ON A MISSED SOURCE OF DIELECTRONS IN NUCLEUS-NUCLEUS COLLISIONS.

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XIX Int. Baldin Sem.
29 Sept. - 4 Oct. 2008
Dubna,Russia

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- Dibaryon mechanism for dielectron production in NN collisions
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- *Contribution of the* $NN \to e^+e^-d_1^*$ *mechanism to the HADES* $AA \to e^+e^-X$ *data*
- Conclusion

INTRODUCTION

Dielectrons are sensetive tool for probing the properties of hot and dense hadronic matter

Their interaction with mater is relatively weak and is known

Dominant mechanisms of dielectron production at 1-2 GeV per nucleon:

- **Dalitz decay of the π^0-, η-, and ω mesons and of the baryon resonances Δ(1232) and N*(1520),...**
- **Direct decay of the π^0-, ρ-, and ω- mesons**
- **Bremsstrahlung in NN and $\pi\pi$ collisions**

DLS Measurements: $A+A \to e^+e^-X$ for C+C and Ca+Ca at 1.04 A GeV $\Longrightarrow$
Substantial Excees of the e^+e^- pairs in the mass region $0.15 < M_{ee} < 0.6$ GeV

To understand the origin of this excess (the DLS puzzle) the DLS has measured the spectra for the $pp \to e^+e^-X$ and $pd \to e^+e^-X$ reactions at T_p = 1-5 GeV
Excees of the e^+e^- pairs in the same mass region as in the AA collisions

HADES Measurements: $A+A \to e^+e^-X$ spectra for C+C collisions at 1A and 2A GeV confirmation of the DLS finding.

Exsess origin $\Longrightarrow$ a new source of dielectron production ?

The aim of this talk: the exsess is due to a new source $NN \to \gamma^* d^*_1(1956) \to e^+e\, d^*_1$

Experimental evidences for the $d^*_1(1956)$ in the processes with real photons

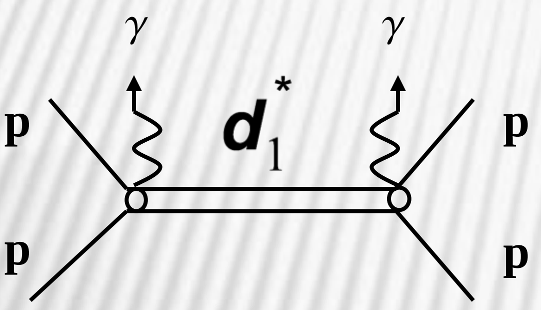
FIRST EVIDENCE FOR THE $d_1^*(1956)$

A.S. Khrykin et al., Phys.Rev.C64,034002(2001)

pp→$\gamma\gamma X$

T_p=216 MeV; θ_γ=±90^0

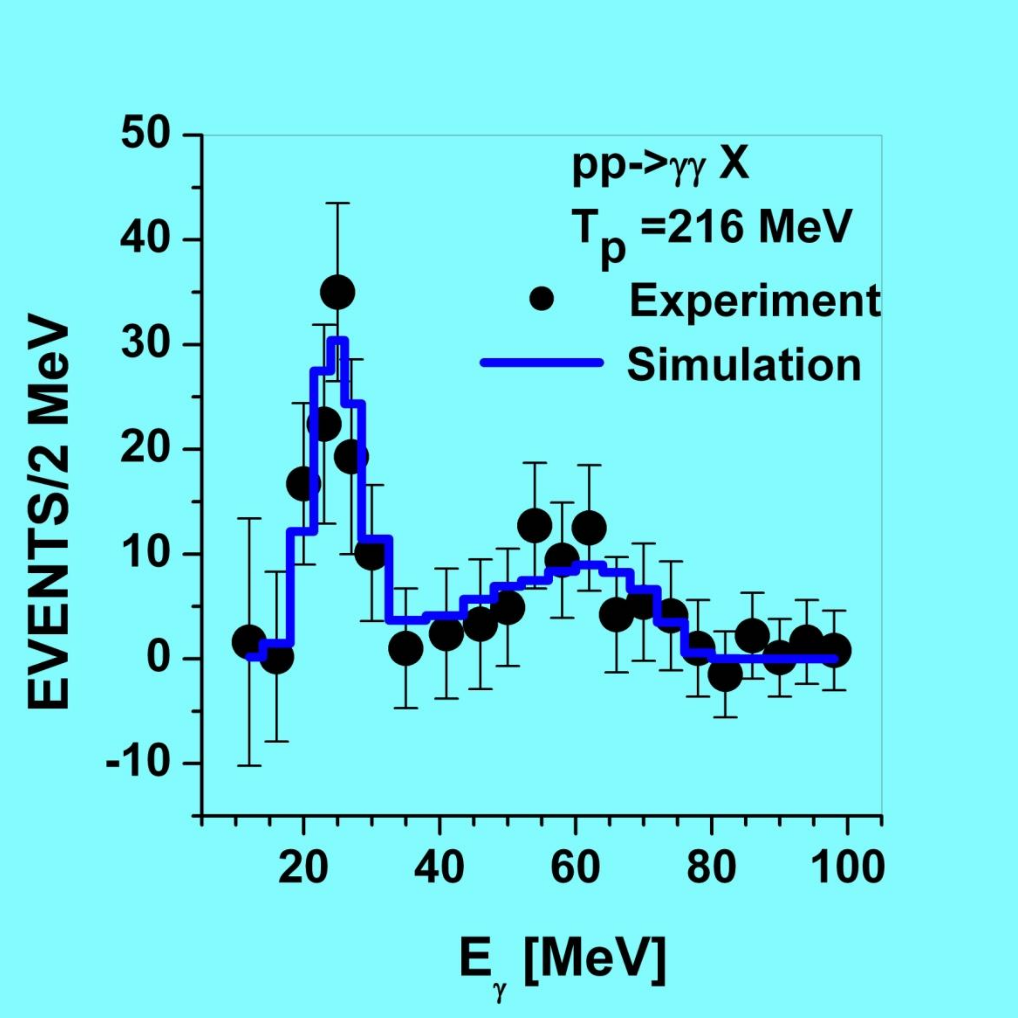
St.sign.=5.3σ & =3.5σ



$pp \rightarrow \gamma d_1^* \rightarrow \gamma\gamma pp$

M_R~1956 MeV

FWHM ~ 8 MeV



FURTHER EVIDENCES FOR THE $d_1^*(1956)$

A.S. Khrykin, Nucl. Phys. A721, 625c (2003)

Reaction $p+d \to \gamma X$

Experiment

T_p=195 MeV; $\theta_\gamma=90^0$

Michigan State group

J. Clayton et al., Phys. Rev. C45, 1810 (1992).

T_p=200 MeV; $\theta_\gamma=90^0$

Grenoble group

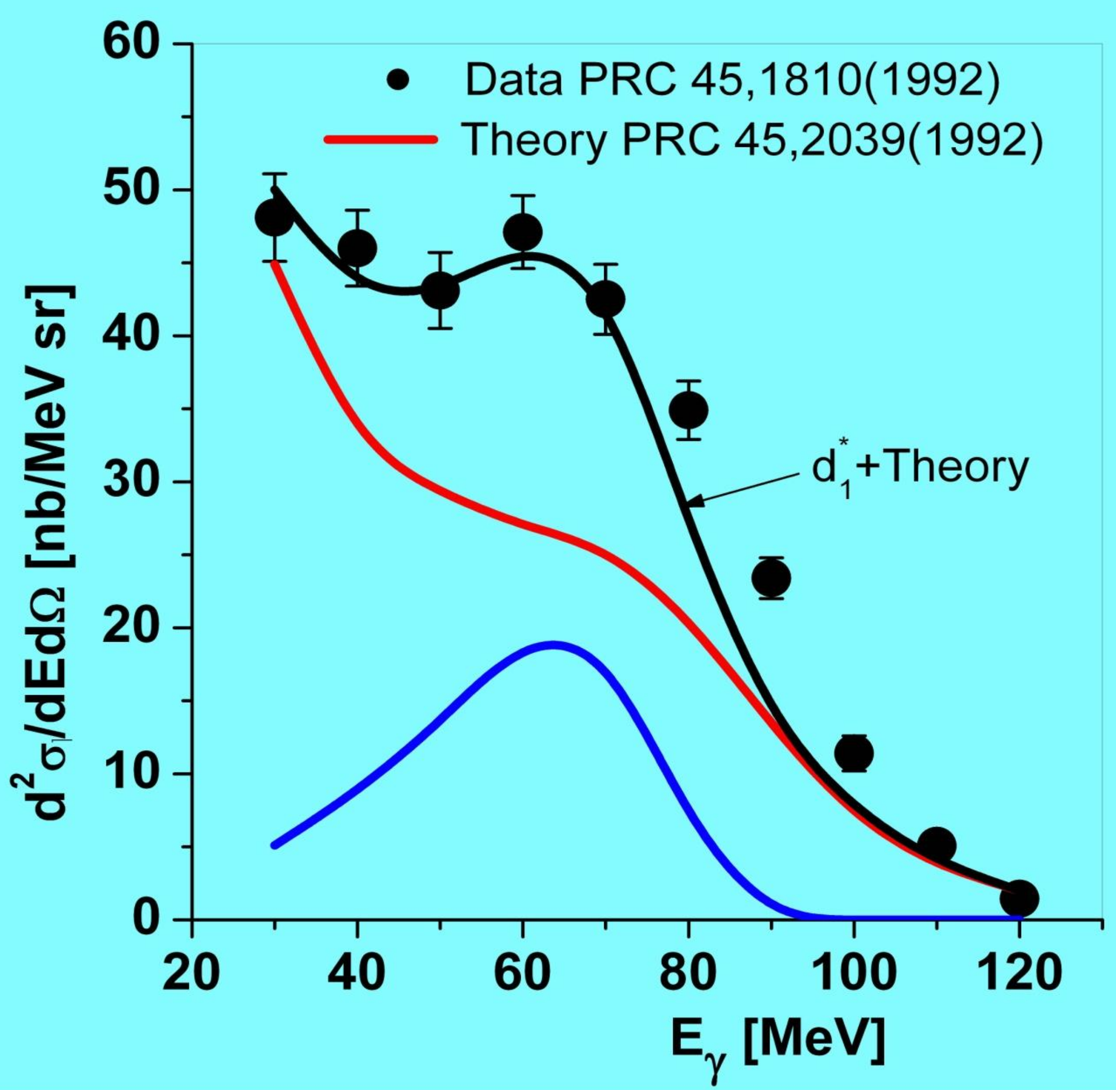
J.A. Pinston et al.,

Phys.Lett. B249, 402(1990)

Theory

K.Nakayama,

Phys.Rev. C45, 2039 (1992).



Inclusive photon spectrum for the np→γX reaction

A.S. Khrykin, Nucl. Phys. A721, 625c (2003)

Reaction n+*p*→*γX*

<u>Experiment</u>

At the Saturne National Laboratory in Saclay.

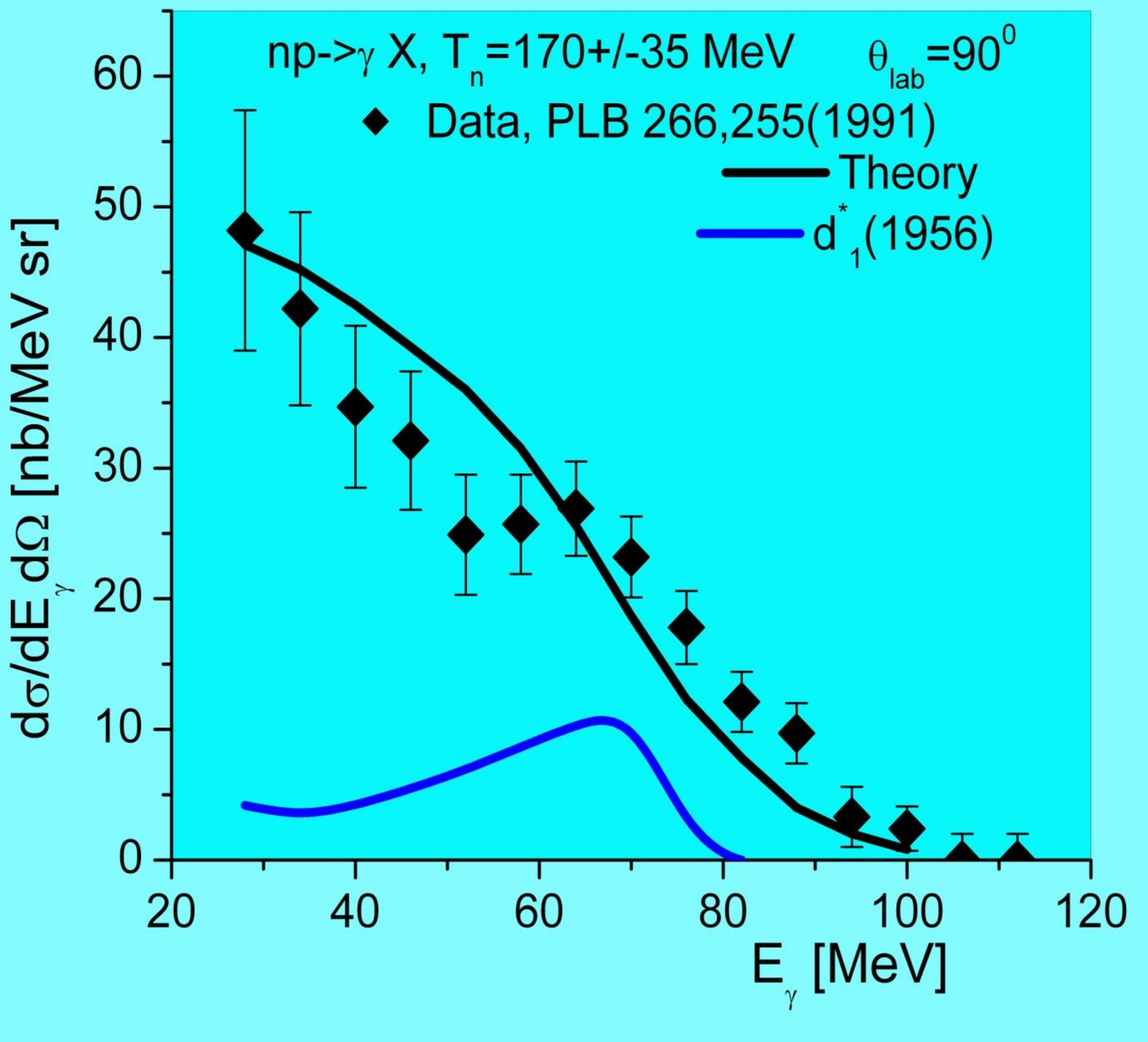
T_n=170±35 MeV ; θ_γ=90^0

F.Malek et al., Phys.Lett. B266, 255(1991).

