Production and Dalitz decays of baryon resonances in proton-proton interaction at $\sqrt{s} = 3.16$ GeV with HADES

Adrian Dybczak

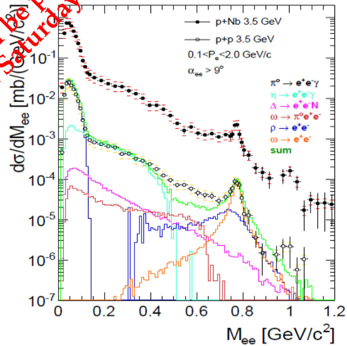
FAIRNESS, HERSONISSOS

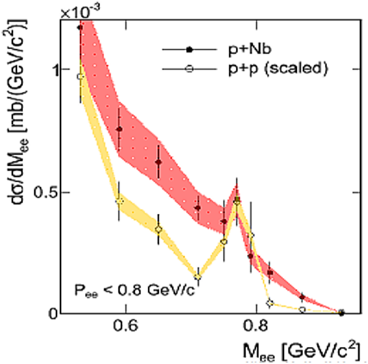
September 4, 2012

HADES

Motivations

Will be presented on Saturday session





Inclusive e^+e^- spectra can be described by incoherent sum of various hadronic sources, but:

▲ e^+e^- yield below vector meson pole ($M_{inv}^{e^+e^-} \in (0.5 - 0.7)$) is not fully described,

▲ barionic Dalitz decays are included for $\Delta(1232)$ only.

offshell ρ meson, higher resonances contributions?

Exclusive channel ppe^+e^- can better constraint elementary sources of dilepton production:

▲ selection on $M_{miss}^{pe^+e^-} \approx M_p$

▲ no η Dalitz contribution.

▲ yield below vector meson pole sensitive to Resonance decays $R \rightarrow Ne^+e^-$

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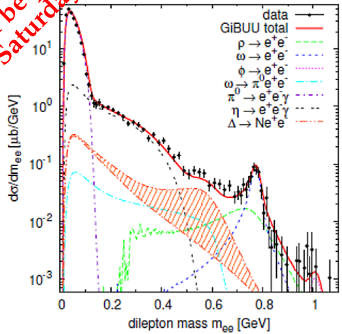

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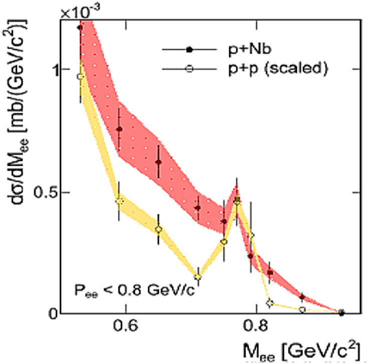

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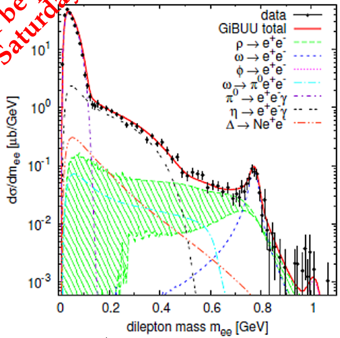

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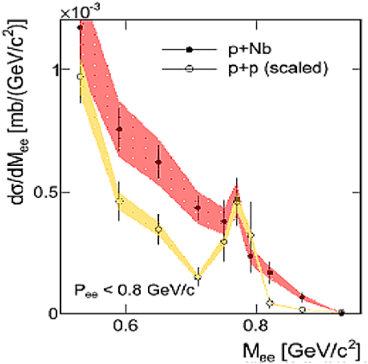

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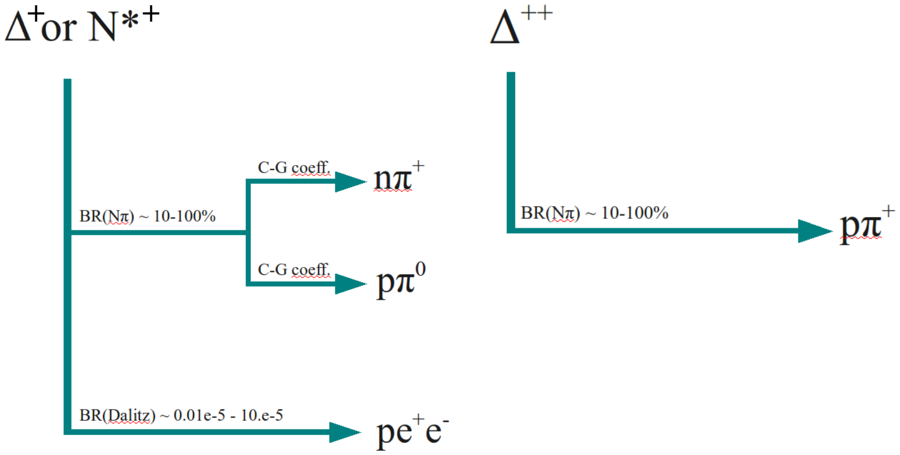
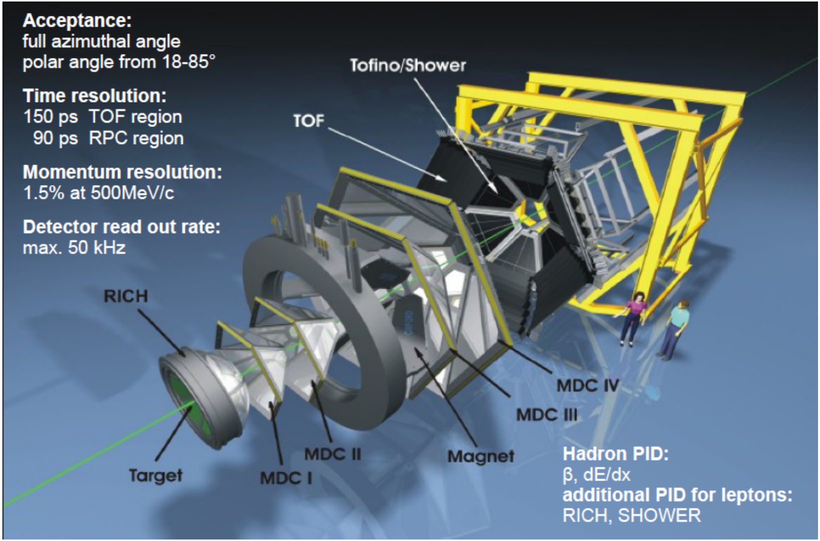
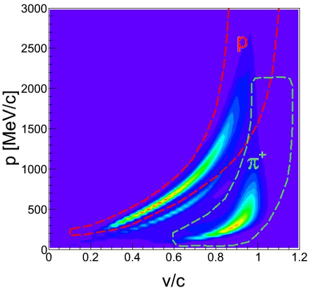
General idea

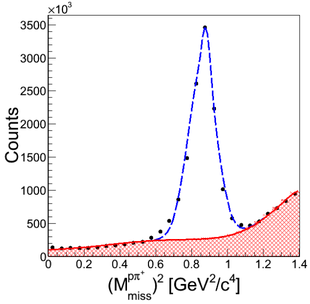


HADES spectrometer



Analysis of $pn\pi^+$, $pp\pi^0$ final states





GENERAL STRATEGY

- Selection of events with two positive tracks.
- Charged particles [p, π^+] identification via β vs *mom* correlation.
- Channel selection via conditions on missing mass of neutral particle [π^0, n].

