A Search for the LHCb Charmed 'Pentaquark' using Photo-production of J/ψ at Threshold in Hall C at Jefferson Lab

The proposal PR12-16-007 was approved with an 'A' rating and a 'high-impact' label by the Jefferson Lab PAC 44 in July 2016 (https://arxiv.org/abs/1609.00676)

On behalf of

Jefferson Lab Hall C E12-16-007 Experiment Collaboration

Burcu Duran

7th Workshop of the APS Topical Group on Hadronic Physics, 1 February 2017

COLLABORATION

A. Asaturyan, H. Mkrtchyan, V. Tadevosyan, S. Zhamkochyan
Alikhanyan National Science Laboratory (YerPhI), Yerevan, Armenia

J. Arrington, W. Armstrong, K. Hafidi, M. Hattawy, Z. Ye
Argonne National Laboratory, Chicago, IL

K. Aniol
California State University, Los Angeles, CA

H. Gao, Z. Zhao, T. Liu, X. Yan, C. Gu, C. Peng, X. Li, W. Xiong
Duke University, Durham, NC

P. Markowitz
Florida International University, Miami, FL

K. Adhikari, H. Bhatt, D. Bhetuwal, J. Dunne, D. Dutta, L. El-Fassi, L. Ye
Mississippi State University, Starkville, MS

F. R. Wesselmann
Old Dominion University, Norforlk, VA

X. Chen, Q. Fu, R. Wang, Y. Zhang, F. Zhao
Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China.

R. Dupré
Institut de Physique Nuclaire d'Orsay, Orsay, France

G. M. Huber, W. Li, A. Zafar
University of Regina, SK, Canada

S. Bae, H. Choi, S. Choi, H. Go, J. Ha
Seoul National University, Seoul, Korea

H. Atac, B. Duran, S. Joosten[1],
Z.-E. Meziani[2], M. Paolone[3], M. Rehfuss, N. Sparveris
Temple University, Philadelphia, PA

J.-P. Chen, E. Chudakov[4], M. Diefenthaler, O. Hansen, D. Higinbotham, M. Jones[5], D. Meekins, L. Pentchev, E. Pooser, S. Wood
Thomas Jefferson National Accelerator Facility, Newport News, VA

MOTIVATION

INSPIRE HEP

Welcome to INSPIRE, the High Energy Physics information system. Please direct questions, comments or concerns to feedback@inspirehep.net.

HEP :: HEPNAMES :: INSTITUTIONS :: CONFERENCES :: JOBS :: EXPERIMENTS :: JOURNALS :: HELP

Information | References (55) | Citations (328) | Files | Plots

Observation of $J/\psi p$ Resonances Consistent with Pentaquark States in $\Lambda_b^0 \to J/\psi K^- p$ Decays - LHCb Collaboration (Aaij, Roel *et al.*)
Phys.Rev.Lett. 115 (2015) 072001 arXiv:1507.03414 [hep-ex] CERN-PH-EP-2015-153, LHCB-PAPER-2015-029

Update these references

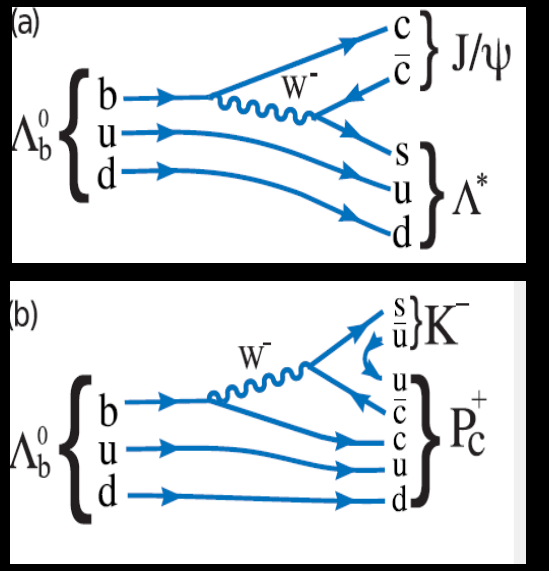
[1] A Schematic Model of Baryons and Mesons - Gell-Mann, Murray Phys.Lett. 8 (1964) 214-215
[2] Multi-Quark Hadrons. 1. The Phenomenology of (2 Quark 2 anti-Quark) Mesons - Jaffe, Robert L. Phys.Rev. D15 (1977) 267 SLAC-PUB-1772
[3] Multi - Quark Baryons and the MIT Bag Model - Strottman, D. Phys.Rev. D20 (1979) 748-767
[4] New Possibilities for Exotic Hadrons: Anticharmed Strange Baryons - Lipkin, Harry J. Phys.Lett. B195 (1987) 484-488 WIS-87/32-PH
[5] On the conundrum of the pentaquark - Hicks, Kenneth H. Eur.Phys.J. H37 (2012) 1-31
[6] Observation of a resonance-like structure in the pi+- psi-prime mass distribution in exclusive B ---> K pi+- psi-prime decays - Belle Collaboration (Choi, S.K. *et al.*) Phys.Rev.Lett. 100 (2008) 142001 arXiv:0708.1790 [hep-ex] BELLE-CONF-0773
[7] Experimental constraints on the spin and parity of the $Z(4430)^+$ - Belle Collaboration (Chilikin, K. *et al.*) Phys.Rev. D88 (2013) no.7, 074026 arXiv:1306.4894 [hep-ex] BELLE-PREPRINT-2013-12, KEK-PREPRINT-2013-22
[8] Observation of the resonant character of the $Z(4430)^-$ state - LHCb Collaboration (Aaij, Roel *et al.*) Phys.Rev.Lett. 112 (2014) no.22, 222002 arXiv:1404.1903 [hep-ex] LHCB-PAPER-2014-014, CERN-PH-EP-2014-061
[9] A possible global group structure for exotic states - Li, Xue-Qian *et al.* Eur.Phys.J. C74 (2014) no.12, 3198 arXiv:1409.3332 [hep-ph]
[10] Precision measurement of the ratio of the Λ_b^0 to $\overline{B}^0$ lifetimes - LHCb Collaboration (Aaij, Roel *et al.*) Phys.Lett. B734 (2014) 122-130 arXiv:1402.6242 [hep-ex] CERN-PH-EP-2014-027, LHCB-PAPER-2014-003
Precision measurement of the Λ_b baryon lifetime - LHCb Collaboration (Aaij, R *et al.*) Phys.Rev.Lett. 111 (2013) 102003 arXiv:1307.2476 [hep-ex] CERN-PH-EP-2013-117, LHCB-PAPER-2013-032
[11] Review of Particle Physics - Particle Data Group (Oli
[12] The LHCb Detector at the LHC - LHCb Collaboration
[13] Performance of the LHCb Vertex Locator - Aaij, R. e ins-det] CERN-LHCB-DP-2014-001