<u>Theory</u>

M.Schafer et al.

Z. Phys. A 339, 391 (1991).



Exlusive pp→ppγγ reaction

A.S.Khrykin and S.B.Gerasimov, in : *Proc. of the MENU2007,* IKP, Forschungentrum Juelich, Germany, September 10-14, 2007, edited by H. Machner and S. Krewald, eConf C070910(2008),250.

- **Experiment**

CELSIUS-WASA *Collaboration*

Bashkanov et al. Int. Jour. of Mod. Phys. A20,554(2005); hep-ex/0406081

$M^2_{\gamma\gamma}=(k_1+k_2)^2=2E_{\gamma 1}{}^*E_{\gamma 2}{}^*(1-\cos\theta_{12})$

T_p=1.36 GeV and T_p=1.2 GeV

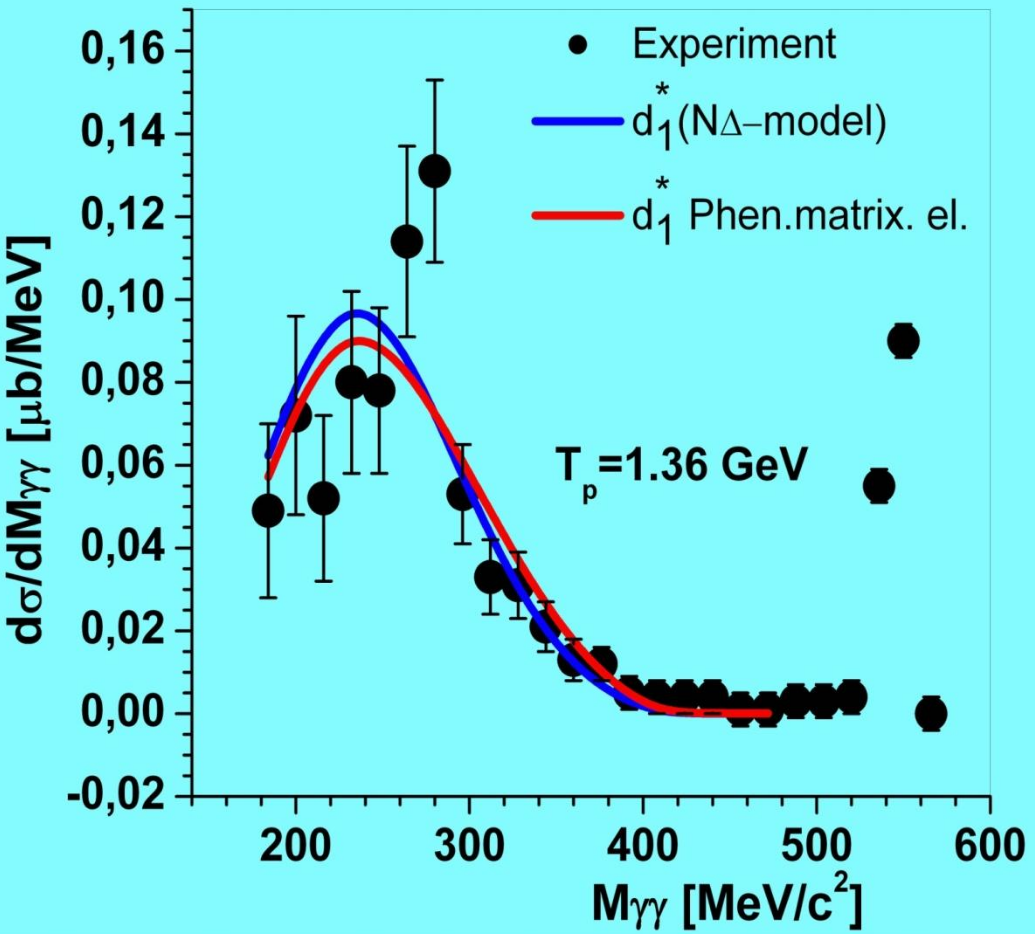
St.sign.=$N_S/(N_S+2N_B)^{1/2}$: **4.5σ & 3.5σ**

Calculations: $|M(NN\to\gamma d_1^*)|^2$ ⟹

1. **d^*_1(1956)→(NΔ)$_{bound}$ S.B.Gerasimov**

2. **$d\sigma/d\Omega_{cms}$ =C•exp($-p_\perp$/b) J.V. Allaby et al. Phys.Lett . B29, 198(1969)**

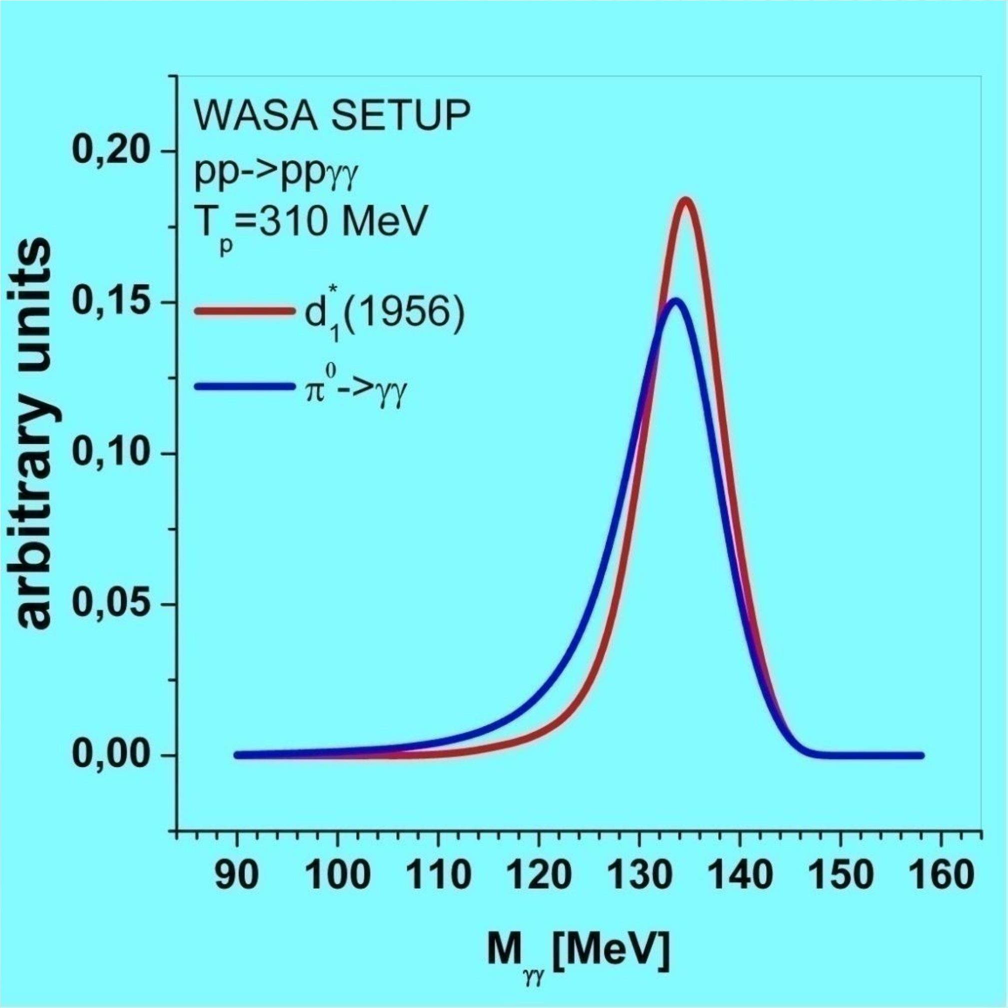
χ^2=1.1/dof



Why the Celsius-Wasa Collaboration did not find the dibaryon signal in their pp $\rightarrow pp\gamma$ data?

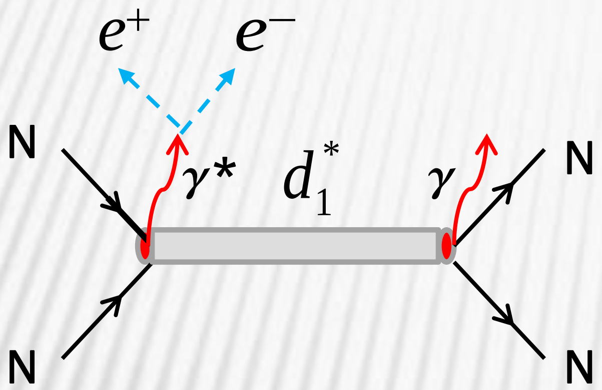
Two-photon inv. mass spectra were calculated for the $pp \rightarrow \gamma d^*_1(1956) \rightarrow pp\gamma\gamma$ and $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$ channels of the reaction **pp→ pp$\gamma\gamma$** for the geometry and kinematics of the experiment PL**B427**,248 (1998).

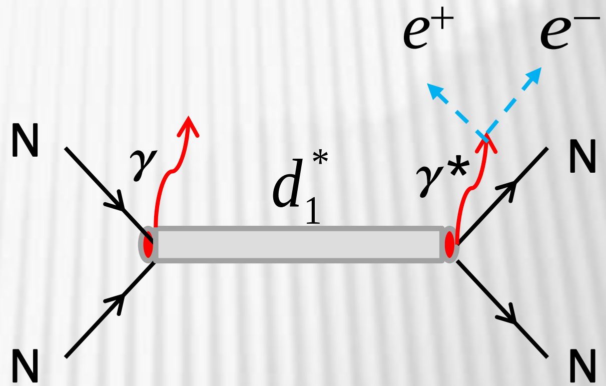
So,all events (at least most of them) associated with the resonance $d^*_1(1956)$ were removed!

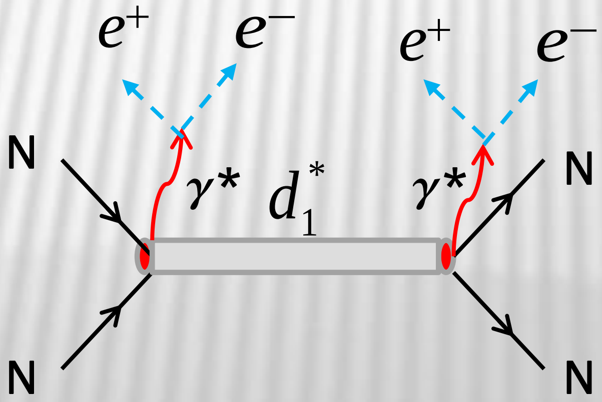


Dibaryon mechanism for dielectron production in NN Collisions

$$NN \Rightarrow \gamma^* d_1^* \Rightarrow e^+ e^- d_1^*$$







$$NN \Longrightarrow \gamma^* d_1^*(1956) \longrightarrow e^+e^- d_1^*(1956)$$

$$p_a + p_b = p_1 + p_2 + p_3$$

$p = p_a + p_b$, p_a- and p_b- the four-momenta of colliding nucleons, $p^2 = s$ – the total energy of the colliding nuclens in c.m.s.

$p_1(E_1, \vec{p}_1)$, $p_2(E_2, \vec{p}_2)$ and $p_3(E_3, \vec{p}_3)$ -the four-momenta of dielectrons and resonance.

$$\frac{d\Gamma}{d\mathrm{M}} = \frac{1}{32\pi^5\sqrt{S}} \int \prod_{i=1}^{3} \frac{d^3\vec{p}_i}{2\mathrm{E}_i} |\mathcal{M}|^2 \bullet \delta(p - \sum_{i=1}^{3} p_i) \bullet \delta(\mathrm{M} - \mathrm{M}(\vec{p}_1, \vec{p}_2))$$

M- *the invariant mass of the* e^+e^- - pair

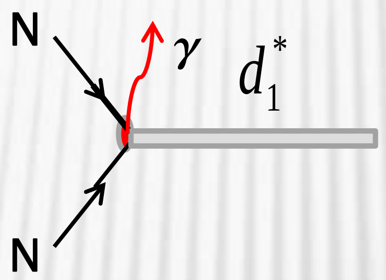
$|\mathcal{M}|^2$ – ***the squared matrix element for the transition*** $NN \rightarrow e^+e^- d_1^*$

$$\left|\mathcal{M}_{NN\to e^+e^-d_1^*}\right|^2 = \left|\mathcal{M}_{\gamma^*\to e^+e^-}\right|^2 \frac{1}{M^4} \left|\mathcal{M}_{NN\to\gamma^* d_1^*}\right|^2$$

$$\left|\mathcal{M}_{\gamma^*\to e^+e^-}\right|^2 = \frac{4\pi\alpha}{3}(M^2 + 2m_e^2)$$

The matrix element for the $NN \to \gamma^* d_1^*$ ***transition***

$J^P(d_1^*) = 0^-$ **the vertex**



is magnetic in structure

$1^- \xrightarrow{M1} 0^-$ **O. Scholton et al. PRC71,034005(2005)**

$$\left|\mathcal{M}_{NN\to\gamma d_1^*}\right|^2 = 16\alpha g^2 (p_a \cdot q)(p_b \cdot q)/m^4 \qquad \left|\mathcal{M}_{NN\to\gamma^* d_1^*}\right|^2 = C\cdot(p_a \cdot p_M)(p_b \cdot p_M)$$

q- four momentum of real photon p_M **- four- momentum of massive photon**

Phenomenological matrix element

J.V. ALLABY, et al., Phys.Lett., B29,198(1969)

$pp \to \pi^+ d \implies (d\sigma/d\Omega)_{cms} = C(s) \bullet \exp(-p_\perp/b)$, for p>3.6 GeV

$p_\perp = p \bullet \sin(\theta)$ - the transverse momentum of π^+ ,
C- and b- parameters. (b=507 MeV the same as for the $pp \to pp\gamma\gamma$ reaction)