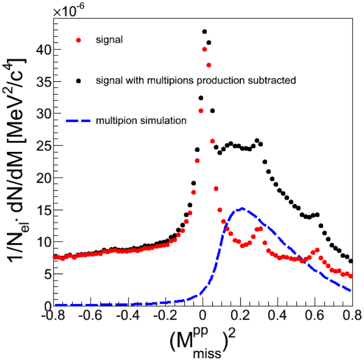
SIGNAL EXTRACTION

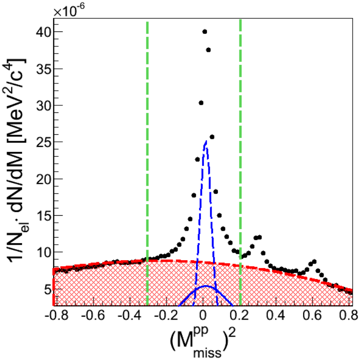
Signal is estimated as a number of counts in peak of neutron missing mass after background subtraction.

Advantages of $p(n)\pi^+$ final state

- This channel allows for unique resonance association:
$p\pi^+$ - double charged
$n\pi^+$ - single charged
- Larger acceptance

$pp(\pi^0)$ channel selection





Signal is estimated in 3 step process:

1. Elimination of elastic scattering events via conditions on coplanarity and polar angles of outgoing protons.
2. Subtraction of simulated multipion production.
3. Estimation of signal in π^0 missing mass peak.

Comparison with simulation

GENERAL STRATEGY

- Full analysis chain ($GEN \to GEANT \to DST \to ANALISYS$) done for assuming **incoherent sum of resonances**.

- Estimation of resonances cross sections via **simultanous comparison of data to simulation for two channels** $pp\pi^0$ **and** $pn\pi^+$ by means of:

  invariant masses - $M_{inv}^{p\pi^+}$, $M_{inv}^{n\pi^+}$, $M_{inv}^{p\pi^0}$

  angular distributions - $cos\theta_{CM}^{p\pi^+}$, $cos\theta_{CM}^{n\pi^+}$, $cos\theta_{CM}^{p\pi^0}$.

- Normalization to number of elastic scattering events.

- Model dependent acceptance/efficiency correction.

Resonances included in fit

	Teis model[1]		newest PWA[2]		PDG (my fit)		
Resonances	Γ_R[MeV]	$\Gamma^{N\pi}$	Γ_R[MeV]	$\Gamma^{N\pi}$	Γ_R[MeV]	$\Gamma^{N\pi}$	
$\Delta(1232)$	120	1	120	1	120	1	
$N^*(1440)$	350	0.65	350	0.65	350	0.65	
$N^*(1520)$	120	0.55	120	0.55	120	0.55	$\Longleftarrow$ constrainted
$N^*(1535)$	203	0.50	125	0.46	125	0.46	(see Khaled Teilab PhD thesis)
$\Delta(1600)$	350	0.15	350	0.175			} REGION REPRESENTED BY
$\Delta(1620)$	150	0.3	150	0.25	150	0.25	$\Delta(1620)$
$N^*(1650)$	150	0.8	103	0.51			}
$N^*(1675)$	150	0.45	151	0.40			REGION REPRESENTED BY
$N^*(1680)$	130	0.7	113	0.65	130	0.65	$N^*(1680)$
$N^*(1720)$	150	0.2	450	0.10			
$\Delta(1700)$	300	0.15	300	0.15	300	0.15	
$\Delta(1905)$	350	0.15	300	0.13			}
$\Delta(1910)$	250	0.25	350	0.12	250	0.25	REGION REPRESENTED BY
$\Delta(1950)$	300	0.75	243	0.45			$\Delta(1910)$

- Only 4 stars resonances included above.
- Δ (N^*) resonances distinguished by final state $p\pi^+$ ($n\pi^+$).
- For regimes of overlaping mass, resonances with biggest predicted contribution to dilepton production ([3],[4]) were included, but model uncertainty will be show as well.

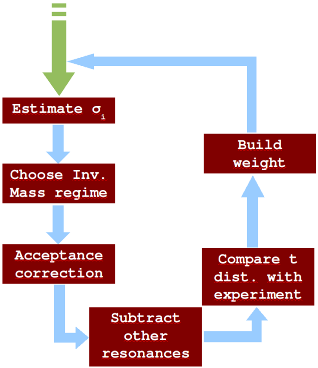
[1] S. Teis et al., Z. Phys. A 356 (1997) 421-435

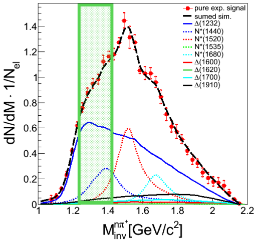
[2] A. V. Anisovich, arXiv:1112.4937v1

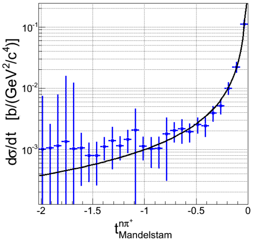
[3] M.I. Krivoruchenko et al., Annals Phys.296:299-346,2002

[4] M. Zetenyi and Gy. Wolf., Heavy Ion Phys. 17 (2003) 27-39

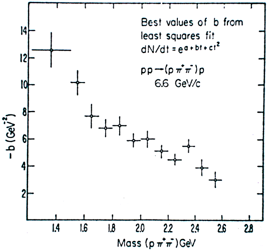
Adjusting resonance model in Hades acceptance







$$\Longleftarrow \quad \frac{d\sigma}{dt} = \frac{b}{t^a}$$



Phys. Rev. D 3, 10631088 (1971)
Eugene Colton and Peter E. Schlein

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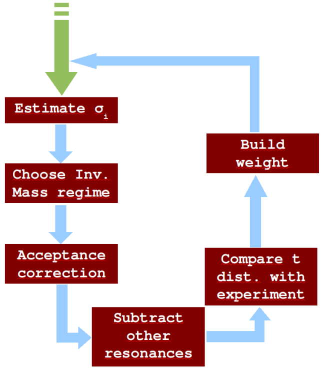

