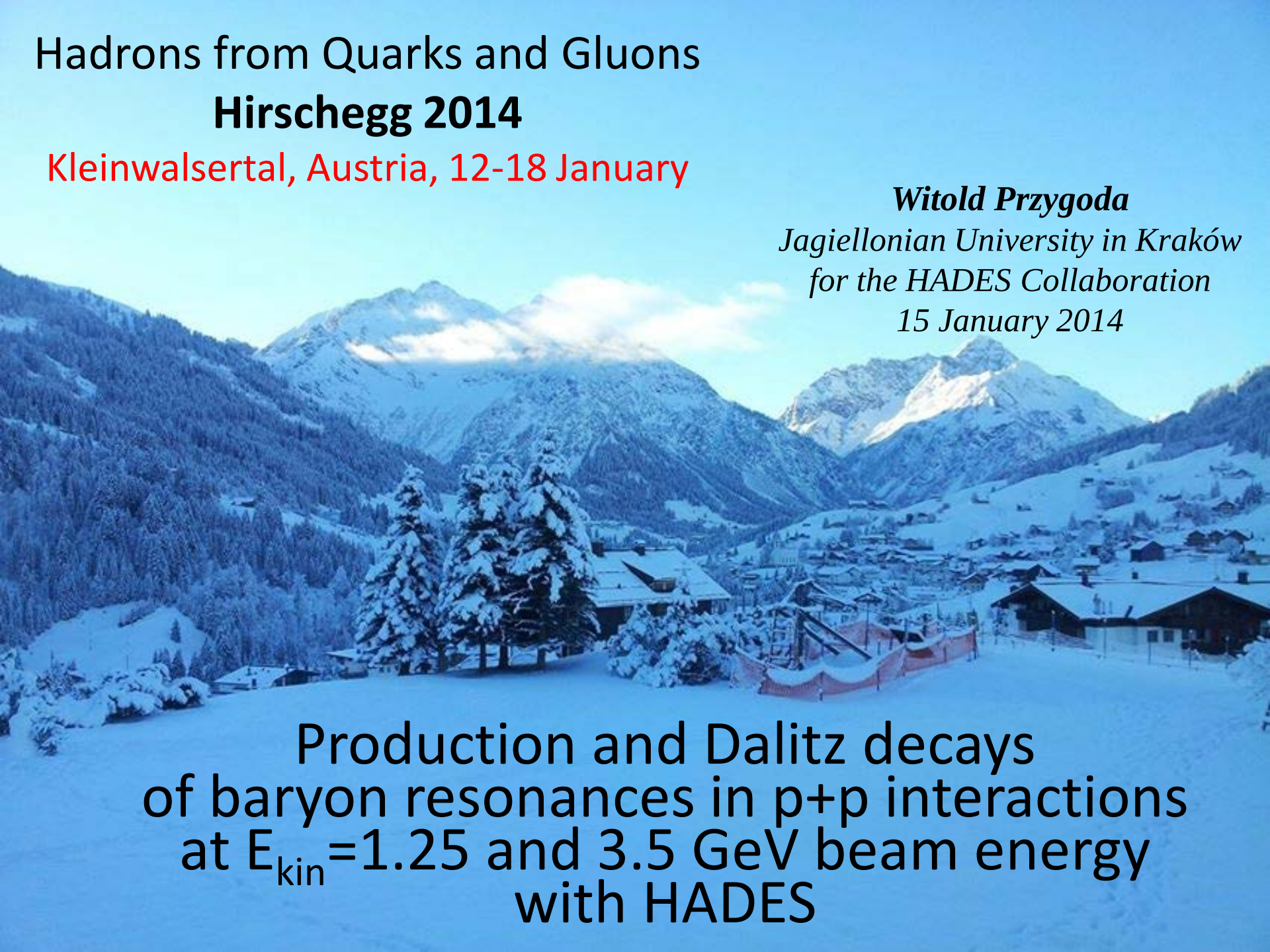
Kleinwalsertal, Austria, 12-18 January

Witold Przygoda

Jagiellonian University in Kraków

for the HADES Collaboration

15 January 2014

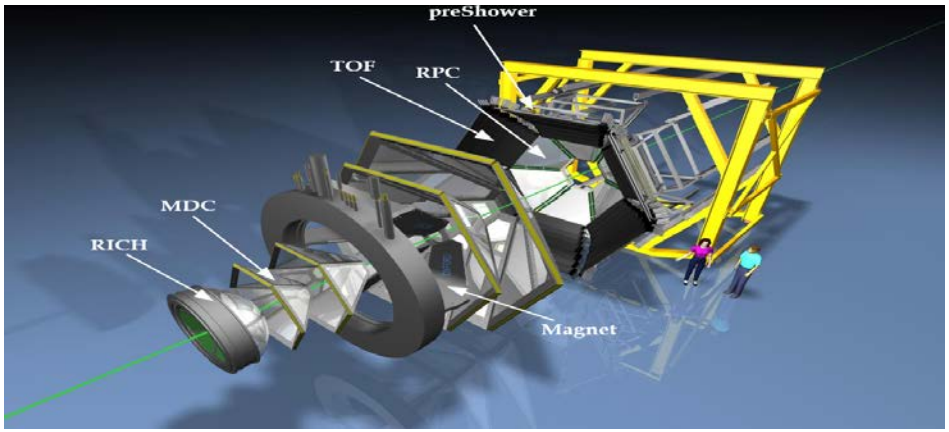


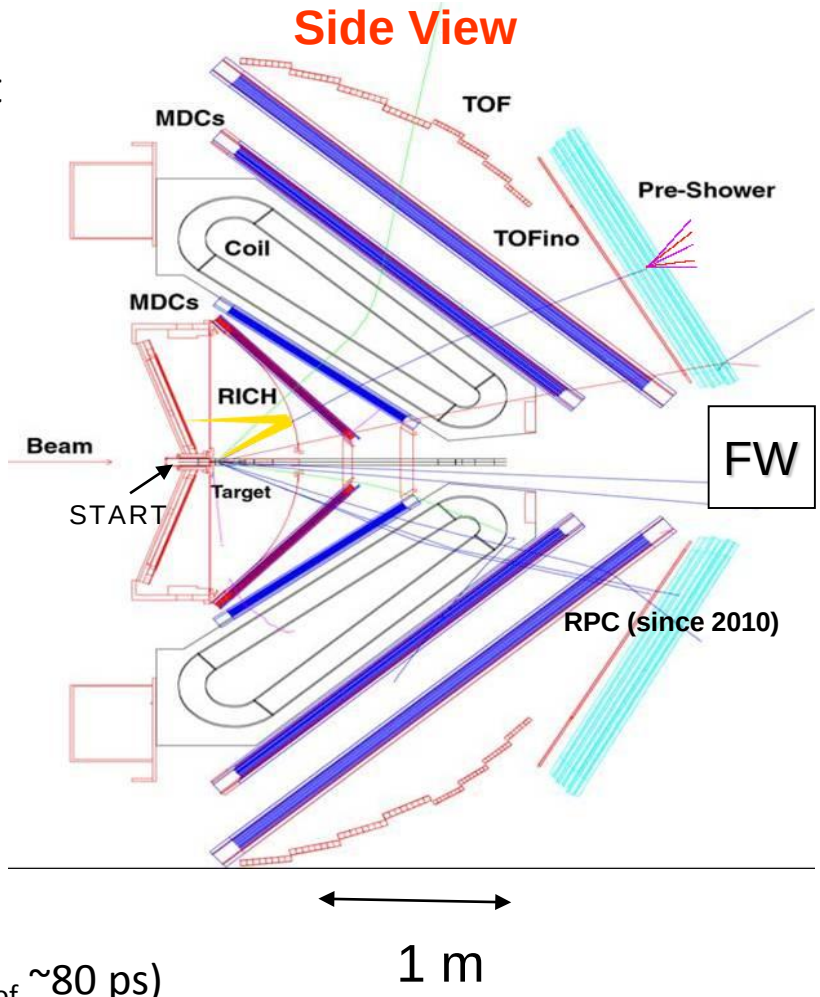
Production and Dalitz decays of baryon resonances in p+p interactions at E_{kin}=1.25 and 3.5 GeV beam energy with HADES

The HADES Spectrometer

G. Agakichiev *et al.*
Eur. Phys. J. **A41** (2009) 243

φ: full (6 sectors) **θ**: 18°-85°
e^+e^- pair acceptance ≈ 0.35
~80.000 channels, segmented solid or LH_2 target





- ❖ SIS18 beam: π, p, A
- ❖ Δm/m ~ 2-3% at ρ/ω
- ❖ Versatile detector for rare particle decays:
- dielectrons (e^+, e^-)
- strangeness: Λ, $K^{\pm,0}$, Ξ^- φ
- upgrade(2010): new DAQ (~20 KHz), Tof-RPC (σ_{tof} ~80 ps)

p+p @ 1.25 GeV - plan

$p + p$ elementary reactions at E_{kin} = 1.25 GeV below ppη production threshold are well situated to investigate Δ(1232) Dalitz decay

I. HADRON ANALYSIS

(npπ⁺, ppπ⁰)

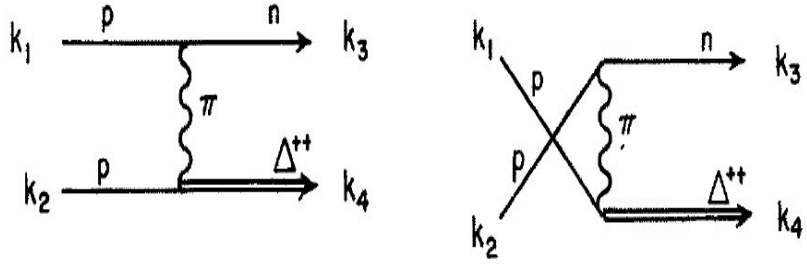
II. LEPTON ANALYSIS

(ppe⁺e⁻, ppe⁺e⁻)

Resonance model

Z. Teis *et al.*, Z. Phys. A**356** (1997) 421

V. Dmitriev *et al.* Nucl. Phys. A**459** (1986) 503



Production: OPEM

Form factor at vertices:

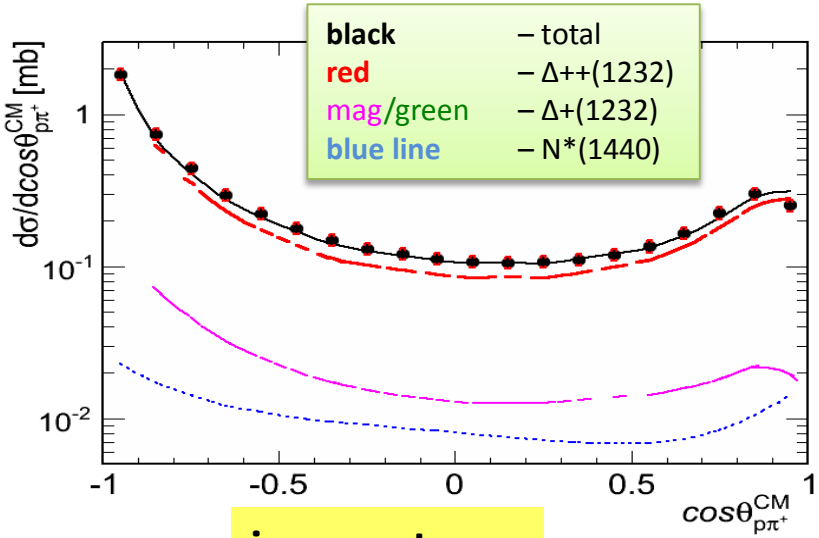
$$F(q^2) = \frac{{\Lambda_\pi}^2 - {m_\pi}^2}{{\Lambda_\pi}^2 - q^2}$$

Λ_π fitted in accordance with the data (Λ_π = 0.75)