328 citations since July 2015 !

The LHCb charmed ‘pentaquark’

$\Lambda_b \rightarrow K^- p J/\Psi$

Aaij, R, et. al (LHCb) PRL 115-7 (2015)

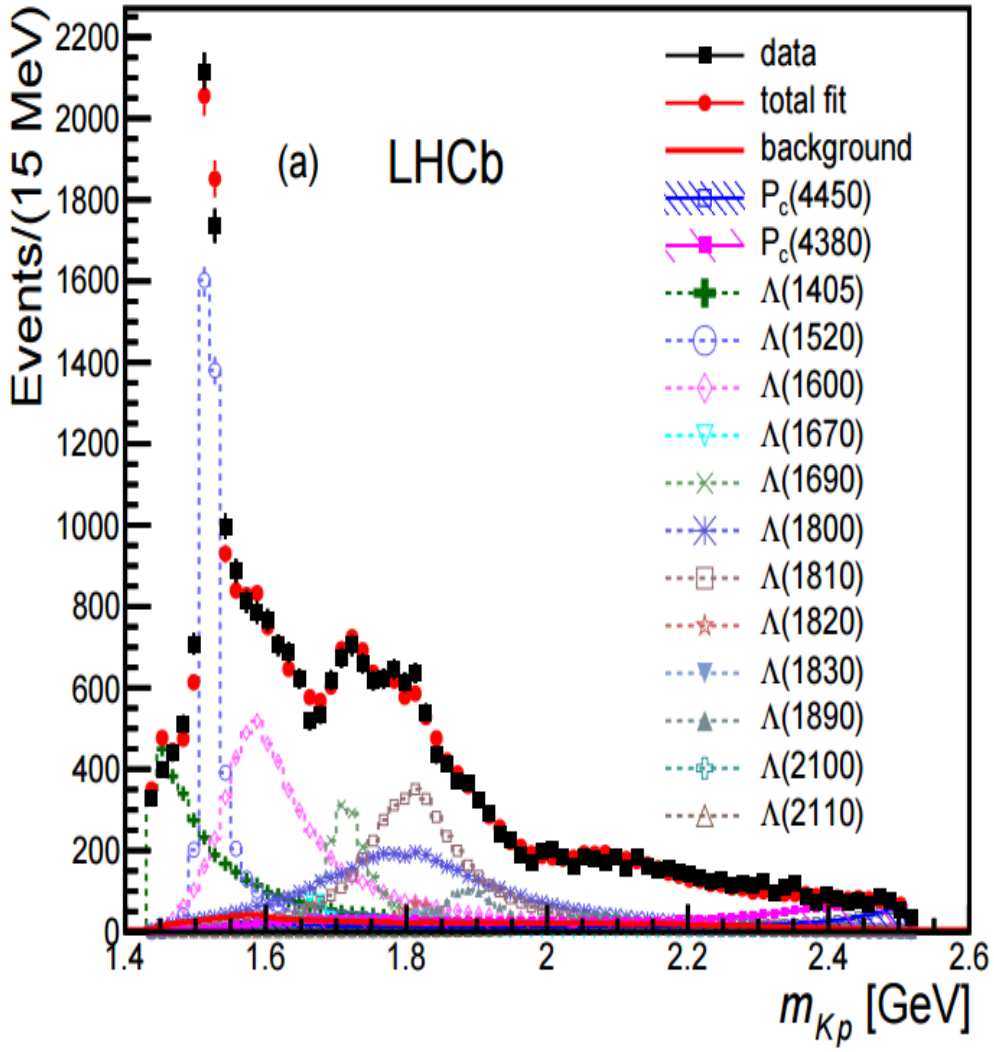


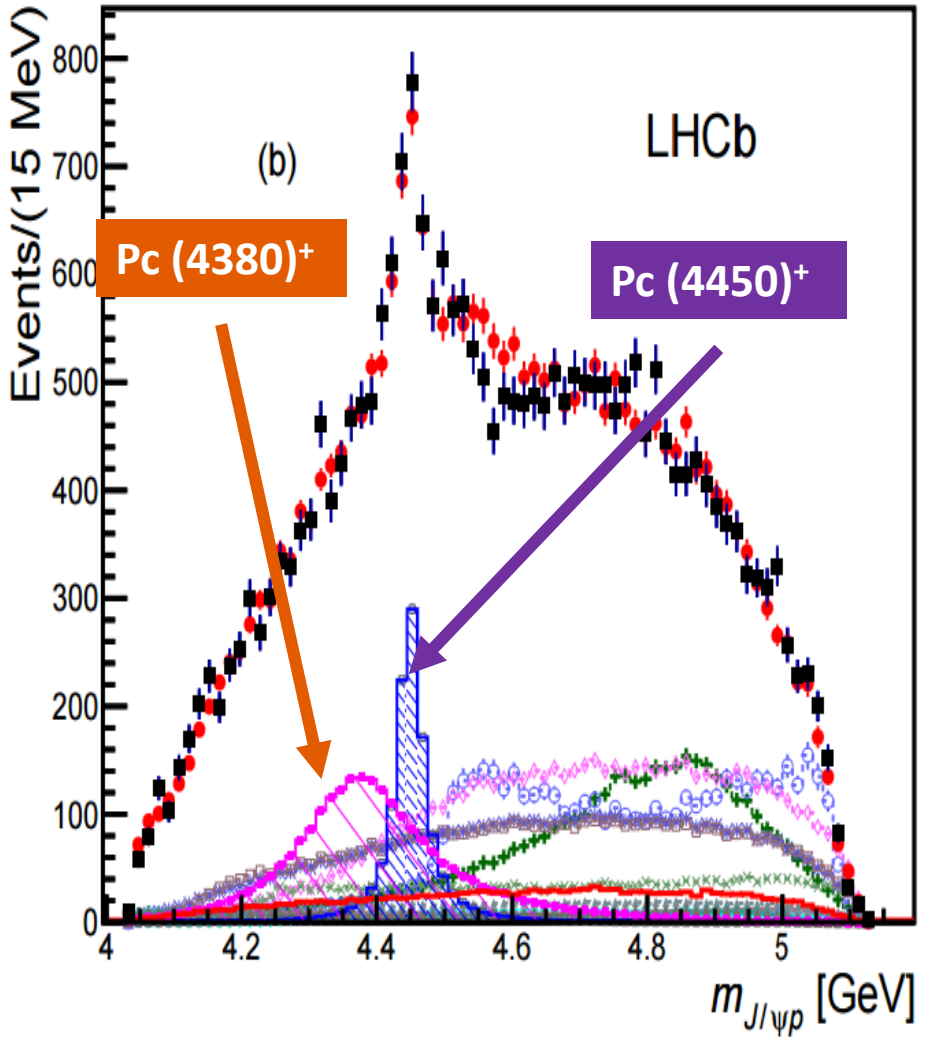
spin/parity possibilities

5/2+, 3/2- (Most likely)