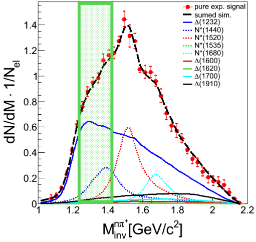

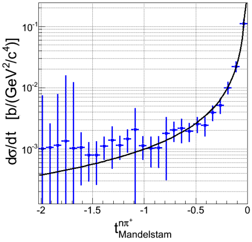

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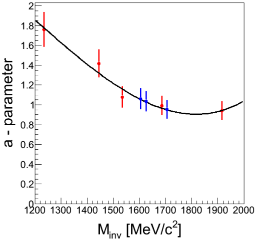
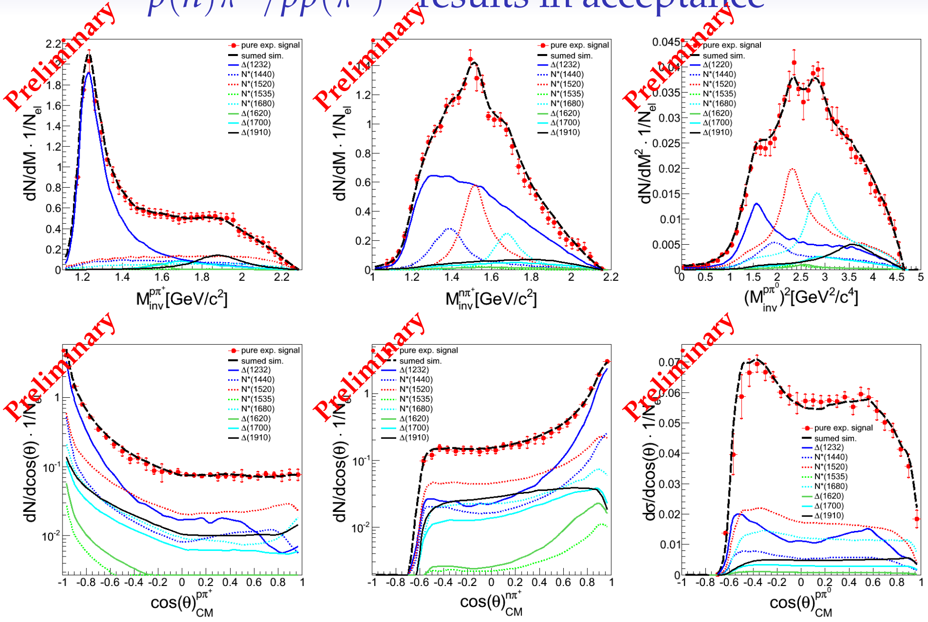
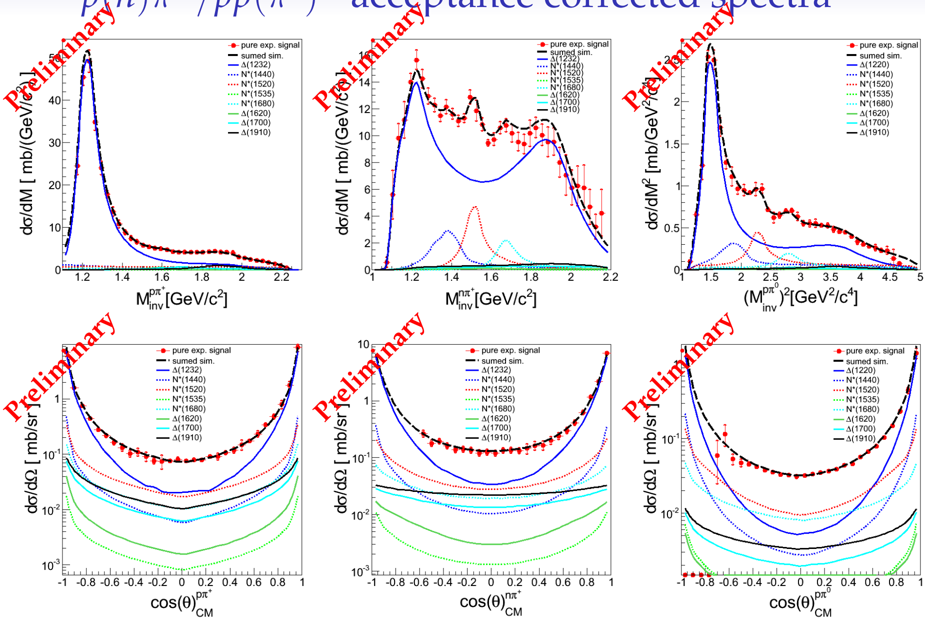


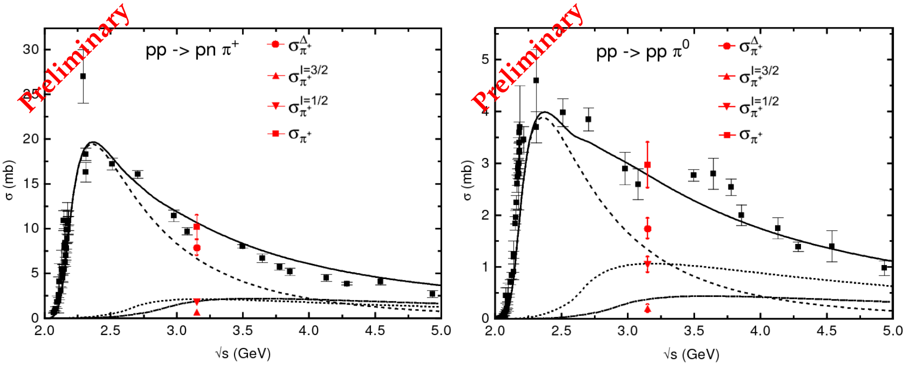
$p(n)\pi^+/pp(\pi^0)$ - results in acceptance



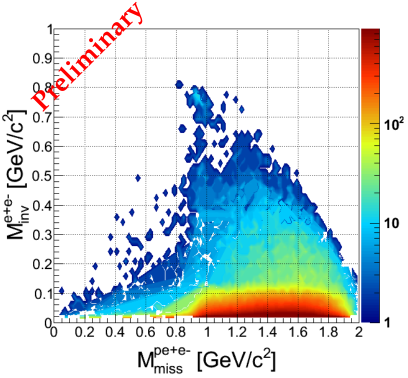
$p(n)\pi^+/pp(\pi^0)$ - acceptance corrected spectra

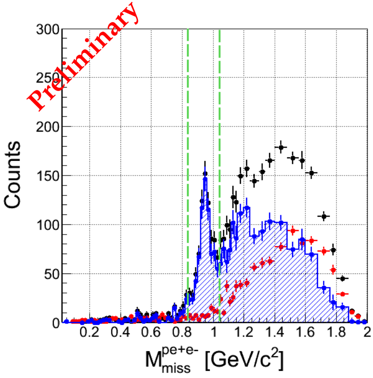


Comparison with Teis model



Dilepton analysis

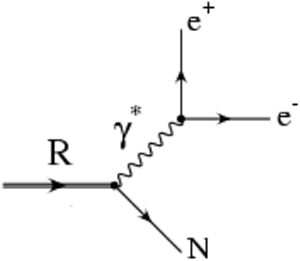




General conditions of signal extraction:

- only events with lvl2 trigger
- pair opening angle $> 9[°]$
- angle to closest partner $> 5[°]$
- $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$
- combinatorial background estimated as sum of like-sign pairs

Comparison of Zetenyi-Wolf model (QED) with data

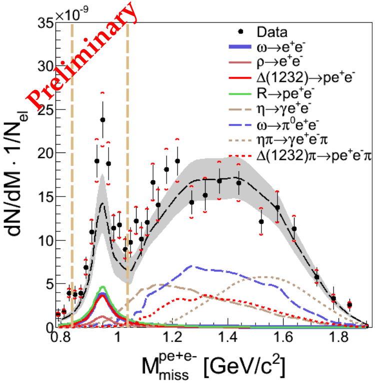


„*Dilepton decays of baryon resonances*" - M. Zetenyi and Gy. Wolf, Heavy Ion Phys. 17 (2003) 27-39

- Formula of $\Gamma_{pee}(M)$ has been applied in PLUTO++ calculations and compared with data.
- Cross section for exclusive ω, η channels from Khaled. ρ assumed to be half of ω.
- Cross section for Resonances production, and angular distributions taken from previous chapter.
- Comparison was done inside HADES acceptance on uncorrected spectra (efficiency and smearing included in simulation).