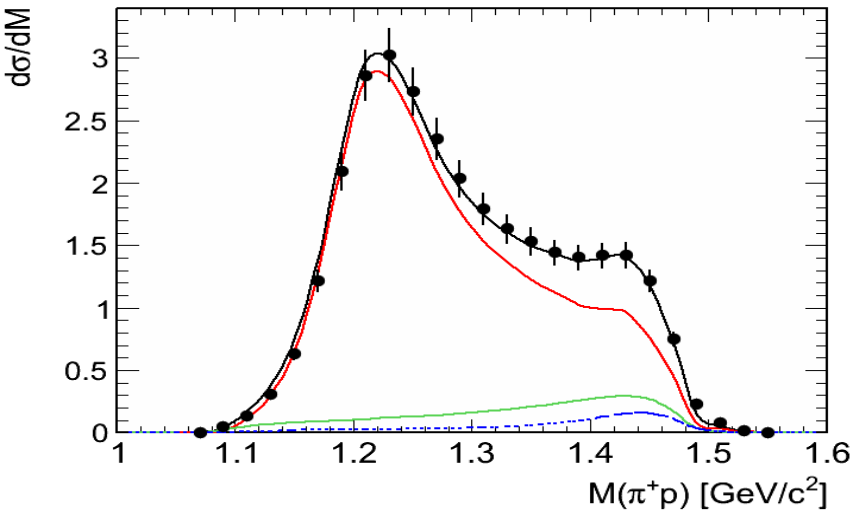
G. Agakishiev *et al.* Eur. Phys. J. A**48** (2012) 74

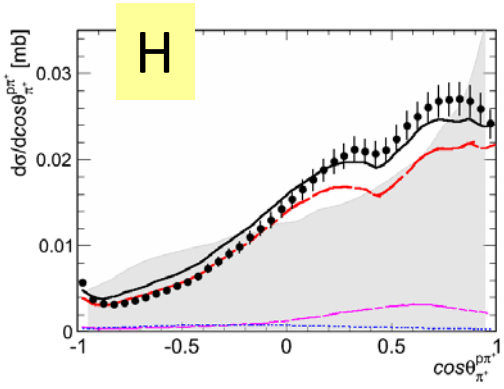
Δ production (n **p** **π⁺**)

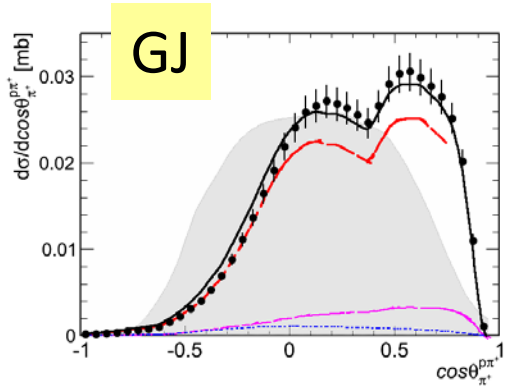
OPEM (Λ_π = 0.75 modified)
Δ resonance + FSI + N(1440) small

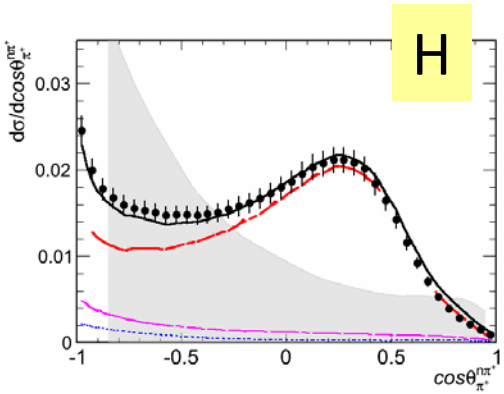


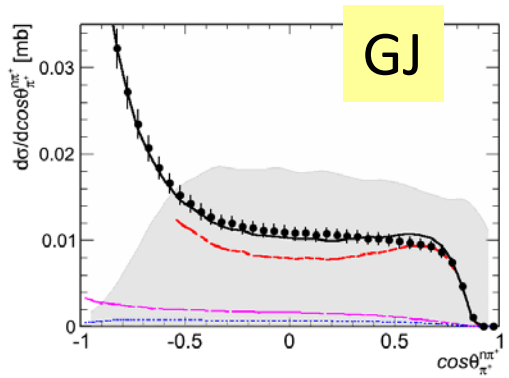
in acceptance

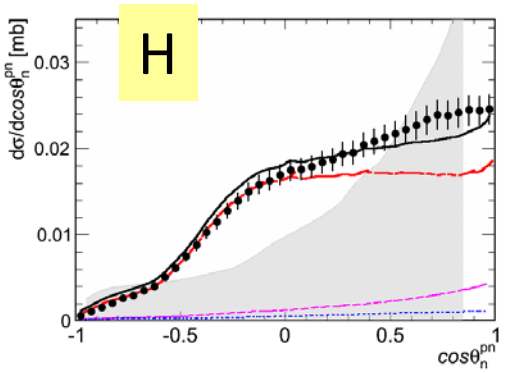


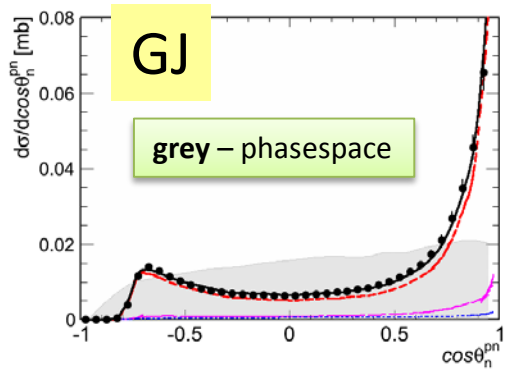




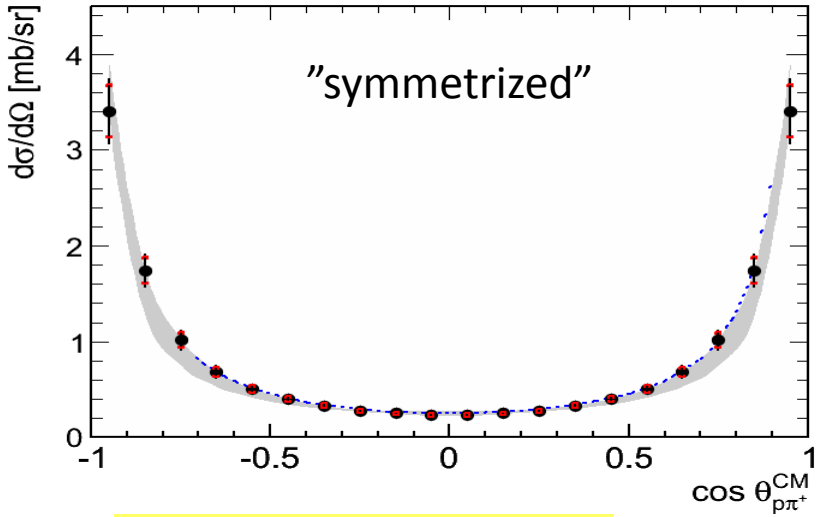




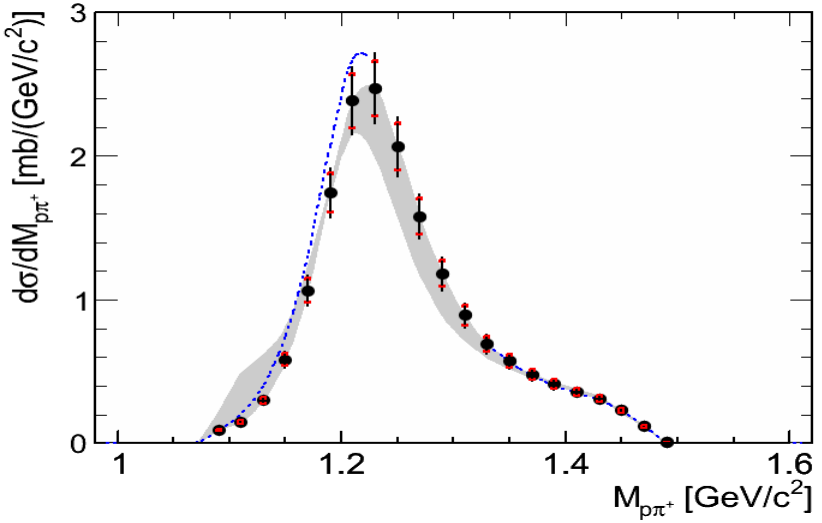




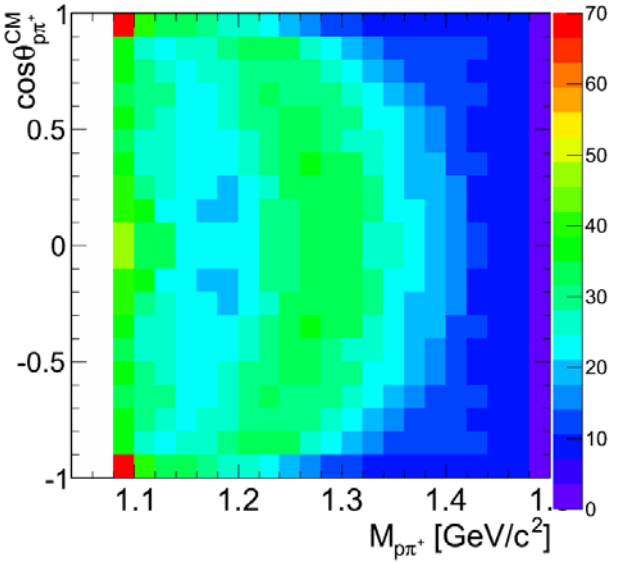
Δ production (n **p** **π⁺**) - acceptance corrected



ACCEPTANCE corrected



2-dim correction matrix:



grey band:
correction with various OPEM parametrisations (Λ_π = 0.63, 0.75, 1.00)
blue curve: modified OPEM (total cross section 19.2 mb)

cross section:
17.5 ± 2.2 mb

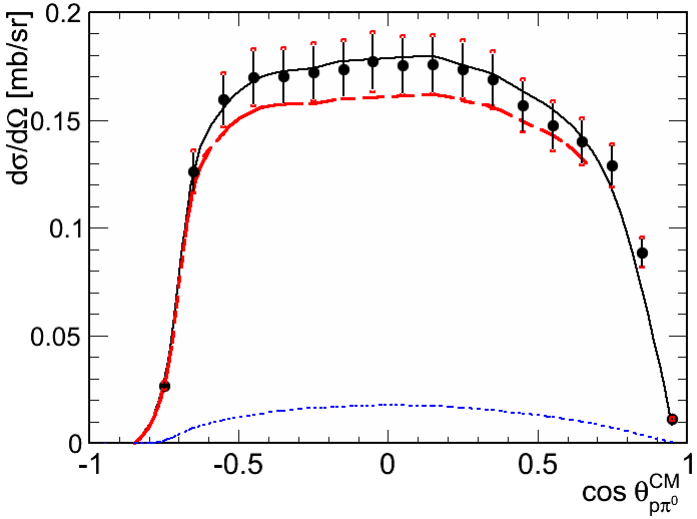
Δ production (p p π^0)

Identifying **2 protons**

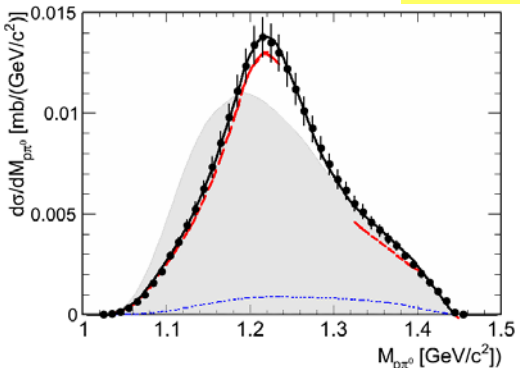
- strongly reduces acceptance
- favours large 4-mom transfer

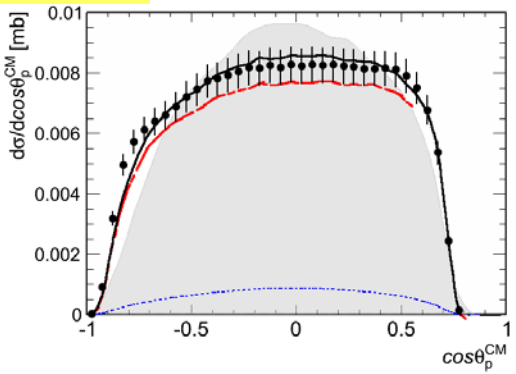
parametrisation deduced from the npπ^+ channel

black – total
red line – $\Delta^+(1232)$
blue line – N*(1440)

