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

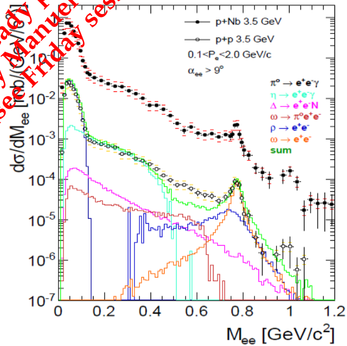
Adrian Dybczak

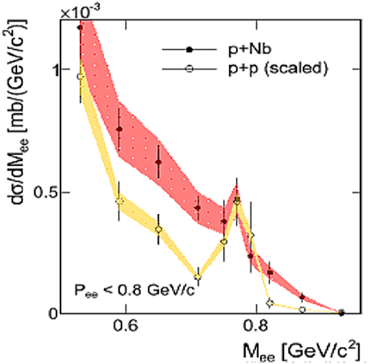
Jagiellonian University Cracow

June 4, 2012

Motivations

Already presented by Manuel Lorenz (see Friday session E2)





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 $R \to Ne^+e^-$

Already presented by Manuel Lorenz (see Friday session E2)

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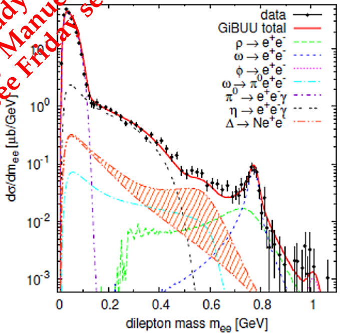

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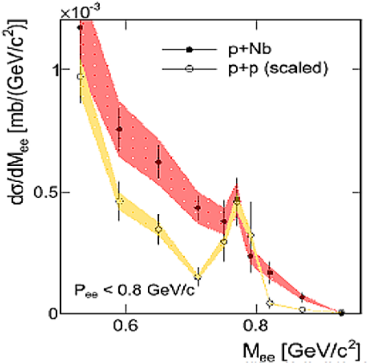

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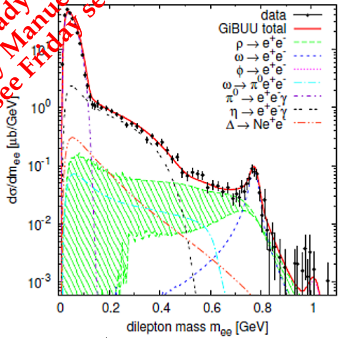

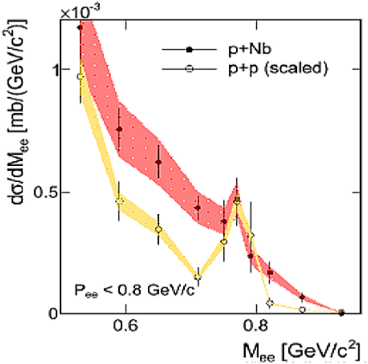

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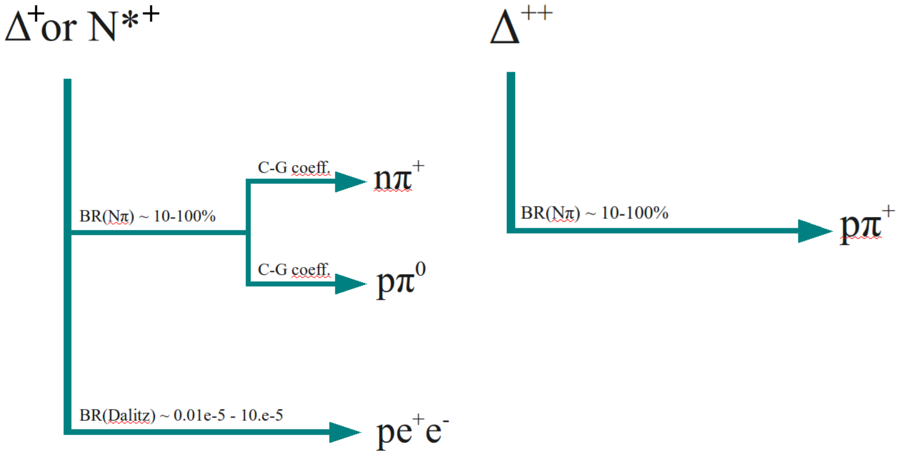
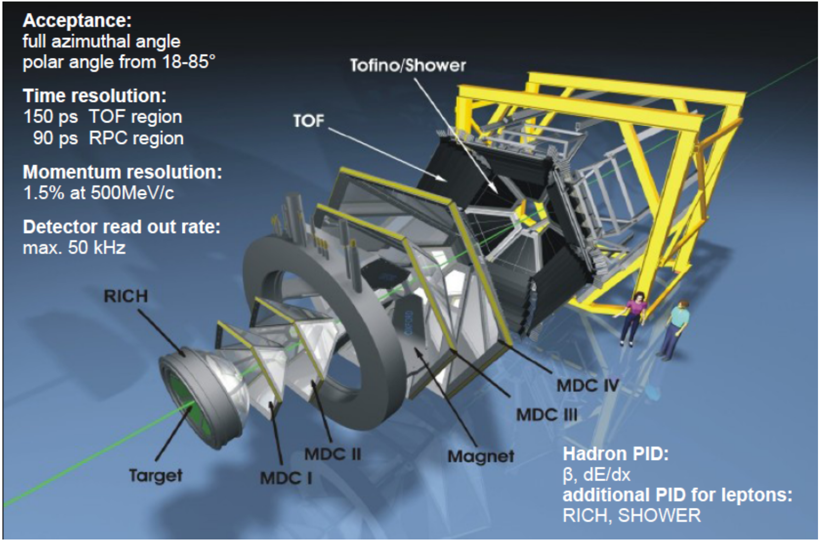
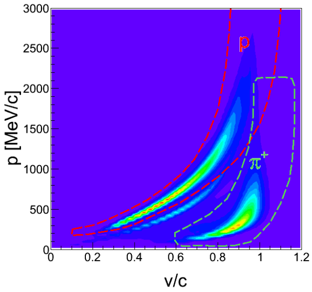
General idea

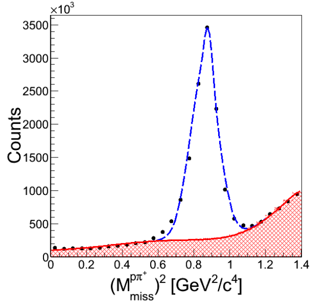


HADES spectrometer



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].

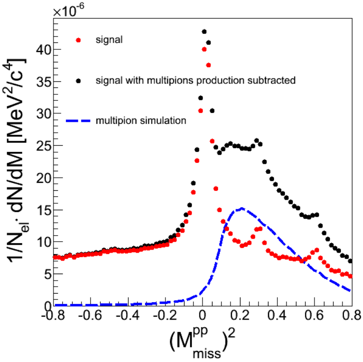
SIGNAL EXTRACTION

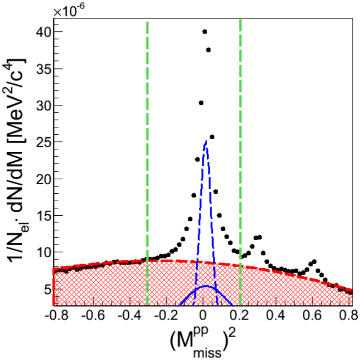
Signal is estimated as a number of counts in peak of neutron missing mass after background subtraction.

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 ($GEN \rightarrow GEANT \rightarrow DST \rightarrow ANALISYS$) 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	Teis model Γ_R[MeV]	Teis model $\Gamma^{N\pi}$	newest PWA Γ_R[MeV]	newest PWA $\Gamma^{N\pi}$	PDG (my fit) Γ_R[MeV]	PDG (my fit) $\Gamma^{N\pi}$	
$\Delta(1232)$	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	
$N^*(1535)$	203	0.50	125	0.46	125	0.46	⟸ constrainted (see Khaled Teilab PhD thesis)
$\Delta(1600)$	350	0.15	350	0.175			} REGION REPRESENTED BY $\Delta(1620)$
$\Delta(1620)$	150	0.3	150	0.25	150	0.25	
$N^*(1650)$	150	0.8	103	0.51			} REGION REPRESENTED BY $N^*(1680)$
$N^*(1675)$	150	0.45	151	0.40			
$N^*(1680)$	130	0.7	113	0.65	130	0.65	
$N^*(1720)$	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			} REGION REPRESENTED BY $\Delta(1910)$
$\Delta(1910)$	250	0.25	350	0.12	250	0.25	
$\Delta(1950)$	300	0.75	243	0.45			

- 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.