Comparison of Zetenyi-Wolf (QED) model with data

- Cocktail: $\eta + \omega + \rho + \Delta(1232)$ + Higher res.
  + $\Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- ρ produced via phase space. $\sigma_\rho = \frac{1}{2}\sigma_\omega$ see (Phys. Rev. Lett. 89(2002) 092001).



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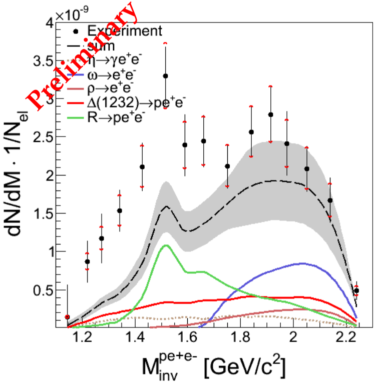
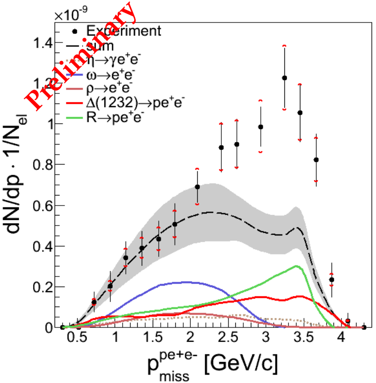
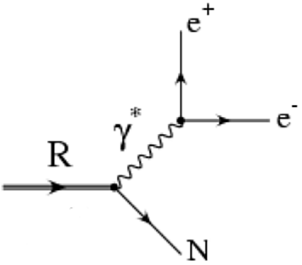


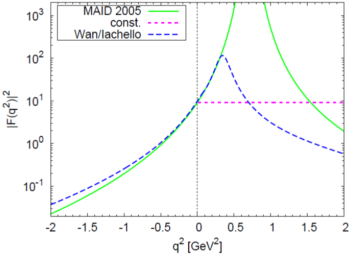


Comparison of QED model + $\Delta(1232)$ FF with data



$+$

Wan/Iachello model of $\Delta(1232)$ FF



Int. J. Mod. Phys. A 20 (2005)

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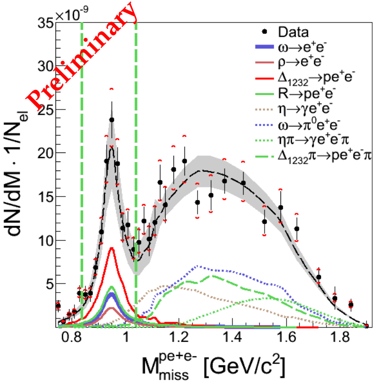

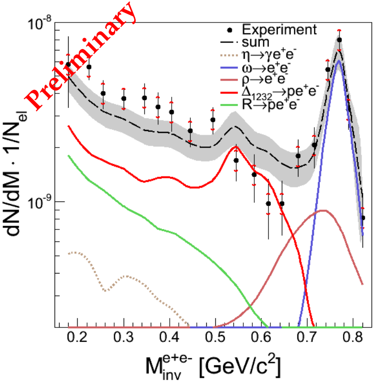

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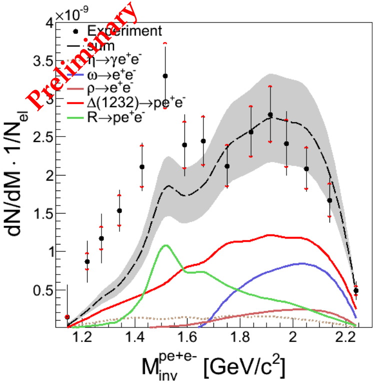
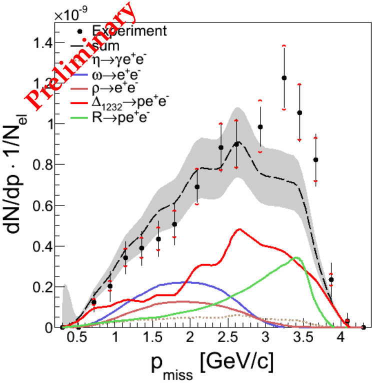
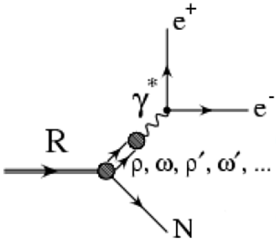




Comparison of Martemyanov-Krivoruchenko (eVMD) model with data

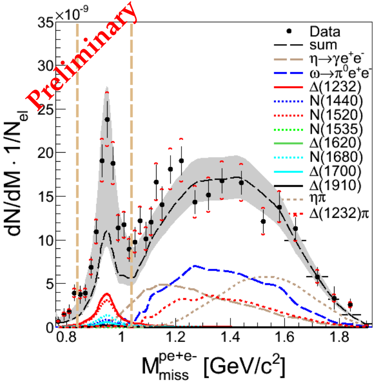


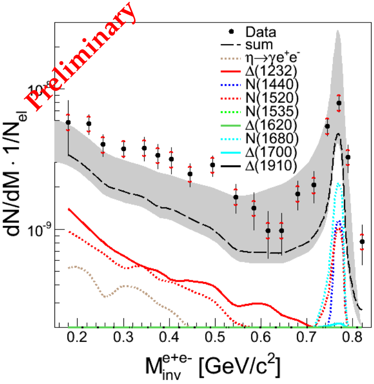
„Electromagnetic transition form factors and dilepton decay rates of nucleon resonances" - M.I. Krivoruchenko, B.V. Martemyanov, Annals Phys. 296: 299-346, 2002

- Calculations provided by authors.
- No free ω, ρ production.
- Cross section for Resonances production, and angular distributions taken from previous chapter.
- Comparison was done inside HADES acceptance on uncorrected spectra (efficiency and smearing included in simulation).

Comparison of Martemyanov-Krivoruchenko (eVMD) model with data

- Cocktail: η + $\Delta(1232)$ + Higher res.
  + $\Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- no ρ and ω free production !!!