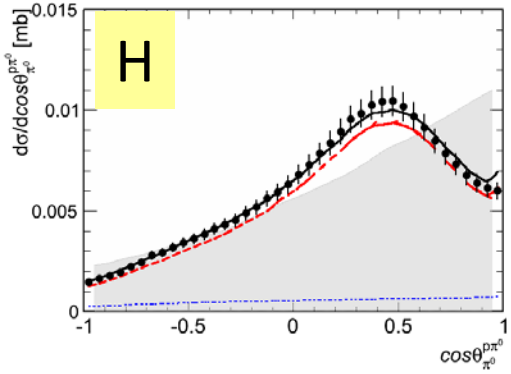


in acceptance

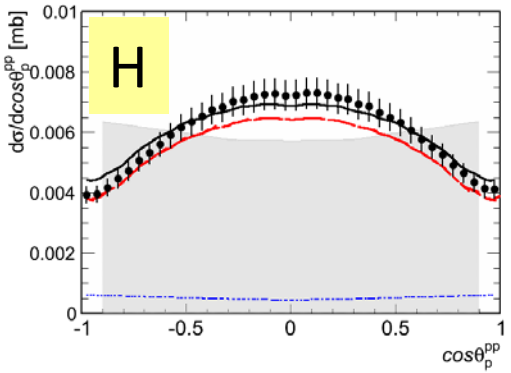




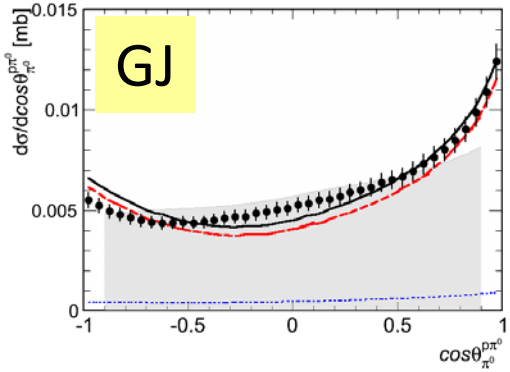
H



H

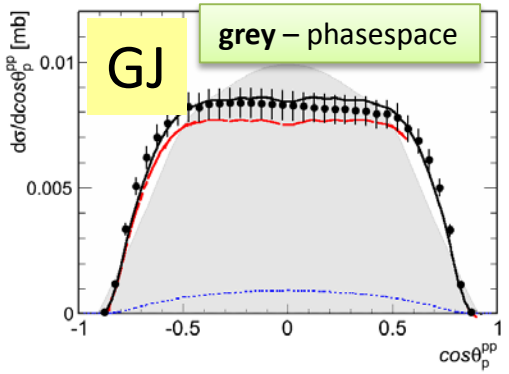


GJ

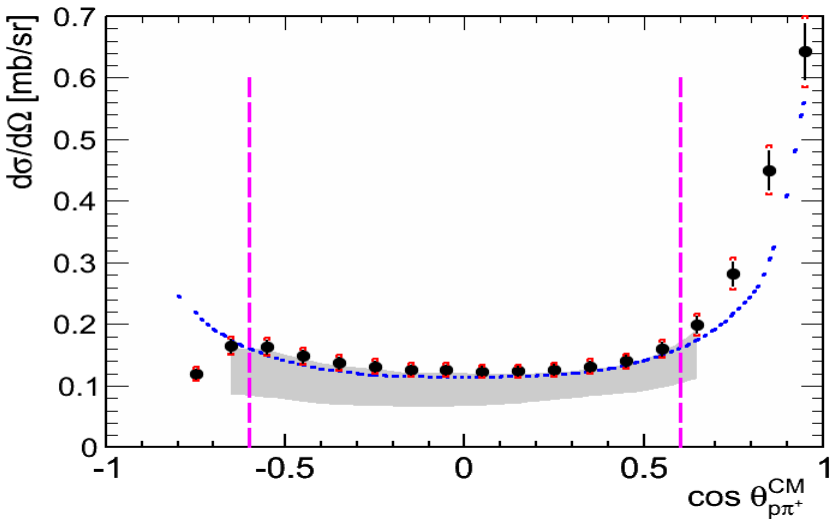


GJ

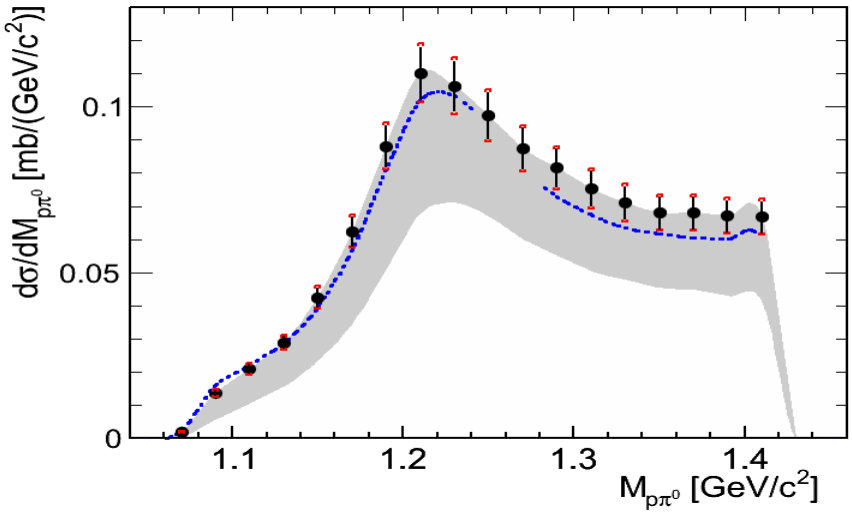
grey – phasespace



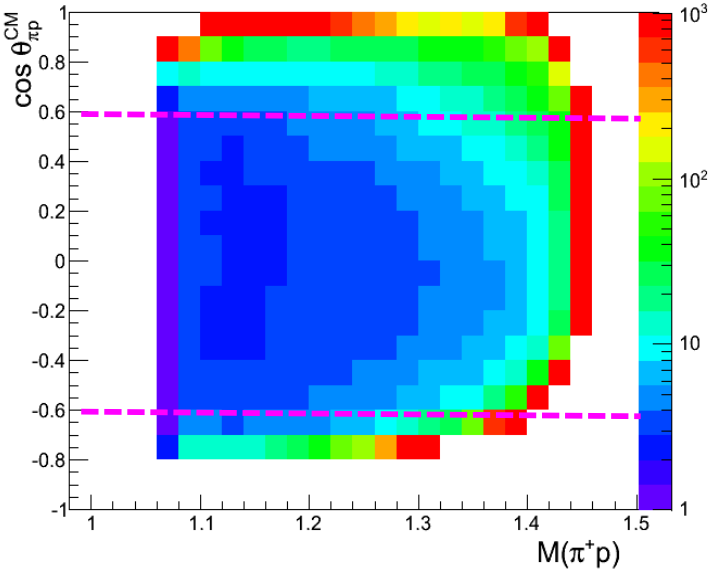
Δ production (p p π^0) - acceptance corrected



ACCEPTANCE corrected



Acceptance correction:



”fiducial volume”
in angular distribution i.e.
$-0.6 < \cos\theta < +0.6$

cross section:

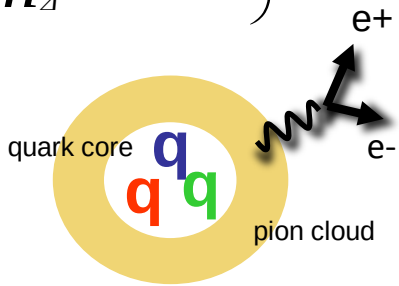
see dilepton analysis
(next slides)

$\Delta \rightarrow Ne^+e^-$

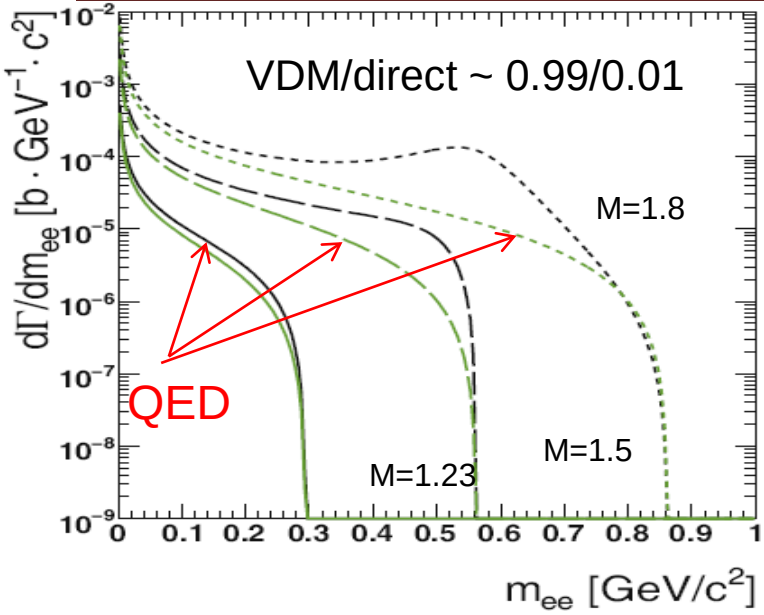
M.I. Krivoruchenko *et al.*
Phys. Rev. D**65** (2002) 017502

$$\frac{d\Gamma(\Delta \rightarrow Ne^+e^-)}{dq^2} = f\left(m_\Delta, q^2\right)\left(\left|G_M^2\left(q^2\right)\right| + 3\left|G_E^2\left(q^2\right)\right| + \frac{q^2}{2m_\Delta^2}\left|G_C^2\left(q^2\right)\right|\right)$$

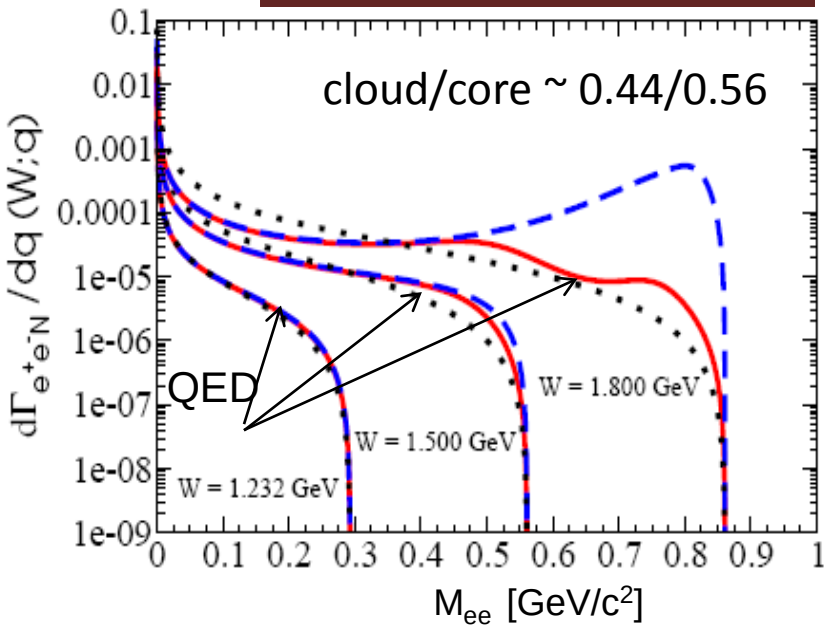
Time Like ($q^2 > 0$)
Δ (J=3/2) ->N (J=1/2) γ^* transition:



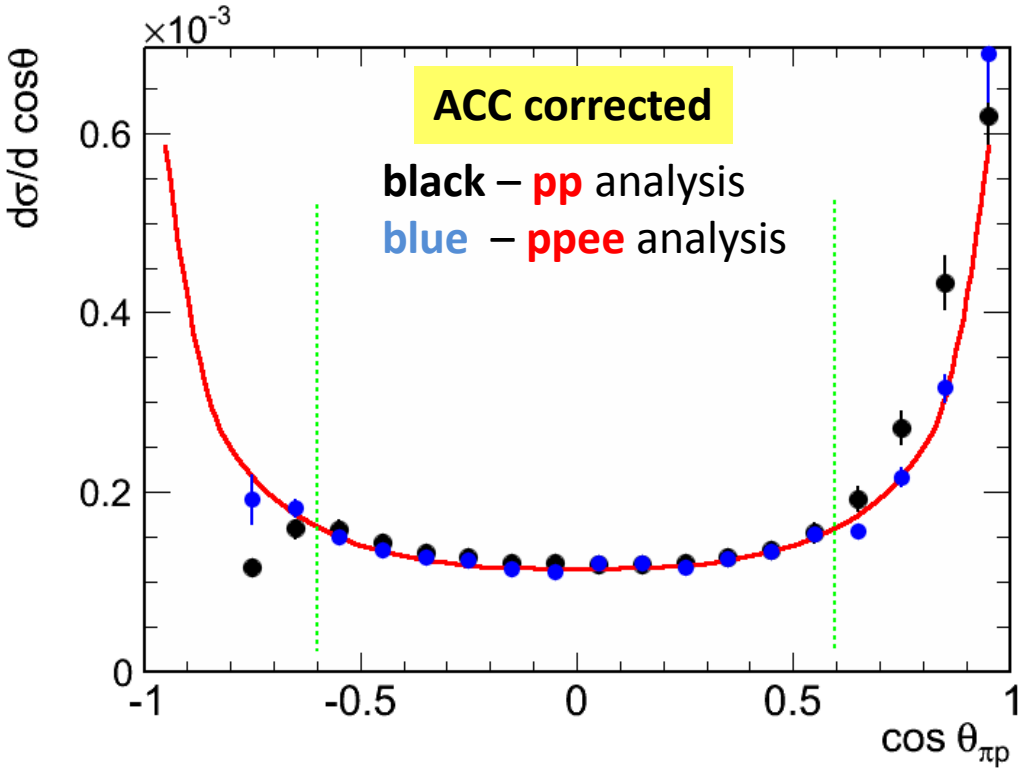
Q. Wann, F. Iachello
Int. J. Mod. Phys. A**20** (2005) 1846