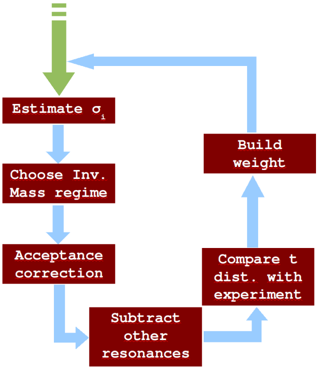
[1] S. Teis et al., Z. Phys. A 356 (1997) 421-435

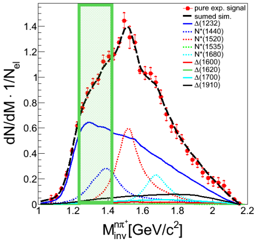
[2] A. V. Anisovich, arXiv:1112.4937v1

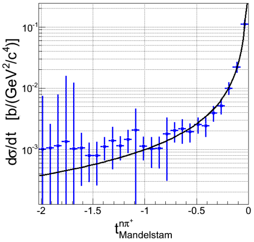
[3] M.I. Krivoruchenko et al., Annals Phys.296:299-346,2002

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

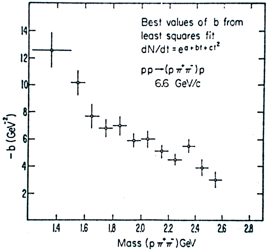
Adjusting resonance model in Hades acceptance







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



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

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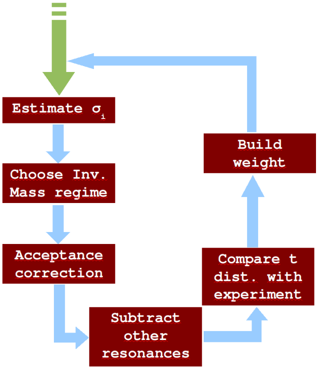

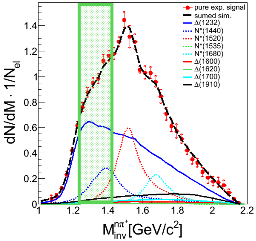

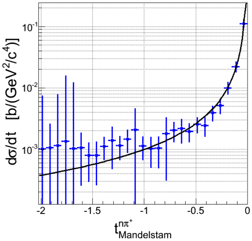

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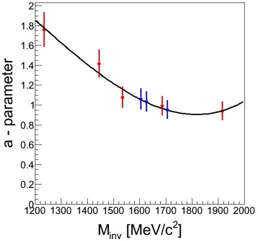
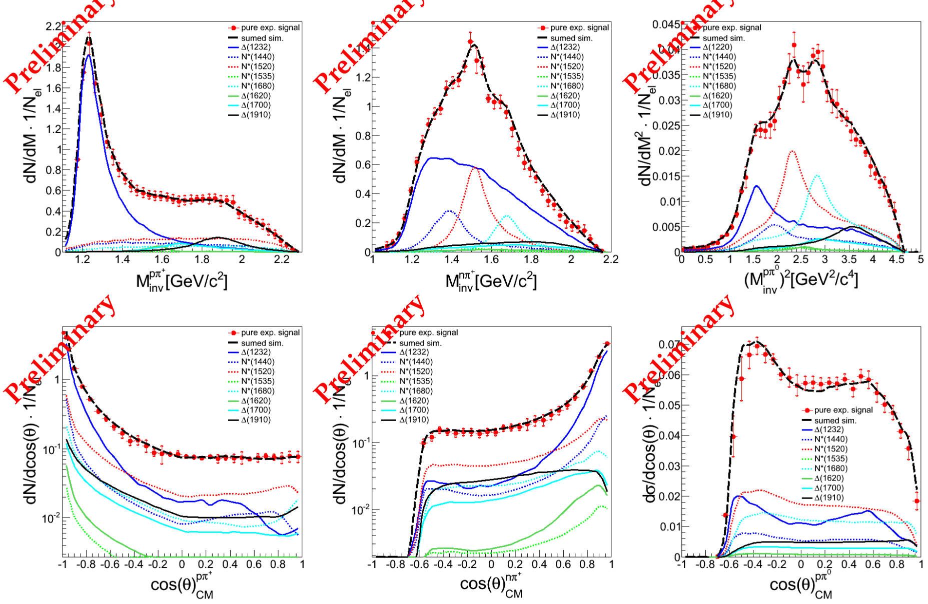
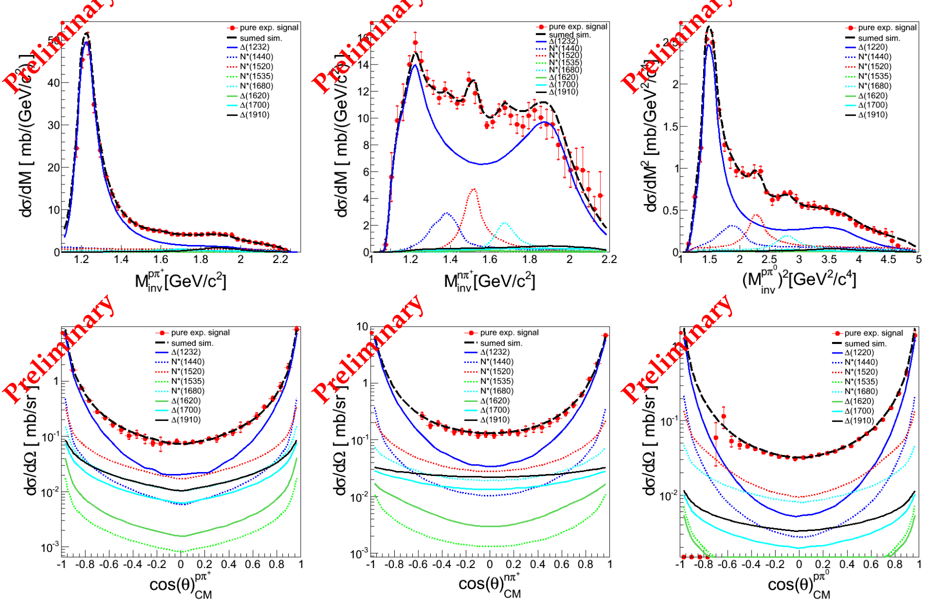


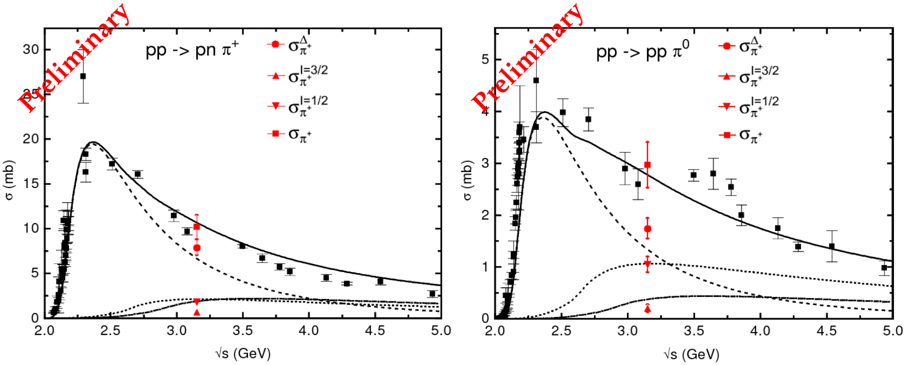
$p(n)\pi^+/pp(\pi^0)$ - results in acceptance



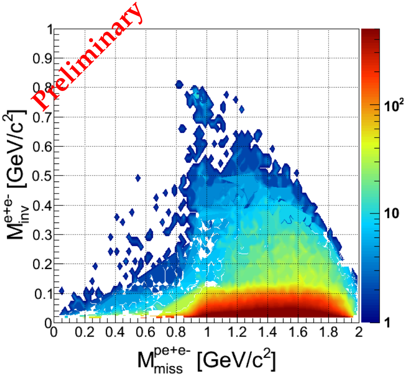
$p(n)\pi^+/pp(\pi^0)$ - acceptance corrected spectra

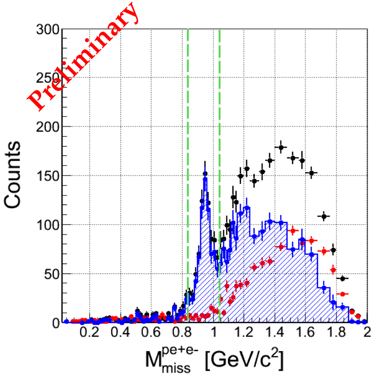


Comparison with Teis model



Dilepton analysis

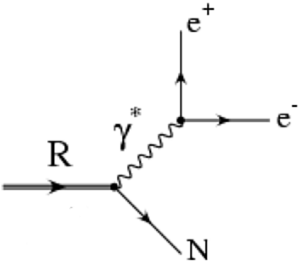




General conditions of signal extraction:

- 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

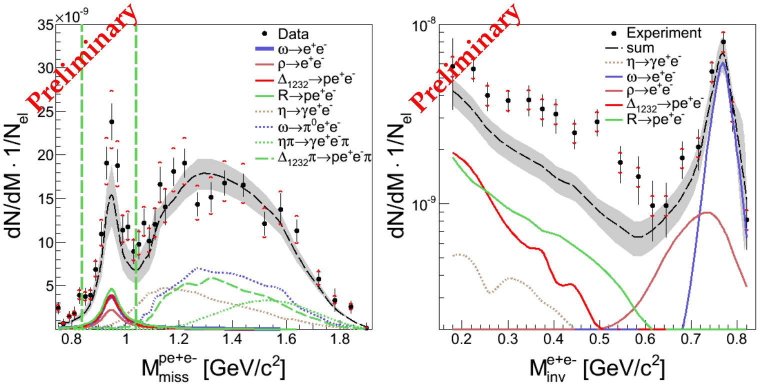


„Dilepton decays of baryon resonances" - M. Zetenyi and Gy. Wolf, Heavy Ion Phys. 17 (2003) 27-39