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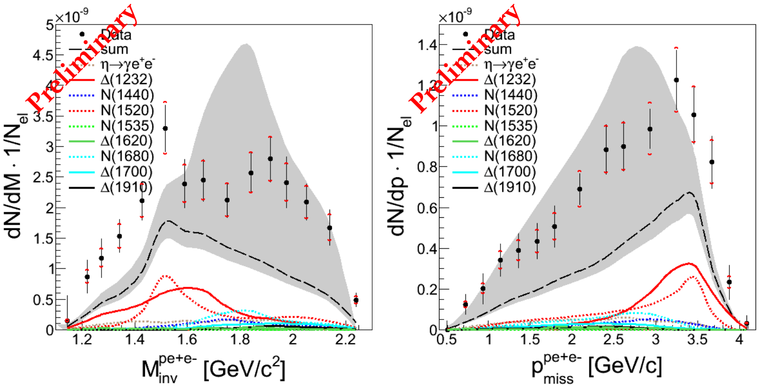
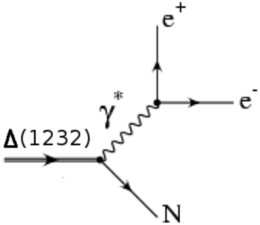


Comparison of UrQMD calculations with data



$$+ \qquad R \to \rho N \to e^+e^-N$$

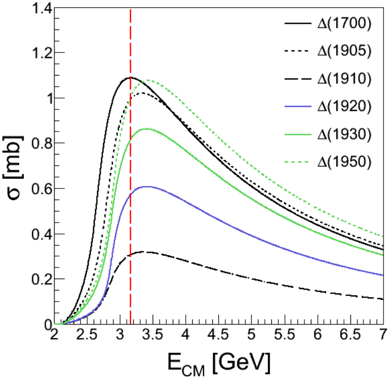
„*Microscopic Models for Ultrarelativistic Heavy Ion Collisions*" - S. A. Bass et al., arXiv:nucl-th/9803035v2

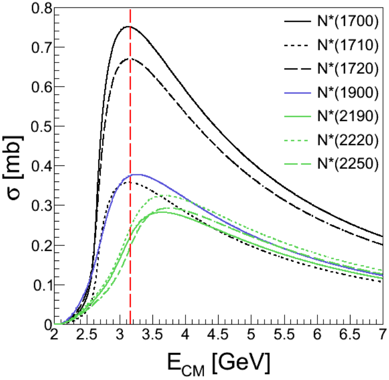
- σ_R has been calulated using formulas from arXiv:nucl-th/9803035v2.
- Resonances propeties taken from arXiv:nucl-th/9803035v2.
- Cross section for exclusive $\omega,\ \eta$ channels from Khaled.
- No free ρ production.
- Angular distributions taken from previous chapter.
- Comparison was done inside HADES acceptance on uncorrected spectra (efficiency and smearing included in simulation).

Resonances in UrQMD model

resonance	mass	width	$N\gamma$	$N\pi$	$N\eta$	$N\omega$	$N\varrho$	$N\pi\pi$	$\Delta_{1232}\pi$	$N^*_{1440}\pi$	ΛK
N^*_{1440}	1.440	200		0.70				0.05	0.25		
N^*_{1520}	1.520	125		0.60				0.15	0.25		
N^*_{1535}	1.535	150	0.001	0.55	0.35			0.05		0.05	
N^*_{1650}	1.650	150		0.65	0.05			0.05	0.10	0.05	0.10
N^*_{1675}	1.675	140		0.45					0.55		
N^*_{1680}	1.680	120		0.65				0.20	0.15		
N^*_{1700}	1.700	100		0.10	0.05		0.05	0.45	0.35		
N^*_{1710}	1.710	110		0.15	0.20		0.05	0.20	0.20	0.10	0.10
N^*_{1720}	1.720	150		0.15			0.25	0.45	0.10		0.05
N^*_{1900}	1.870	500		0.35		0.55	0.05		0.05		
N^*_{1990}	1.990	550		0.05			0.15	0.25	0.30	0.15	0.10
N^*_{2080}	2.040	250		0.60	0.05		0.25	0.05	0.05		
N^*_{2190}	2.190	550		0.35			0.30	0.15	0.15	0.05	
N^*_{2220}	2.220	550		0.35			0.25	0.20	0.20		
N^*_{2250}	2.250	470		0.30			0.25	0.20	0.20	0.05	
Δ_{1232}	1.232	115.	0.01	1.00							
Δ^*_{1600}	1.700	200		0.15					0.55	0.30	
Δ^*_{1620}	1.675	180		0.25					0.60	0.15	
Δ^*_{1700}	1.750	300		0.20			0.10		0.55	0.15	
Δ^*_{1900}	1.850	240		0.30			0.15		0.30	0.25	
Δ^*_{1905}	1.880	280		0.20			0.60		0.10	0.10	
Δ^*_{1910}	1.900	250		0.35			0.40		0.15	0.10	
Δ^*_{1920}	1.920	150		0.15			0.30		0.30	0.25	
Δ^*_{1930}	1.930	250		0.20			0.25		0.25	0.30	
Δ^*_{1950}	1.950	250	0.01	0.45			0.15		0.20	0.20	

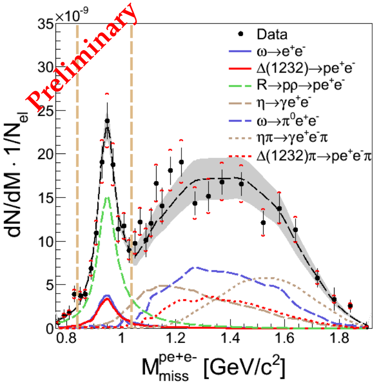
Cross sections for Resonances production in UrQMD model

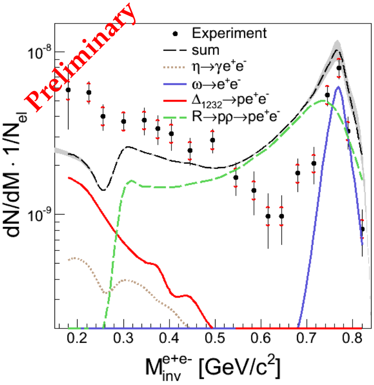




Comparison of UrQMD model with data

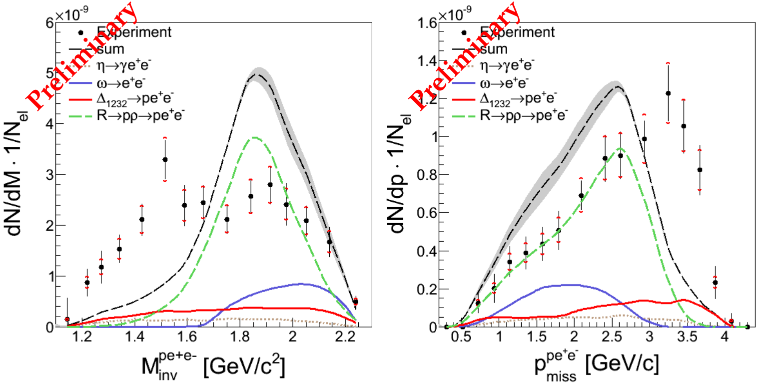
- Cocktail: $\eta + \omega + \Delta(1232)$ + Higher res.
  $+ \Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- no ρ free production !!!



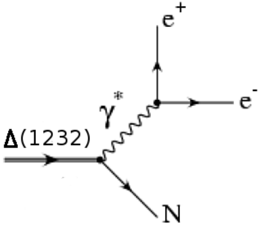


Comparison of UrQMD model with data

- Cocktail: $\eta + \omega + \Delta(1232)$ + Higher res.
  $+ \Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- no ρ free production !!!



