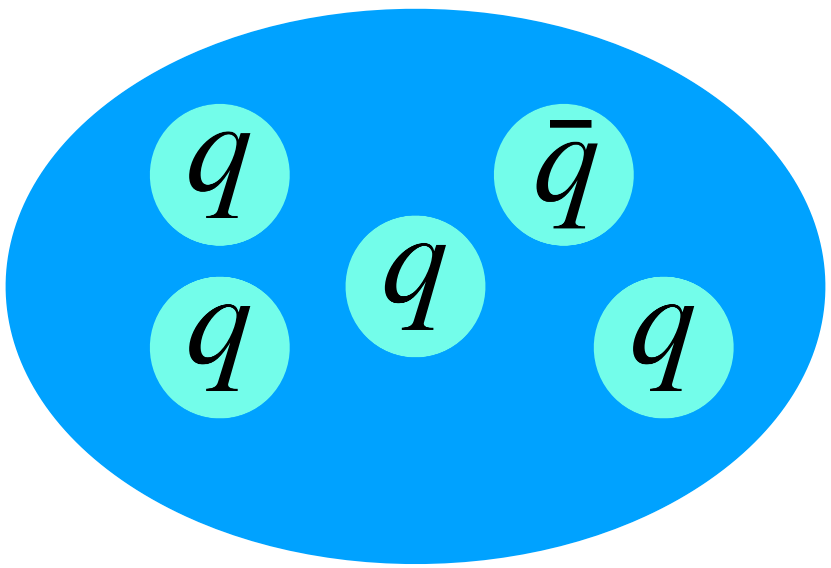
PWA10/ATHOS5

Beijing

Pentaquark photoproduction

2018-07-19



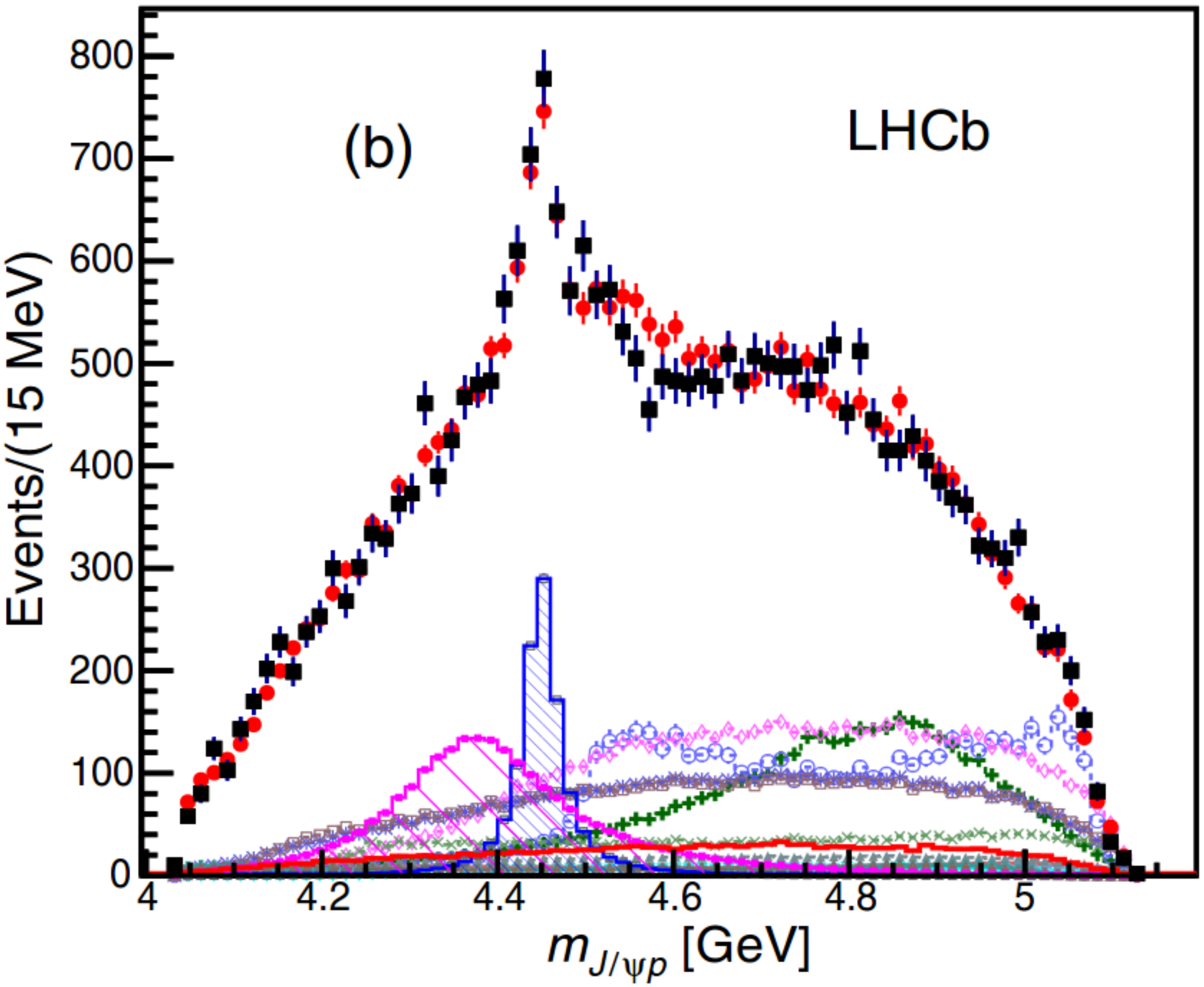
Astrid N. Hiller Blin

JGU Mainz

Phys. Rev. D 94 (2016) 034002

In collaboration with JPAC

LHCb discovery



2015: discovery of **exotic-like** structures in $J/\psi\ p$ channel

LHCb collaboration, PRL 115 (2015) 072001

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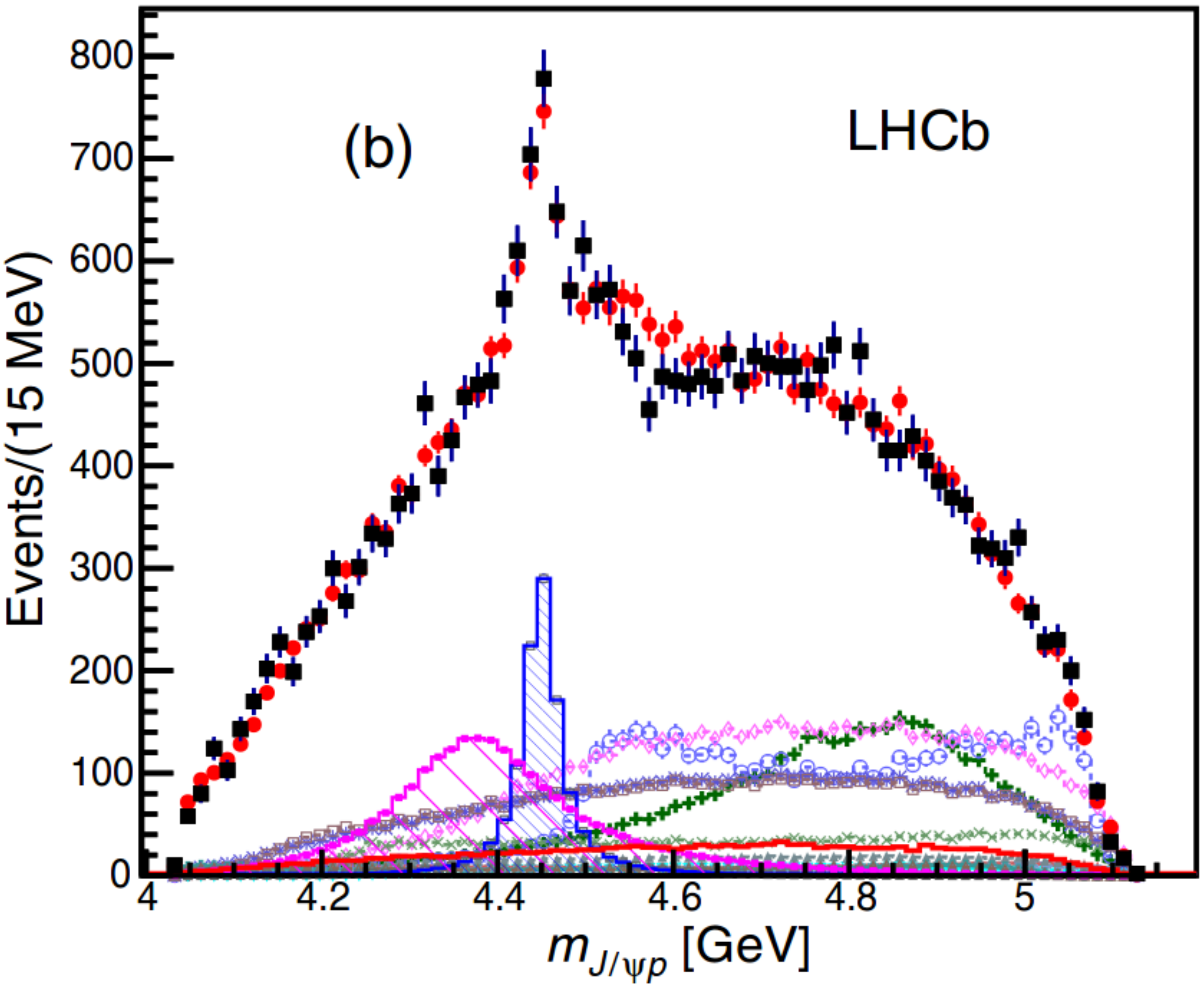