- 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: Mesonic channels + $\Delta(1232)$ + 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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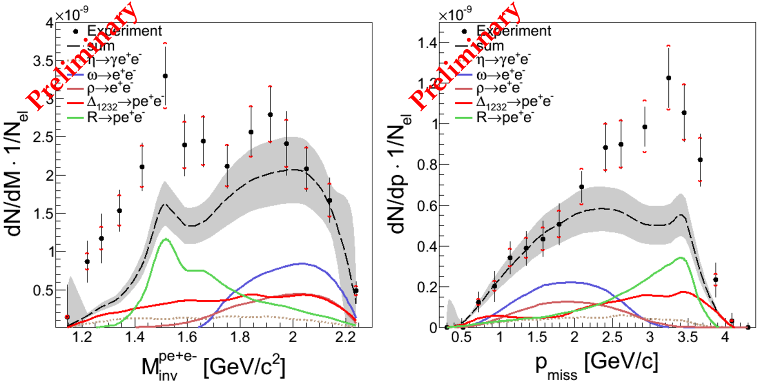
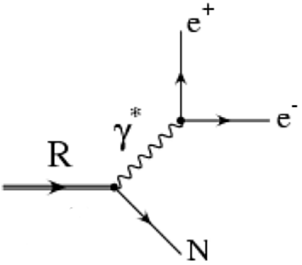
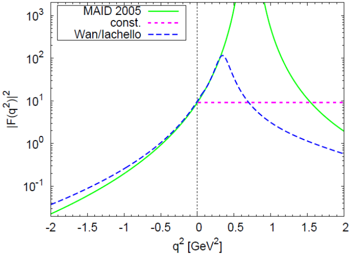


Comparison of QED model + $\Delta(1232)$ FF with data



+

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



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

Comparison of Zetenyi-Wolf (QED) model with data

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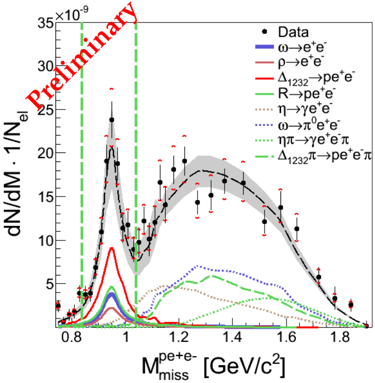

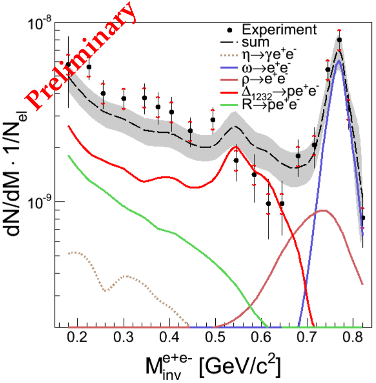

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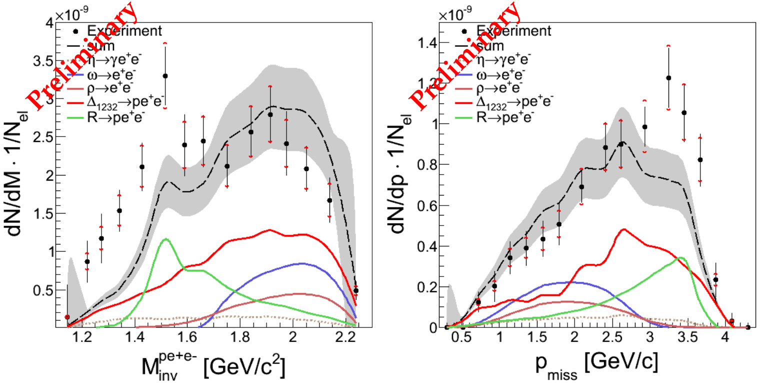
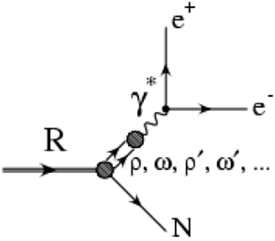


Comparison of Martemyanov-Krivoruchenko (eVMD) model with data

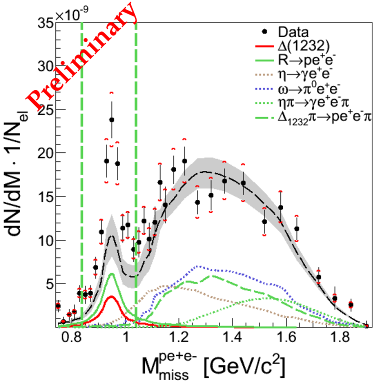


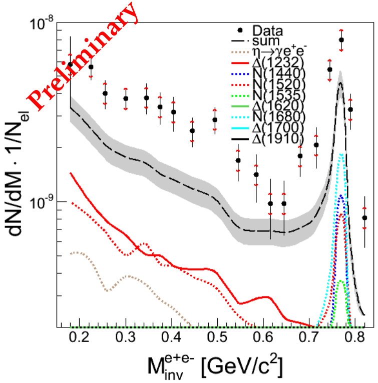
„Electromagnetic transition form factors and dilepton decay rates of nucleon resonances" - M.I. Krivoruchenko, B.V. Martemyanov, Annals Phys. 296: 299-346, 2002

- 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 !!!
- grey band do not contain model uncertainty.





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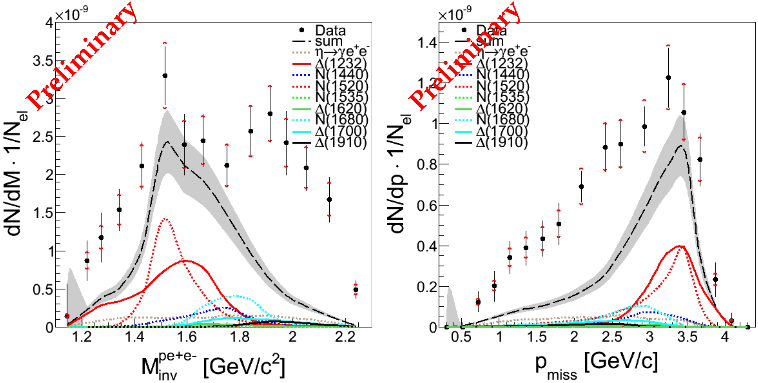
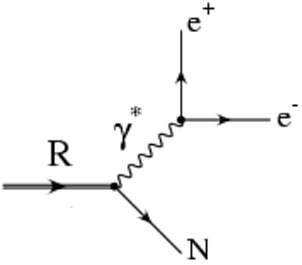


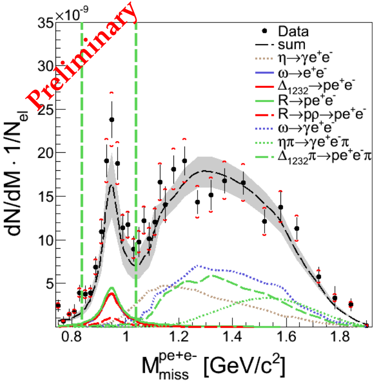
A poor man‘s approach

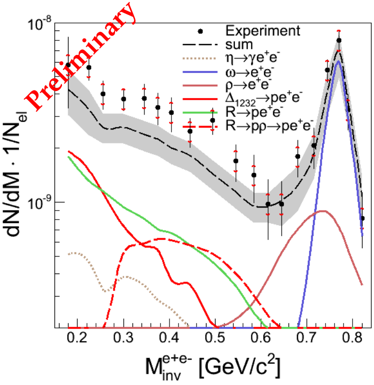


$$+ \quad R \to \rho N \to e^+e^-N$$

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 $N^*(1520)$, $\Delta(1620)$!!!





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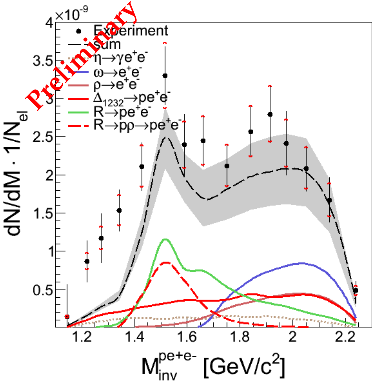


OUTLOOK & CONCLUSIONS

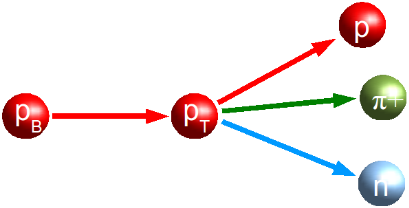
Hadronic part

- 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.

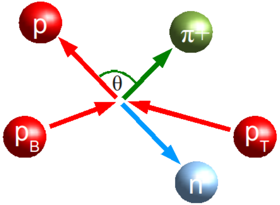
Leptonic part

- 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 ($M_{inv}^{pe^+e^-}$).
- A poor man‘s approach can describe shapes of observables in error range so seem to be second way to describe data, but has double counting problem.