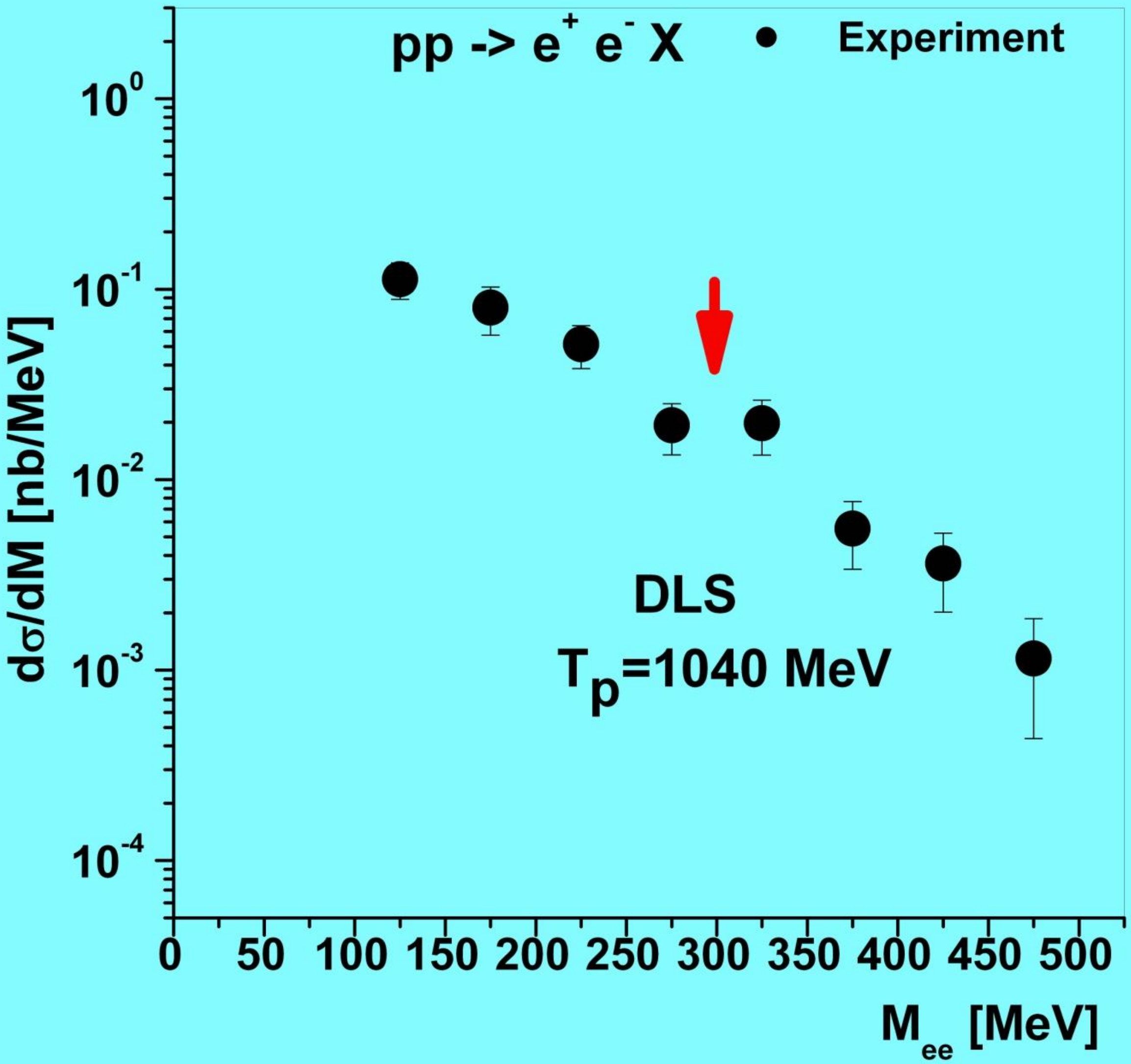
The calculations $\implies$ Monte Carlo method. Event generator $\implies$ GENBOD. It used to randomly generate four momenta of the outgoing particles of the explored reaction. The probabilty of any event has been given its weight:

$$WT = \left| \mathcal{M}_{NN \to e^+ e^- d_1^*} \right|^2$$

Energy resolution: by procedure of smearing the spectrum with a Gaussian distribution with the corresponding σ.

Contribution of the $pp \to e^+ e^- d_1^*$ mechanism to the DLS $pp \to e^+ e^- X$ data

DLS data:W.K.Wilson et al.,Phys.Rev. C **57**, 1865(1998)
Theoretical data:Amand Faessler et al.,J.Phys. G **29**, 603(2003)



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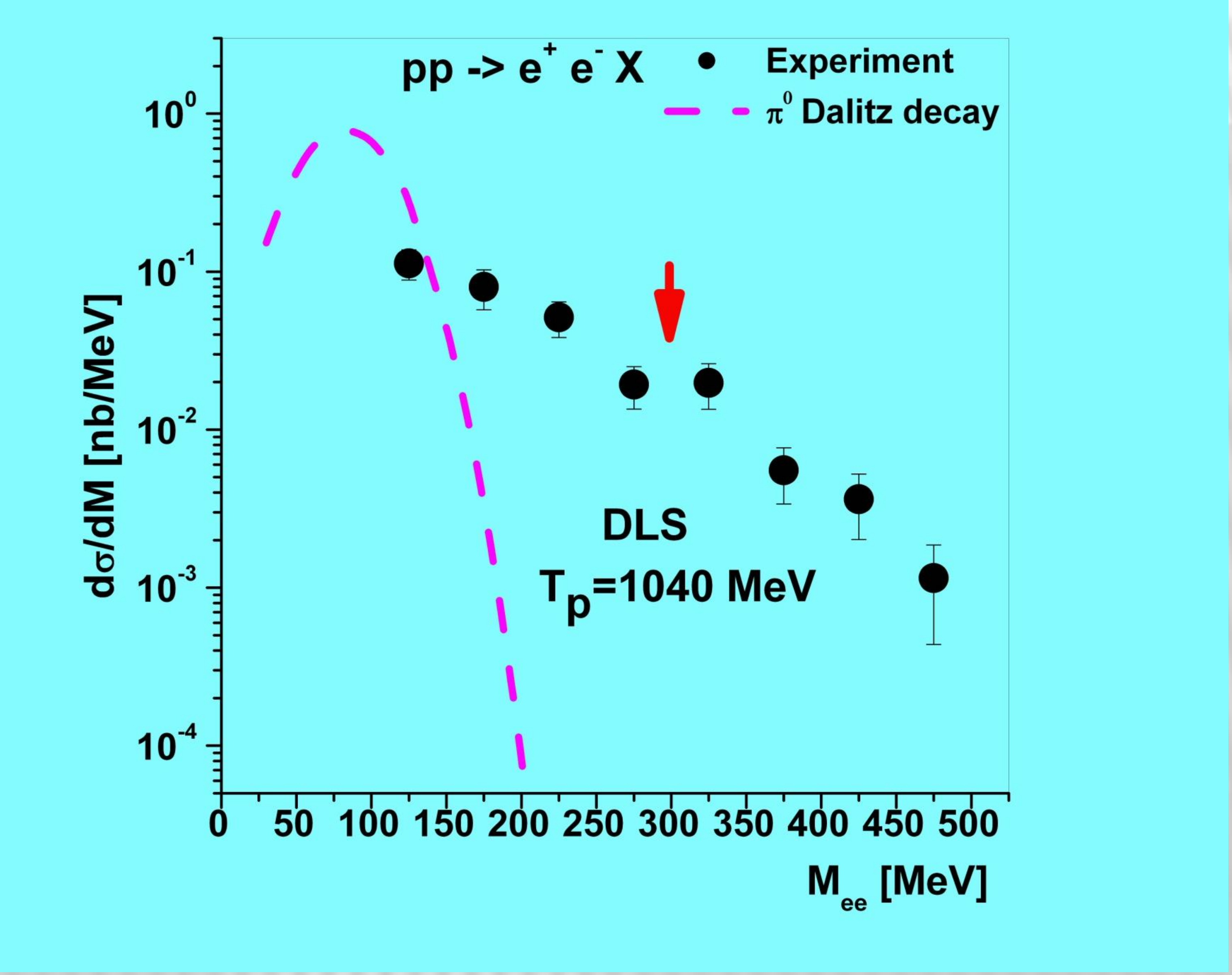

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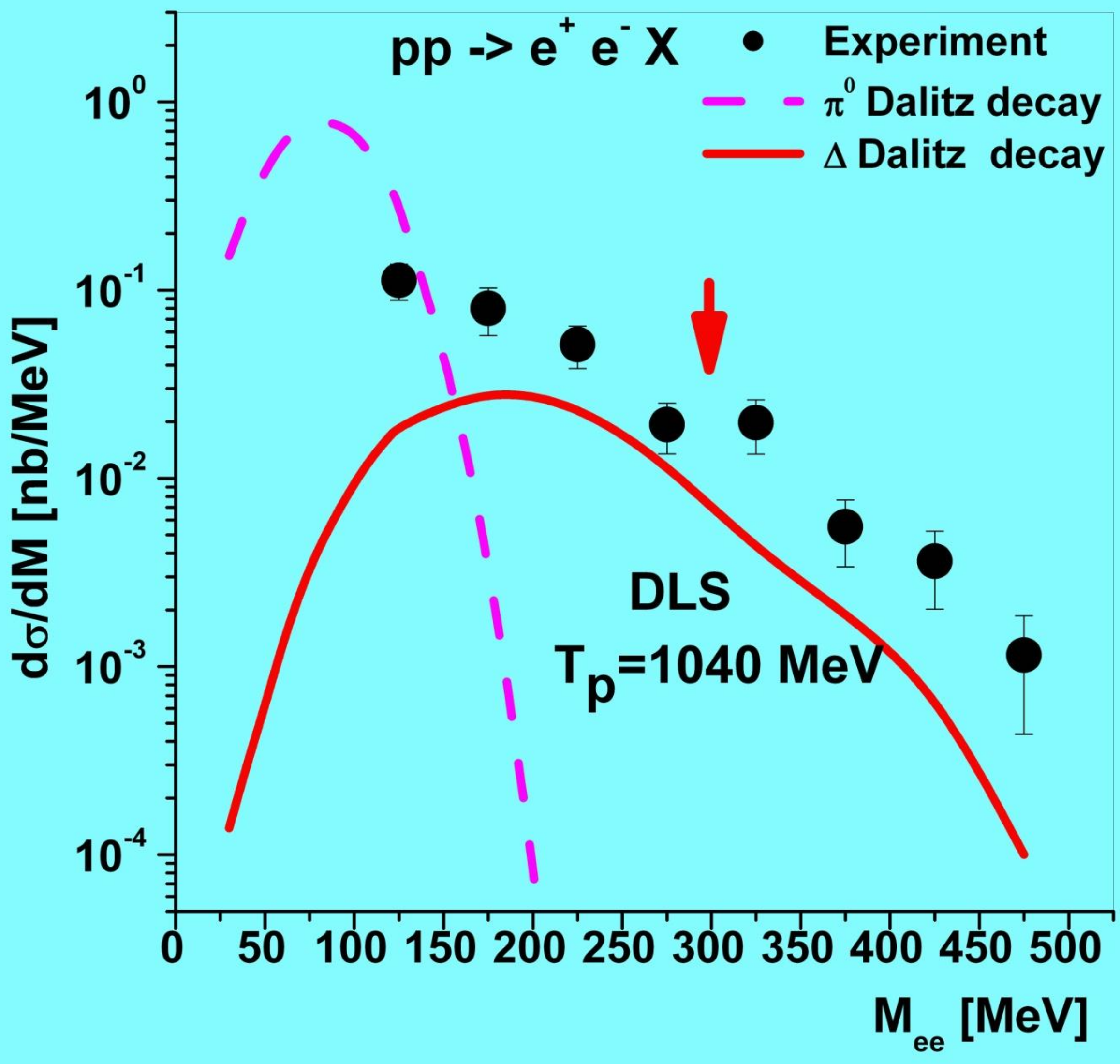

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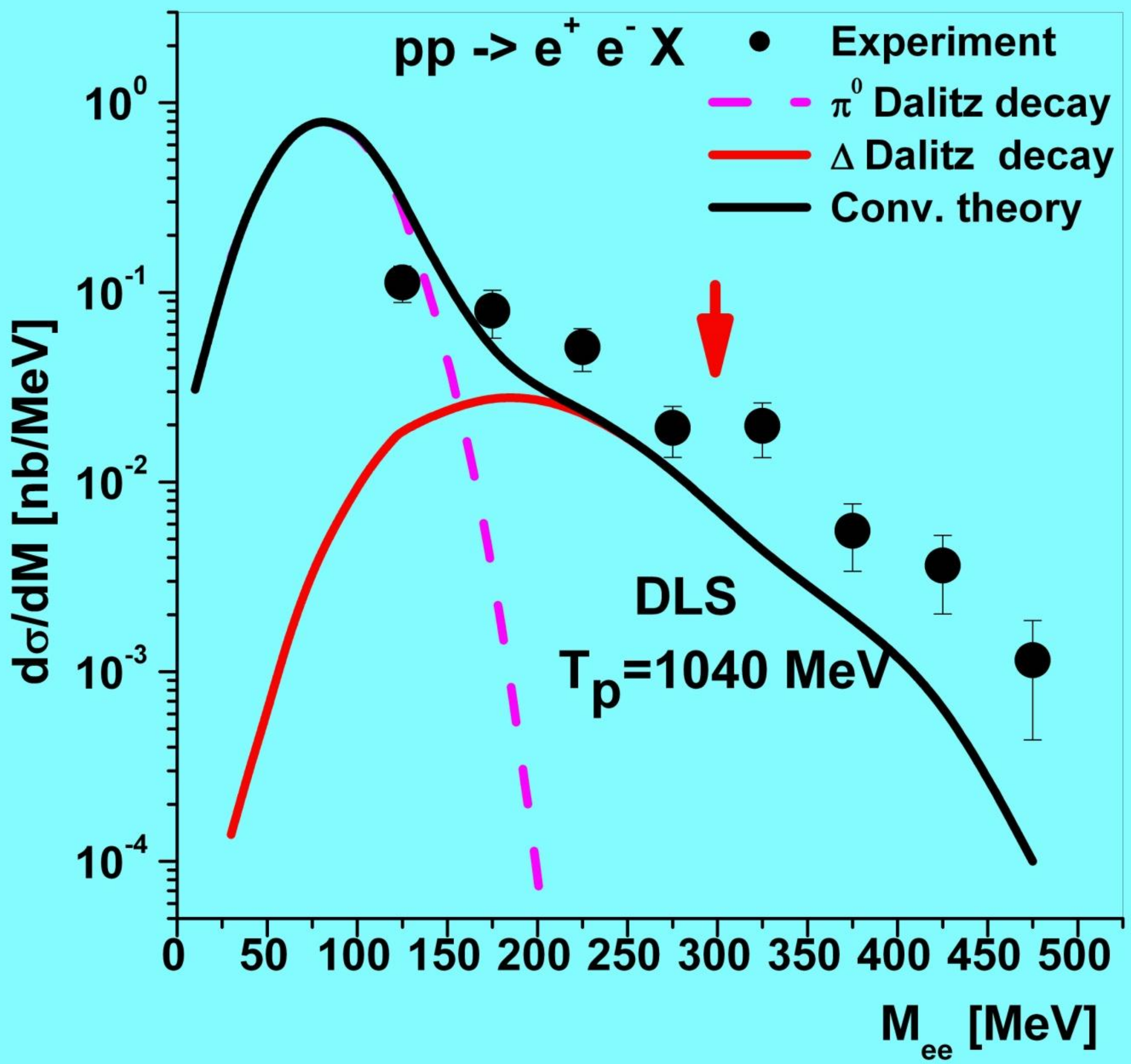