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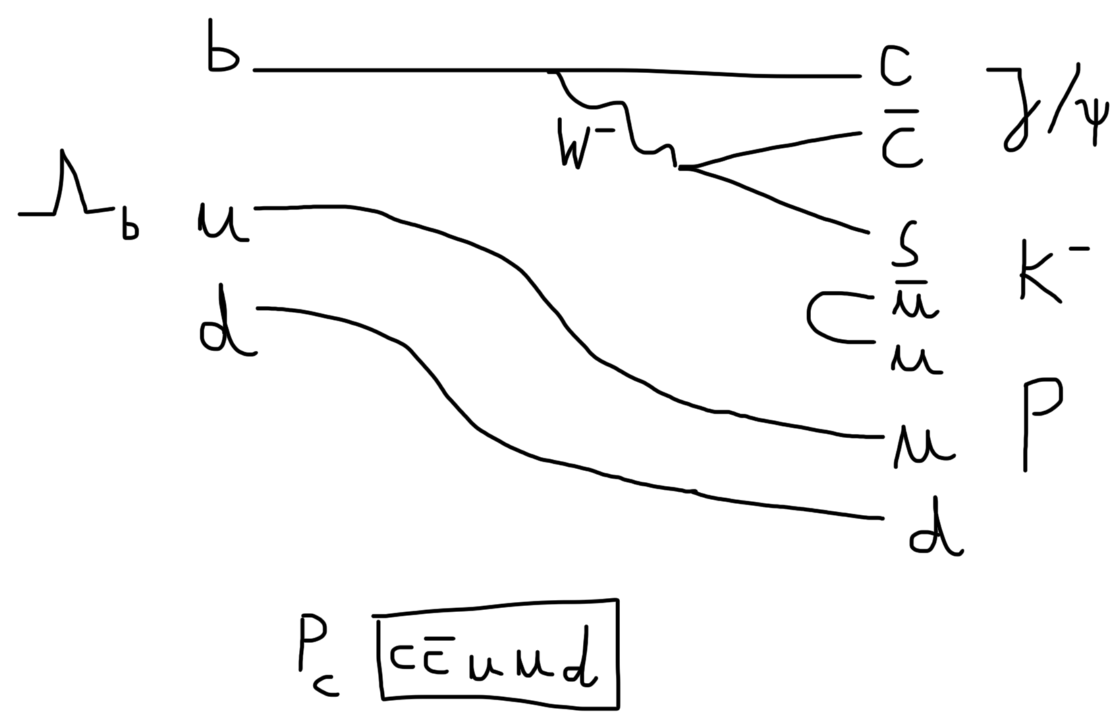
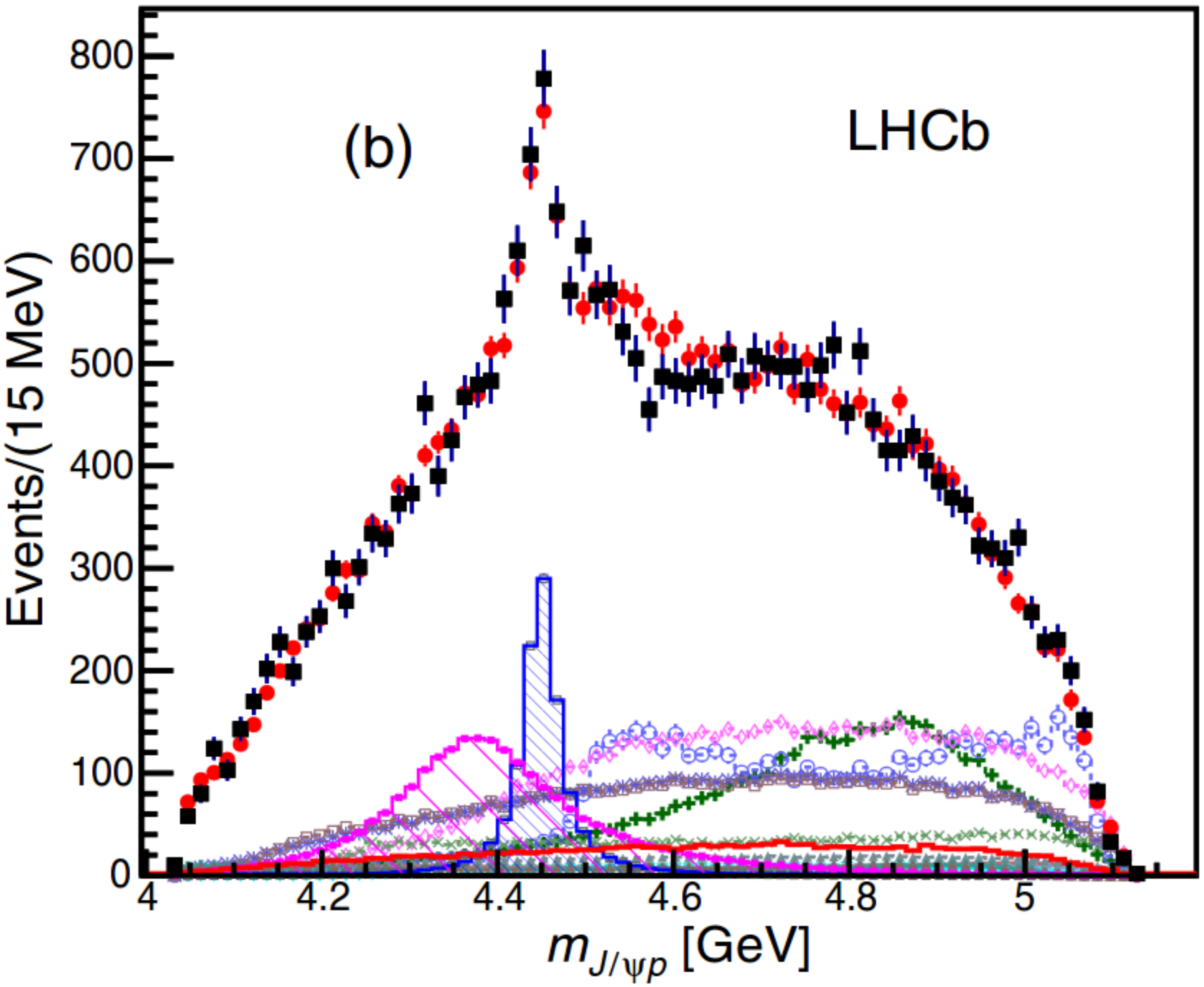


K- p resonances (Λ: *sud* content) alone were NOT sufficient to fit the data well.

LHCb discovery



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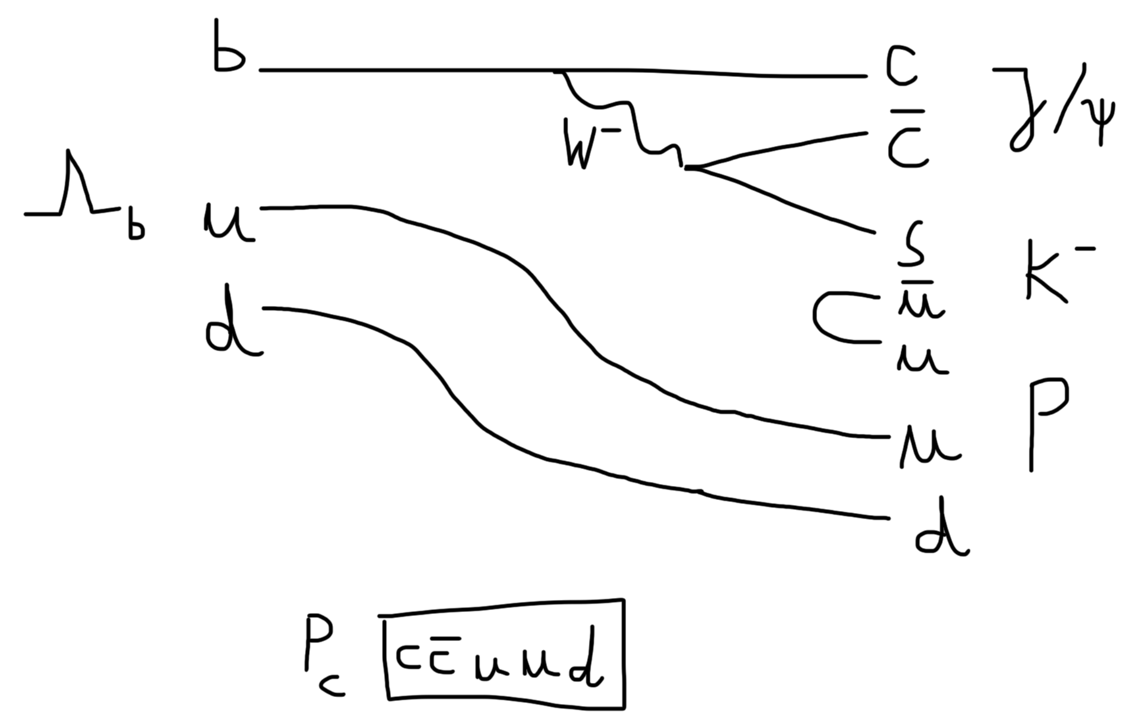
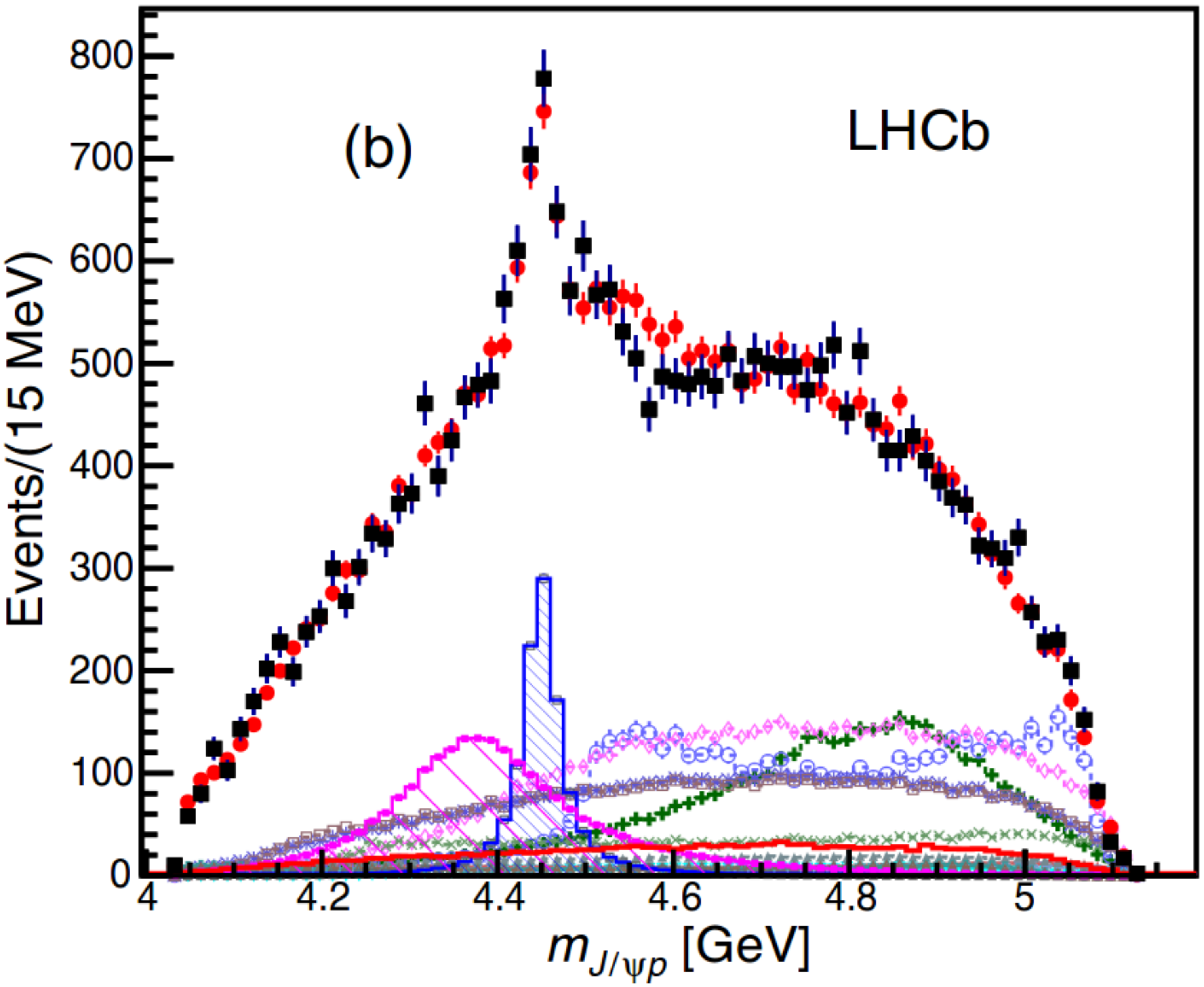