5/2-, 3/2+

3/2-, 5/2+





Possible interpretations

- True pentaquark resonant states
- Kinematic enhancements

Tool to solve the true nature of exotic pentaquark particles

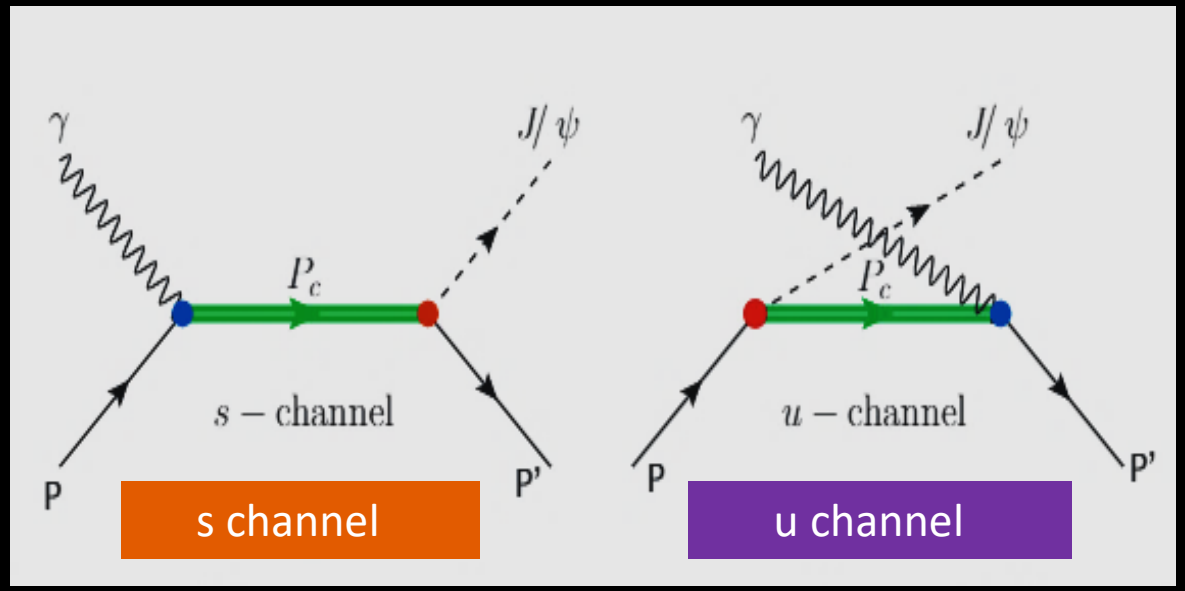
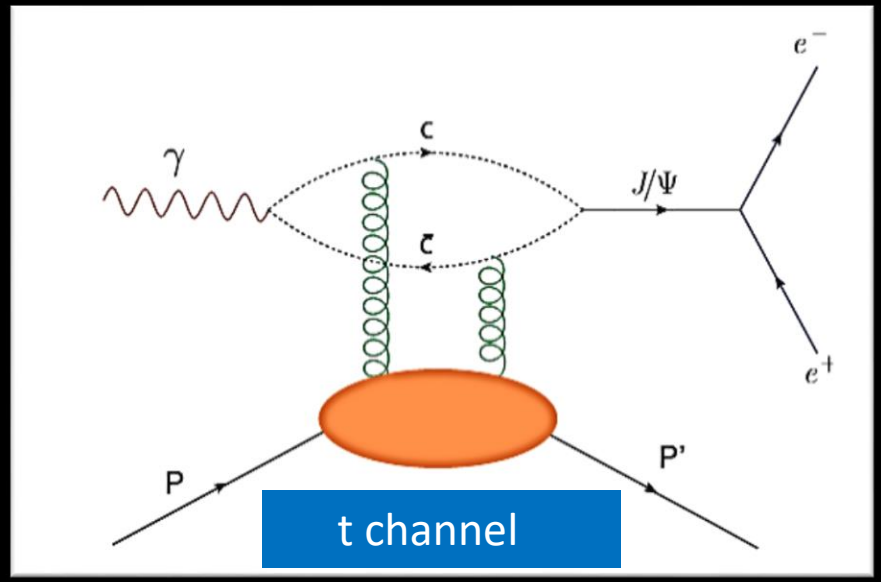