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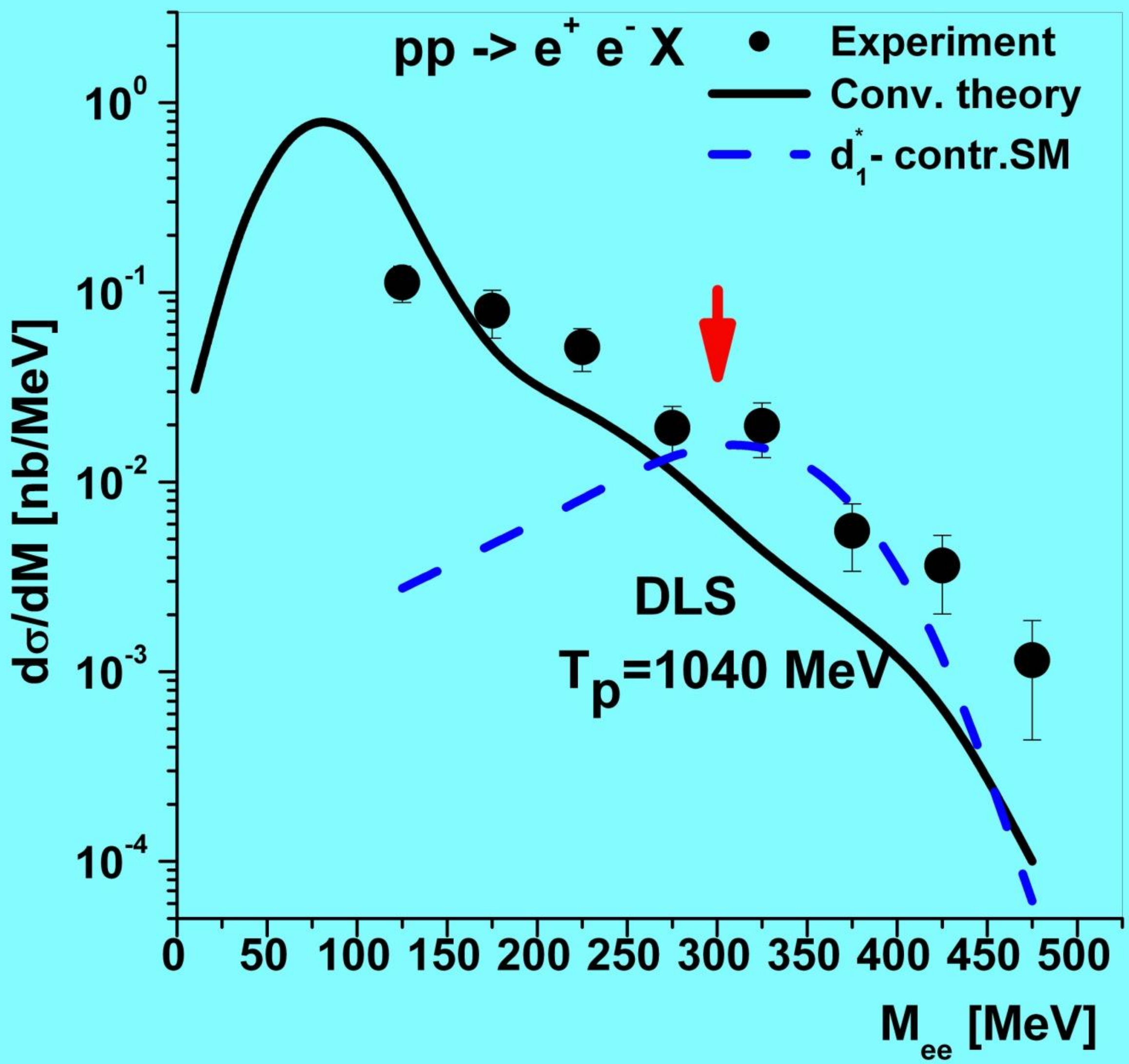

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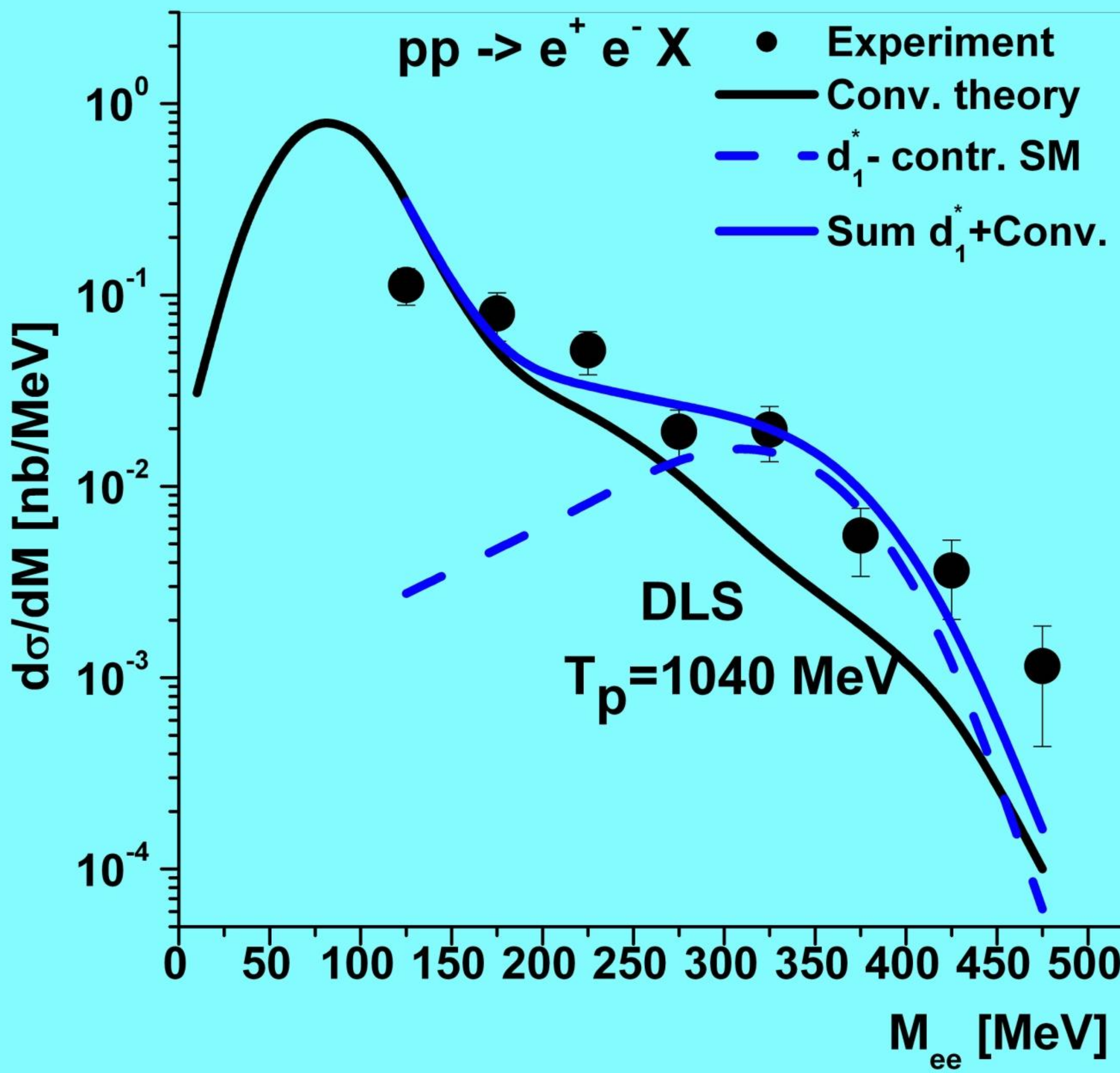

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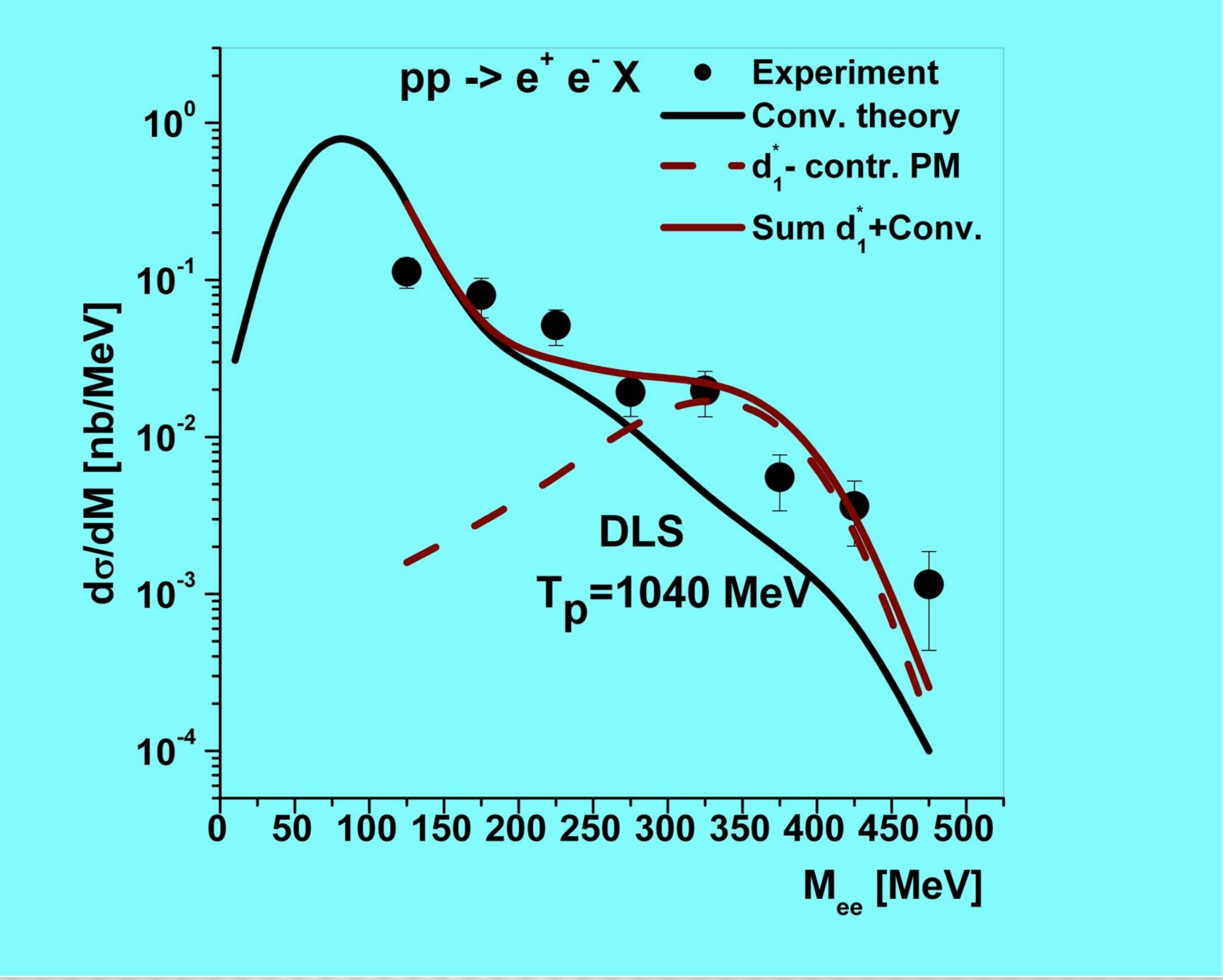