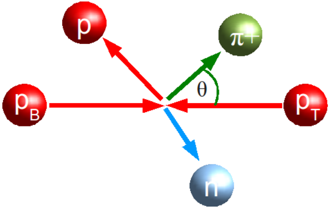
Angle definitions



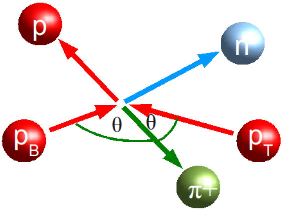
Input-output channel



Helicity

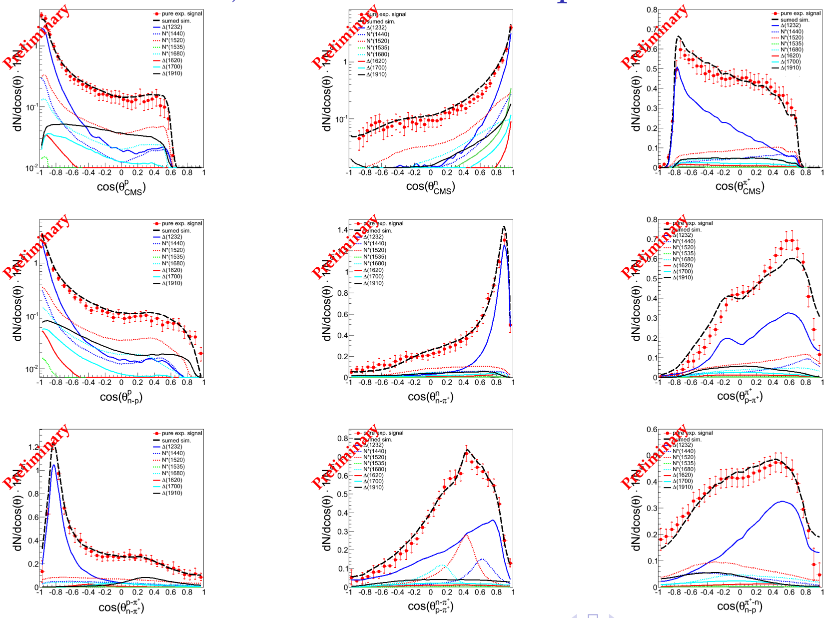


CMS

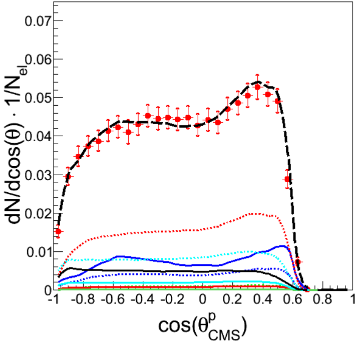


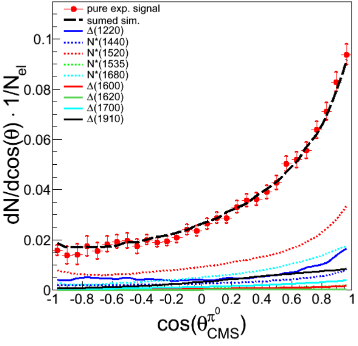
Godfrey-Jackson

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

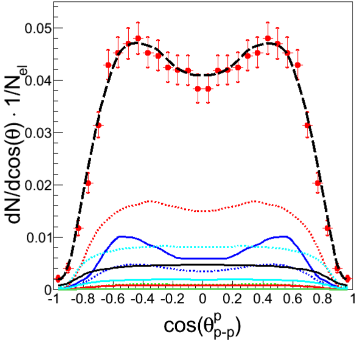


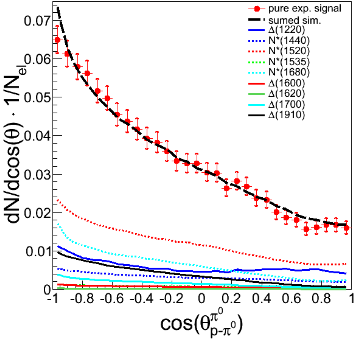
$pp(\pi^0)$ - Helicity & Godfrey-Jakcson angle



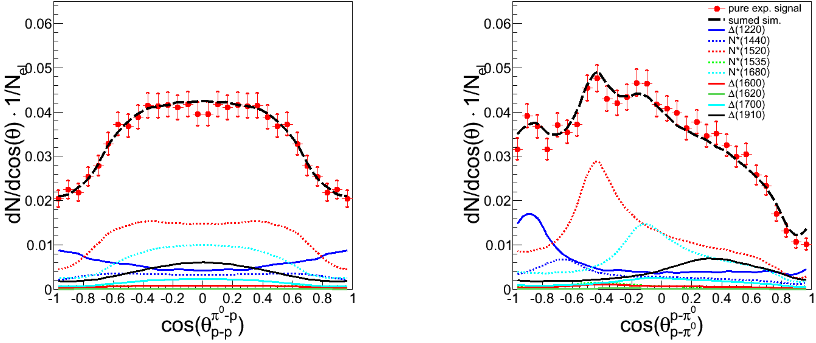


$pp(\pi^0)$ - Helicity & Godfrey-Jakcson angle





$pp(\pi^0)$ - 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

		Teis model		Fit	
J^P	Resonance	σ_{π^0} [mb]	σ_{π^+} [mb]	σ_{π^0} [mb]	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		

Backup slides

eVMD vs QED

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

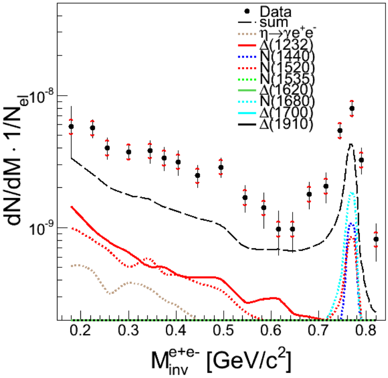
QED

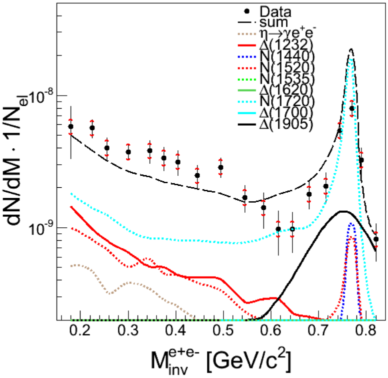
$BR(e^+e^-)$ at the pole
calulated as ratio of $BR(p\gamma)$ and 137
(arXiv.org/abs/nucl-th/0202047v1, page 12)

eVMD

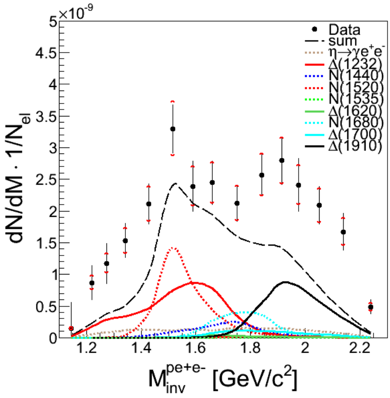
$BR(e^+e^-)$ at the pole
calulated as ratio of $\Gamma^{e^+e^-}$ and Γ^{tot}
(arXiv.org/abs/nucl-th/0110066v2, page 35)