photo-production of J/ψ on proton

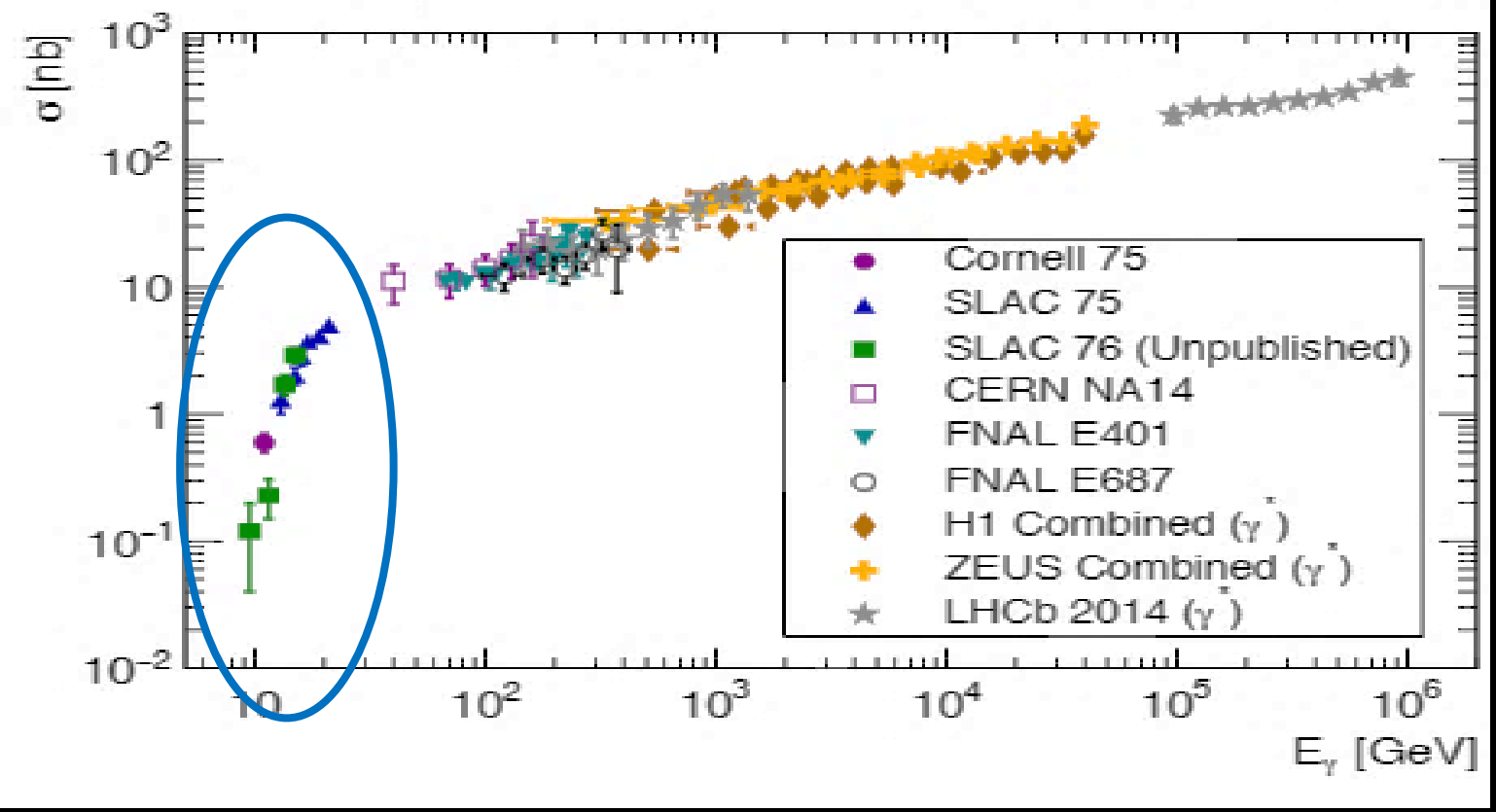
- If true resonant states, can be observed in photoproduction too !

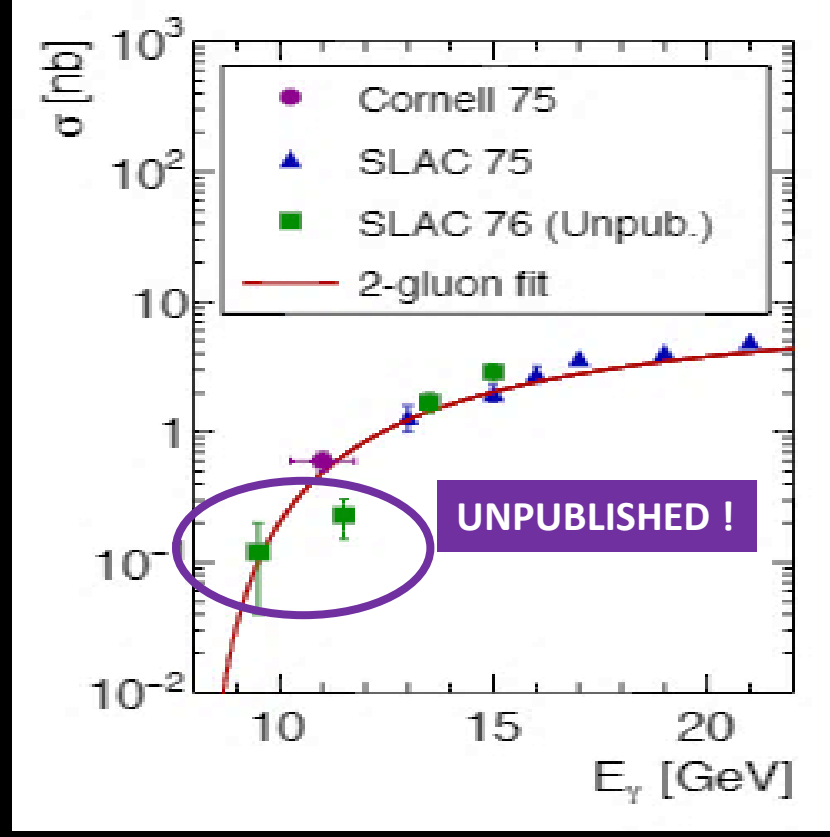
Standard way for **J/ψ** photo-production