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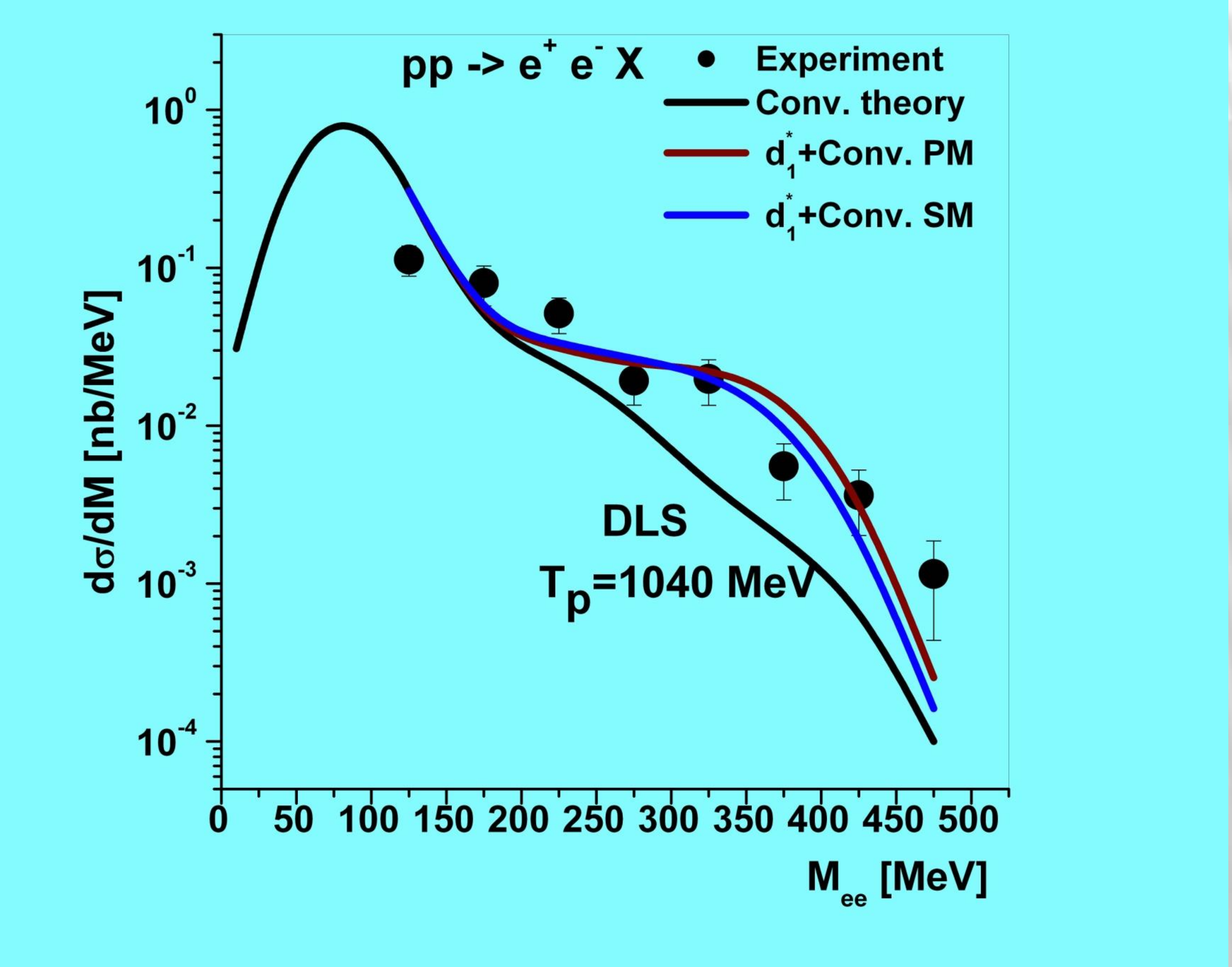

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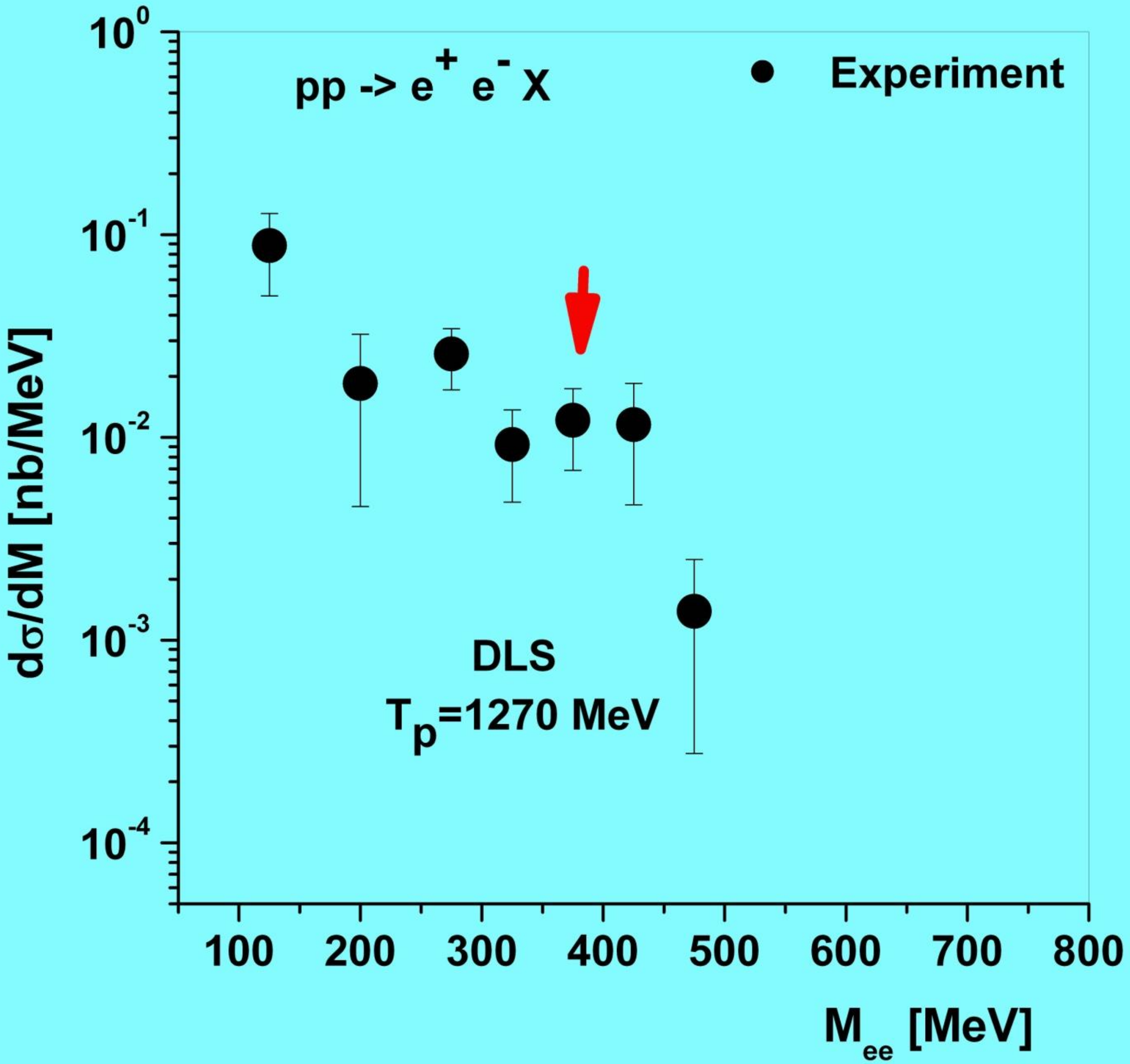

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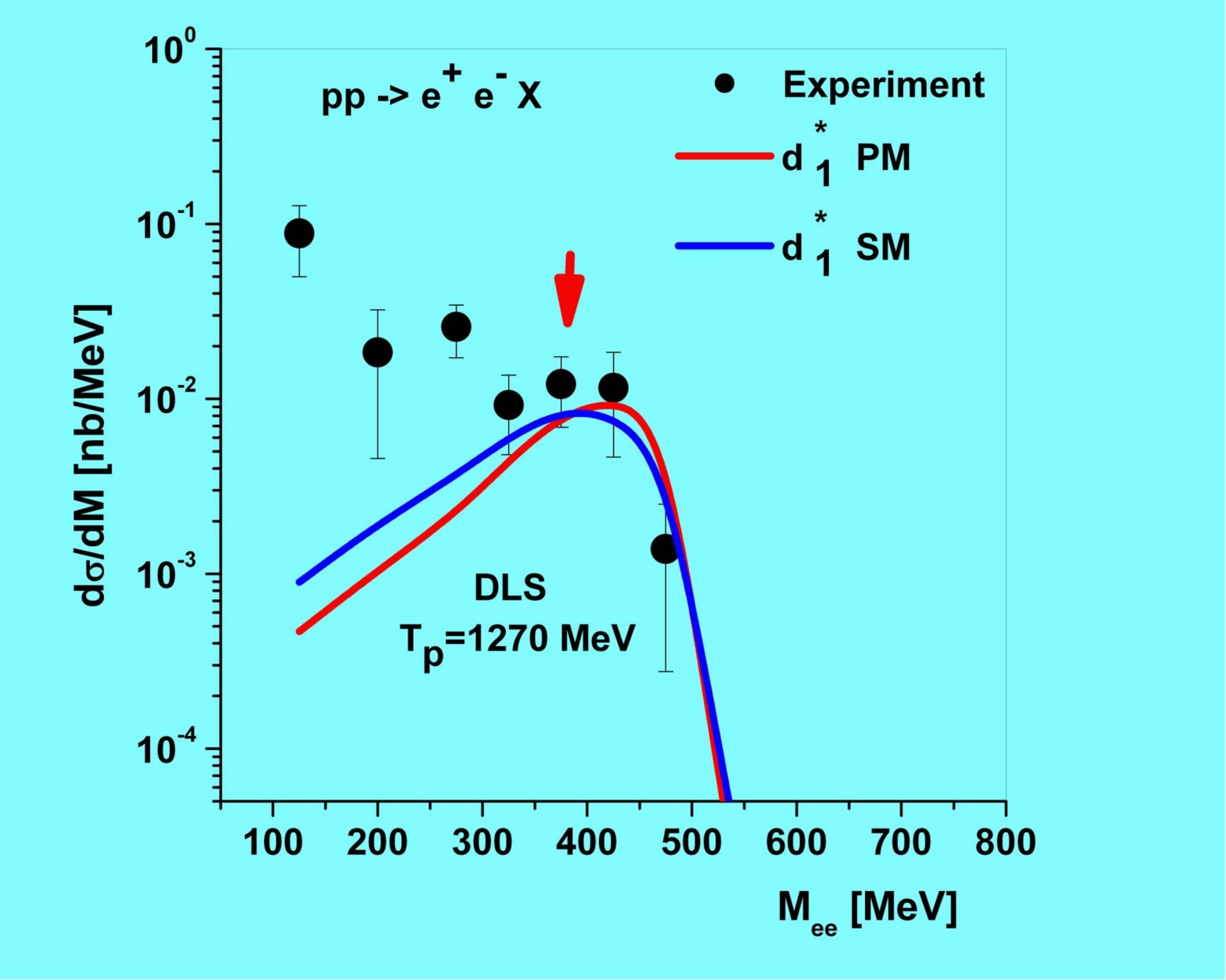

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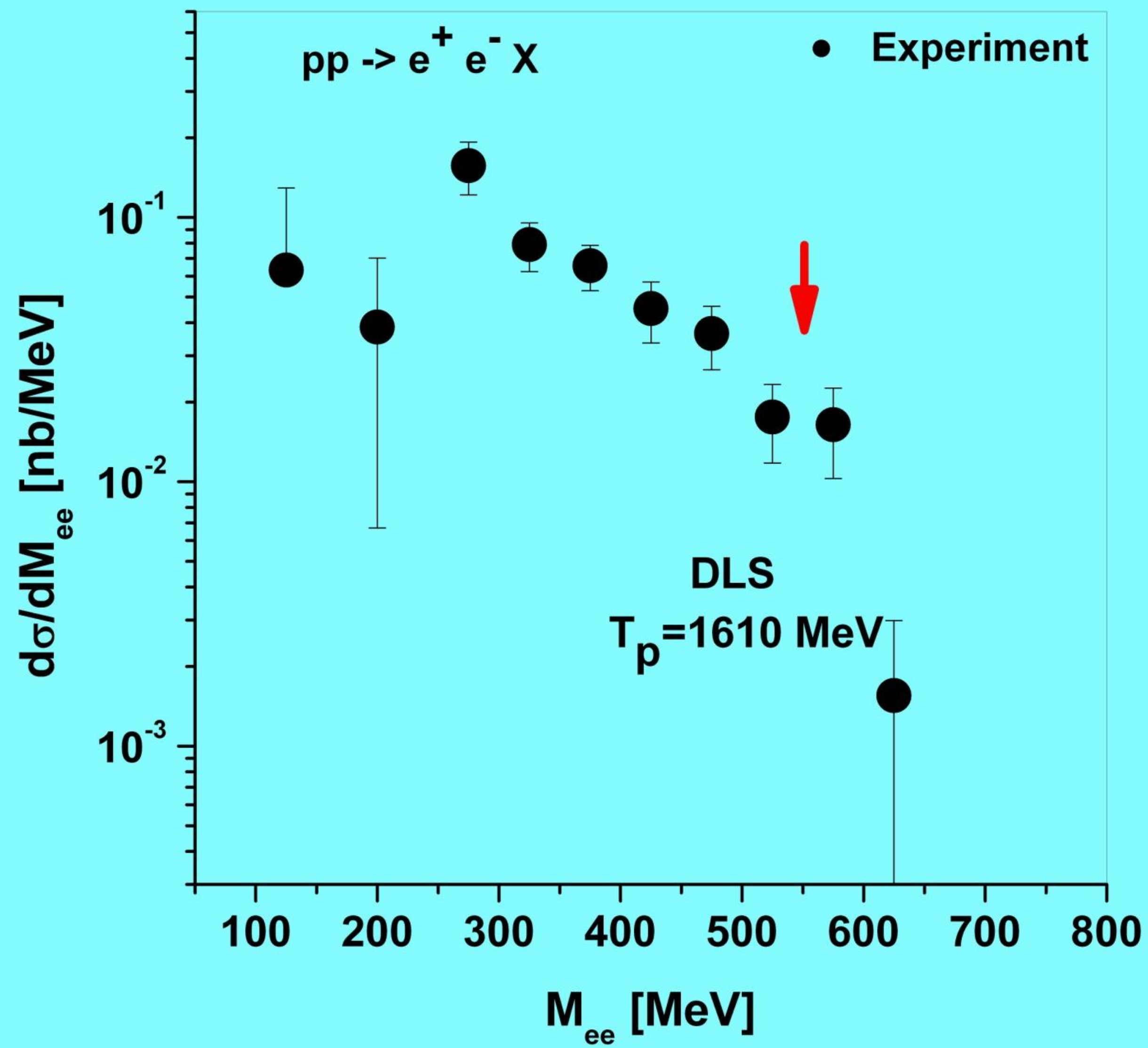
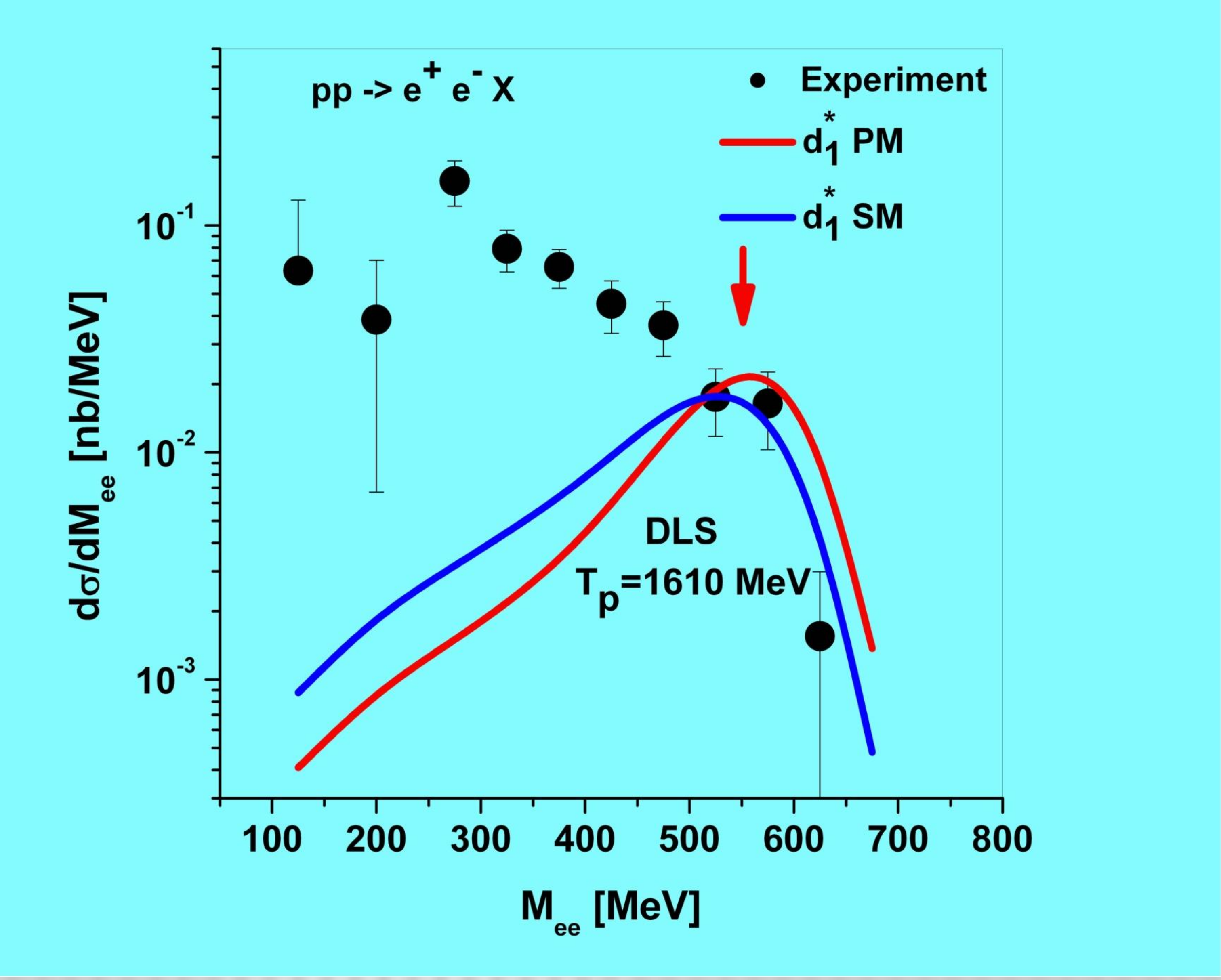