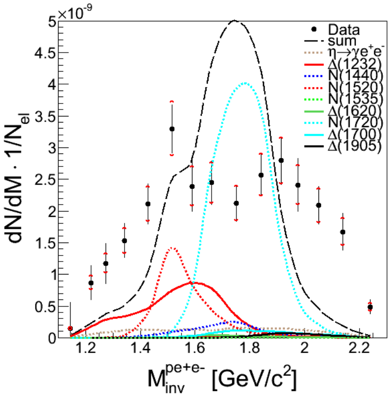
Model uncertainty in eVMD model



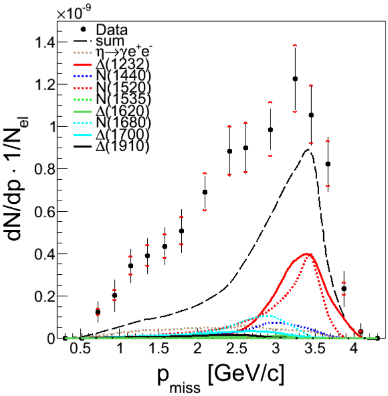


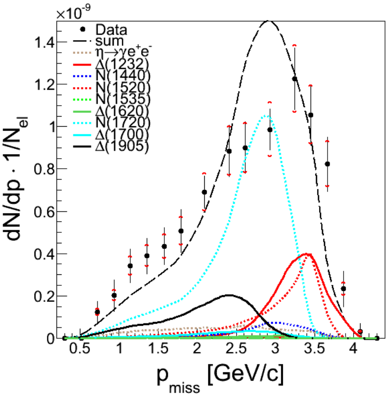
Model uncertainty in eVMD model



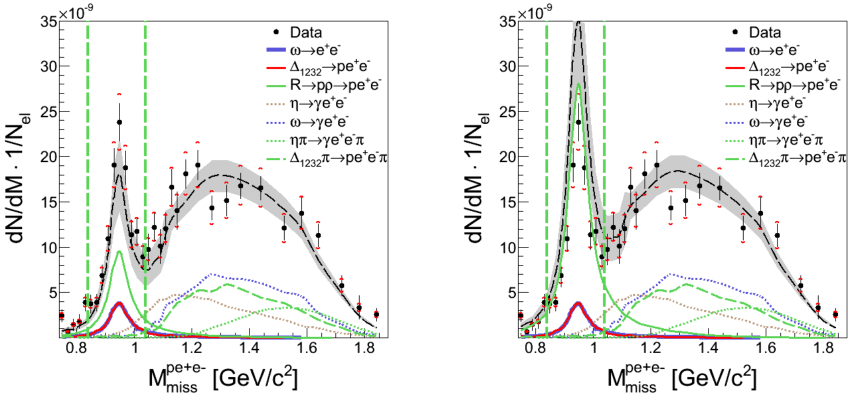


Model uncertainty in eVMD model

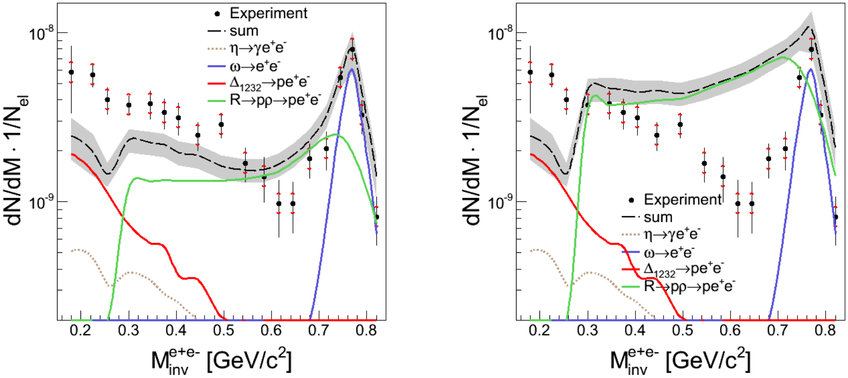




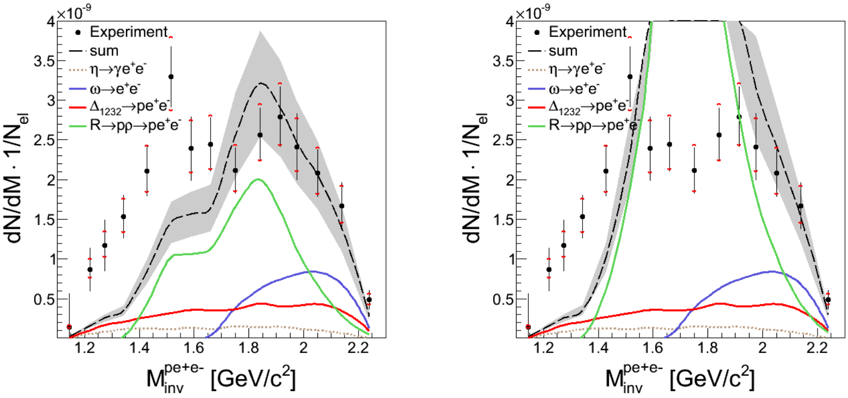
Model uncertainty in GiBUU model



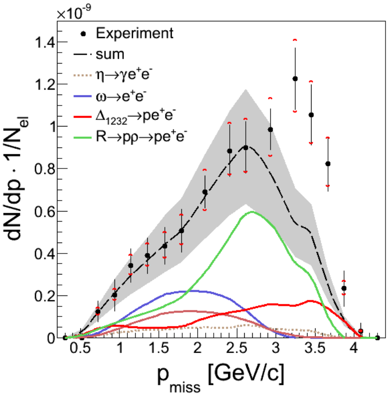
Model uncertainty in GiBUU model

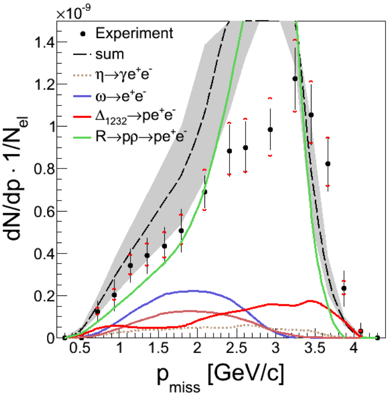


Model uncertainty in GiBUU model

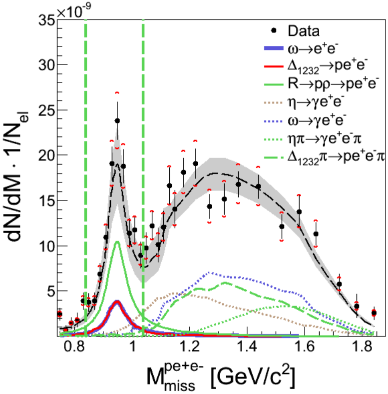


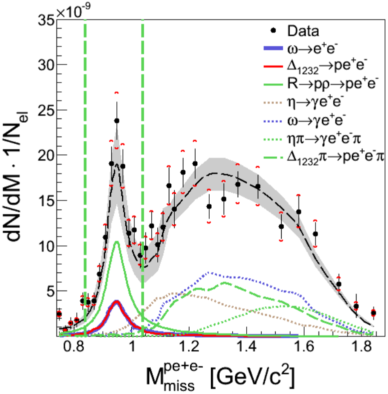
Model uncertainty in GiBUU model



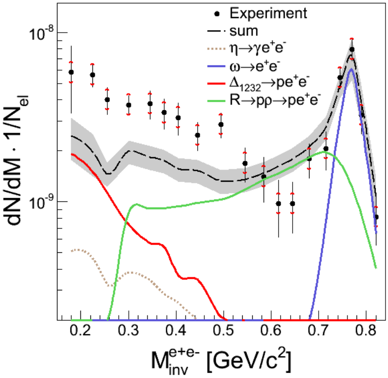


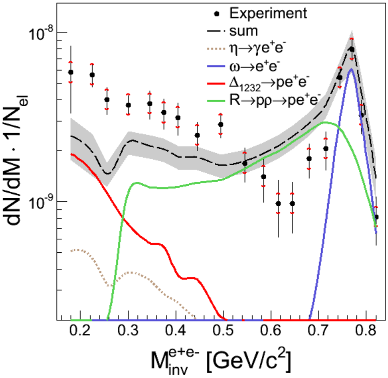
Model uncertainty in UrQMD model



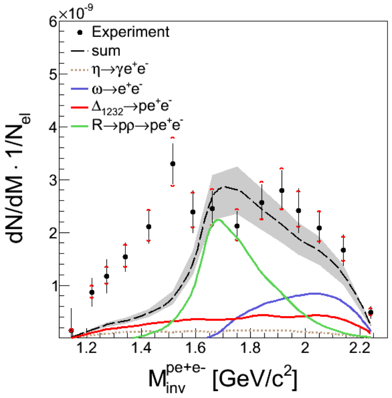


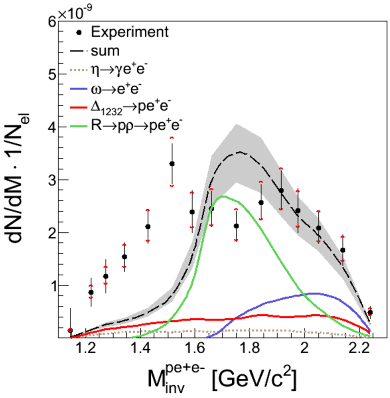
Model uncertainty in UrQMD model



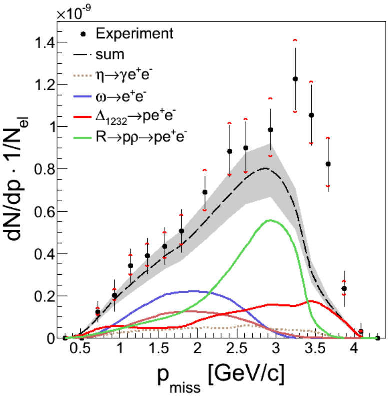


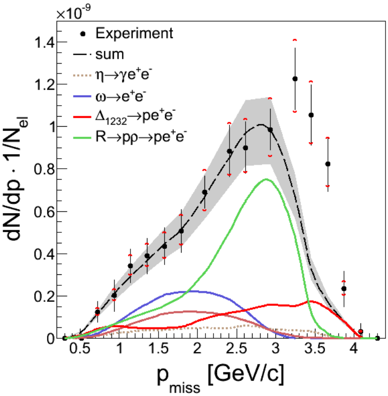
Model uncertainty in UrQMD model





Model uncertainty in UrQMD model





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

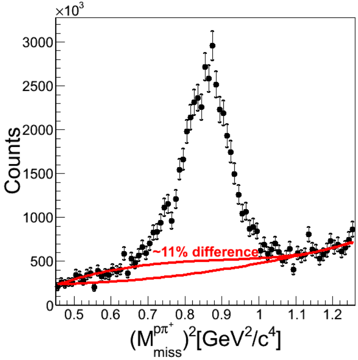
Review of BR($N\rho$) in a'la transport models

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	

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

	rating	M_0 [MeV]	Γ_0 [MeV]	$\lvert\mathcal{M}^2\rvert/16\pi$ [mb GeV^2] NR	ΔR	branching ratio in % πN	ηN	$\pi\Delta$	ρN	σN	$\pi N^*(1440)$	$\sigma\Delta$
$P_{11}(1440)$	****	1462	391	70	—	69	—	22_P	—	9	—	—
$S_{11}(1535)$	***	1534	151	8	60	51	43	—	$2_S + 1_D$	1	2	—
$S_{11}(1650)$	****	1659	173	4	12	89	3	2_D	3_D	2	1	—
$D_{13}(1520)$	****	1524	124	4	12	59	—	$5_S + 15_D$	21_S	—	—	—
$D_{15}(1675)$	****	1676	159	17	—	47	—	53_D	—	—	—	—
$P_{13}(1720)$	*	1717	383	4	12	13	—	—	87_P	—	—	—
$F_{15}(1680)$	****	1684	139	4	12	70	—	$10_P + 1_F$	$5_P + 2_F$	12	—	—
$P_{33}(1232)$	****	1232	118	OBE	210	100	—	—	—	—	—	—
$S_{31}(1620)$	**	1672	154	7	21	9	—	62_D	$25_S + 4_D$	—	—	—
$D_{33}(1700)$	*	1762	599	7	21	14	—	$74_S + 4_D$	8_S	—	—	—
$P_{31}(1910)$	****	1882	239	14	—	23	—	—	—	—	67	10_P
$P_{33}(1600)$	***	1706	430	14	—	12	—	68_P	—	—	20	—
$F_{35}(1905)$	***	1881	327	7	21	12	—	1_P	87_P	—	—	—
$F_{37}(1950)$	****	1945	300	14	—	38	—	18_F	—	—	—	44_F

Errors estimation



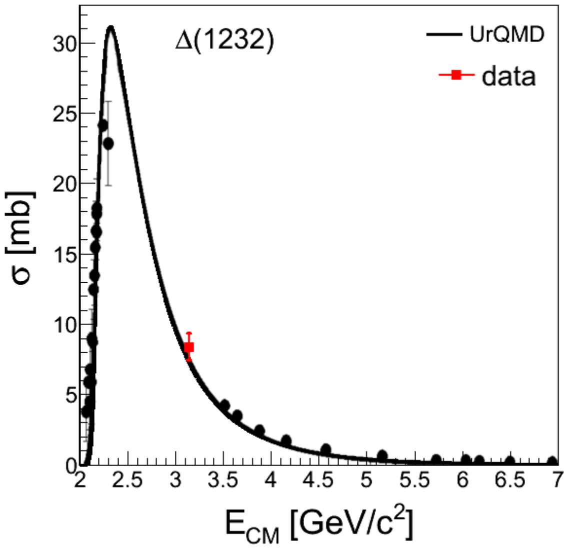
- Systematical error has been calculated as a largest deviation of signal counts for different background polynomial functions in each bin of signal separately.