Two exotic peaks of opposite parity absolutely necessary in order to correctly fit data. Otherwise the angular distributions would be symmetric, contrary to observation.

Jurik, CERN-THESIS-2016-086

LHCb discovery



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LHCb collaboration, PRL 115 (2015) 072001

Width 39 MeV at 4.45 GeV

Width 205 MeV at 4.38 GeV

of preferred J^P: $5/2^+$ and $3/2^-$

Two exotic peaks of opposite parity absolutely necessary in order to correctly fit data. Otherwise the angular distributions would be symmetric, contrary to observation.

Jurik, CERN-THESIS-2016-086

The family of exotics

- ***Mesons*** **e.g. whose** J^P **cannot be matched by** $q\bar{q}$ **content (X, Y, Z)**
- ***Baryons*** **with exotic flavor content, e.g. negative strangeness or charm**
- **Pentaquarks, di-baryons, gluonium, quark-gluon hybrids, …**

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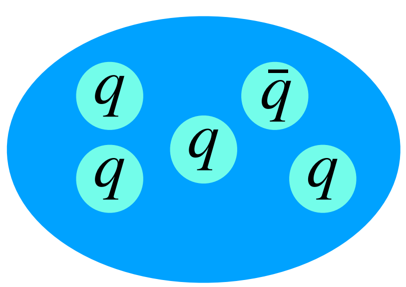

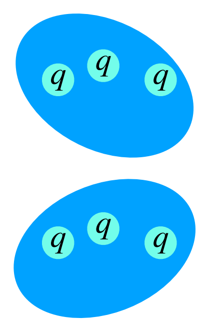

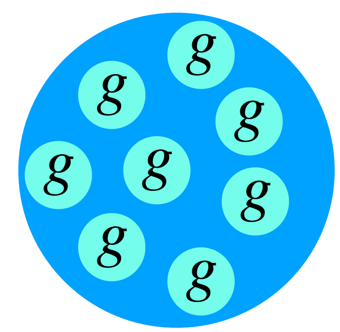

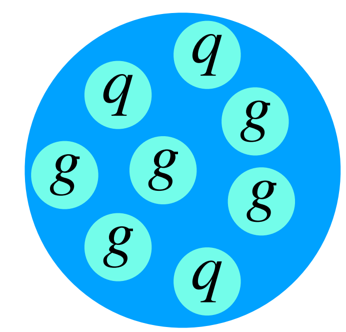

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In the 90's: narrow low-mass pentaquarks with anti-strangeness predicted.
In 2003: several experiments claimed evidence for these states!
Ultimately NONE of the candidates was confirmed at higher statistics.

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"The conclusion that pentaquarks in general […] do not exist appears compelling."

Review of Particle Physics, J. Phys. G 33 (2006) 1

Exciting news? Advantages of photoproduction

Theoretical overview

Experimental status at JLAB

Newest results on asymmetries

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Which is the nature of the LHCb peaks?

Triangle singularities: not a resonance!

Guo et al., PRD 92 (2015) 071502
Liu et al., PLB 757 (2016) 231
Guo et al., EPJA 52 (2016) 318
...

Quark degrees of freedom

Maiani et al., PLB 749 (2015) 289
Lebed, PLB 749 (2015) 454
Li et al., JHEP 12 (2015) 128
Wang, EPJC 76 (2016) 70
Ghosh et al., PPNL 14 (2017) 550
Wu et al., PRD 95 (2017) 034002
...

Meson-baryon molecules

Meißner and Oller, PLB 751 (2015) 59
Roca et al., PRD 92 (2015) 094003
Chen et al., PRL 115 (2015) 172001
He, PLB 753 (2016) 547
Eides et al., PRD 93 (2016) 054039
Shimizu et al., PRD 93 (2016) 114003
Shen et al., NPA 954 (2016) 393
Xiao, PRD 95 (2017) 014006
...

Photoproduction — advantages

Exclusion of scenarios of kinematical effects!
Resonant nature would be confirmed

Kubarovsky and Voloshin, PRD 92 (2015) 031502
Wang et al., PRD 92 (2015) 034022
Karliner and Rosner, PLB 752 (2016) 329
Hiller Blin et al., PRD 94 (2016) 034002

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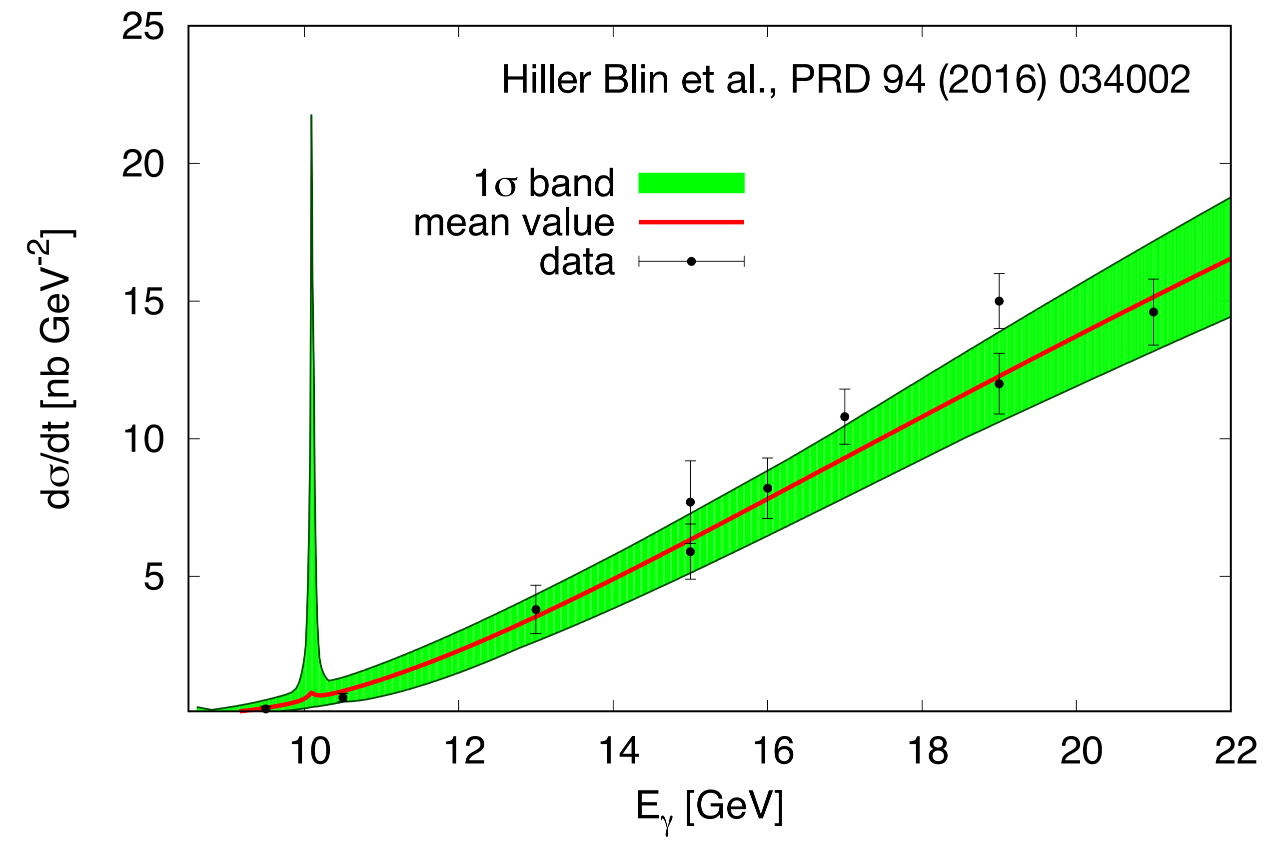
The narrow peak would appear close to J/ψ production threshold:
Low background, clear signal possible!