G. Ramalho, M. T. Peña
Phys. Rev. D**85** (2012) 113014

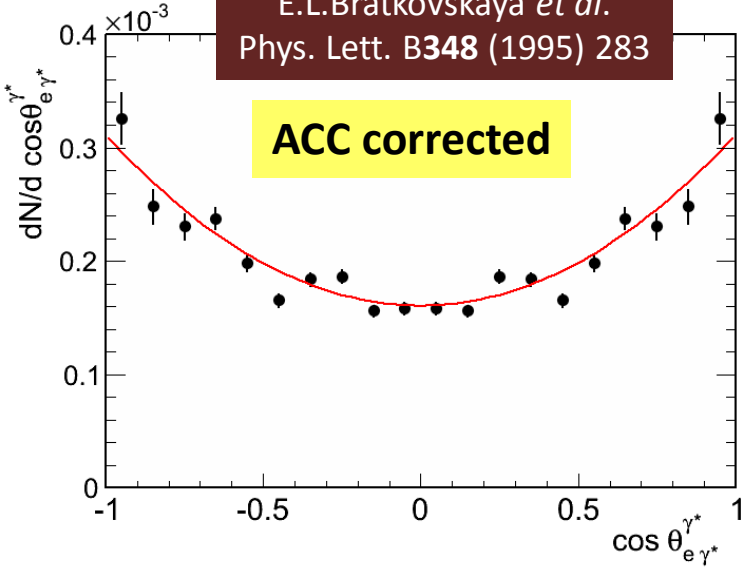


Δ+ identification via pp π^0 { $\rightarrow e^+e^-\gamma$ }



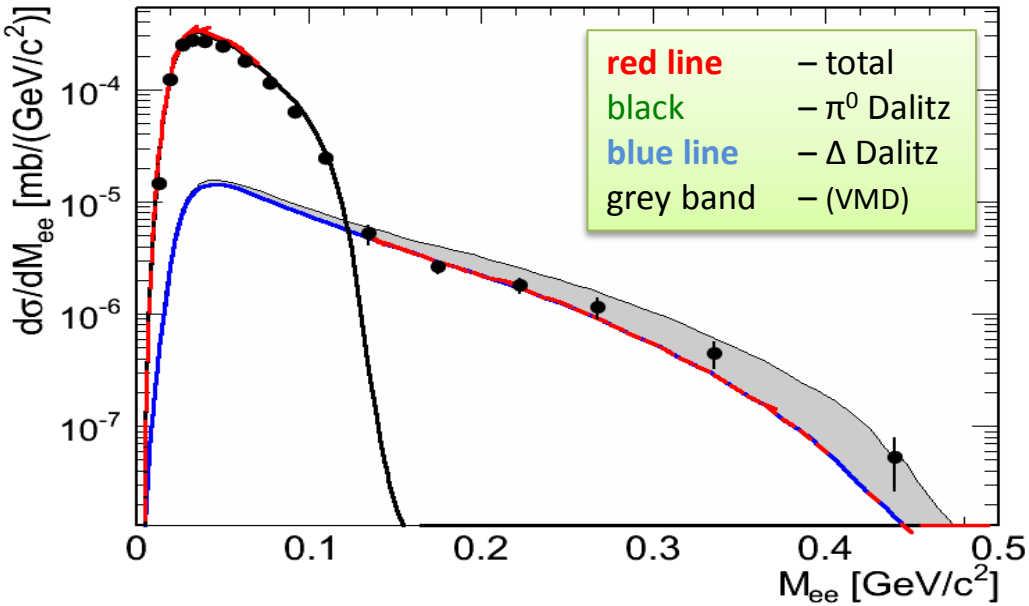
π^0 helicity

E.L.Bratkovskaya *et al.*
Phys. Lett. B**348** (1995) 283



both channels with 2 protons (**pp** and **ppe^+e^-**)
support the description of Δ angular distribution
according to OPE (modified) with parameter $\Lambda_\pi = 0.75$
Cross section deduced (blue points) **4.18 ± 0.5 mb**

Δ^+ Dalitz decay via $pn\Delta^+$ { $\rightarrow pe^+e^-$ }

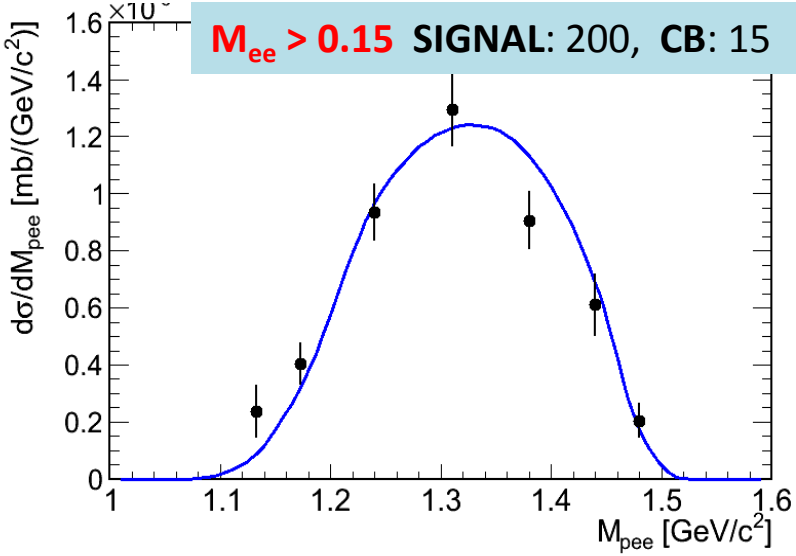


Δ Dalitz decay BR

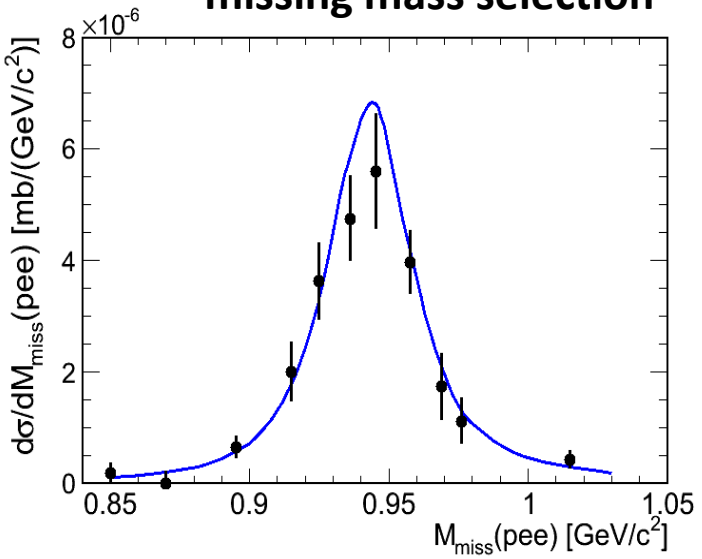
M.I. Krivoruchenko *et al.*
Phys. Rev. D**65** (2002) 017502

$G_M(0)\sim3 \quad G_E(0)\sim0 \quad G_C(0)\sim0$

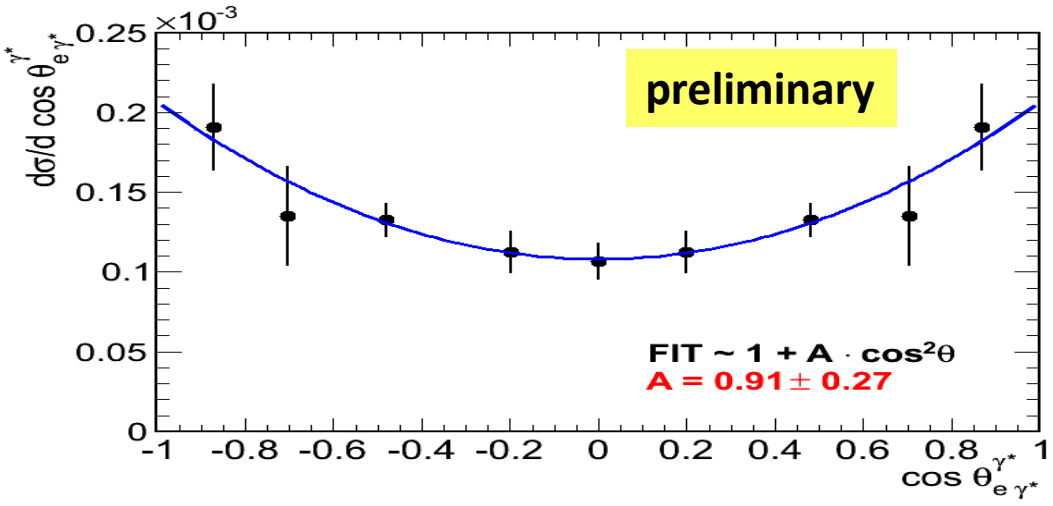
Δ form-factors important at higher energy!

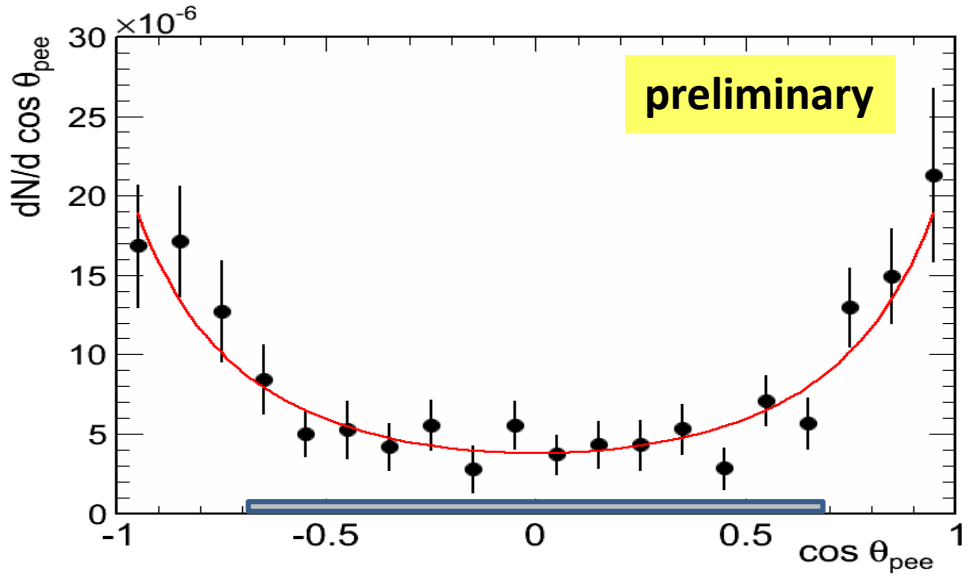


missing mass selection



(Δ→pe⁺e⁻) angular observables, BR





Δ helicity

in agreement with QED

$$1 + A \cdot \cos^2\theta$$

when neglecting Coulomb amplitude

$$\mathrm{BR} = \frac{N_{\Delta \to pe^+e^-}}{N_{\Delta \to p\pi^0}}$$

derived in the "fiducial area"

$$-0.7 < \cos\theta^{CM}_{pee} < 0.7$$

BR = 4.42 · 10⁻⁵

± 20% (syst.)

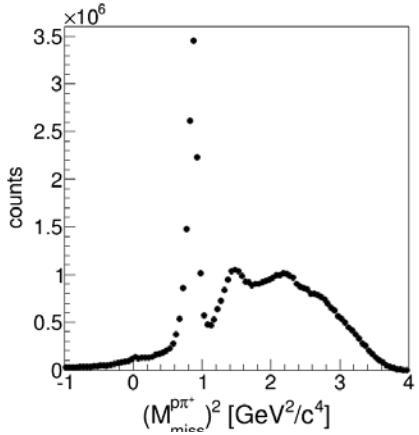
± 9% (stat.)