DLS data:W.K.Wilson et al.,Phys.Rev. C **57**, 1865(1998)



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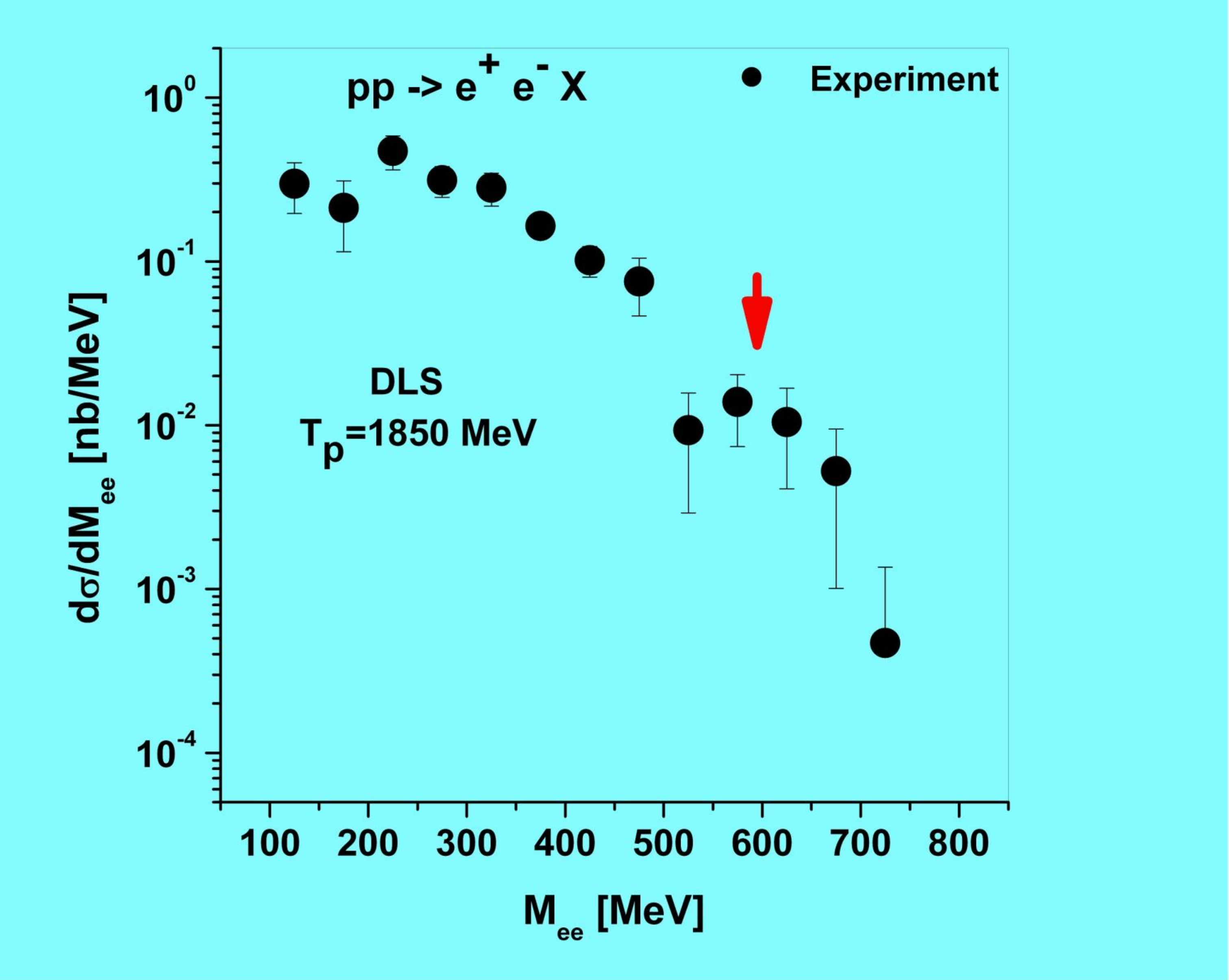

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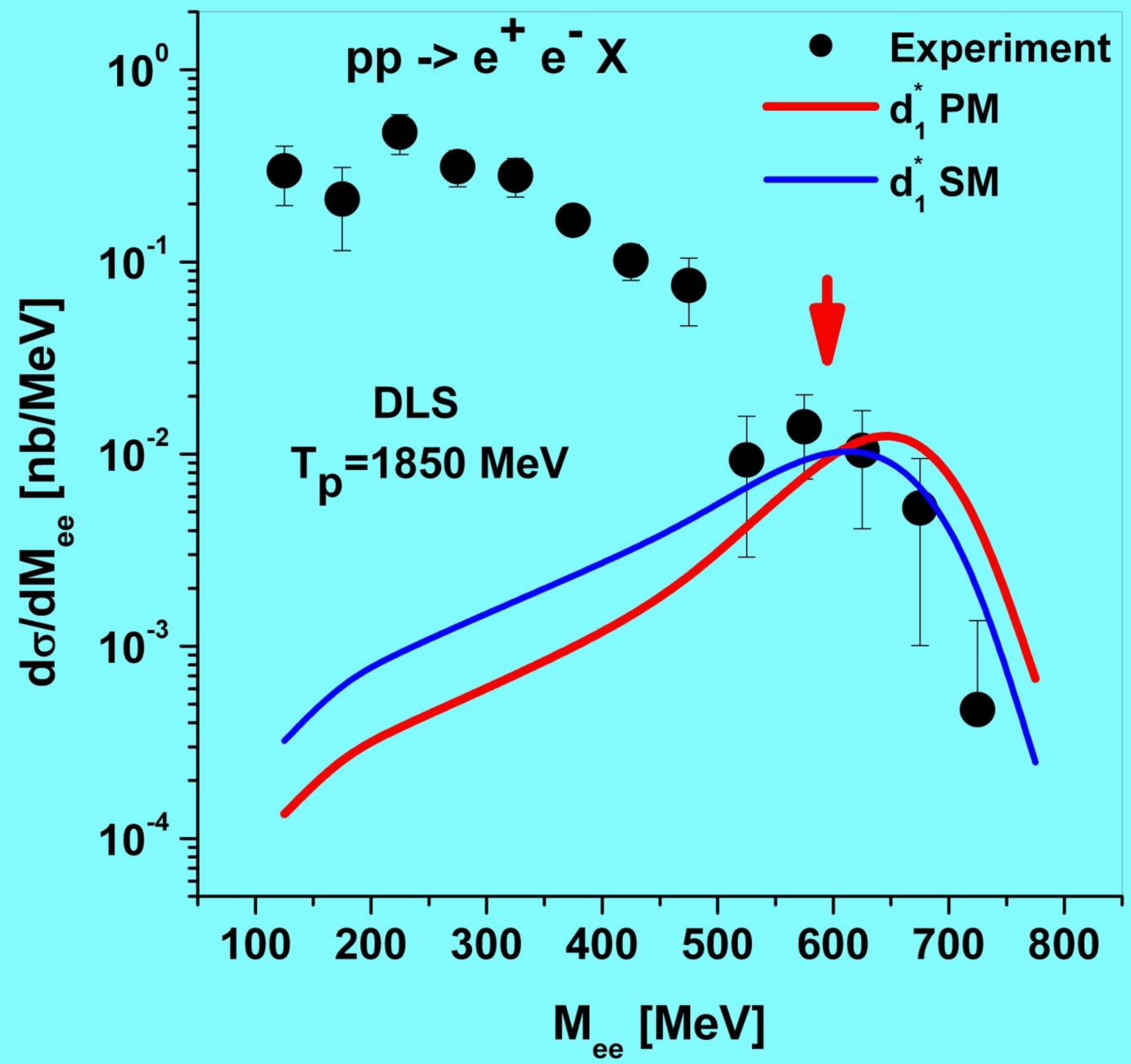

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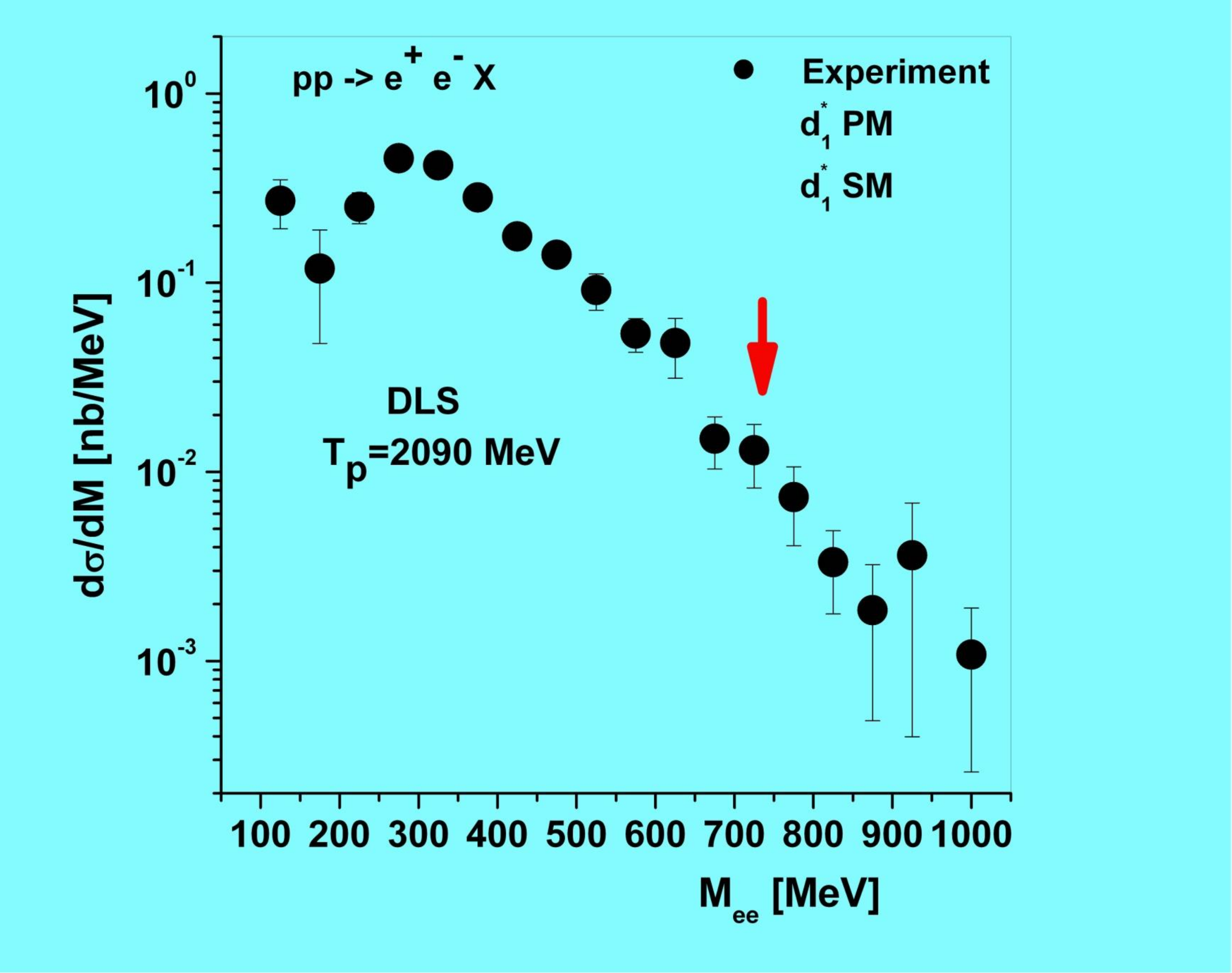