Comparison of GiBUU calculations with data



$$+ \quad R \to \rho N \to e^+e^-N$$

„Dilepton production in proton-induced reactions at SIS energies with the GiBUU transport model" - J. Weil, U. Mosel, arXiv:submit/0437528 [nucl-th], 2012

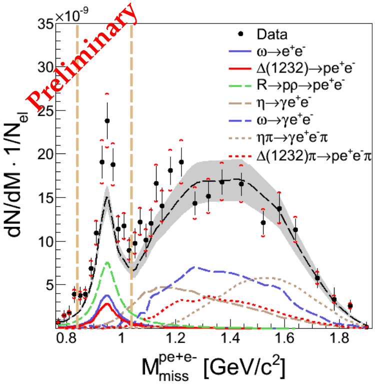
- σ_R has been calulated using formulas from Z. Phys. A 356 (1997) 421-435.
- Resonances propeties taken from arXiv:submit/0437528 [nucl-th].
- Cross section for exclusive ω, η channels from Khaled.
- No free ρ production.
- Angular distributions taken from previous chapter.
- Comparison was done inside HADES acceptance on uncorrected spectra (efficiency and smearing included in simulation).

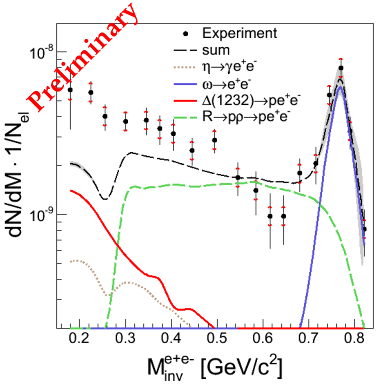
Resonances in GiBUU model

	rating	M_0 [MeV]	Γ_0 [MeV]	branching ratio in % πN	ηN	$\pi\Delta$	ρN	σN	$\pi N^*(1440)$	$\sigma\Delta$
$P_{11}(1440)$	****	1462	391	69	—	22_P	—	9	—	—
$S_{11}(1535)$	***	1534	151	51	43	—	$2_S + 1_D$	1	2	—
$S_{11}(1650)$	****	1659	173	89	3	2_D	3_D	2	1	—
$D_{13}(1520)$	****	1524	124	59	—	$5_S + 15_D$	21_S	—	—	—
$D_{15}(1675)$	****	1676	159	47	—	53_D	—	—	—	—
$P_{13}(1720)$	*	1717	383	13	—	—	87_P	—	—	—
$F_{15}(1680)$	****	1684	139	70	—	$10_P + 1_F$	$5_P + 2_F$	12	—	—
$P_{33}(1232)$	****	1232	118	100	—	—	—	—	—	—
$S_{31}(1620)$	**	1672	154	9	—	62_D	$25_S + 4_D$	—	—	—
$D_{33}(1700)$	*	1762	599	14	—	$74_S + 4_D$	8_S	—	—	—
$P_{31}(1910)$	****	1882	239	23	—	—	—	—	67	10_P
$P_{33}(1600)$	***	1706	430	12	—	68_P	—	—	20	—
$F_{35}(1905)$	***	1881	327	12	—	1_P	87_P	—	—	—
$F_{37}(1950)$	****	1945	300	38	—	18_F	—	—	—	44_F

Comparison of GiBUU model with data

- Cocktail: $\eta + \omega + \Delta(1232)$ + Higher res.
  $+ \Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- no ρ free production !!!





Comparison of GiBUU model with data

- Cocktail: $\eta + \omega + \Delta(1232)$ + Higher res.
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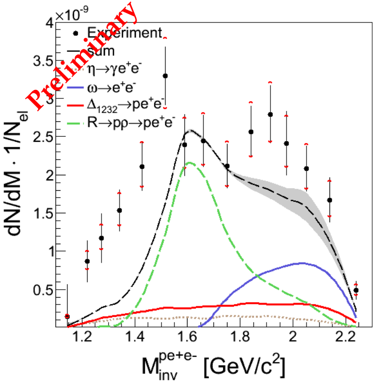
- no ρ free production !!!



OUTLOOK & CONCLUSIONS

Hadronic part

- All distributions in hadronic channels are described very well.
- **Not isotropic production of resonances** concluded from comparison with data.
- Cross section for resonances production via analisys of $pn\pi^+$ and $pp\pi^0$ channel with error calculation and isospin relation conservation.
- Estimated cross sections for π^0 and π^+ productions in good agreement with previous observations.

Leptonic part

- Zetenyi-Wolf model of $\Gamma_{R \to pe^+e^-}$ cannot fully describes data (coupling ρ, ω to resonances maybe?).
- Adding Wan/Iachello $\Delta(1232)$ FF seem to be one of the way to describe data.
- Martemyanov-Krivoruchenko model of $\Gamma_{R \to pe^+e^-}$ has huge uncertainty but still cannot describe data ($M_{inv}^{pe^+e^-}$).
- UrQMD approach overshoot all observables.
- GiBUU approach seem to be second way to describe data.

Backup slides

Backup slides

Review of BR(e^+e^-)

J^P	Resonance	σ_R	QED	eVMD
3/2+	$\Delta(1232)$	2.53±0.31	4.2e-5	4.2e-5
1/2+	$N^*(1440)$	1.50±0.27	3.06e-6	4.0e-6
3/2-	$N^*(1520)$	2.10±0.34	3.72e-5	5.0e-5
1/2-	$N^*(1535)$	0.12±0.04	1.45e-5	1.34e-5
3/2+	$\Delta(1600)$	0.24±0.10	0.73e-6	0.68e-6
1/2-	$\Delta(1620)$	0.10±0.03	1.73e-6	8.8e-6
1/2-	$N^*(1650)$	0.81±0.13	8.03e-06	1.95e-5
5/2-	$N^*(1675)$	1.65±0.27	1.02e-06	1.40e-06
5/2+	$N^*(1680)$	0.90±0.15	1.97e-5	1.98e-5
3/2+	$N^*(1720)$	4.41±0.72	3.65e-06	3.69e-05
3/2-	$\Delta(1700)$	0.45±0.16	1.38e-5	2.0e-5
5/2+	$\Delta(1905)$	0.85±0.53	1.46e-06	3.19e-05
1/2+	$\Delta(1910)$	0.38±0.25	0.73e-5	0.53e-5
1/2-	$\Delta(1950)$	0.10±0.06	3.06e-6	1.12e-05

Equivalent cross section

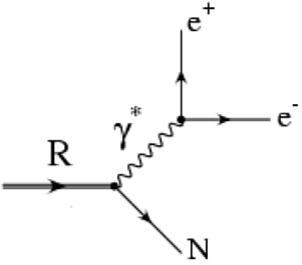
QED

$BR(e^+e^-)$ at the pole
calulated as ratio of $BR(p\gamma)$ and 137
(arXiv.org/abs/nucl-th/0202047v1, page 12)

eVMD

$BR(e^+e^-)$ at the pole
calulated as ratio of $\Gamma^{e^+e^-}$ and Γ^{tot}
(arXiv.org/abs/nucl-th/0110066v2, page 35)