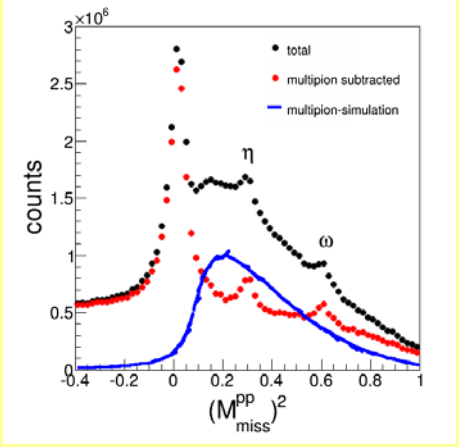
p+p @ 3. 5 GeV - plan

$p + p$ elementary reactions at E_{kin} = 3.5 GeV to investigate the wealth of baryonic resonances and their properties

I. HADRON ANALYSIS

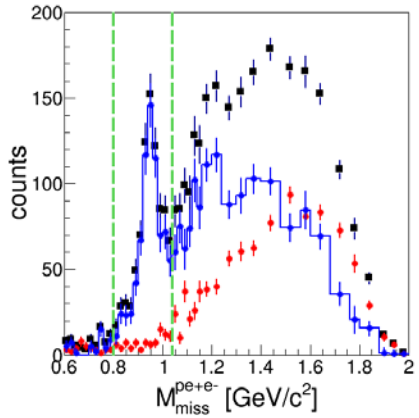
(n$p\pi^+$, $pp\pi^0$)



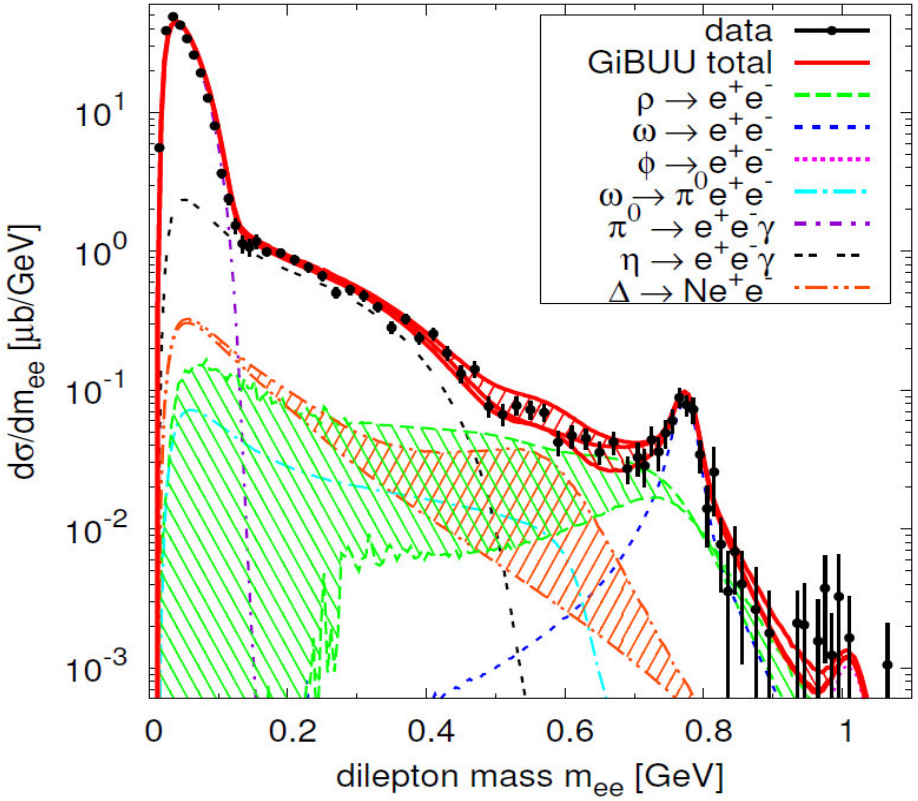


II. LEPTON ANALYSIS

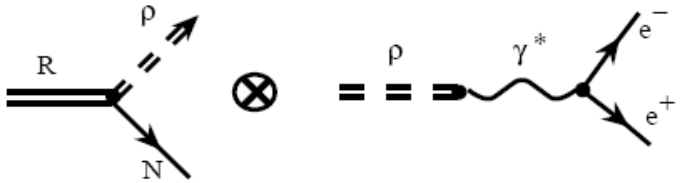
(ppe^+e^-)



Inclusive e^+e^- spectrum p+p @ 3.5 GeV



J. Weil *et al.* (**GiBUU**)
Eur. Phys. J. A**48** (2012) 111



Cross sections deduction
PYTHIA+PLUTO (UrQMD)

	π^o	η
σ_i [mb]:	18± 2.7 (16 ± 2.6)	1.14±0.2 (0.93± 0.14)

$\Delta^{o,+}$	ρ	ω
7.5 ± 1.3	0.233 ± 0.06	0.273 ± 0.07

for details, see:

G. Agakishiev *et al.*
Eur. Phys. J. A **48** (2012) 64

How to treat R → N e^+ e^-

- ρ mesons produced via baryonic resonances (**R → ρ N → e^+ e^- N**)
- Resonance model with **electromagnetic Transition Form Factor** from model seems to describe nicely data – *only* Δ?

Baryon resonances in p+p @ 3.5 GeV

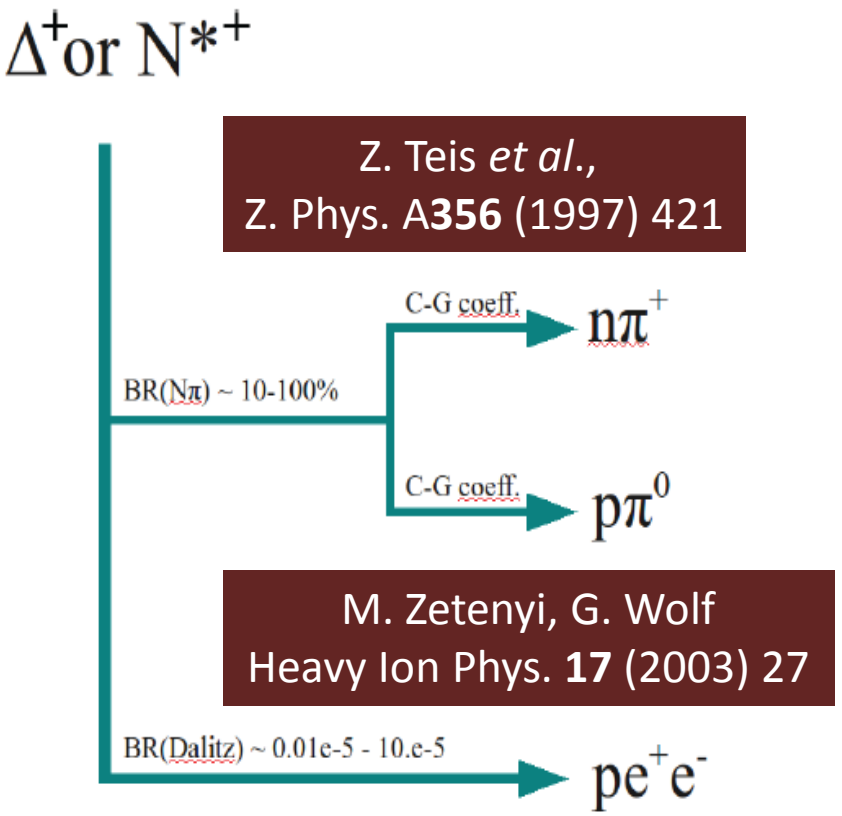
Study of 3 connected exclusive channels:

- $pp \rightarrow pn\pi^+$ to **fix R (Δ,N*) cross sections**
- $pp \rightarrow pp\pi^0$ to check the result (izospin relations)
- convert $R \rightarrow pe^+e^-$ and check in $pp \rightarrow ppe^+e^-$

J^P	Resonances	Γ_R [MeV]	$BR(N\pi)$	$BR(pe^+e^-)$
$3/2^+$	**Δ(1232)**	120	1	4.2e-5
$1/2^+$	**N*(1440)**	350	0.65	3.06e-6
$3/2^-$	**N*(1520)**	120	0.55	3.72e-5
$1/2^-$	**N*(1535)**	150	0.46	1.45e-5
$3/2^+$	Δ(1600)	350	0.15	0.73e-6
$1/2^-$	**Δ(1620)**	150	0.25	1.73e-6
$1/2^-$	N*(1650)	150	0.8	8.03e-6
$5/2^-$	N*(1675)	150	0.45	1.02e-6
$5/2^+$	**N*(1680)**	130	0.65	1.97e-5
$3/2^+$	N*(1720)	150	0.2	3.65e-6
$3/2^-$	**Δ(1700)**	300	0.15	1.38e-5
$5/2^+$	Δ(1905)	350	0.15	1.46e-6
$1/2^+$	**Δ(1910)**	280	0.25	0.73e-5
$7/2^+$	Δ(1950)	285	0.4	3.06e-6

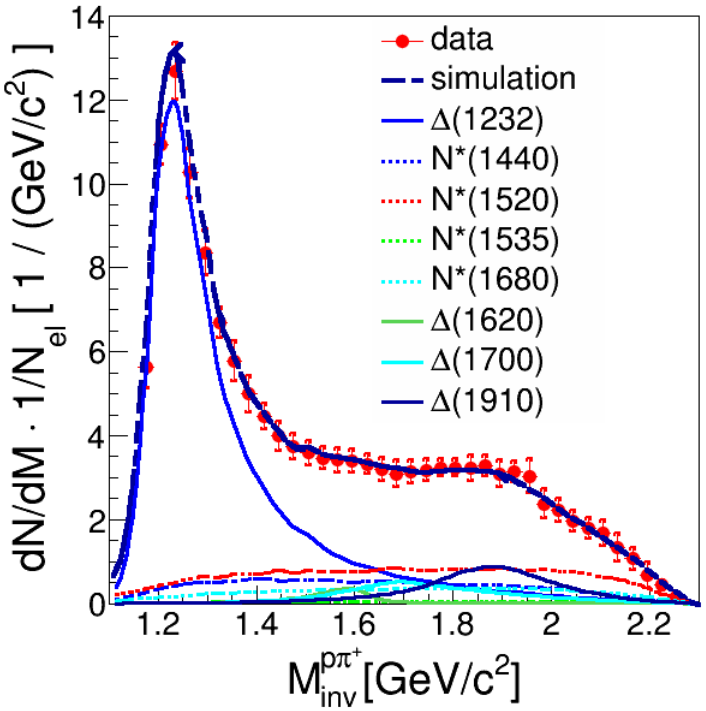
Resonance model

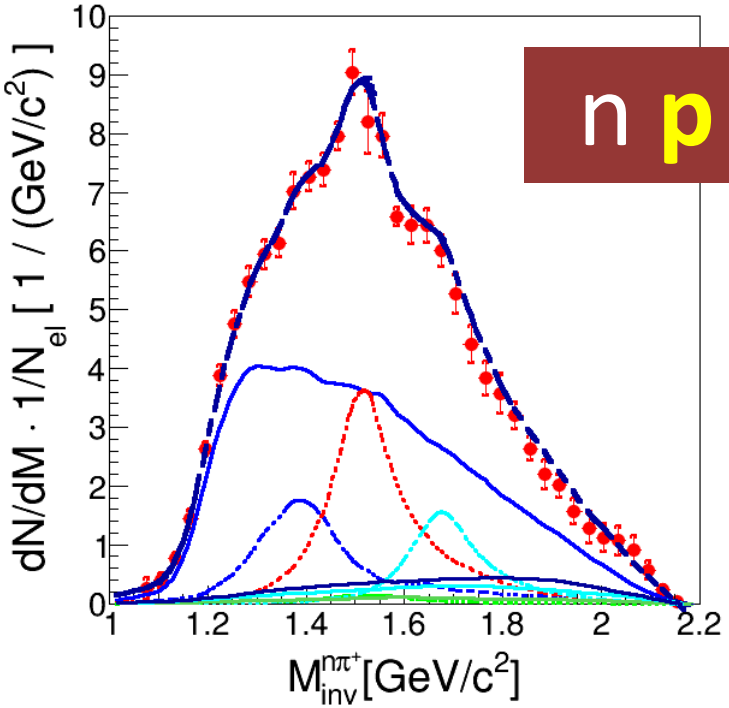
production amplitude given by **incoherent** sum of resonance contributions + isospin relations



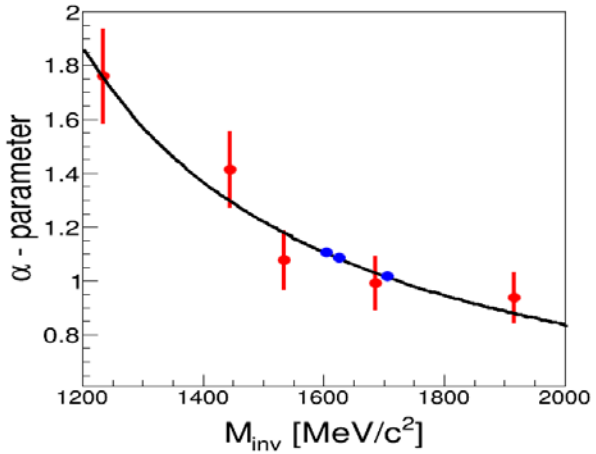
For the overlaping resonances only one resonance with largest BR(pe^+e^-) selected.