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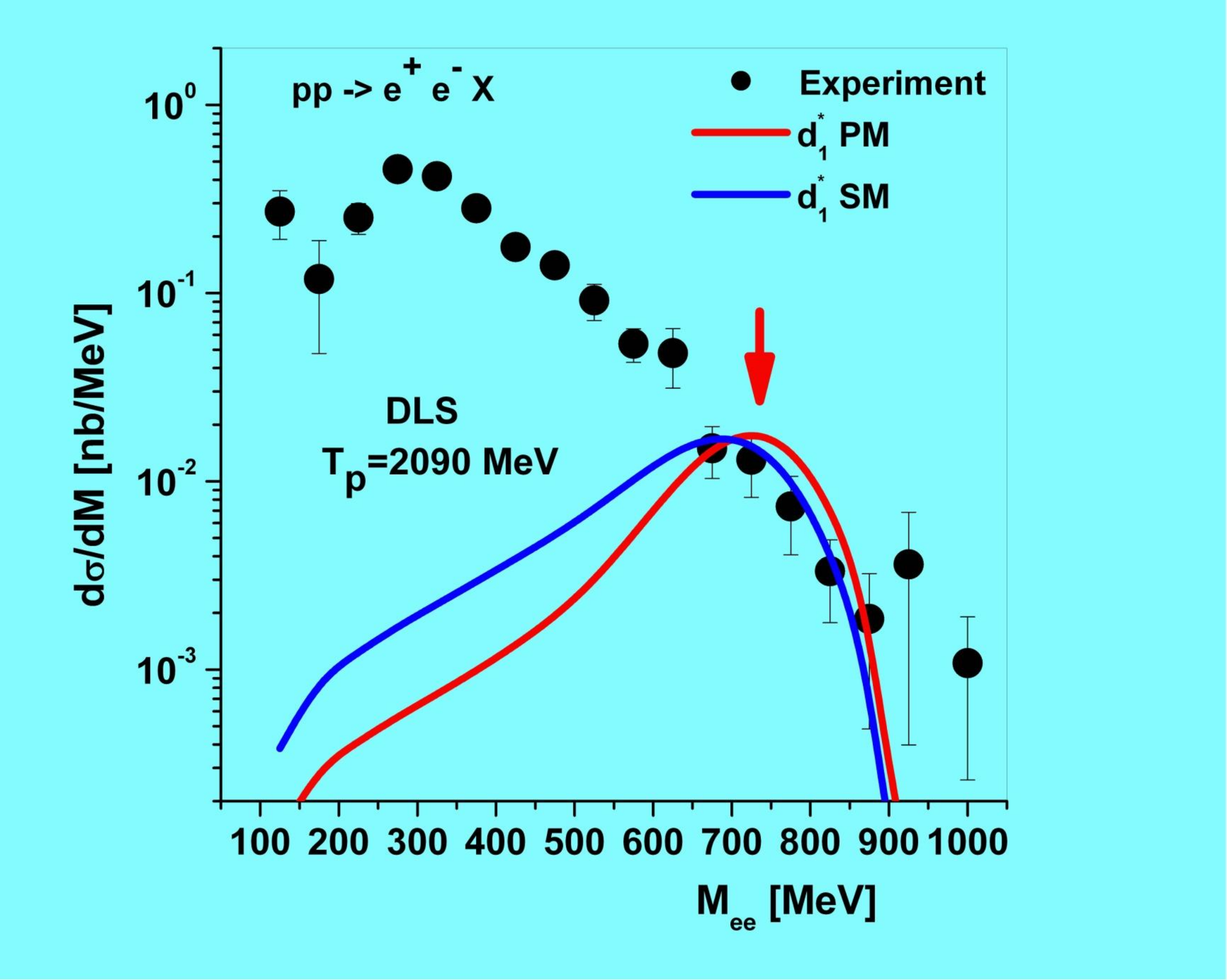
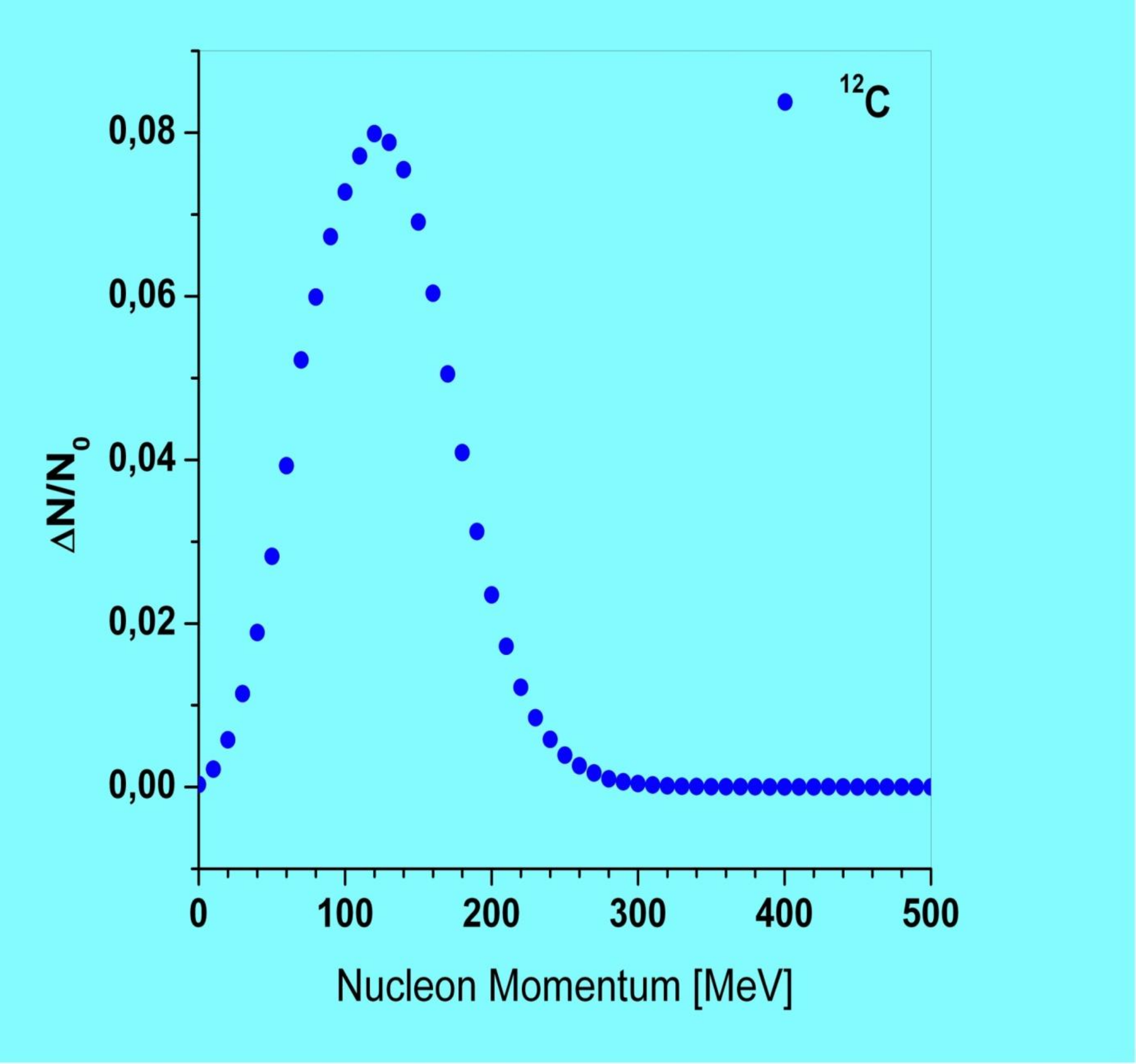


Contribution of the $NN \to \gamma^* d_1^* \to e^+e^- d_1^*$ mechanism to the HADES data.

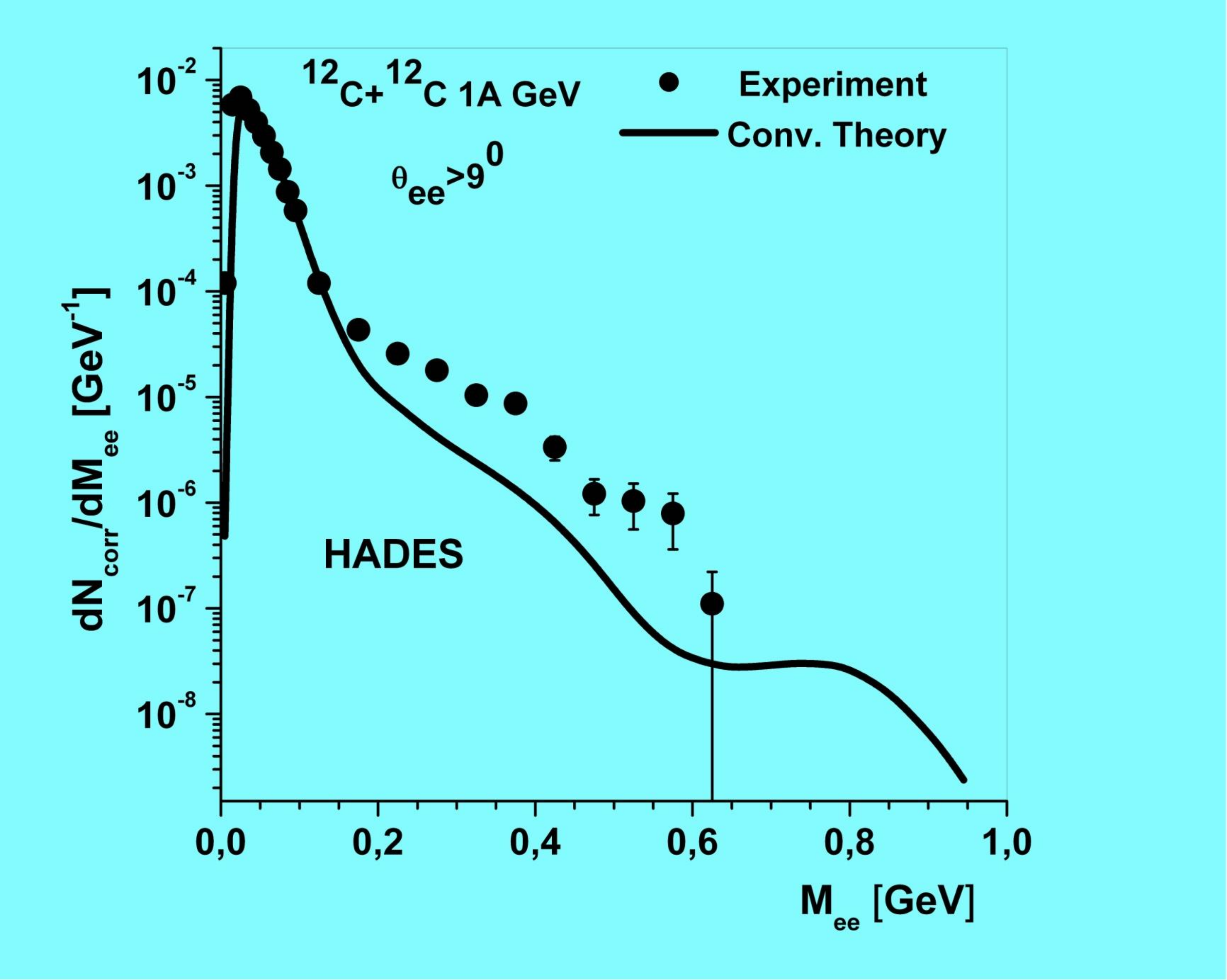
$^{12}C+^{12}C$ –collisions

Fermi motion- C.Ciofi degli Atti and S.Liuti, PLB225,215(1989)

$\Delta M/M=0.09$



HADES data: G.Agakishiev et al.,Phys.Lett. B663, 43(2008)