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

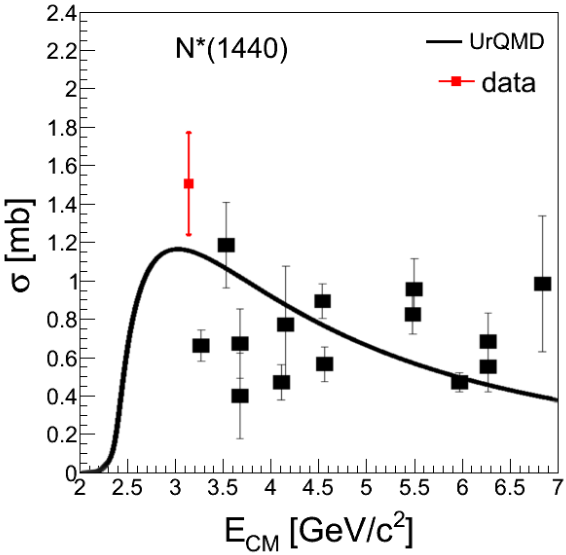
- $\chi^2 = \sum \frac{(Y_i^{fit} - Y_i^{data})^2}{(\sigma_i^{TOTAL})^2}/NDF$
where *NDF* is number of fitted point minus 8 parameters (resonances amplitudes) minus 1.
$\chi^2_{TOTAL} = 0.91$
In the same way χ^2 can be calulated for each resonance.

- 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}

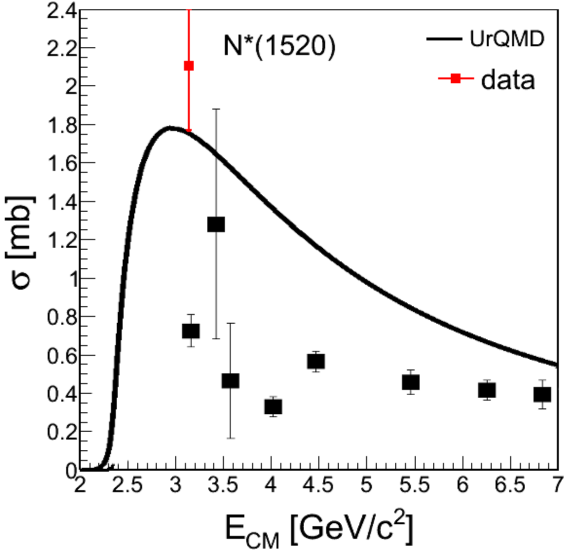
Comparison with UrQMD



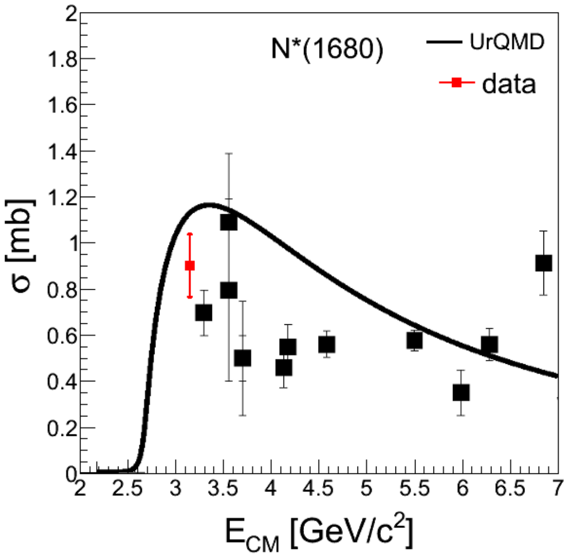
Comparison with UrQMD



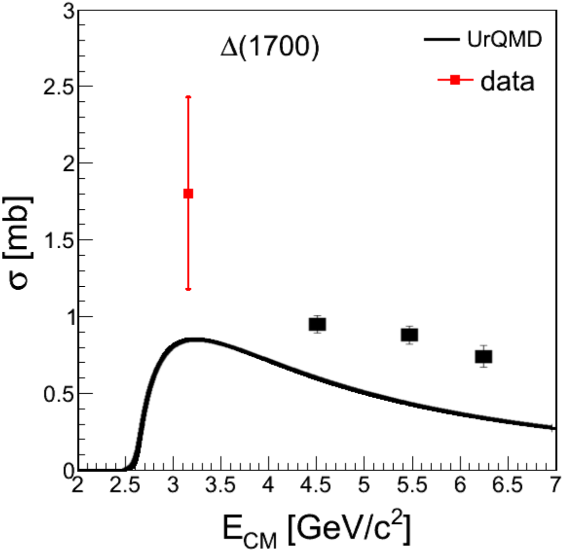
Comparison with UrQMD



Comparison with UrQMD



Comparison with UrQMD

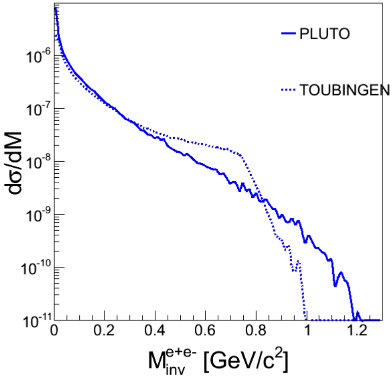


$\Delta(1232)$

- 4π

Condition	Integral QED	Integral eVMD
4π	2.34e-07	1.40e-07
oa$>9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	eVMD	QED
$BR(e^+e^-)$	4.00e-6	3.06e-6

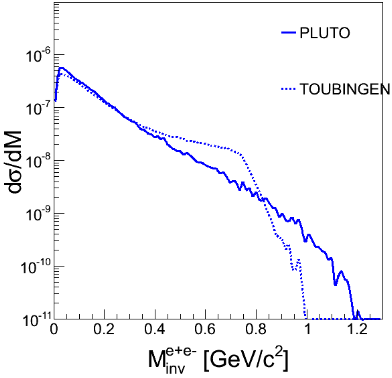


$\Delta(1232)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	2.34e-07	1.40e-07
oa$>9[°]$	8.05e-08	7.53e-08
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	eVMD	QED
$BR(e^+e^-)$	4.00e-6	3.06e-6

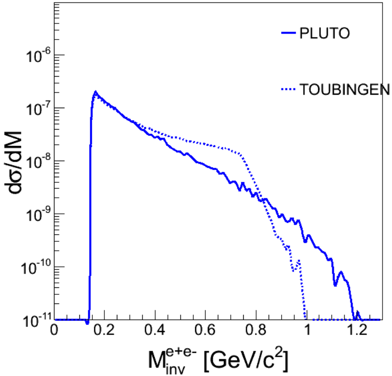


$\Delta(1232)$

- 4π + oa$>9[^\circ]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	2.34e-07	1.40e-07
oa$>9[^\circ]$	8.05e-08	7.53e-08
$M_{inv}^{e^+e^-} > 0.15$	2.63e-08	2.95e-08
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	eVMD	QED
$BR(e^+e^-)$	4.00e-6	3.06e-6

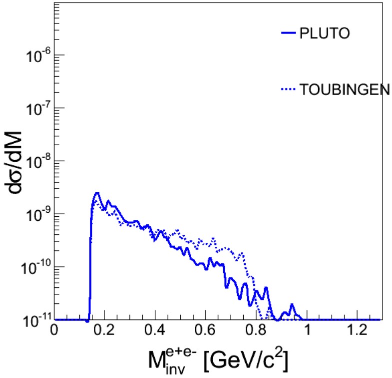


$\Delta(1232)$

- ACC + oa$>9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	2.34e-07	1.40e-07
oa$>9[°]$	8.05e-08	7.53e-08
$M_{inv}^{e^+e^-} > 0.15$	2.63e-08	2.95e-08
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	3.39e-10	3.23e-10

	eVMD	QED
$BR(e^+e^-)$	4.00e-6	3.06e-6

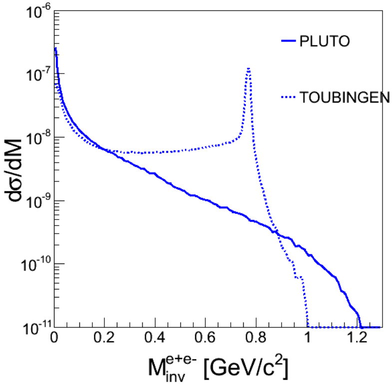


$N^*(1440)$

- 4π

Condition	Integral QED	Integral eVMD
4π	8.3e-9	1.01e-8
oa$>9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.06e-6	4.00e-6

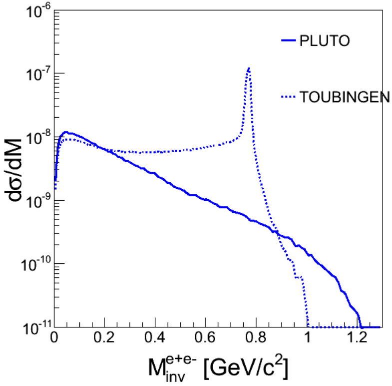


$N^*(1440)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	8.3e-9	1.01e-8
oa$>9[°]$	3.11e-9	7.96e-9
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.06e-6	4.00e-6