Resonance production (HADES acceptance)





n p π⁺

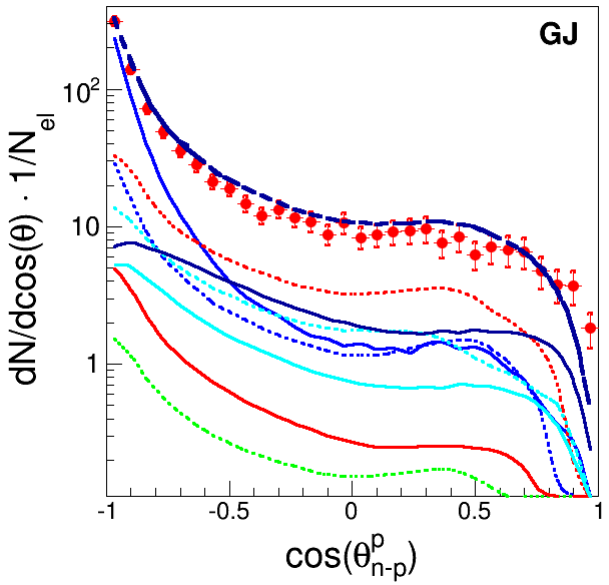


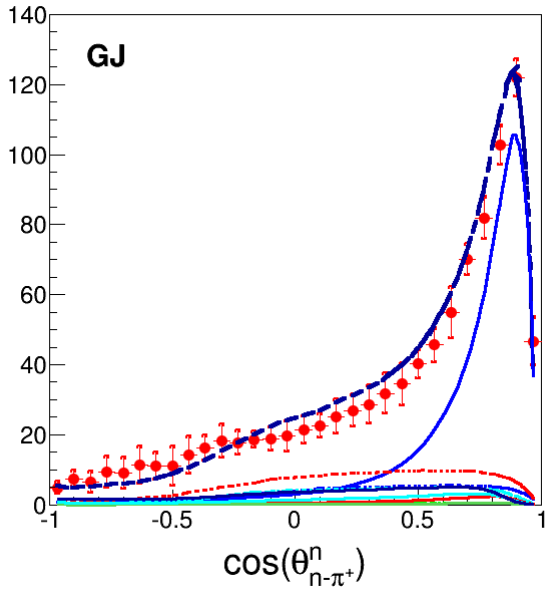
extension of angular parametrisation as a function of ***t*** for **all resonances**

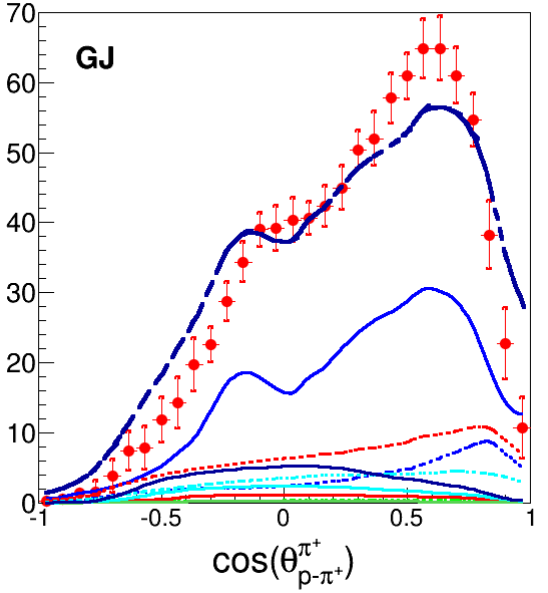
$$\frac{d\sigma}{dt}(M_R) \propto \frac{A}{t^{\alpha(M)}}$$