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Hiller Blin et al., PRD 94 (2016) 034002

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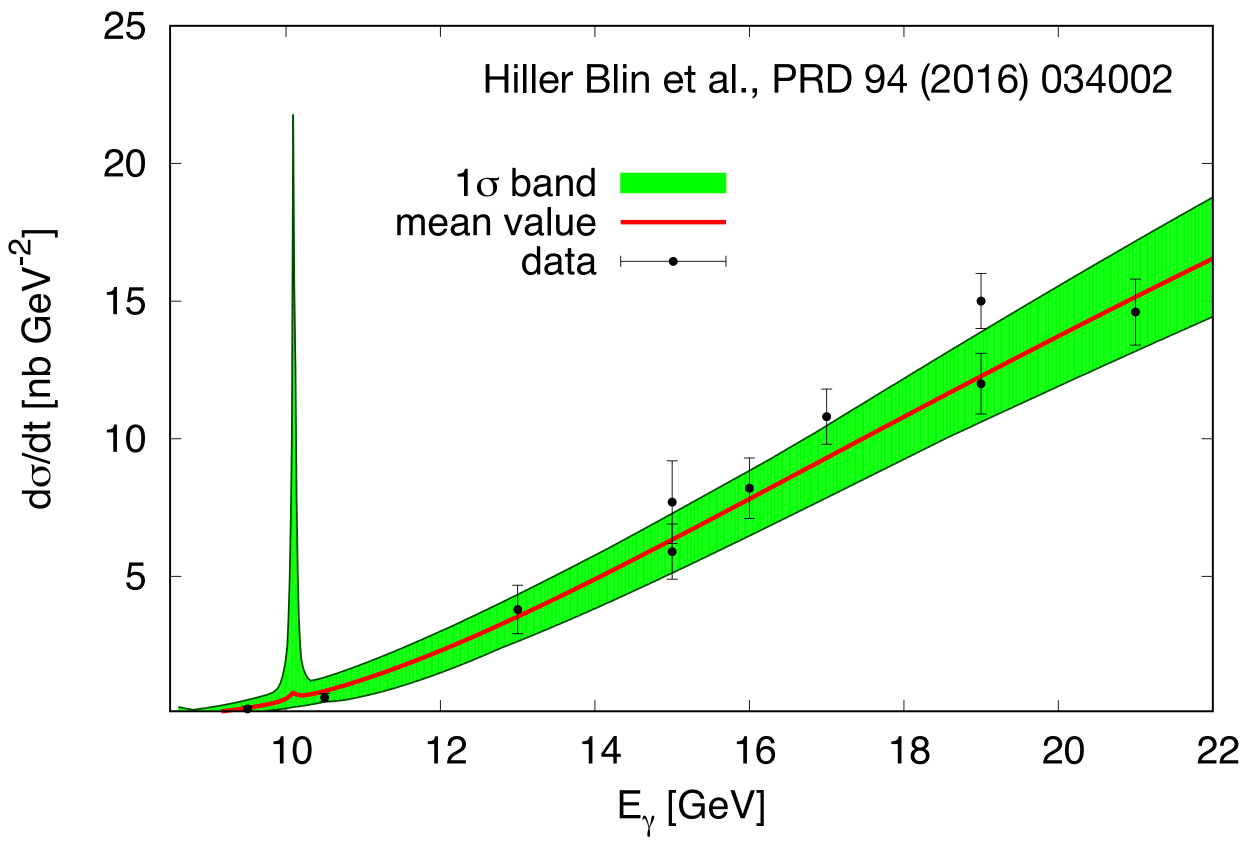
Data status at peak: scarce and only forward — peak might have been overlooked so far

Camerini et al., PRL 35 (1975) 483

Ritson, AIPCP 30 (1976) 75

Anderson, SLAC-PUB-1741 (1976)



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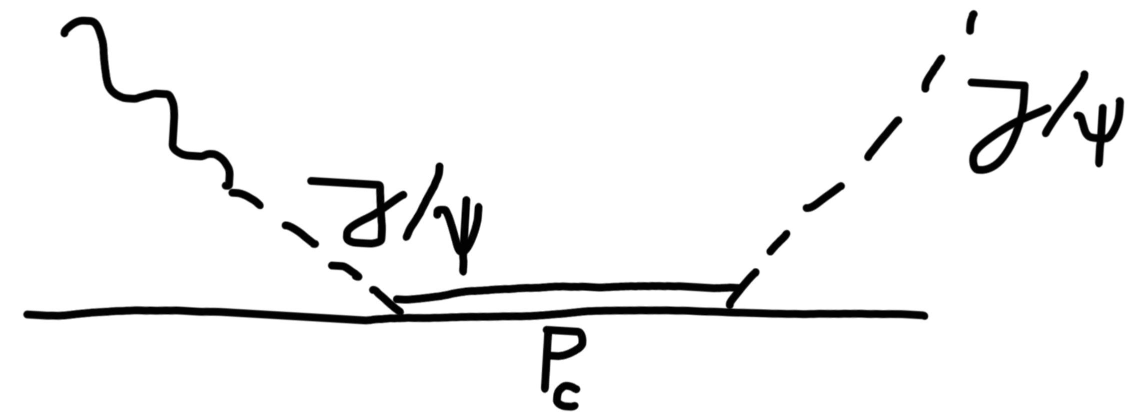

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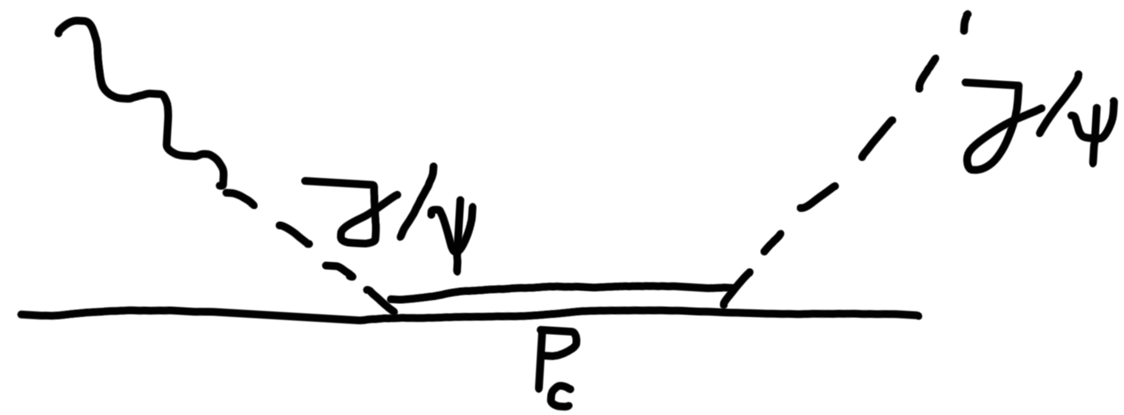

Electromagnetic decay of the P_c estimated via **vector-meson dominance:**

- **Electromagnetic coupling given by hadronic coupling**
- **Due to quantum numbers and mass, other resonant contributions not allowed**

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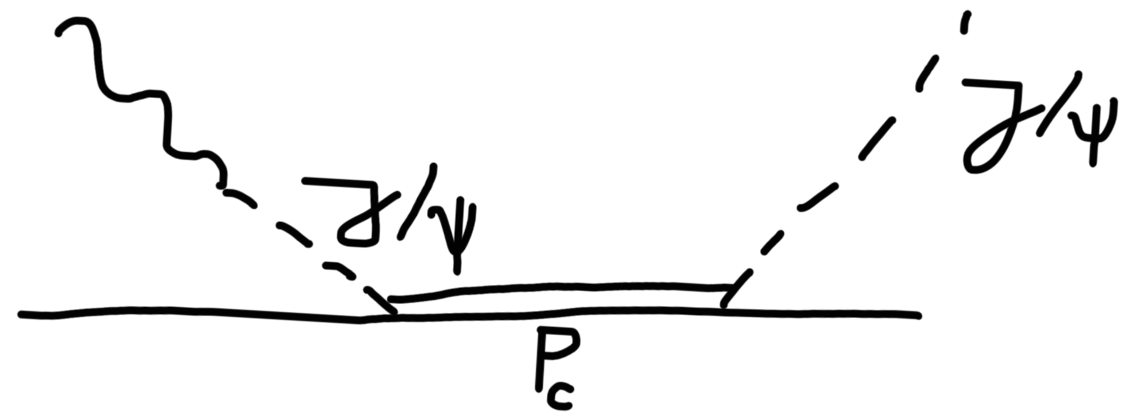