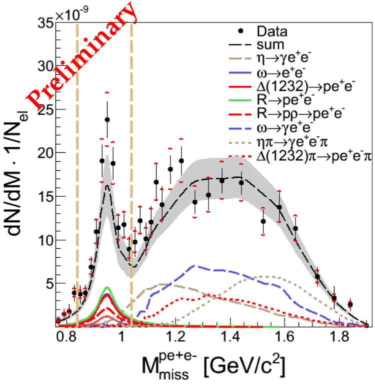
A poor man‘s approach

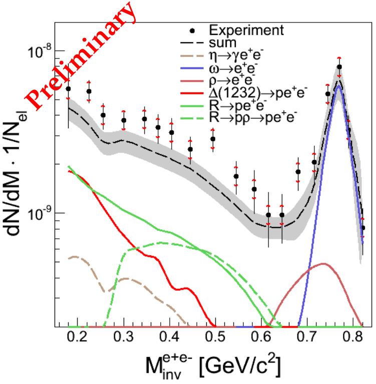


$$+ \quad R \to \rho N \to e^+e^-N$$

A poor man‘s approach

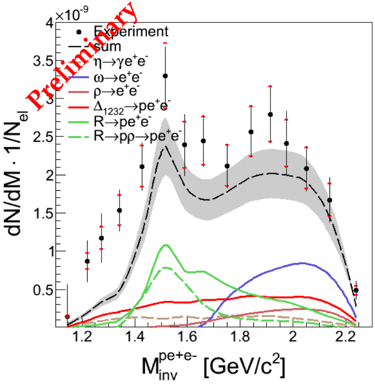
- Cocktail: Mesonic channels + $\Delta(1232)$ + Higher res. + ρ via $N^*(1520)$ + $\Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- ρ produced via phase space. $\sigma_\rho = \frac{1}{2}\sigma_\omega$ see (Phys. Rev. Lett. 89(2002) 092001).
- additional production of ρ via $N^*(1520)$, $\Delta(1620)$!!!

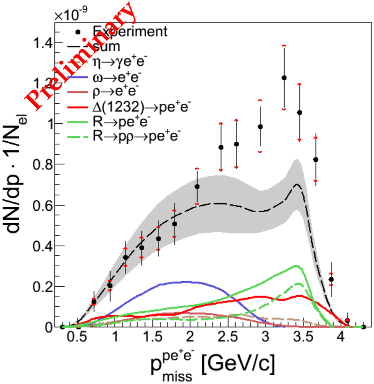




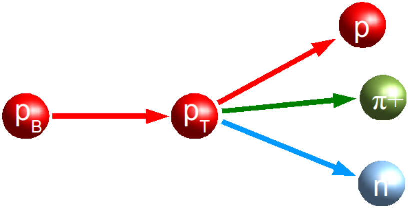
A poor man's approach

- Cocktail: Mesonic channels + $\Delta(1232)$ + Higher res. + ρ via $N^*(1520)$ + $\Delta(1232)\pi$ and $\eta\pi$ $\leftarrow$ free parameters constrainted by inclusive analisys.
- ρ produced via phase space. $\sigma_\rho = \frac{1}{2}\sigma_\omega$ see (Phys. Rev. Lett. 89(2002) 092001).
- additional production of ρ via $N^*(1520)$, $\Delta(1620)$!!!

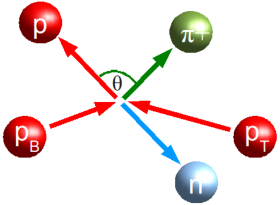




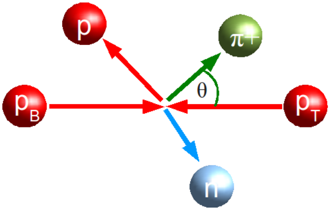
Angle definitions



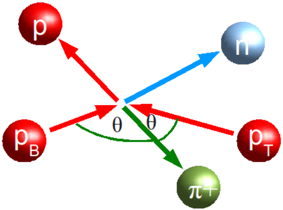
Input-output channel



Helicity

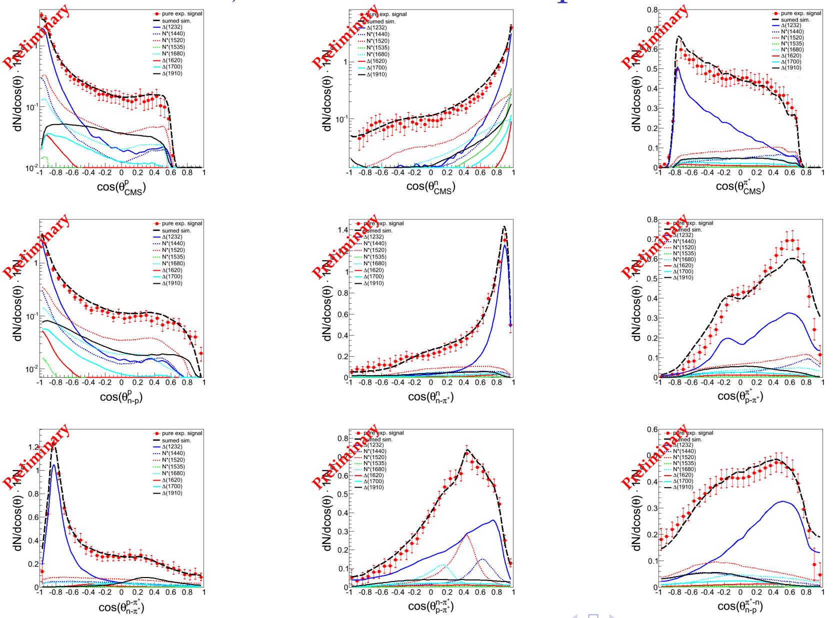


CMS

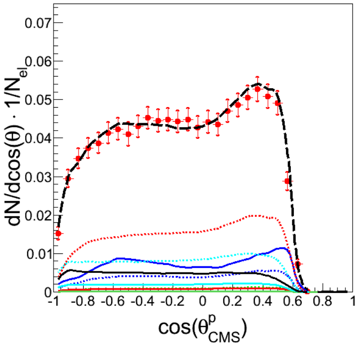


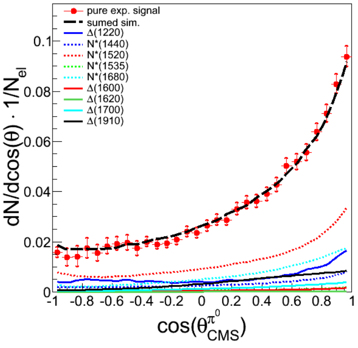
Godfrey-Jackson

$p(n)\pi^+$ - results in acceptance

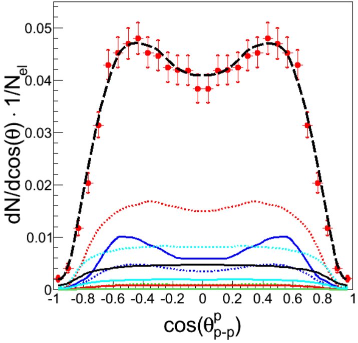


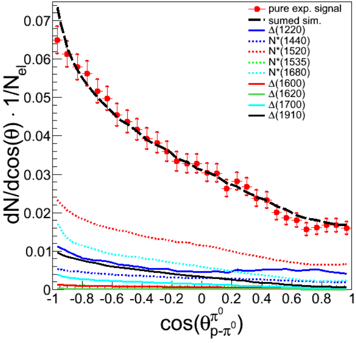
$pp(\pi^0)$ - Helicity & Godfrey-Jakcson angle



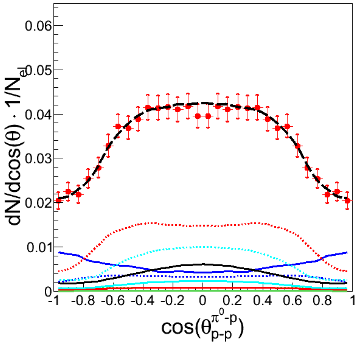


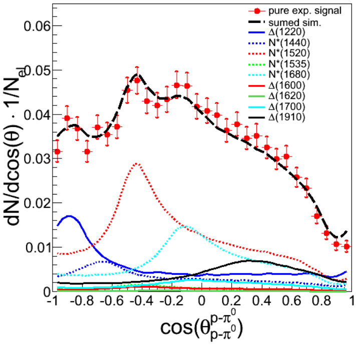
$pp(\pi^0)$ - Helicity & Godfrey-Jakcson angle





$pp(\pi^0)$ - Helicity & Godfrey-Jakcson angle





$N\pi$ - summary table.