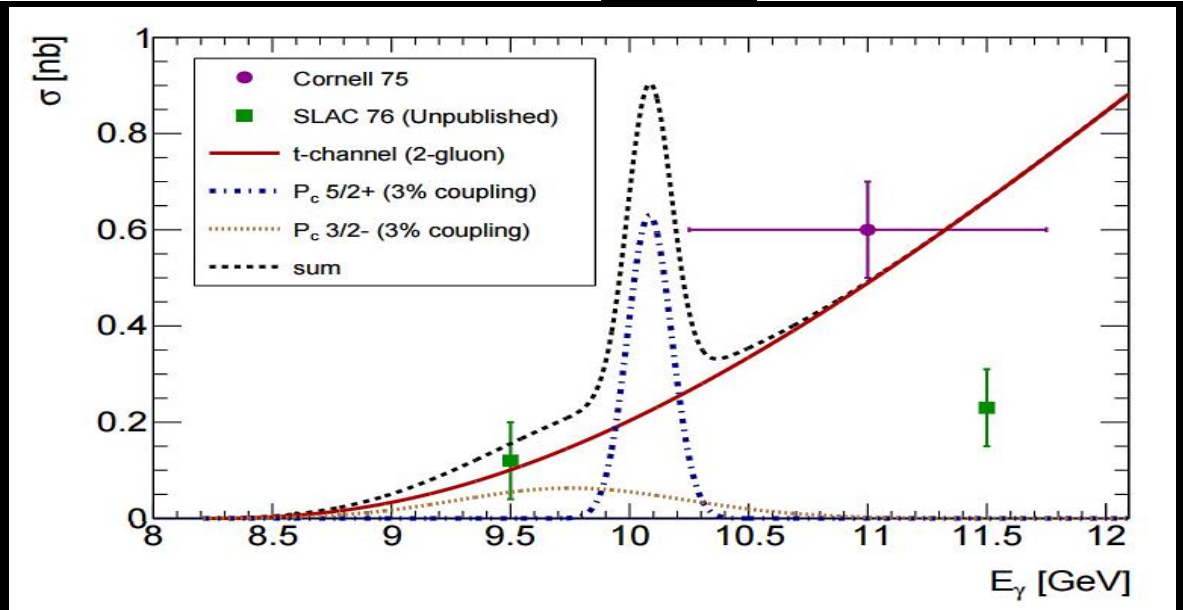


Brodsky S J, *et al.*, PLB 498-1 (2001), p23

Present data status of J/ψ photoproduction





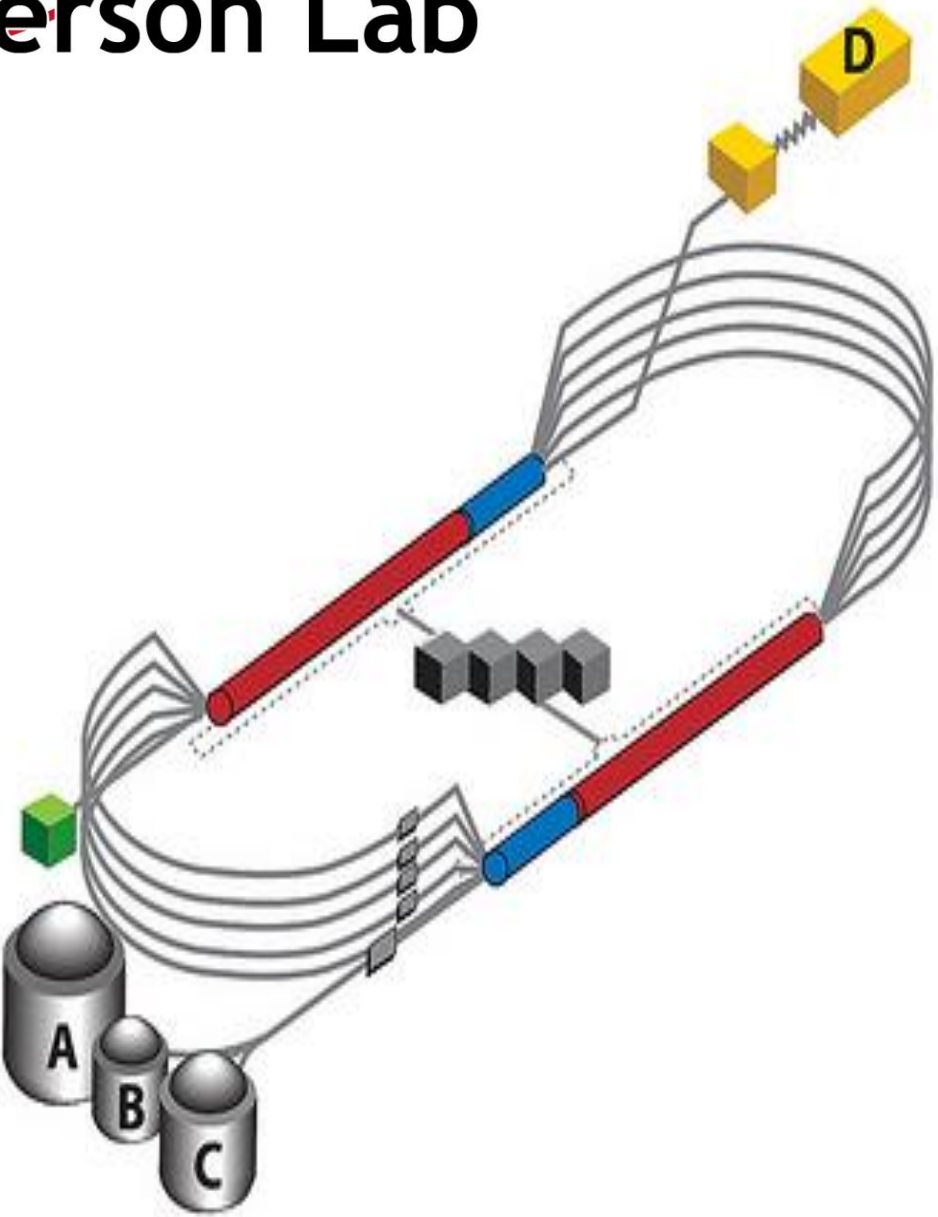


Pentaquark amplitude calculations:

Wang Q., *et al.*, PRD 92-3 (2015) 034022-7