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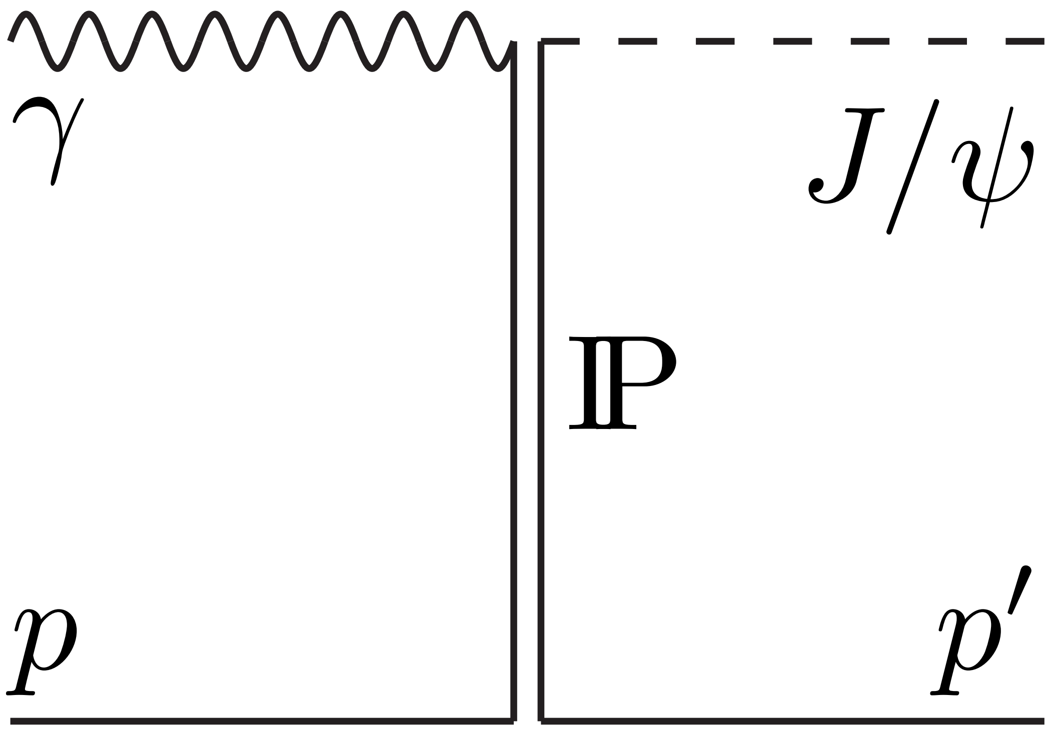
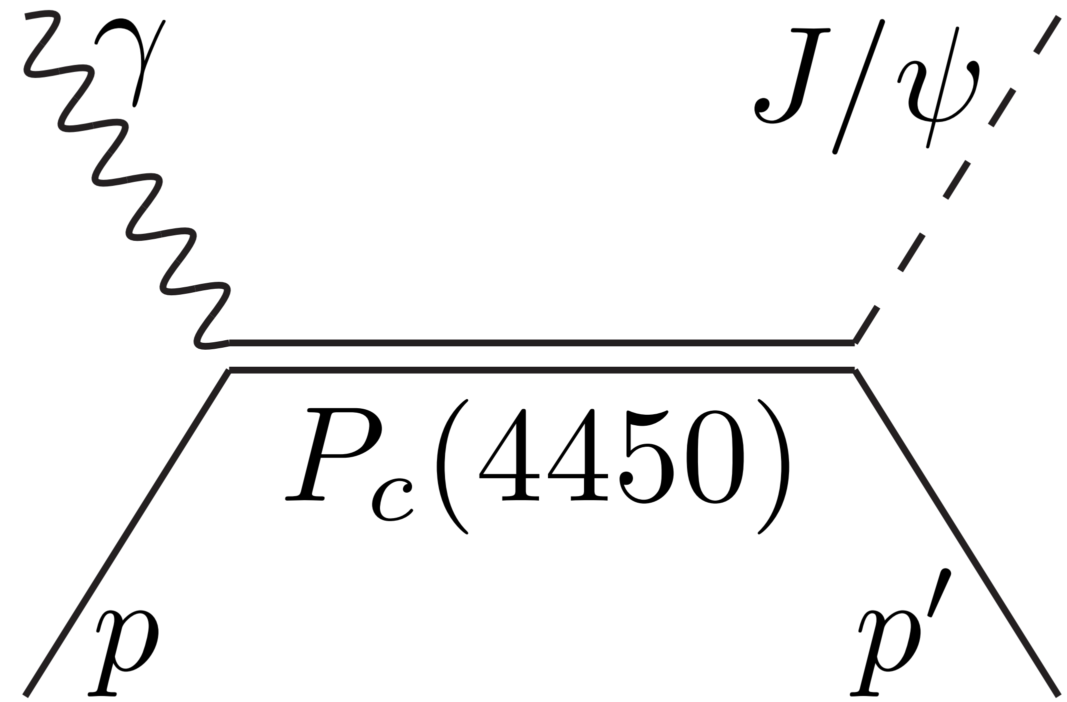
Background behaviour mainly diffractive — forward peaked:

Signal dominant in off-forward directions!

Reaction model

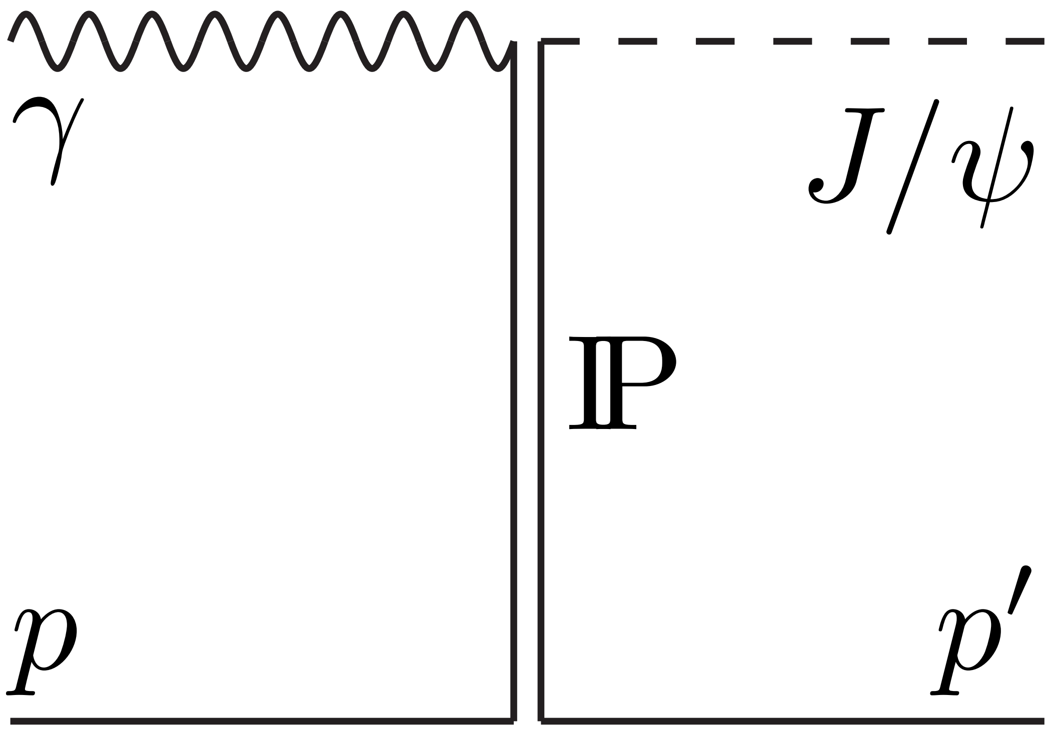




- **Non-resonant contribution — Pomeron exchange**
- **Resonant amplitude — Breit-Wigner ansatz**

Hiller Blin et al., PRD 94 (2016) 034002

Pomeron t-channel exchange



Hiller Blin et al., PRD 94 (2016) 034002

Daniel Winney et al., work in progress

Lesniak and Szczepaniak, A.Phys.Pol.B 34 (2003) 3389

Wang et al., PRD 92 (2015) 034022

$$iA\left(\frac{s-s_{th}}{s_0}\right)^{\alpha(t)}\frac{e^{b_0(t-t_{\text{min}})}}{s}$$

$$\times\,\bar{u}(p_f,\lambda_{p'})\gamma_\mu u(p_i,\lambda_p)[\varepsilon^\mu(p_\gamma,\lambda_\gamma)q^\nu-\varepsilon^\nu(p_\gamma,\lambda_\gamma)q^\mu]\varepsilon^\star_\nu(p_\psi,\lambda_\psi)$$

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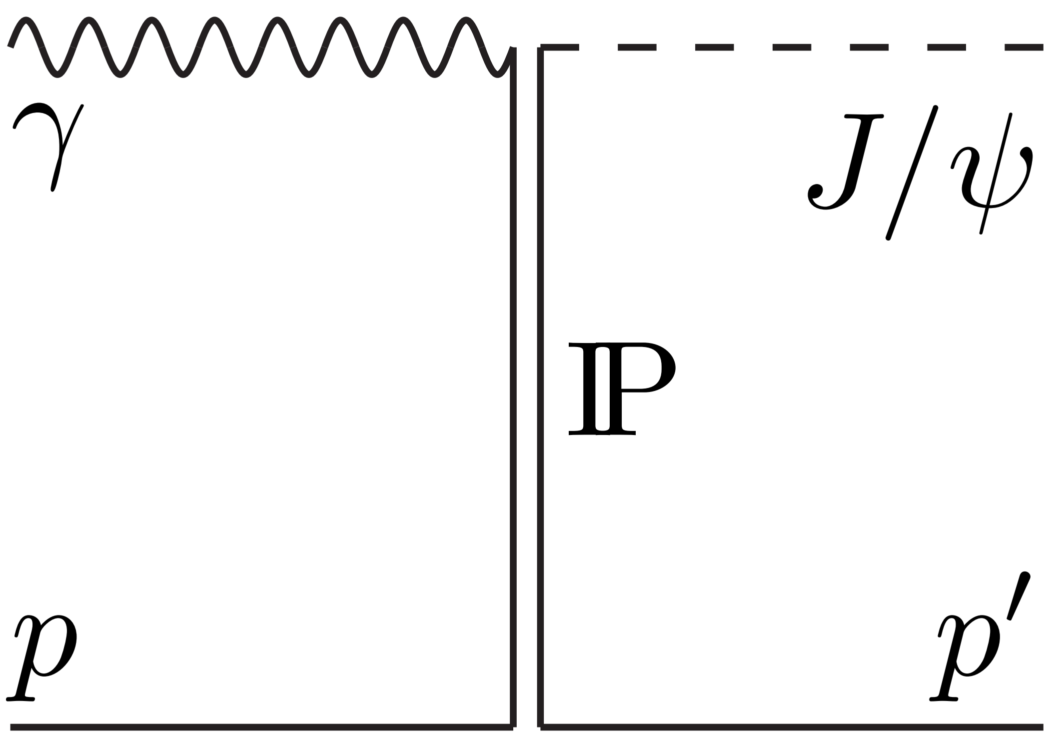