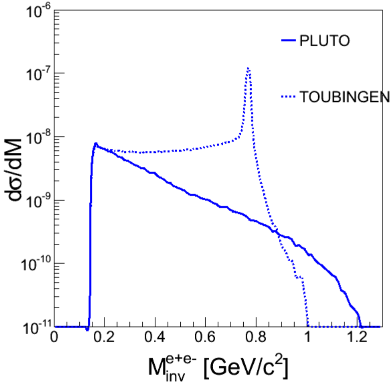


$N^*(1440)$

- 4π + oa$>9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	8.3e-9	1.01e-8
oa$>9[°]$	3.11e-9	7.96e-9
$M_{inv}^{e^+e^-} > 0.15$	1.70e-9	6.81e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.06e-6	4.00e-6

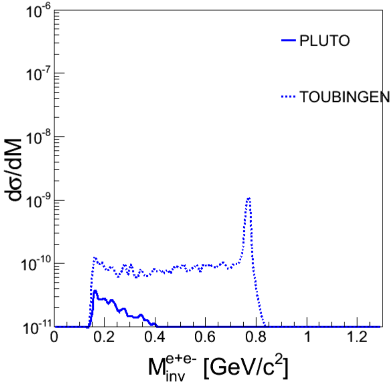


$N^*(1440)$

- ACC + oa$> 9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	8.3e-9	1.01e-8
oa$> 9[°]$	3.11e-9	7.96e-9
$M_{inv}^{e^+e^-} > 0.15$	1.70e-9	6.81e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	6.89e-12	7.86e-11

	QED	eVMD
$BR(e^+e^-)$	3.06e-6	4.00e-6

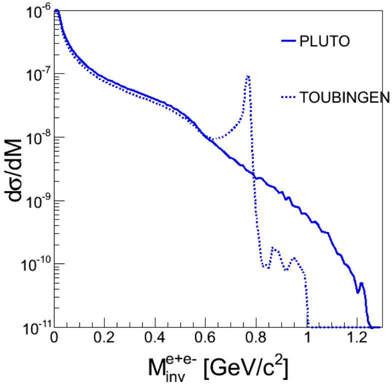


$N^*(1520)$

- 4π

Condition	Integral QED	Integral eVMD
4π	1.08e-7	7.35e-8
oa$> 9[^\circ]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.72e-5	5.0e-5

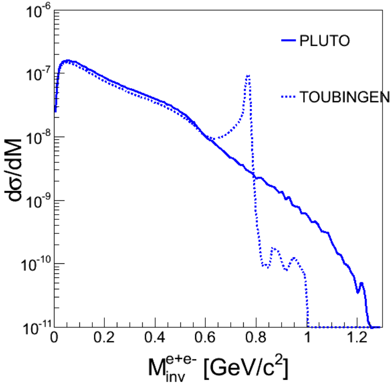


$N^*(1520)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	1.08e-7	7.35e-8
oa$>9[°]$	4.21e-8	4.05e-8
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.72e-5	5.0e-5

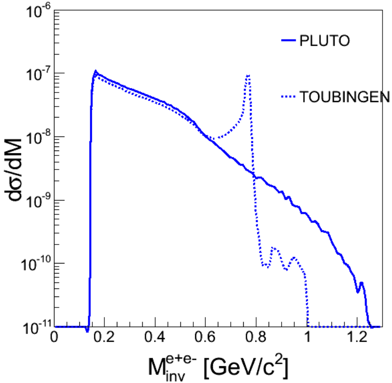


$N^*(1520)$

- 4π + oa> 9[°] + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	1.08e-7	7.35e-8
oa> 9[°]	4.21e-8	4.05e-8
$M_{inv}^{e^+e^-} > 0.15$	2.28e-8	2.29e-8
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	3.72e-5	5.0e-5

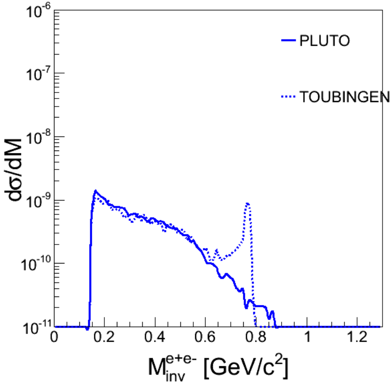


$N^*(1520)$

- ACC + oa$> 9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	1.08e-7	7.35e-8
oa$> 9[°]$	4.21e-8	4.05e-8
$M_{inv}^{e^+e^-} > 0.15$	2.28e-8	2.29e-8
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	2.68e-10	2.27e-10

	QED	eVMD
$BR(e^+e^-)$	3.72e-5	5.0e-5

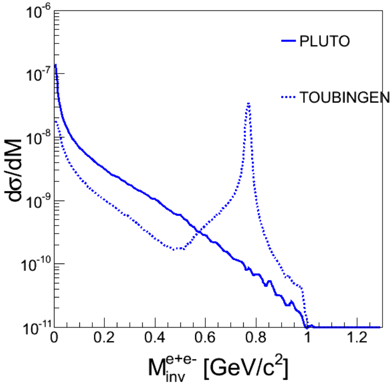


$N^*(1535)$

- 4π

Condition	Integral QED	Integral eVMD
4π	4.22e-9	1.98e-9
oa$> 9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.45e-5	1.34e-5

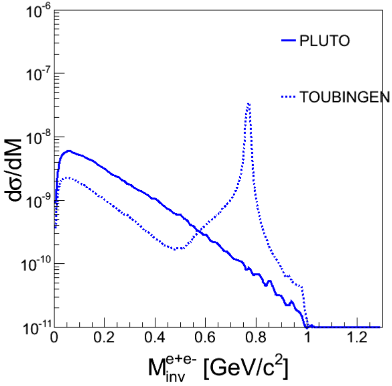


$N^*(1535)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	4.22e-9	1.98e-9
oa$>9[°]$	1.41e-9	1.41e-9
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.45e-5	1.34e-5

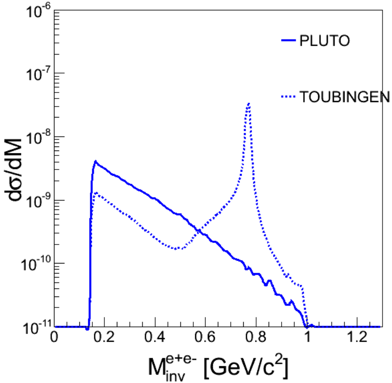


$N^*(1535)$

- 4π + oa$>9[^\circ]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	4.22e-9	1.98e-9
oa$>9[^\circ]$	1.41e-9	1.41e-9
$M_{inv}^{e^+e^-} > 0.15$	0.7e-9	1.17e-9
$M_{miss}^{pe^+e^-} \in (0.84-1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.45e-5	1.34e-5

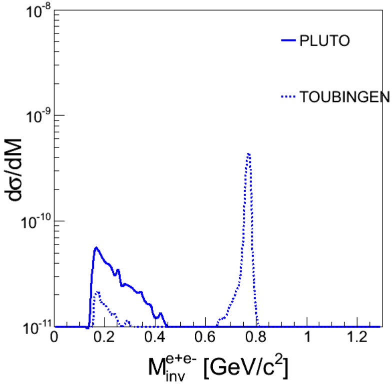


$N^*(1535)$

- ACC + oa$>9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84-1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	4.22e-9	1.98e-9
oa$>9[°]$	1.41e-9	1.41e-9
$M_{inv}^{e^+e^-} > 0.15$	0.7e-9	1.17e-9
$M_{miss}^{pe^+e^-} \in (0.84-1.02)$	9.45e-12	1.89e-11

	QED	eVMD
$BR(e^+e^-)$	1.45e-5	1.34e-5

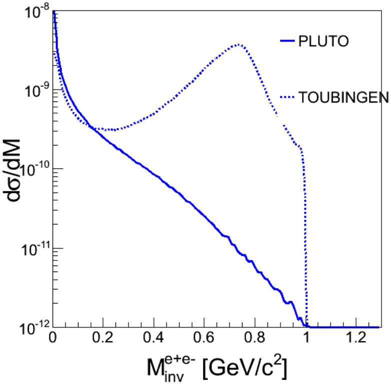


$\Delta(1620)$

- 4π

Condition	Integral QED	Integral eVMD
4π	3.3e-10	1.11e-9
oa$> 9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.75e-6	8.8e-6

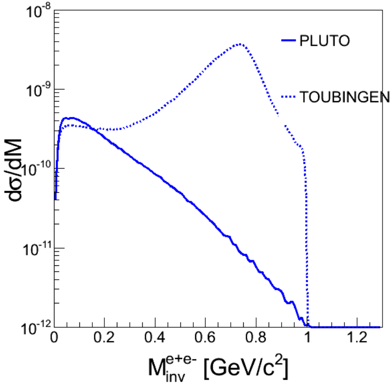


$\Delta(1620)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	3.3e-10	1.11e-9
oa$>9[°]$	1.1e-10	1.02e-9
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.75e-6	8.8e-6

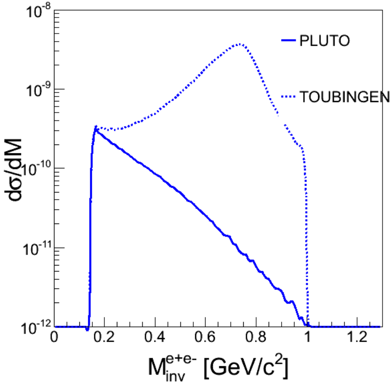


$\Delta(1620)$

- 4π + oa$>9[^\circ]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	3.3e-10	1.11e-9
oa$>9[^\circ]$	1.1e-10	1.02e-9
$M_{inv}^{e^+e^-} > 0.15$	5.76e-11	9.81e-10
$M_{miss}^{pe^+e^-} \in (0.84-1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.75e-6	8.8e-6