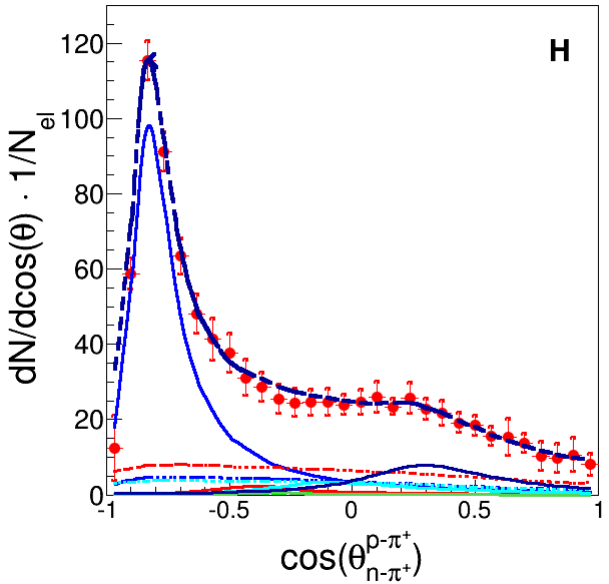
Gottfried-Jackson, Heliciy frames

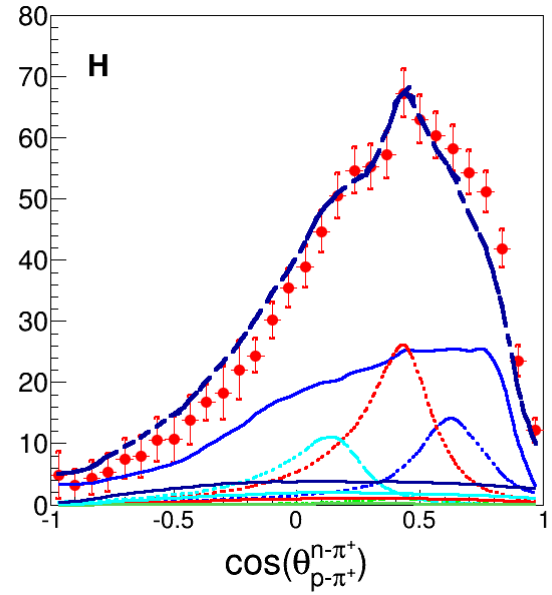
n p π^+

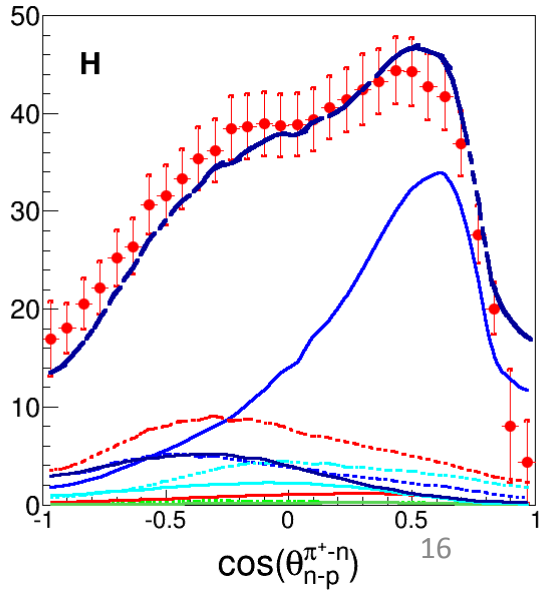






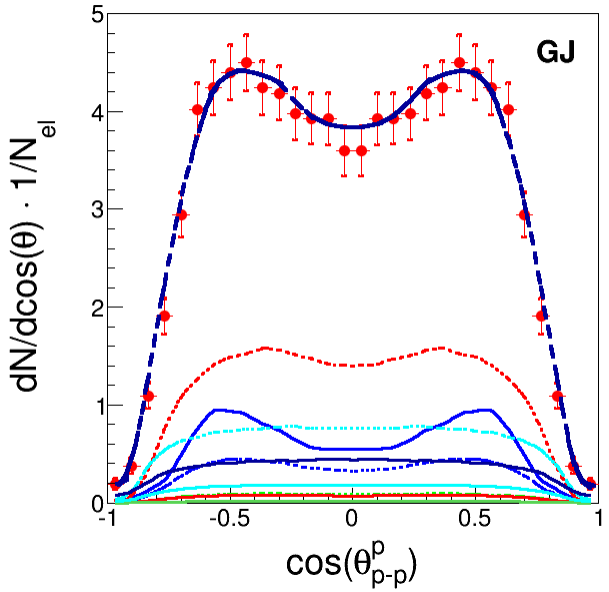


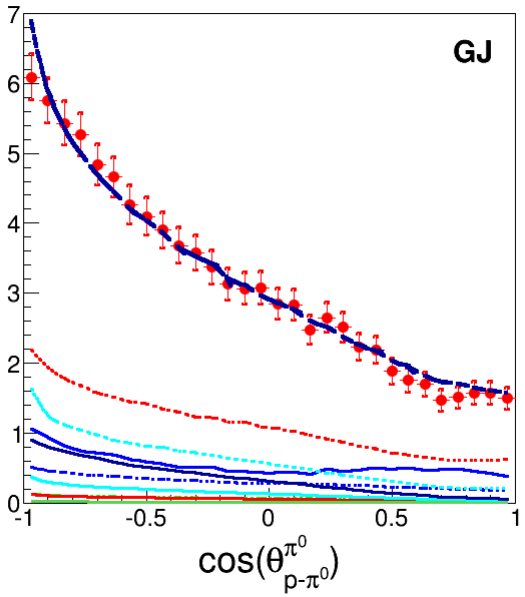


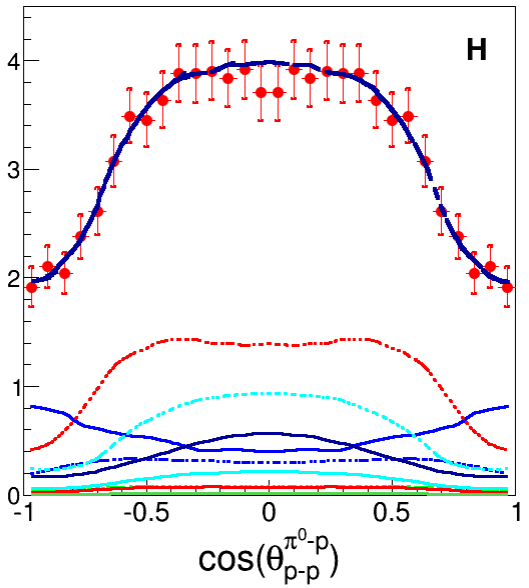


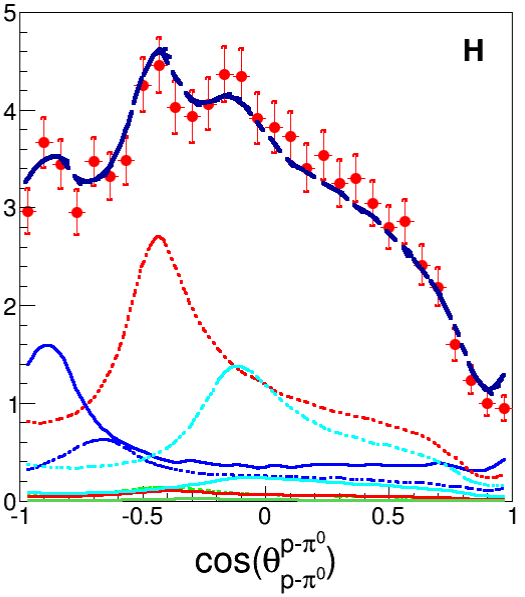
Gottfried-Jackson, Heliciy frames

p p π^0







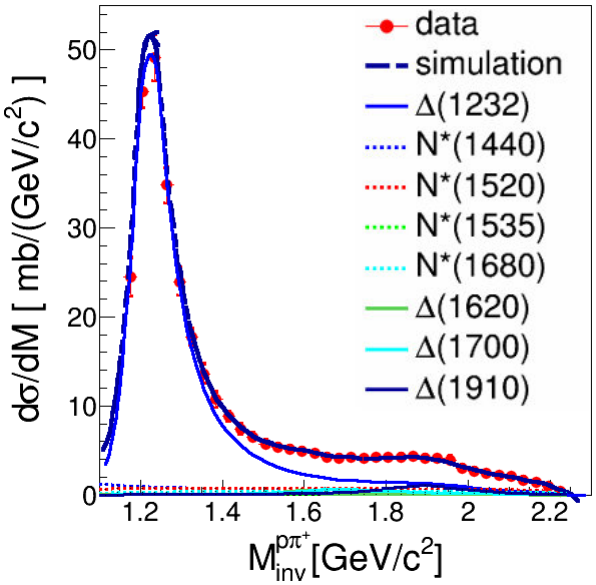


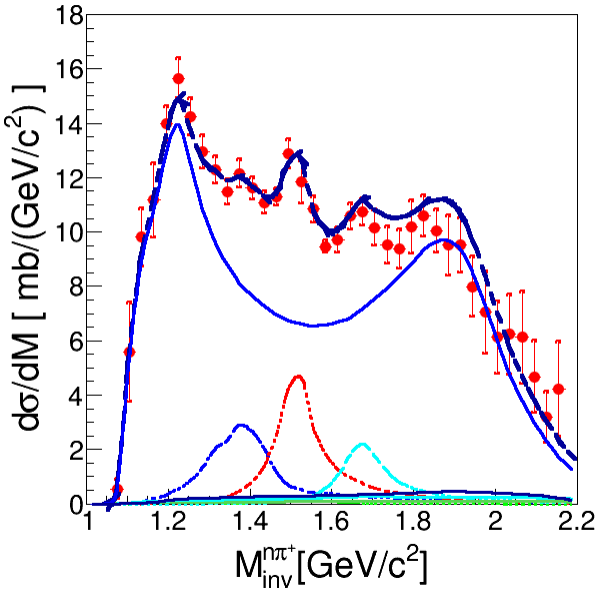
within the HADES acceptance

agreement in various projections

model used for acceptance correction

One pion production: acceptance corrected

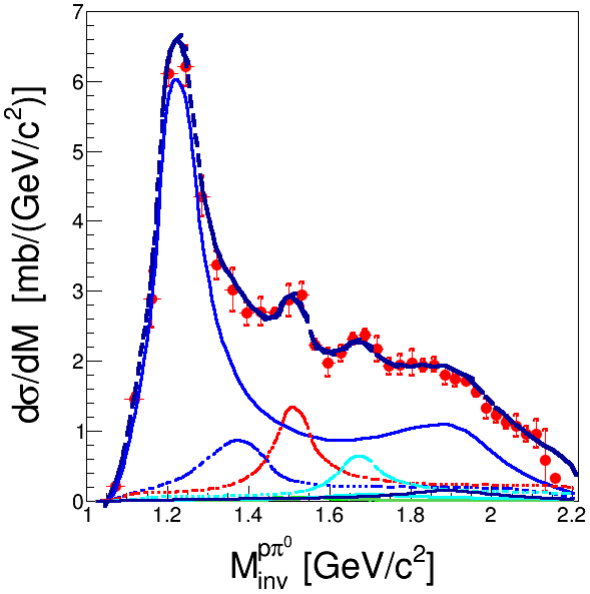


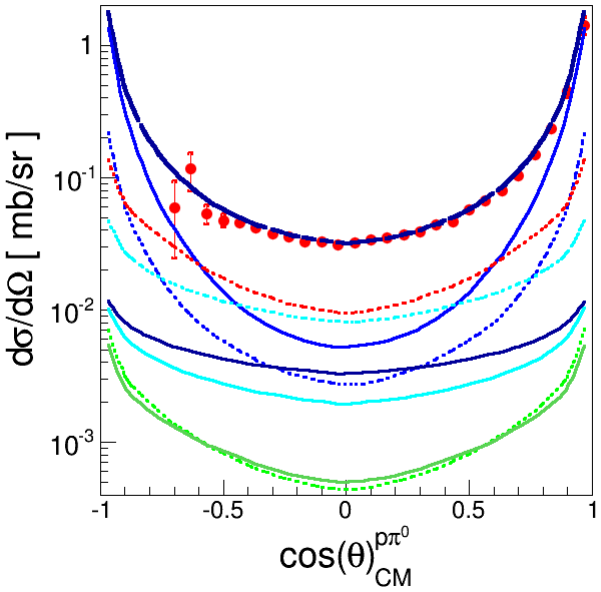


n p π⁺

- Δ^{++} (1232)

very good description of Δ-line shape ("Monitz" parametr.)

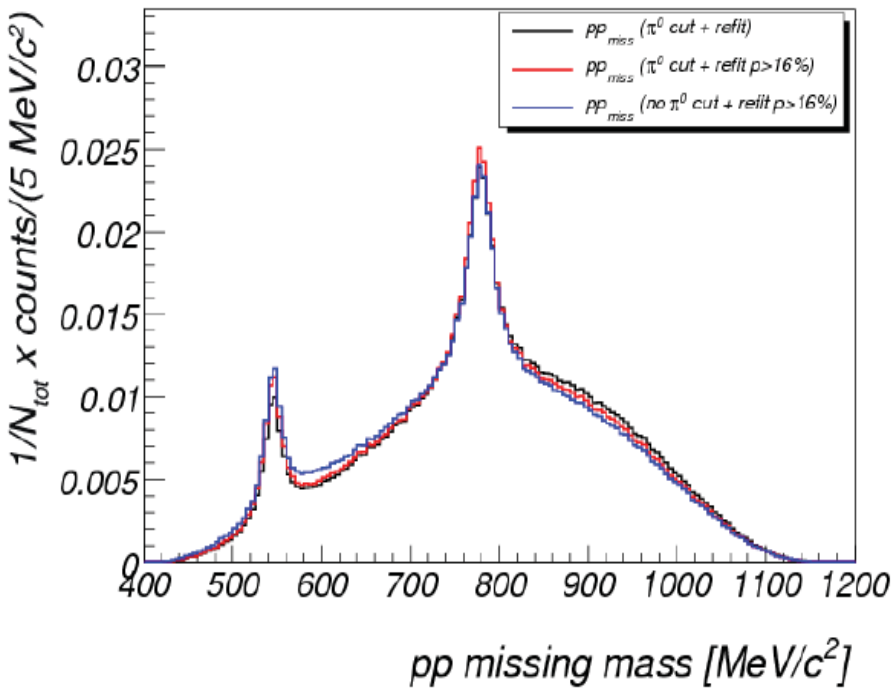




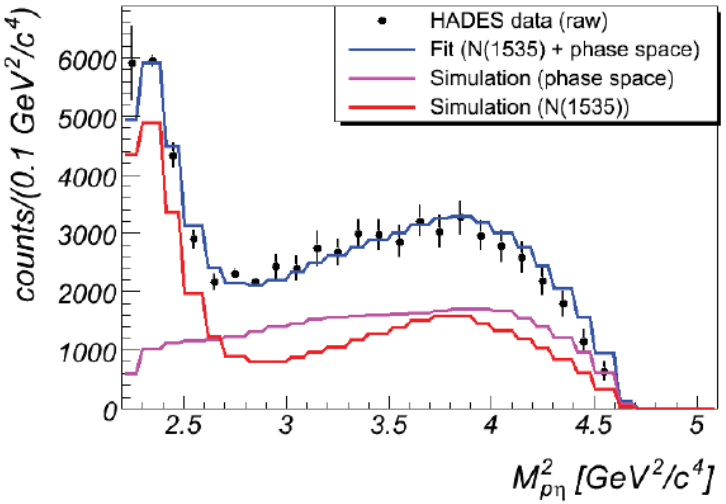
p p π⁰

- Δ^{+}(1232)
- N*(1440)
- N*(1520)
- N*(1680)

Exclusive ω/η production in p+p @ 3. 5 GeV



K. Teilab (PhD Thesis)
Univ. Frankfurt (2011)



$\sigma_\eta = 136.9 \pm 0.9(\text{stat}) \pm 10.1(\text{sys})\ [\mu\text{b}]$

$\sigma_\omega = 106.5 \pm 0.9\ (\text{stat}) \pm 7.9\ (\text{sys})\ [\mu\text{b}]$

$\sigma_{pp\rho} = ½ \cdot \sigma_{pp\omega}$

F. Balestra *et al*. (DISTO)
Phys. Rev. Lett. **89** (2002) 092001

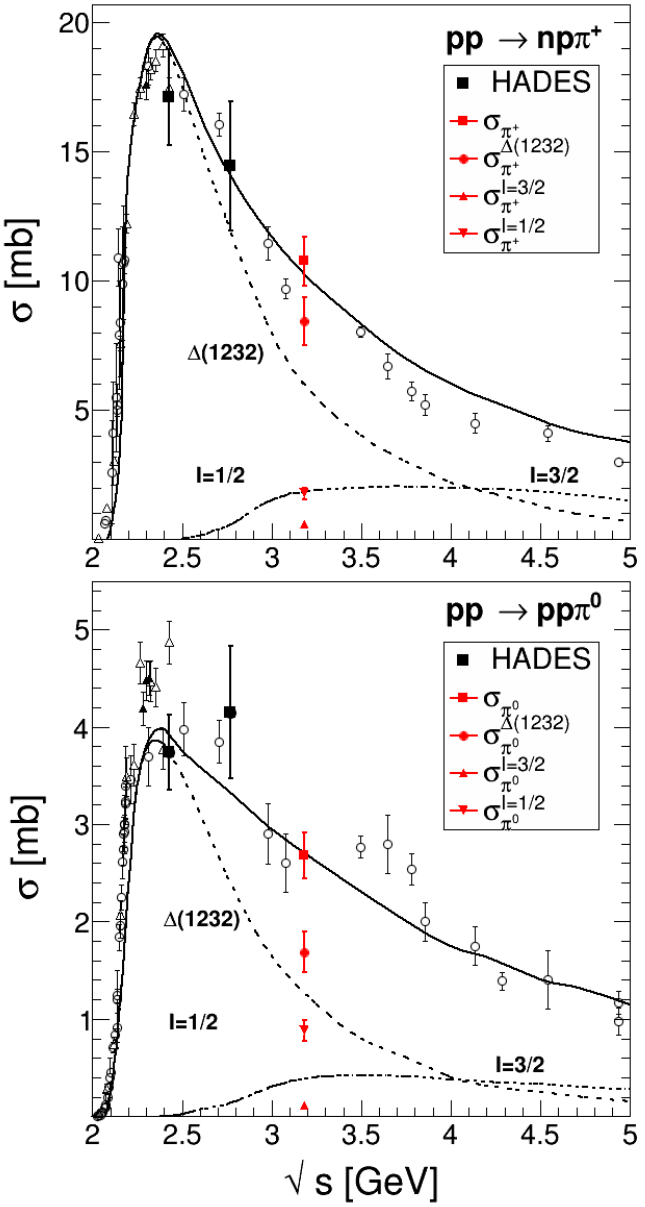
N*(1535) fixed from η Dalitz plot

N*(1535) → pη BR(42%)

$\sigma_{N^*(1535)} = 152 \pm 0.15$ [mb]

Cross sections (HADES, Teis *et al.*, GiBUU, UrQMD)

Resonances	σ_R [mb]	$\sigma_R^{Teis}(GiBUU)$	σ_R^{UrQMD}
$\Delta(1232)$	2.53 ± 0.31	2.0 (2.2)	1.7
$N^*(1440)$	1.5 ± 0.37	0.83 (3.63)	1.15
$N^*(1520)$	1.8 ± 0.3	0.22 (0.27)	1.7
$N^*(1535)$	0.152 ± 0.015	0.53 (0.53)	0.8
$\Delta(1600)$	0.24 ± 0.1	0.70 (0.14)	0.4
$\Delta(1620)$	0.1 ± 0.03	0.60 (0.1)	0.2
$N^*(1650)$	0.81 ± 0.13	0.23 (0.24)	0.4
$N^*(1675)$	1.65 ± 0.27	2.26 (0.94)	1.2
$N^*(1680)$	0.9 ± 0.15	0.21 (0.22)	1.2
$N^*(1720)$	4.41 ± 0.72	0.15 (0.14)	0.68
$\Delta(1700)$	0.45 ± 0.16	0.1 (0.06)	0.35
$\Delta(1905)$	0.85 ± 0.53	0.1 (0.06)	0.25
$\Delta(1910)$	0.38 ± 0.11	0.71 (0.14)	0.08
$\Delta(1950)$	0.1 ± 0.06	0.08 (0.1)	0.25