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Parameters fitted to world J/ψ photoproduction data

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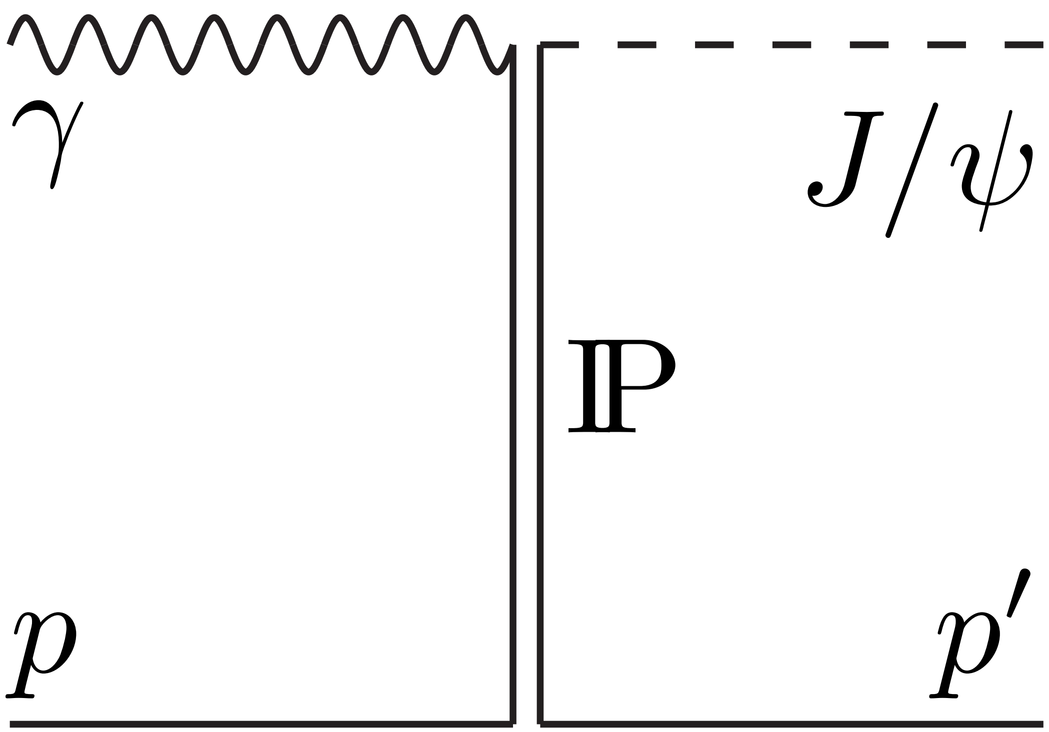

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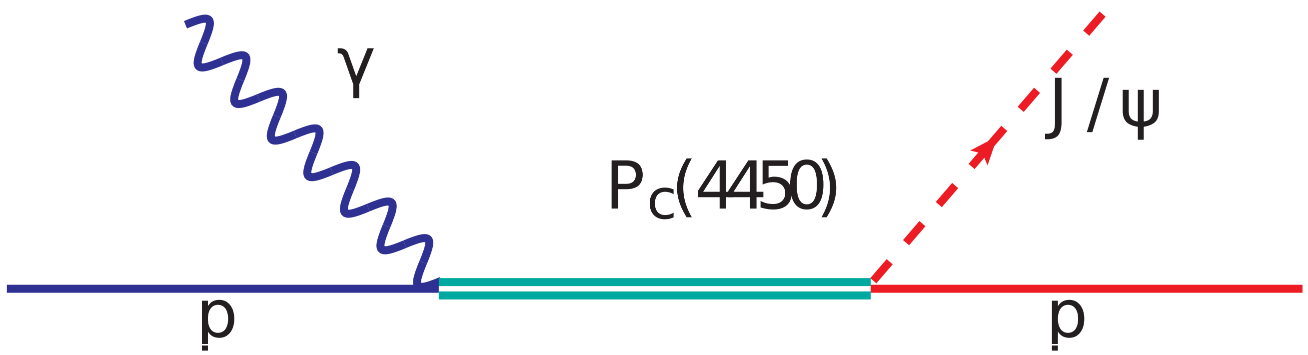
Wang et al., PRD 92 (2015) 034022

Parameters fitted to world J/ψ photoproduction data

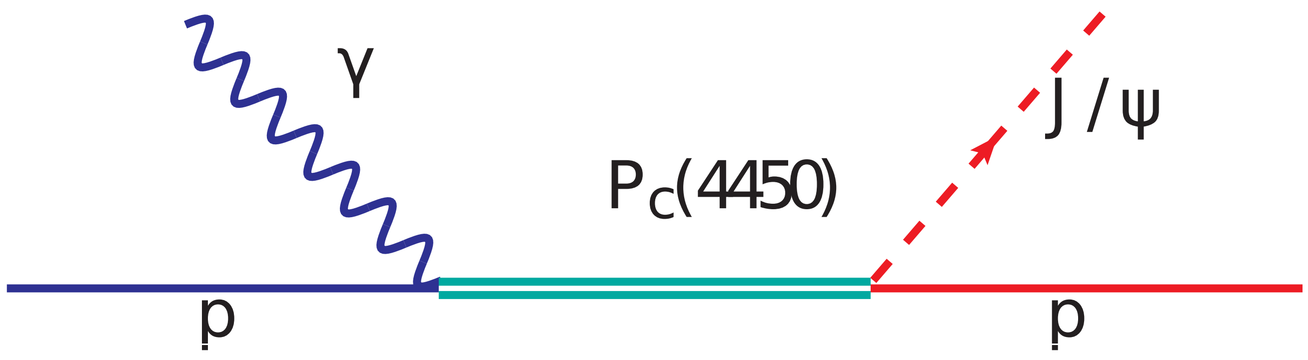
Pomeron exchange: vector coupling between target and recoil proton

Breit Wigners in s-channel



$$\frac{\color{blue}{< \lambda_r | T^\dagger_{em} | \lambda_\gamma \lambda_p >} \ \color{red}{< \lambda_\psi \lambda_{p'} | T_{dec} | \lambda_r >}}{\color{green}{M_r^2 - s - \mathrm{i}\Gamma_r M_r}} f_{th}(s)$$

Breit Wigners in s-channel



$$\frac{<\lambda_r|T^{\dagger}_{em}|\lambda_\gamma\lambda_p> \;\; <\lambda_\psi\lambda_{p'}|T_{dec}|\lambda_r>}{M_r^2 - s - i\Gamma_r M_r} f_{th}(s)$$

Hadronic coupling related to branching ratio of P_c into the relevant channel
— electromagnetic coupling estimated via VMD

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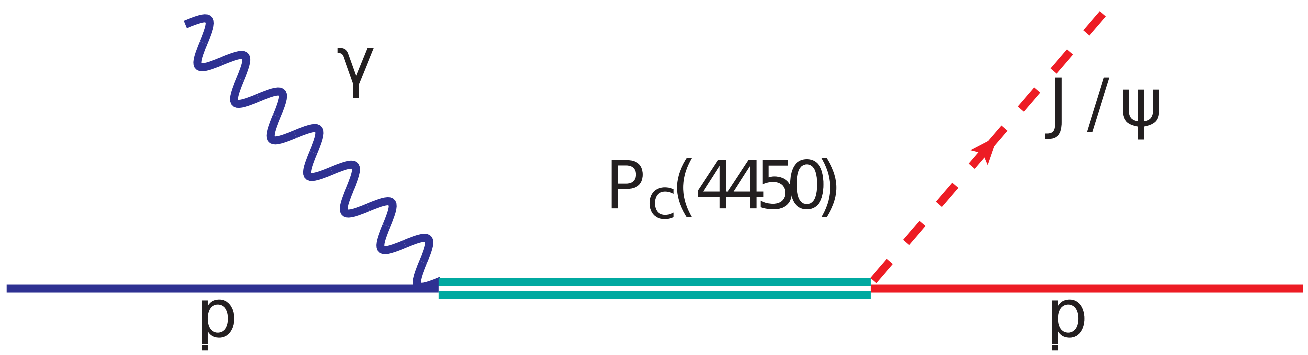