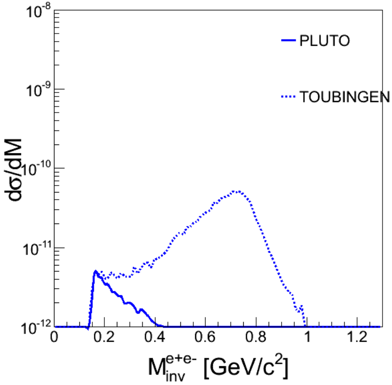


$\Delta(1620)$

- ACC + oa$> 9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	3.3e-10	1.11e-9
oa$> 9[°]$	1.1e-10	1.02e-9
$M_{inv}^{e^+e^-} > 0.15$	5.76e-11	9.81e-10
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	8.10e-13	1.36e-11

	QED	eVMD
$BR(e^+e^-)$	1.75e-6	8.8e-6

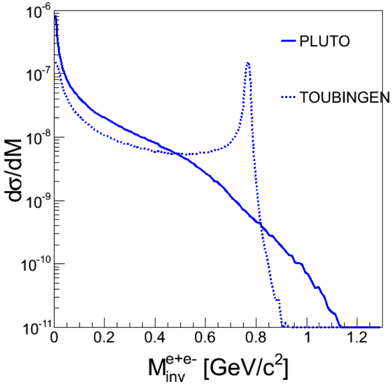


$N^*(1680)$

- 4π

Condition	Integral QED	Integral eVMD
4π	2.59e-8	1.52e-8
oa$>9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.97e-5	1.98e-5

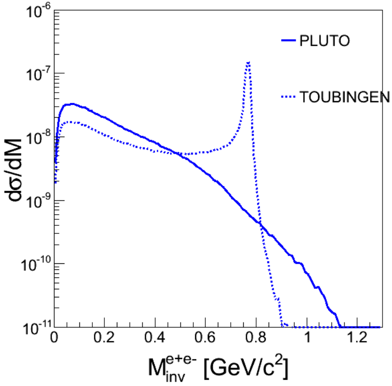


$N^*(1680)$

- 4π + oa$> 9[°]$

Condition	Integral QED	Integral eVMD
4π	2.59e-8	1.52e-8
oa$> 9[°]$	9.06e-9	1.02e-8
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.97e-5	1.98e-5

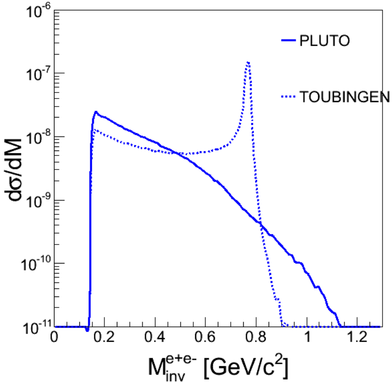


$N^*(1680)$

- 4π + oa$> 9[^\circ]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	2.59e-8	1.52e-8
oa$> 9[^\circ]$	9.06e-9	1.02e-8
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.97e-5	1.98e-5

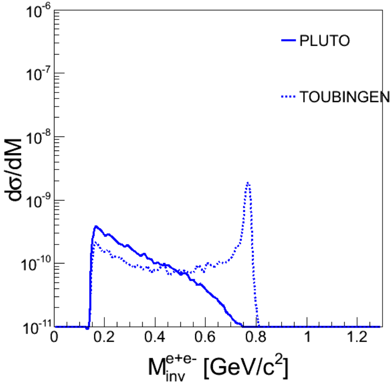


$N^*(1680)$

- ACC + oa$>$ 9[°] + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	2.59e-8	1.52e-8
oa$>$ 9[°]	9.06e-9	1.02e-8
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	7.22e-11	1.11e-10

	QED	eVMD
$BR(e^+e^-)$	1.97e-5	1.98e-5

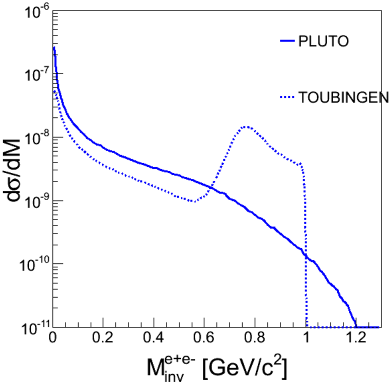


$\Delta(1700)$

- 4π

Condition	Integral QED	Integral eVMD
4π	8.89e-9	6.16e-9
oa$>9[°]$		
$M^{e^+e^-}_{inv} > 0.15$		
$M^{pe^+e^-}_{miss} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.38e-5	2.0e-5

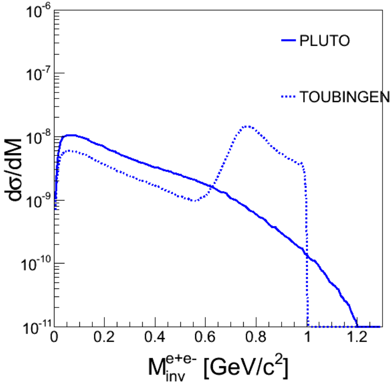


$\Delta(1700)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	8.89e-9	6.16e-9
oa$>9[°]$	3.42e-9	4.42e-9
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.38e-5	2.0e-5

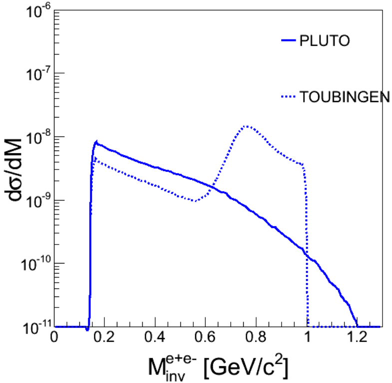


$\Delta(1700)$

- 4π + oa$>9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	8.89e-9	6.16e-9
oa$>9[°]$	3.42e-9	4.42e-9
$M_{inv}^{e^+e^-} > 0.15$	6.62e-9	3.68e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	1.38e-5	2.0e-5

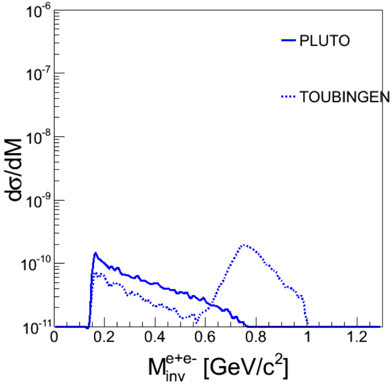


$\Delta(1700)$

- ACC + oa$>$ 9[°] + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	8.89e-9	6.16e-9
oa$>$ 9[°]	3.42e-9	4.42e-9
$M_{inv}^{e^+e^-} > 0.15$	6.62e-9	3.68e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	3.03e-11	4.80e-11

	QED	eVMD
$BR(e^+e^-)$	1.38e-5	2.0e-5

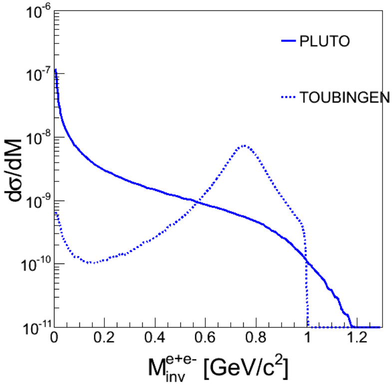


$\Delta(1910)$

- 4π

Condition	Integral QED	Integral eVMD
4π	4.04e-9	1.41e-9
oa$> 9[°]$		
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	0.73e-5	0.52e-5

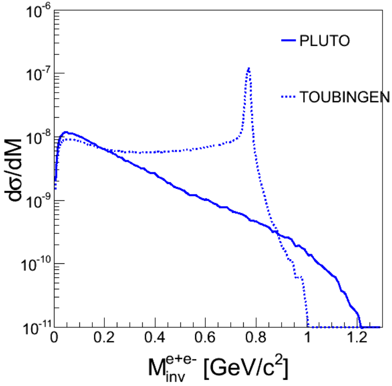


$\Delta(1910)$

- 4π + oa$>9[°]$

Condition	Integral QED	Integral eVMD
4π	4.04e-9	1.41e-9
oa$>9[°]$	1.52e-9	1.39e-9
$M_{inv}^{e^+e^-} > 0.15$		
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	0.73e-5	0.52e-5

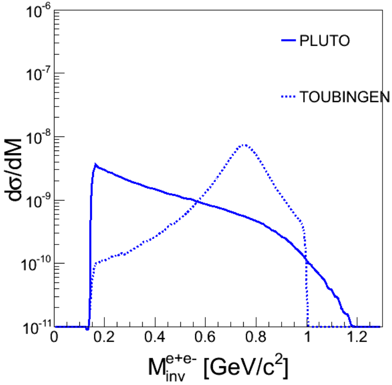


$\Delta(1910)$

- 4π + oa$>9[^\circ]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	4.04e-9	1.41e-9
oa$>9[^\circ]$	1.52e-9	1.39e-9
$M_{inv}^{e^+e^-} > 0.15$	1.0e-9	1.38e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$		

	QED	eVMD
$BR(e^+e^-)$	0.73e-5	0.52e-5



$\Delta(1910)$

- ACC + oa$> 9[°]$ + $M_{inv}^{e^+e^-} > 0.15[GeV/c^2]$ + $M_{miss}^{pe^+e^-} \in (0.84 - 1.02)[GeV/c^2]$

Condition	Integral QED	Integral eVMD
4π	4.04e-9	1.41e-9
oa$> 9[°]$	1.52e-9	1.39e-9
$M_{inv}^{e^+e^-} > 0.15$	1.0e-9	1.38e-9
$M_{miss}^{pe^+e^-} \in (0.84 - 1.02)$	1.62e-11	2.06e-11

	QED	eVMD
$BR(e^+e^-)$	0.73e-5	0.52e-5