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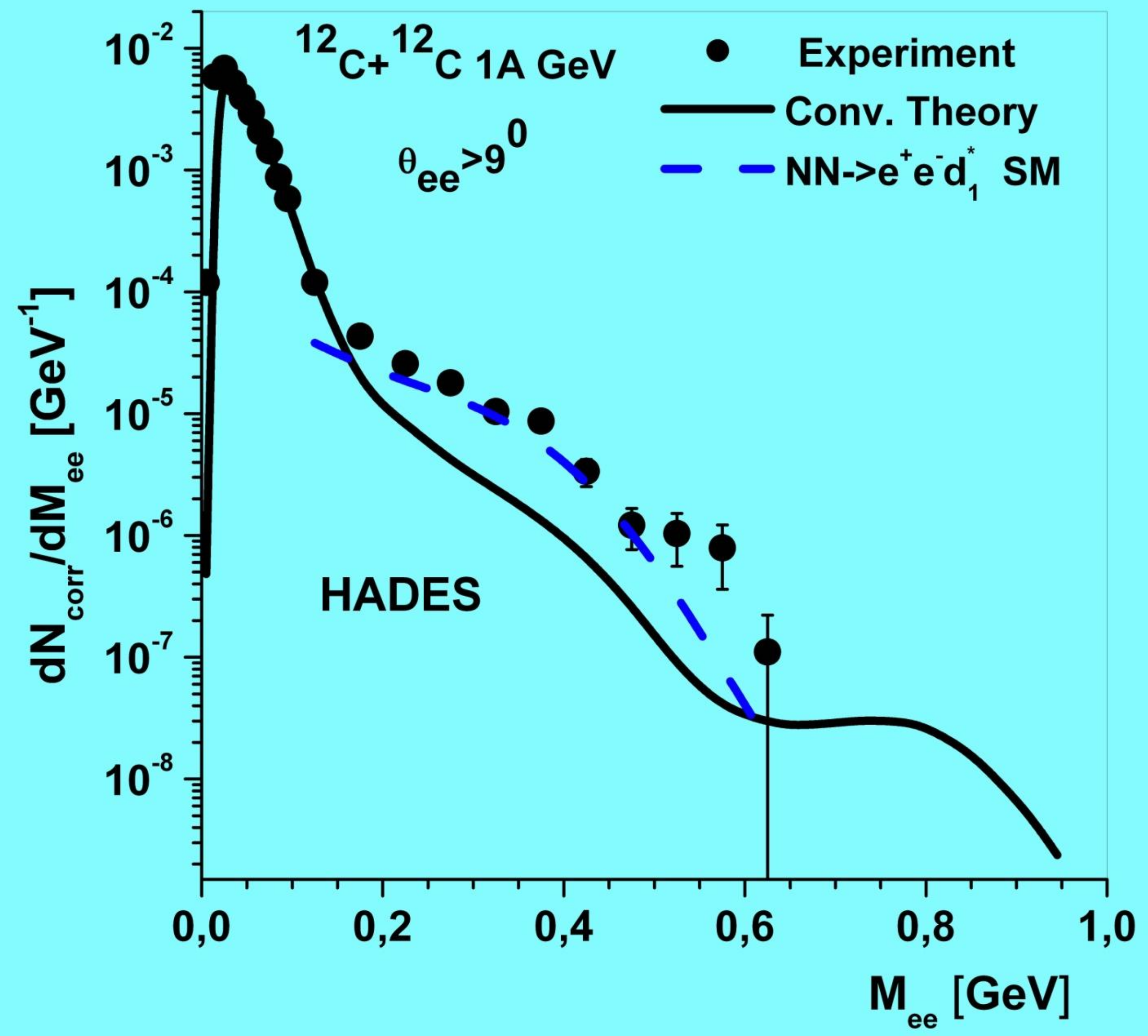
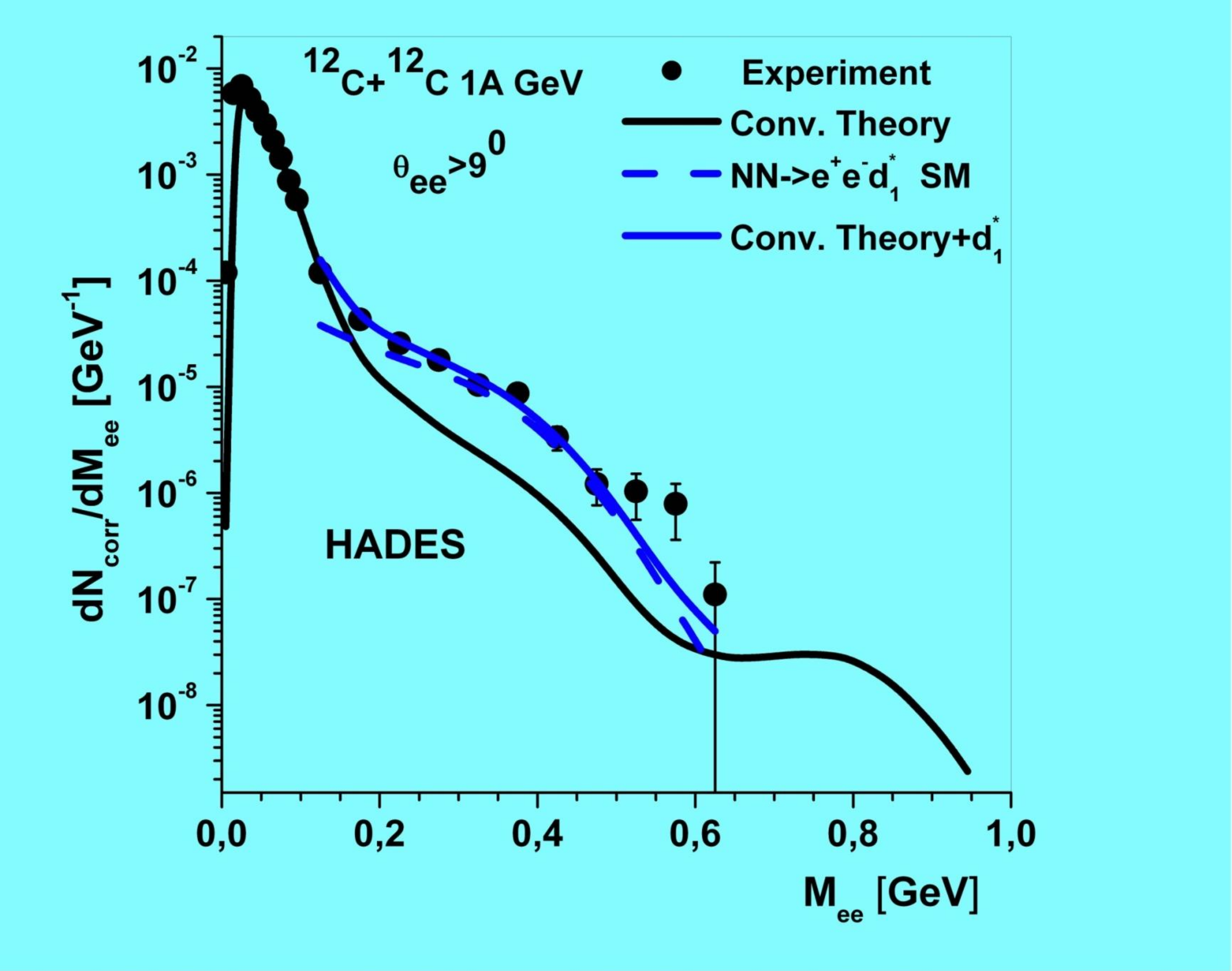
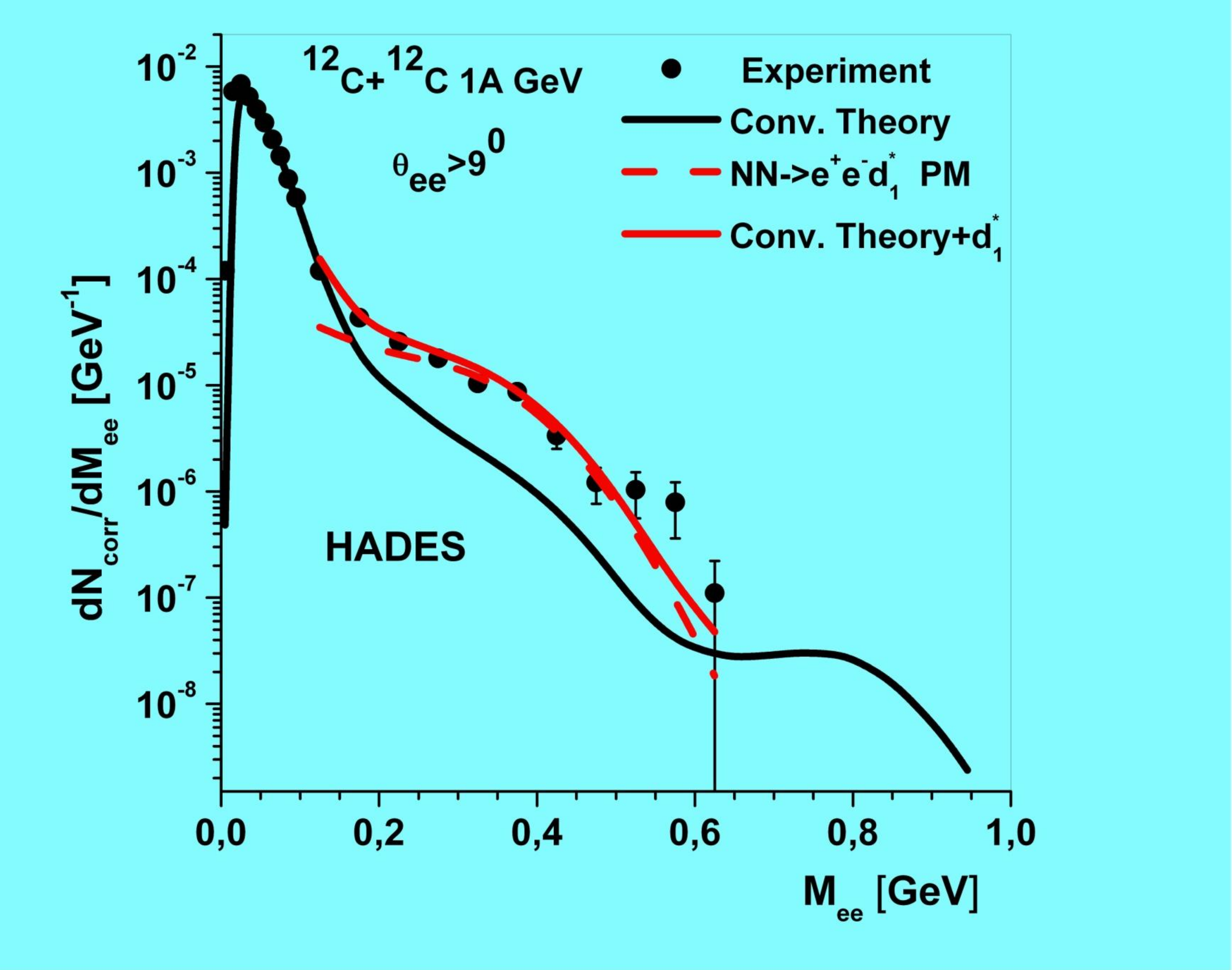


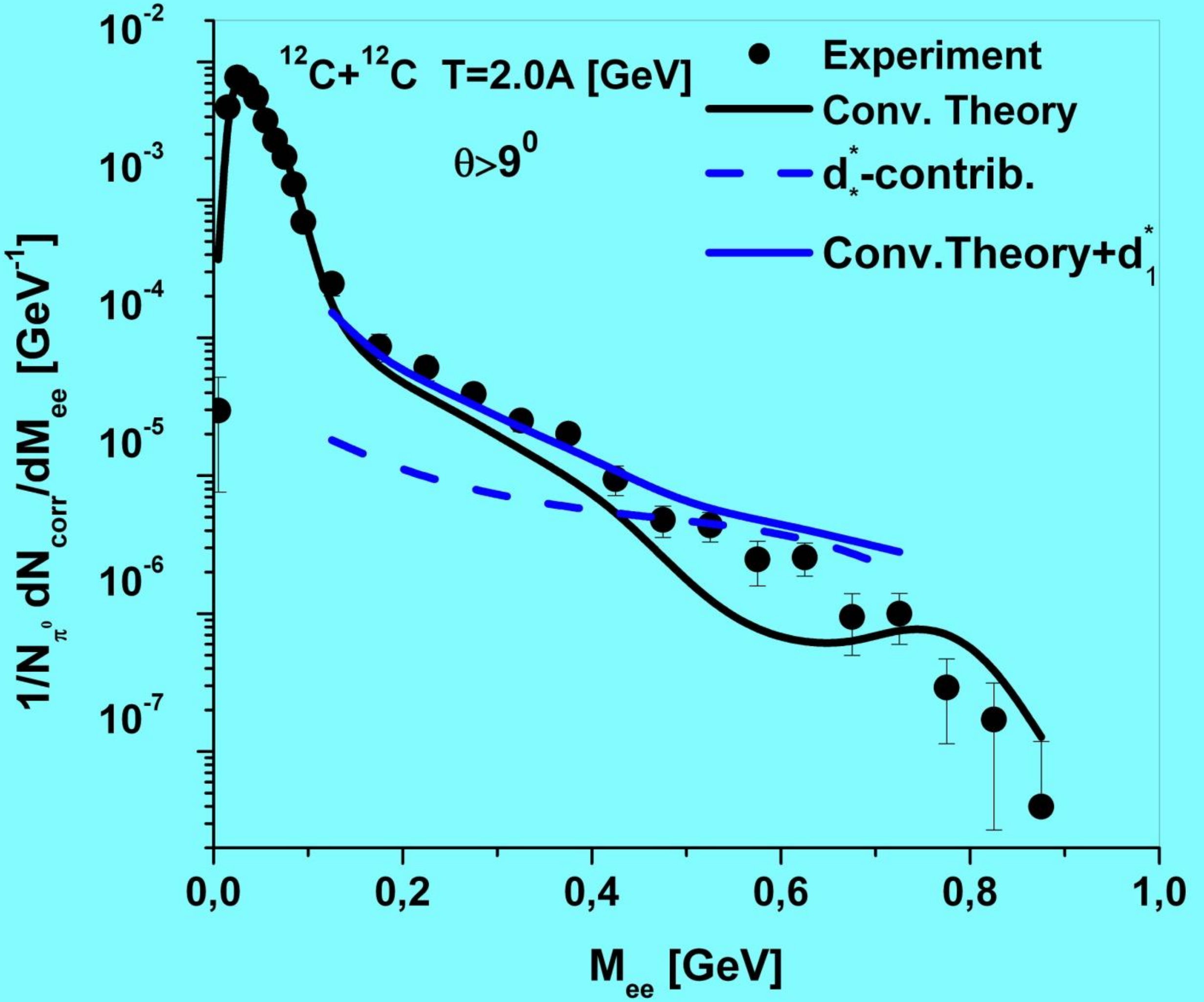
HADES data: G.Agakishiev et al.,Phys.Lett. B663, 43(2008)



HADES data: G.Agakishiev et al.,Phys.Lett. B663, 43(2008)



HADES data: G.Agakishiev et al.,Phys.Rev.Lett. 98, 052302(2007)



Conclusions

- The contributions of the dibaryon mechanism $NN \to e^+e^-d_1^*(1956)$ of dielectron production in NN collisions to the invariant mass spectra of the reaction $pp \to e^+e^-X$ were calculated for the energies and geometry of the DLS experiments.

- Results of the comparison of these contributions with the corresponding DLS data supports the idea that the observed excess of dielectron pairs in the mass region $0.2<M_{ee}<0.5$ *GeV* can be attributed to their production in the process $pp \to e^+e^-d_1^*(1956)$.

- The contributions of the $NN \to e^+e^-d_1^*(1956)$ mechanism to the invariant mass spectra of the reaction $NN \to e^+e^-X$ were calculated for the energies and geometry of the HADES experiments. Adding these contributions to the corresponding theoretical spectra we found that the resultant spectra reasonably well reproduce the experimentally observed ones in the mass region $0.15 < M_{e+e--} < 0.6$ GeV/c^2.

- The idea of the existing of the dibaryon mechanism of dielectron production can be confirmed or refuted by the direct measurement of the missing mass spectrum of the reaction $pp \to e^+e^-X$.

HADES SETUP

Invariant mass spectrum of dielectrons from the reaction

$pp \rightarrow e^+ e^- X$