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Hadronic coupling related to branching ratio of P_c into the relevant channel
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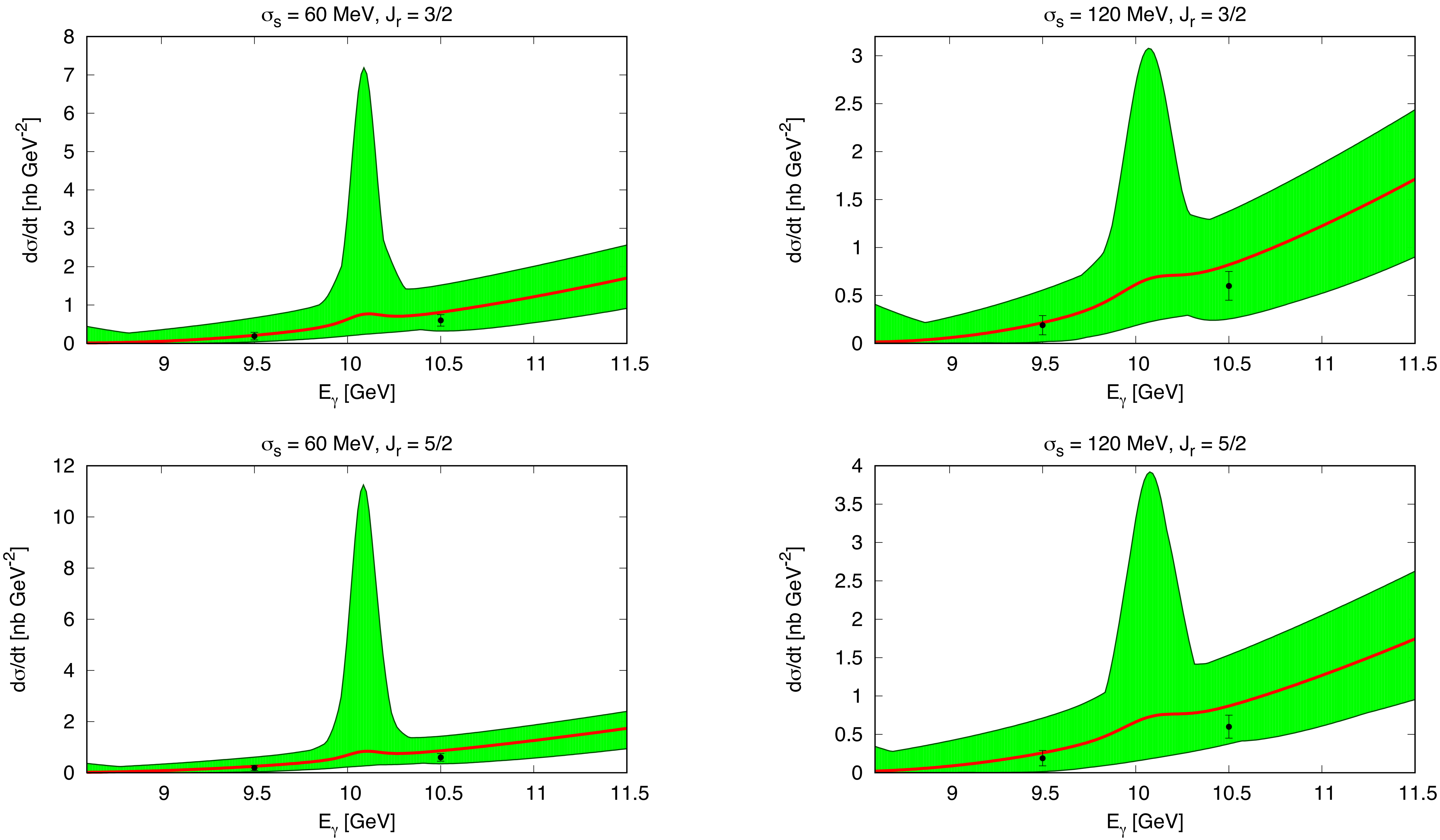
Only one additional fitting parameter:
first estimates for the upper limit of the branching ratio!

Fitting results for narrow peak



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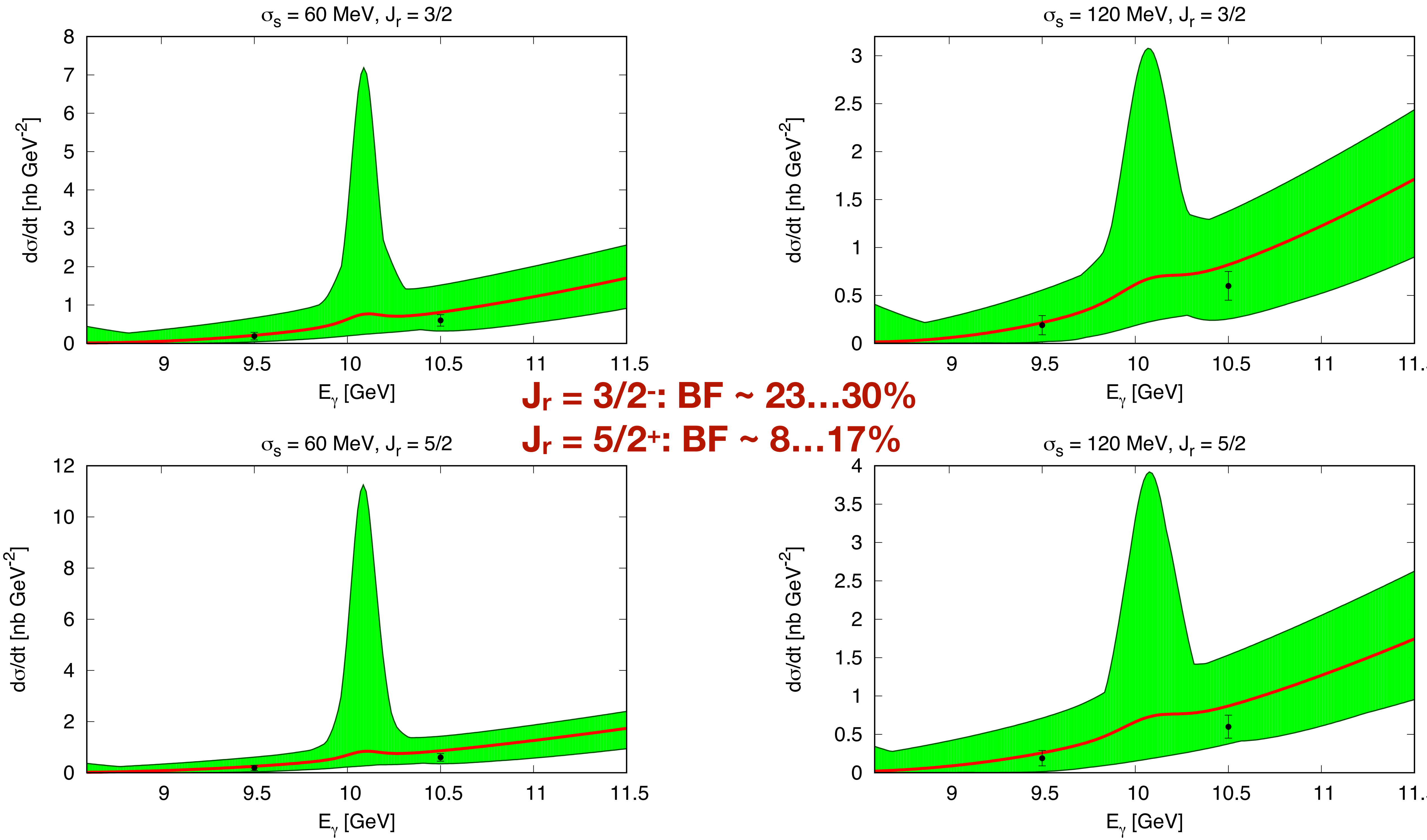
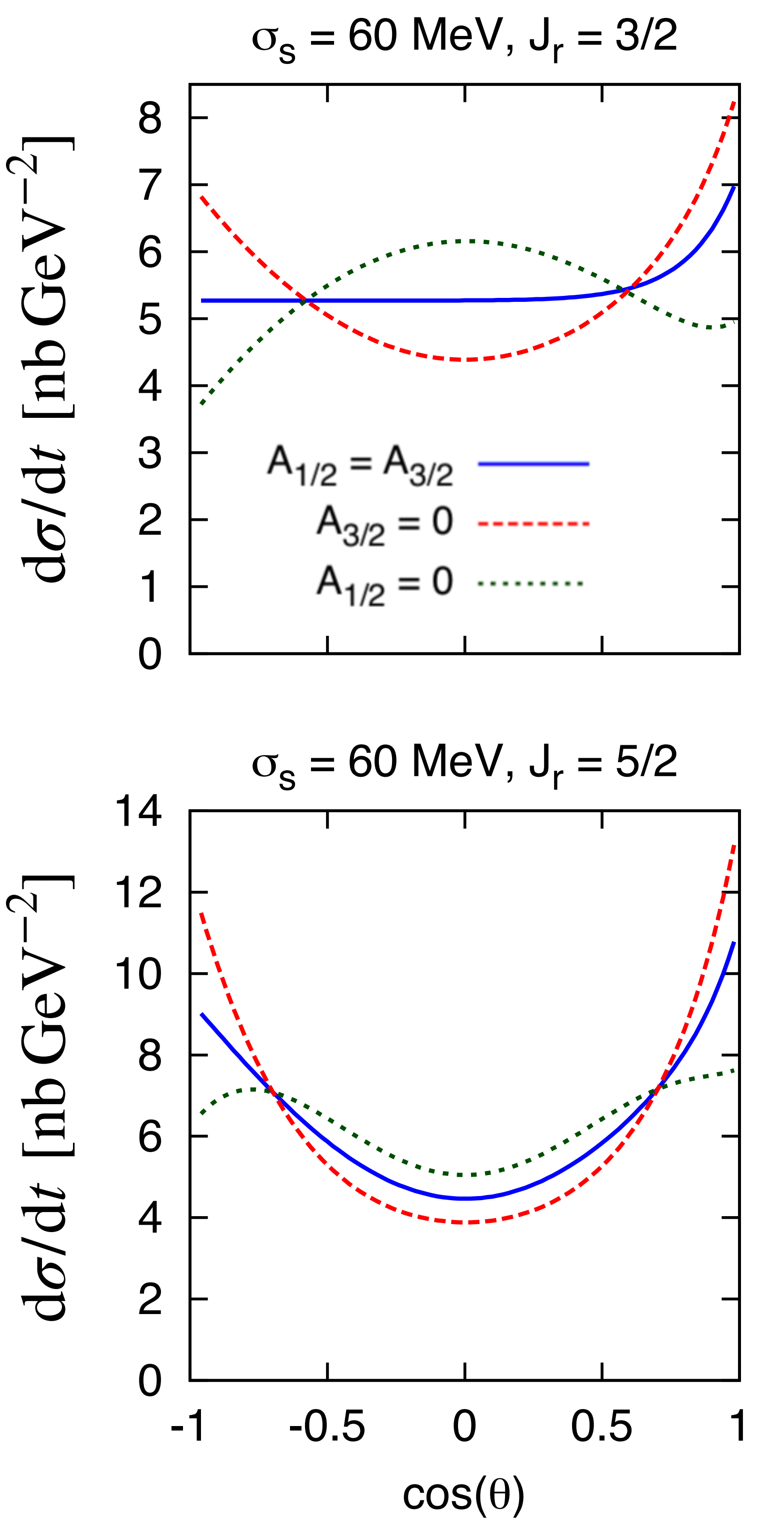


Angular studies — photocouplings



- **Relax VMD condition: 2 independent photocouplings**
- **Angular distributions to be studied at JLAB**
- **Determination of photocoupling ratio!**

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Hall C - approved with “high impact” rating A!