J^P	Resonance	σ_{Res} $[mb]$	σ_{π^+} $[mb]$	σ_{π^0} $[mb]$
3/2+	$\Delta(1232)^{++}$	7.60±0.92	7.60±0.92	—
3/2+	$\Delta(1232)^{+}$	2.53±0.31	0.85±0.10	1.69±0.20
1/2-	$\Delta(1620)^{++}$	0.30±0.07	0.08±0.02	—
1/2-	$\Delta(1620)^{+}$	0.10±0.03	0.01±0.01	0.02±0.01
3/2-	$\Delta(1700)^{++}$	1.35±0.47	0.20±0.07	—
3/2-	$\Delta(1700)^{+}$	0.45±0.16	0.02±0.01	0.05±0.02
1/2+	$\Delta(1910)^{++}$	1.15±0.32	0.29±0.08	—
1/2+	$\Delta(1910)^{+}$	0.38±0.25	0.03±0.01	0.07±0.02
1/2+	$N^*(1440)^+$	1.50±0.27	0.65±0.12	0.39±0.07
3/2-	$N^*(1520)^+$	2.10±0.34	0.77±0.12	0.39±0.06
1/2-	$N^*(1535)^+$	**0.12**±0.04	0.04±0.01	0.02±0.01
5/2+	$N^*(1680)^+$	0.90±0.15	0.39±0.06	0.20±0.03

† - N^*1535 constarinted by $pp \to pp\eta$ channel (Khaled Teilab Phd thesis).

$$N^*(1535) \xrightarrow[\text{only 47\% from resonance}]{BR=52.5\%} p\eta$$

$$(\sigma_\eta = 137[\mu b] \longrightarrow \sigma_{N^*} = 122.5 \pm 6.9(stat) \pm 29.1(sys)\ [\mu b])$$

$\sigma^{\Delta}_{\pi^+} = 8.44 \pm 1.01$ [mb]

========

$\sigma^{I=\frac{3}{2}}_{\pi^+} = 0.63 \pm 0.19$ [mb]

========

$\sigma^{I=\frac{1}{2}}_{\pi^+} = 1.85 \pm 0.31$ [mb]

========

$\sigma_{\pi^+} = 10.92 \pm 1.52$ [mb]

$\sigma^{\Delta}_{\pi^0} = 1.73 \pm 0.21$ [mb]

========

$\sigma^{I=\frac{3}{2}}_{\pi^0} = 0.19 \pm 0.08$ [mb]

========

$\sigma^{I=\frac{1}{2}}_{\pi^0} = 1.03 \pm 0.16$ [mb]

========

$\sigma_{\pi^0} = 2.96 \pm 0.45$ [mb]

Comparison with Teis model

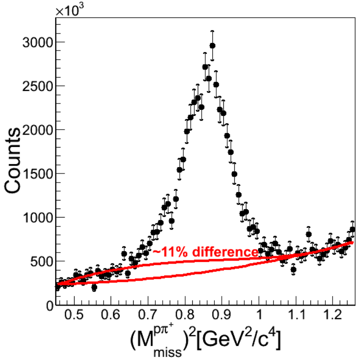
J^P	Resonance	Teis model σ_{π^0} [mb]	Teis model σ_{π^+} [mb]	Fit σ_{π^0} [mb]	Fit σ_{π^+} [mb]
3/2+	$\Delta(1232)$	1.33	6.67	1.69±0.21	8.44±1.01
1/2+	$N^*(1440)$	0.18	0.36	0.33±0.06	0.65±0.12
3/2-	$N^*(1520)$	0.04	0.08	0.39±0.06	0.77±0.12
1/2-	$N^*(1535)$	0.44	0.88	0.02±0.04	0.04
3/2+	$\Delta(1600)$	0.07	0.35		
1/2-	$\Delta(1620)$	0.12	0.62	0.02±0.01	0.09±0.03
1/2-	$N^*(1650)$	0.06	0.12		
5/2-	$N^*(1675)$	0.34	0.68		
5/2+	$N^*(1680)$	0.05	0.1	0.20±0.03	0.39±0.06
3/2+	$N^*(1720)$	0.01	0.03		
3/2-	$\Delta(1700)$	0.01	0.03	0.05±0.02	0.22±0.08
5/2+	$\Delta(1905)$	0.01	0.02		
1/2+	$\Delta(1910)$	0.12	0.65	0.07±0.02	0.32±0.09
1/2-	$\Delta(1950)$	0.04	0.23		

Review of BR($N\rho$) in a'la transport models

J^P	Resonance	σ_R	UrQMD	GiBUU
3/2+	$\Delta(1232)$	2.53±0.31	—	—
1/2+	$N^*(1440)$	1.50±0.27	—	—
3/2-	$N^*(1520)$	2.10±0.34	—	0.21
1/2-	$N^*(1535)$	0.12±0.04	—	0.03
3/2+	$\Delta(1600)$	0.24±0.10	—	—
1/2-	$\Delta(1620)$	0.10±0.03	—	0.29
1/2-	$N^*(1650)$	0.81±0.13	—	0.03
5/2-	$N^*(1675)$	1.65±0.27	—	—
5/2+	$N^*(1680)$	0.90±0.15	—	0.07
3/2+	$N^*(1720)$	4.41±0.72	0.25	0.87
3/2-	$\Delta(1700)$	0.45±0.16	0.10	0.08
5/2+	$\Delta(1905)$	0.85±0.53	0.60	0.87
1/2+	$\Delta(1910)$	0.38±0.25	0.40	—
1/2-	$\Delta(1950)$	0.10±0.06	none	none

Equivalent cross section

Errors estimation



- Systematical error has been calculated as a largest deviation of signal counts for different background polynomial functions in each bin of signal separately.

- Total error of each signal bin has been calculated as a sum of statistical and systematical errors.

- $\chi^2 = \sum \frac{(Y_i^{fit} - Y_i^{data})^2}{(\sigma_i^{TOTAL})^2} / NDF$

where *NDF* is number of fitted point minus 8 parameters (resonances amplitudes) minus 1.
$\chi^2_{TOTAL} = 0.91$
In the same way χ^2 can be calulated for each resonance.

- Error of estimated resonance cross section was calulated as $\sqrt{\frac{\sum (Y_i^{fit} - Y_i^{data})^2}{N-1}}$ with respect to χ^2_{Res}