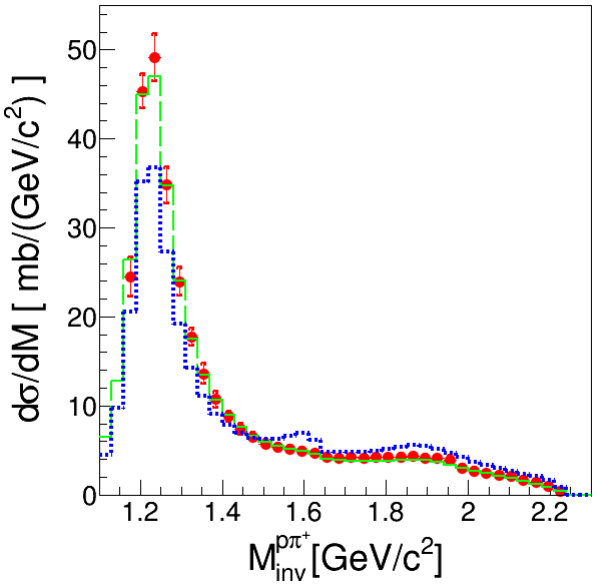


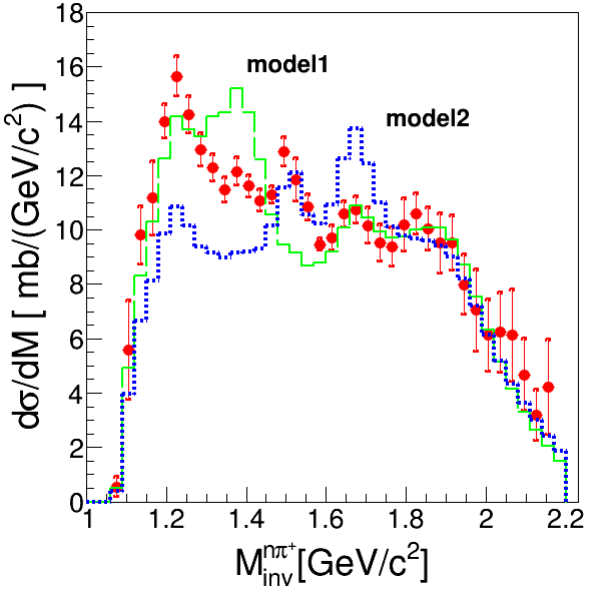
Z. Teis *et al.*,
Z. Phys. A**356** (1997) 421

J. Weil *et al.* (**GiBUU**)
Eur. Phys. J. A**48** (2012) 111

S.A. Bass *et al.* (**UrQMD**)
Prog. Part. Nucl. Phys. **41** (1998) 255

Cross sections (GiBUU – model1, UrQMD – model2)



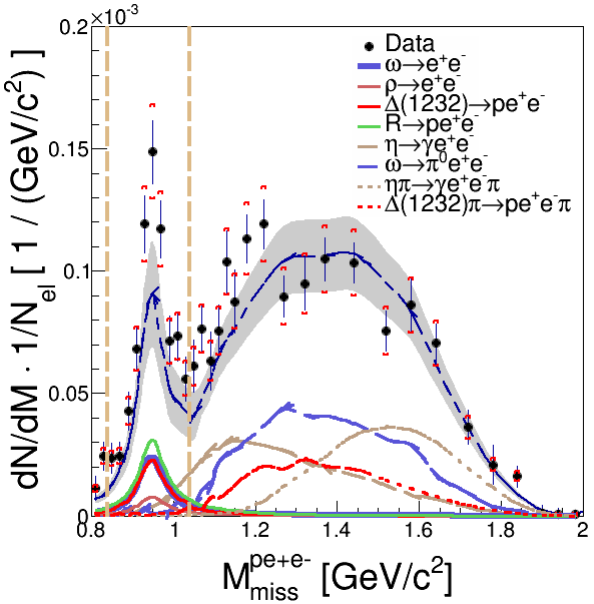


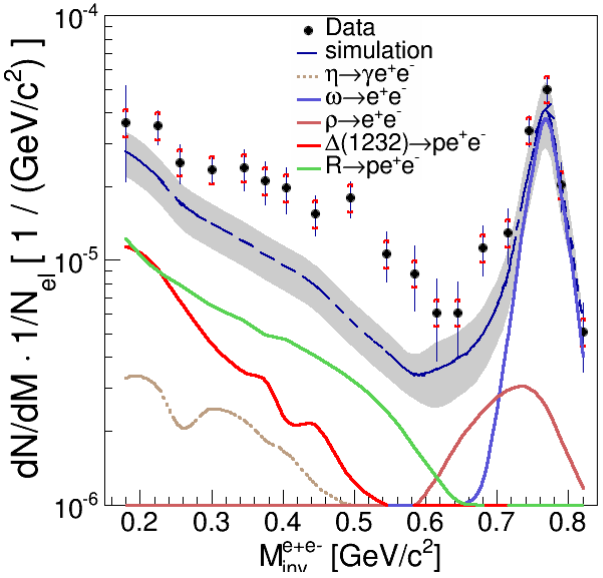
Resonances	HADES	Teis *et al.*	GiBUU	UrQMD
Δ(1232)	**2.53**			
N*(1440)	**1.5**			
N*(1520)	**1.8**			
N*(1535)	**0.15**			
Δ(1620)	**0.1**			
N*(1680)	**0.9**			
Δ(1700)	**0.45**			
Δ(1910)	**0.38**			

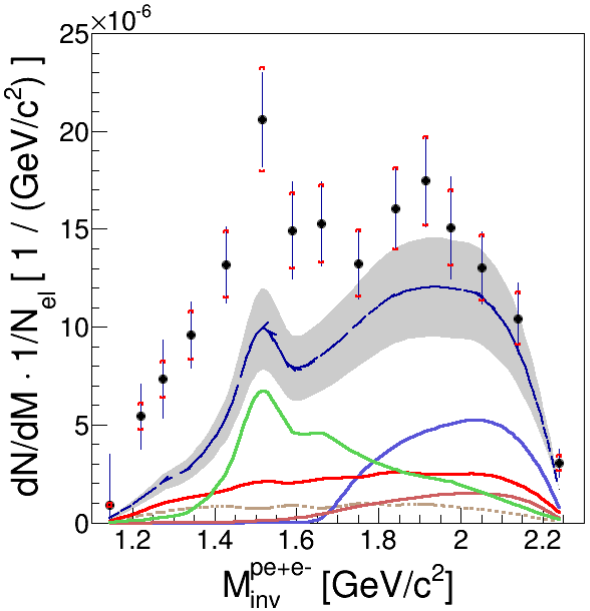
less **similar** **more**

Δ(1232) missing in UrQMD
N*(1440) much more in GiBUU
N*(1520) much less in GiBUU
N*(1440) and N*(1520) similar in UrQMD
N*(1535) much larger in the transport codes
N*(1680) overshoots in UrQMD

Exclusive p+p @ 3.5 GeV (dileptons)







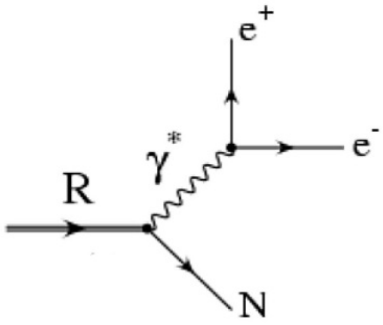
- ✓ constant eTTF
- ✓ no off shell coupling to VM

→ lower limit for e^+e^- emission

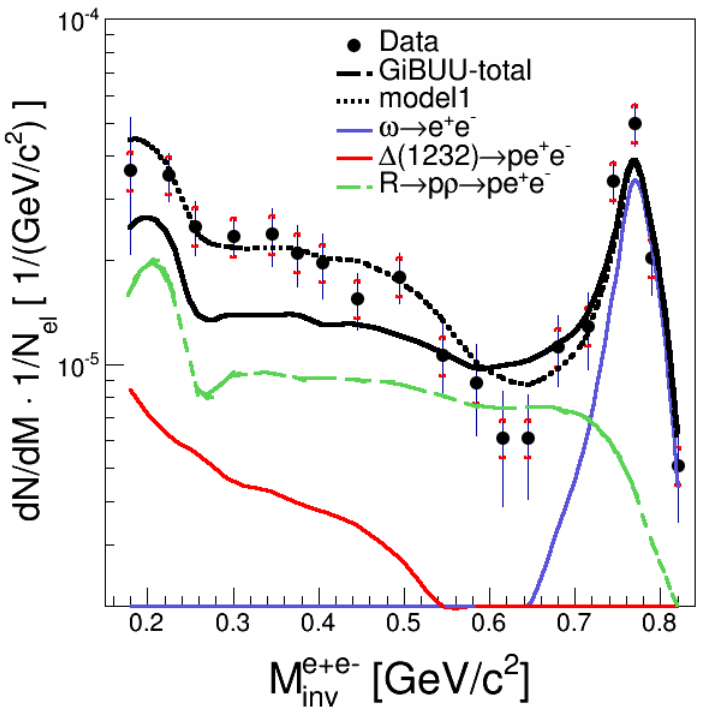
- ✓ experimental σ for ω/ρ used
- ✓ missing yield related to low mass resonances

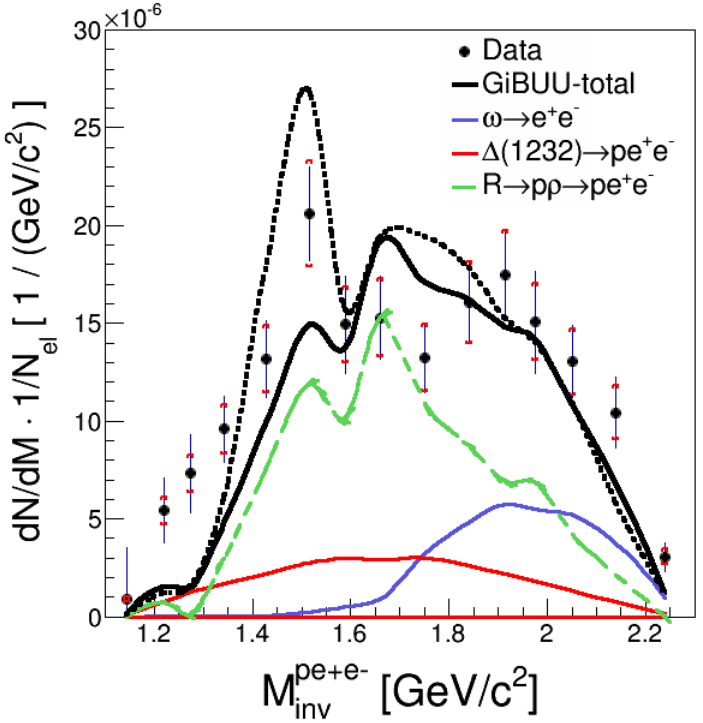
"QED model"
point-like R→Nγ* vertex

M. Zetenyi, G. Wolf
Phys. Rev. C**67** (2003) 044002



p+p @ 3.5 GeV (ρN coupling)





Branching ratios (in percent) for $R \rightarrow N\rho$

Resonances	GiBUU	UrQMD	KSU	BG	CLAS
$N^*(1520)$	21	15	20.9(7)	10(3)	13(4)
$\Delta(1620)$	29	5	26(2)	12(9)	16
$N^*(1720)$	87	73	1.4(5)	10(13)	-
$\Delta(1905)$	87	80	< 14	42(8)	-

KSU: M. Shresta, D.M. Manley
Phys. Rev. C**86** (2012) 055203

BG: A.V. Anisovich *et al.*
Eur. Phys. J. A**48** (2012) 15

CLAS: V. Mokeev *et al.*
Phys. Rev. C**86** (2012) 035203

SUMMARY remarks

- **combined analysis of exclusive channels**
  - **one pion production described within the resonance model with the angular anisotropic production modified**
- **cross sections of R production deduced**
  - **pp@1.25 Δ Dalitz decay identified (BR) in pe^+e^- channel**
  - **PWA (Bonn-Gatchina group) for pp@1.25:**
    - **confirms the Δ resonance contributions and cross sections**
    - **higher PW necessary for good description (i.e. $^1G_4$, $^3H_4$)**
- **pp@3.5 constraints both for eTTF investigation and transport models**
  - **PWA for pp@3.5 in plans for this year**

CREDITS

The HADES Collaboration

Piotr Salabura (spokesperson)

me