Meziani et al., arXiv:1609.00676

- **Bremsstrahlung photon beam from 11-GeV electrons**
- **Optimized detector angle**
- **Tight binning in energy and angular distributions**
- **Statistics should be sufficient for confirmation of narrow peak:**
  For coupling > 1.5%, sensitivity > 5σ!

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- **Tight binning in energy and angular distributions**
- **Statistics should be sufficient for confirmation of narrow peak: For coupling > 1.5%, sensitivity > 5σ!**
- **Run of E12-16-007: January 30, 2019 to February 20, 2019; results expected shortly after run**
- **If confirmed, further insight into J^P and nature**

Hall A - electroproduction with SoLID

JLAB Proposal: PR12-12-006

- **Results expected further in the future**

Hall A - electroproduction with SoLID

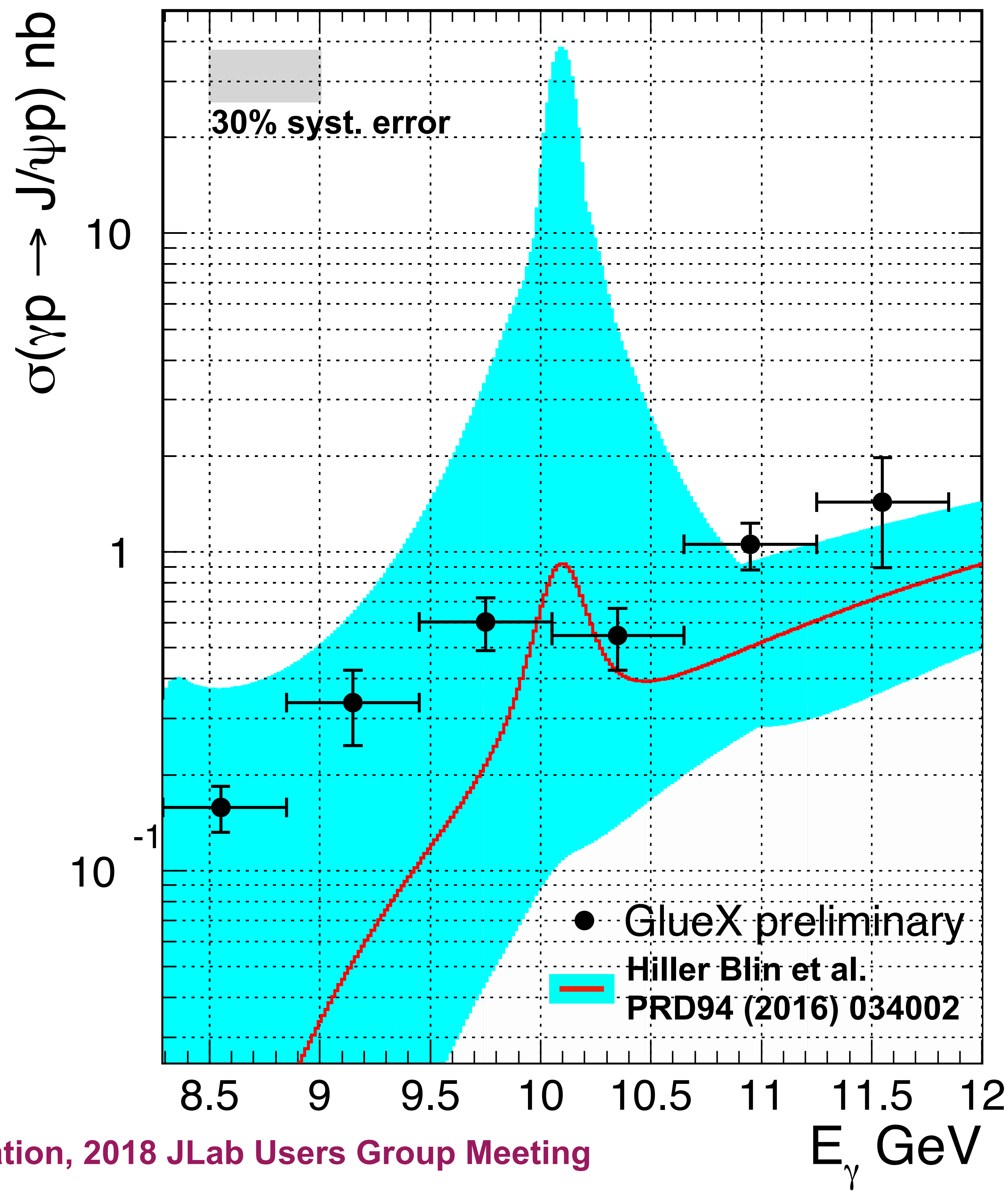
JLAB Proposal: PR12-12-006

- **Results expected further in the future**

Hall B - CLAS12

- **Successful run between February and May 2018**
- e^+e^- **and** $\mu^+\mu^-$ **data taken: more statistics!**
- **Data analysis in progress - first results expected 2019-2020**

Hall D



200 events!

GLUEX

Preliminary

GlueX collaboration, 2018 JLab Users Group Meeting

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Asymmetries A_{LL} and K_{LL}

$$A(K)_{LL} = \frac{\mathrm{d}\sigma(\uparrow\uparrow) - \mathrm{d}\sigma(\uparrow\downarrow)}{\mathrm{d}\sigma(\uparrow\uparrow) + \mathrm{d}\sigma(\uparrow\downarrow)}$$

- A_{LL} — between photon and target
- K_{LL} — between photon and recoil proton

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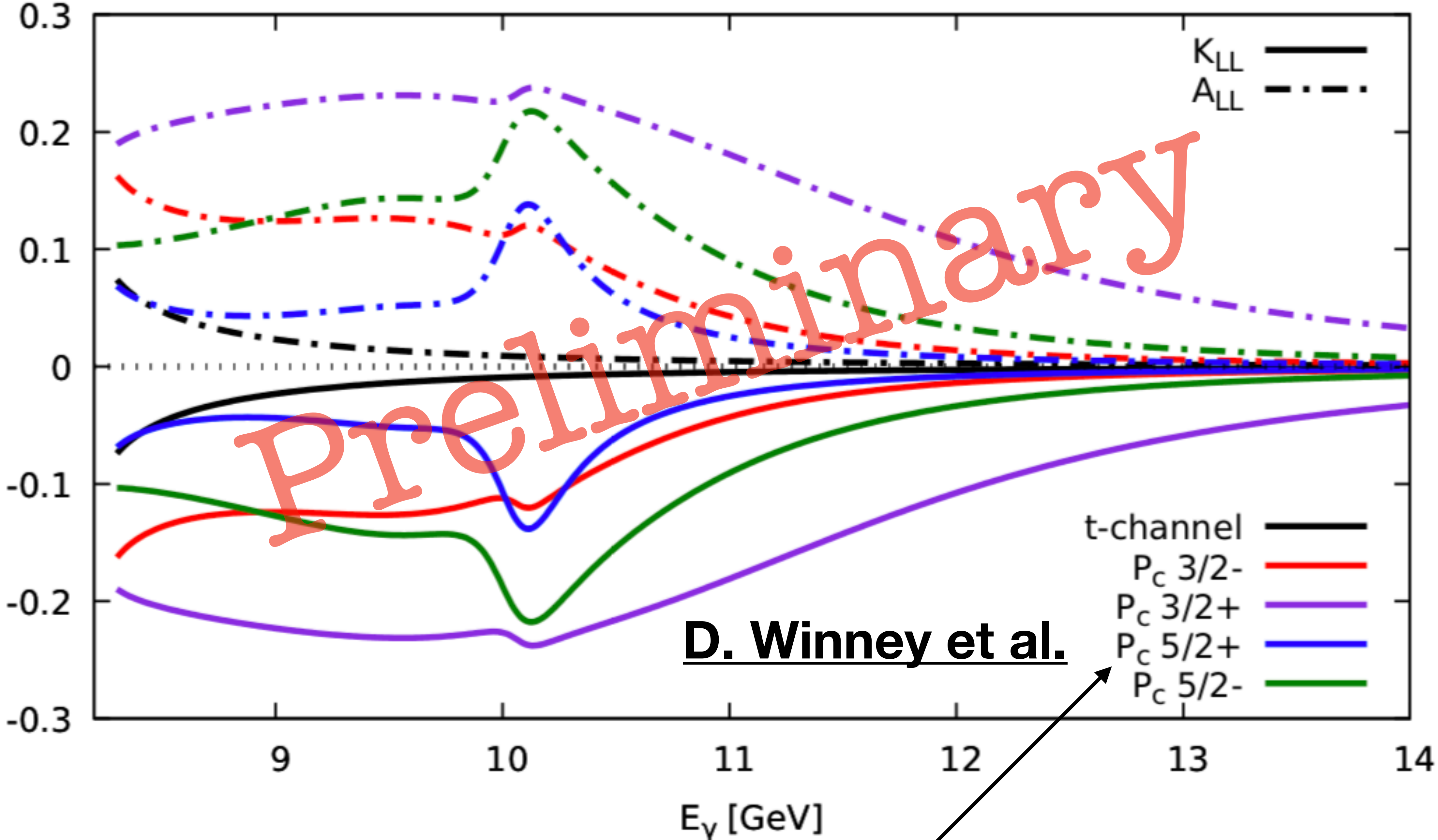
Proposed by the SBS experiment in Hall A!

LoI12-18-001 (PAC 46)
C. Fanelli, L. Pentchev, B. Wojtsekhowski

Serves as secondary measurement and bound on photocouplings

New results including the two signals



Quoted J^P of $P_c(4450)$ ($P_c(4380)$ has the other J and opposite P)

Summary

- **Pentaquark photoproduction: benchmark to confirm resonances**
- **Fit to world data: constrained branching fraction into J/ψ p channel**
- **Angular behaviour: information on photocouplings**
- **Many ongoing and near-future experiments at JLAB**
- **LoI for K_{LL} and A_{LL} submitted for Hall A — theoretical studies ready**