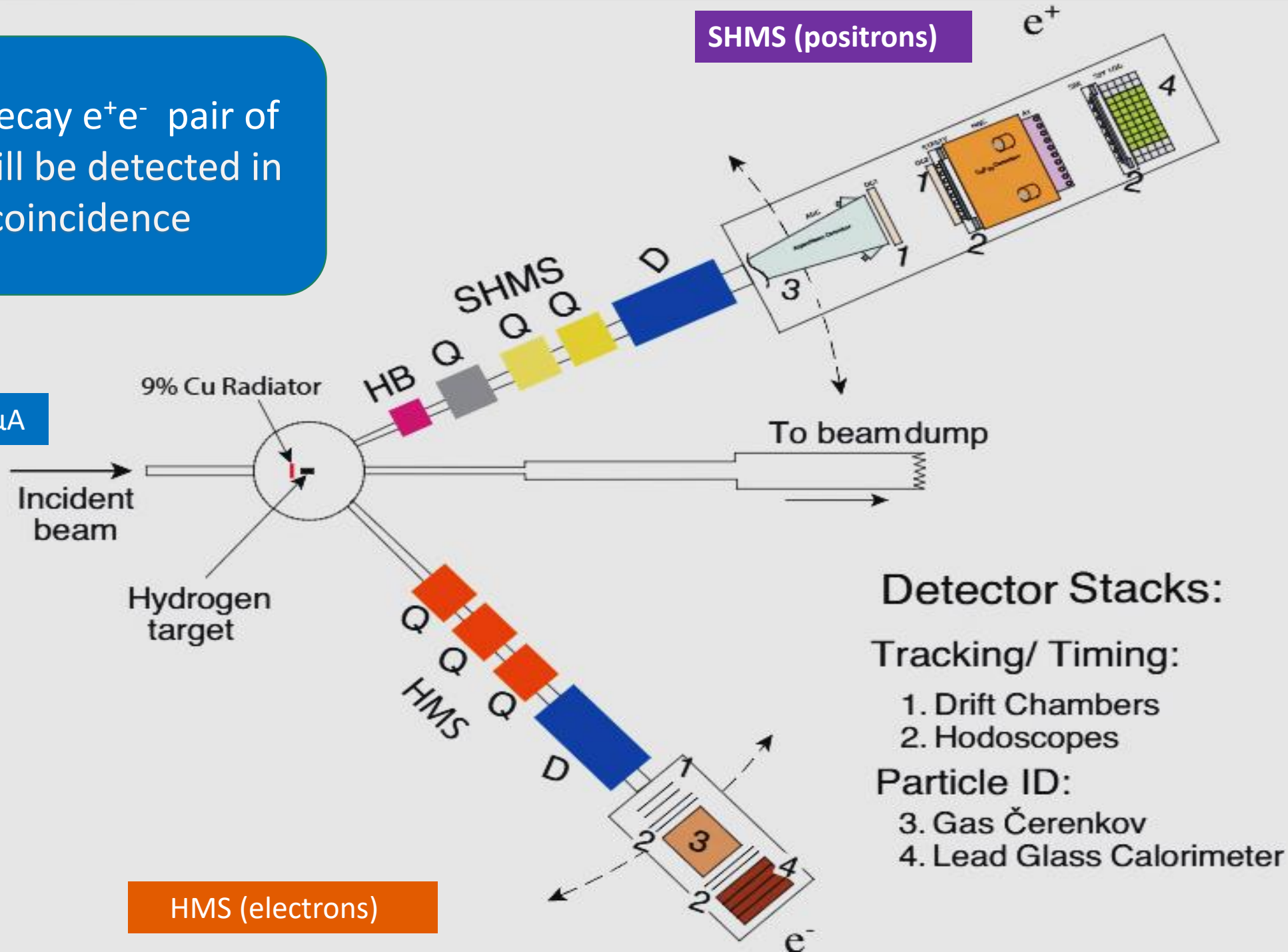
The experiment in Hall C at JLab

Jefferson Lab



The decay e^+e^- pair of J/ψ will be detected in coincidence

SHMS (positrons)



HMS (electrons)

Detector Stacks:

Tracking/ Timing:

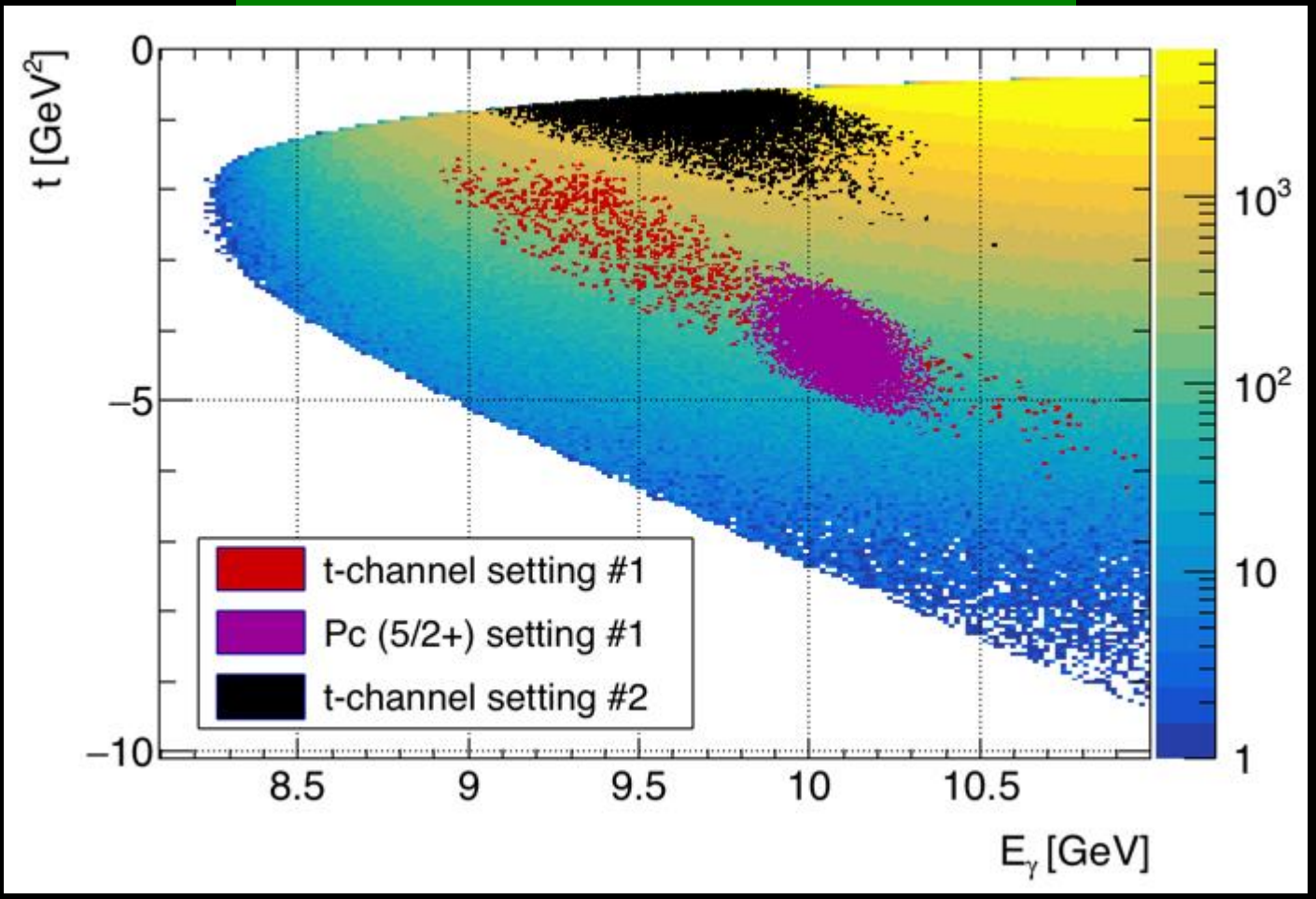
1. Drift Chambers
2. Hodoscopes

Particle ID:

3. Gas Čerenkov
4. Lead Glass Calorimeter

Maximizing Pc signal over t-channel background signal

Phase space of t-channel J/ψ production with acceptance rate

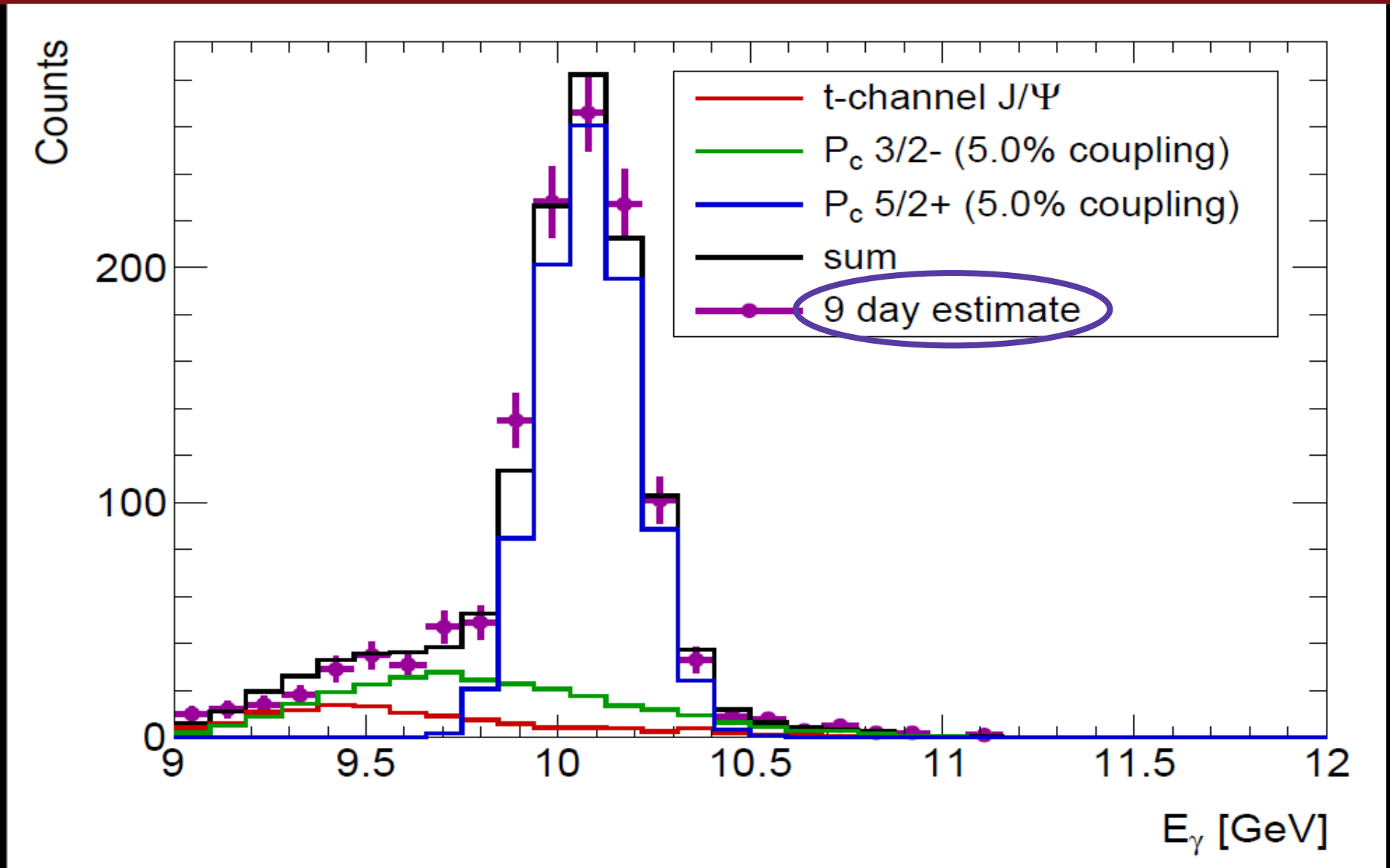


- Setting #1: Pc resonant channel
- Setting #2: background channel

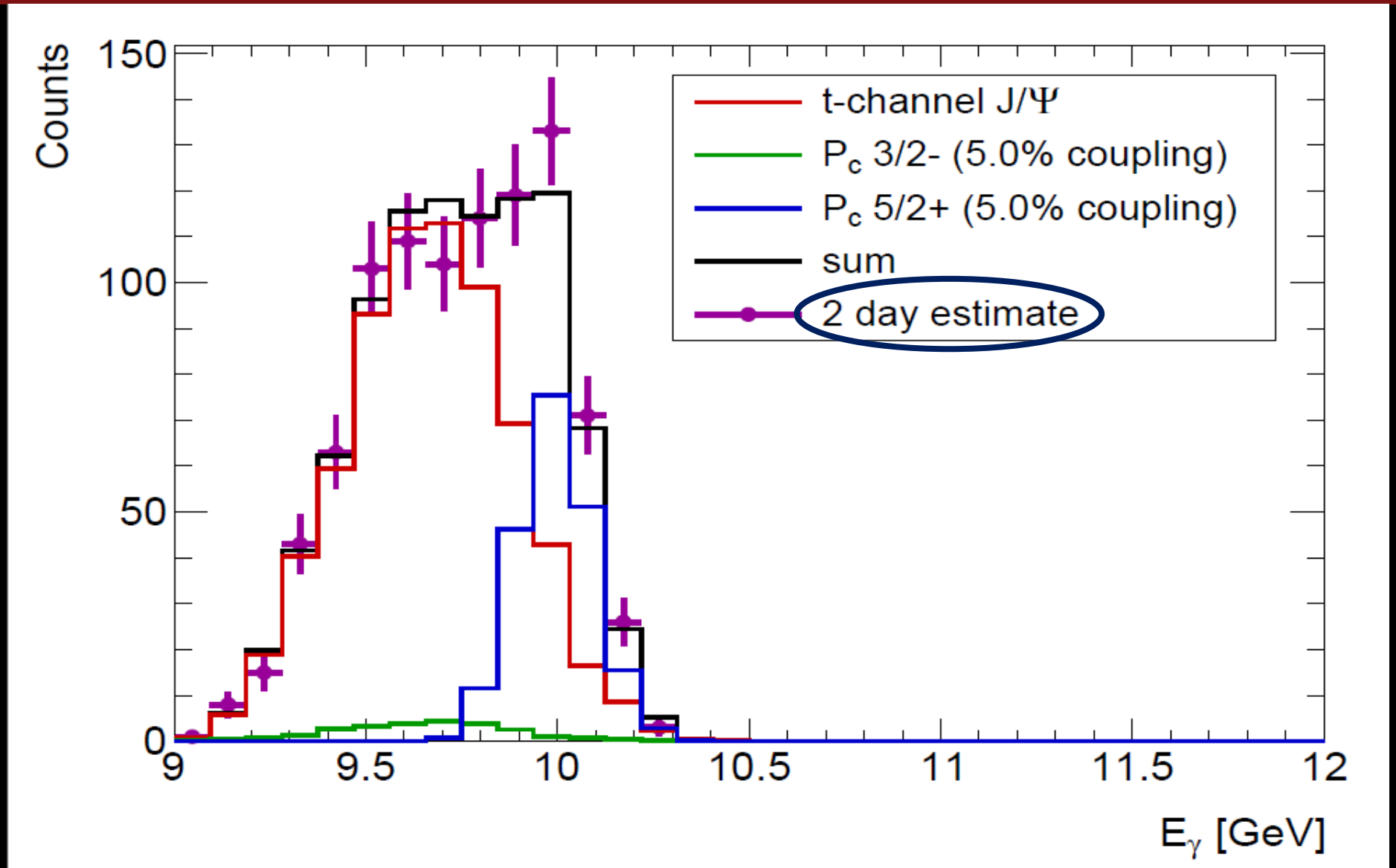
- Spectrometer settings are optimized to select high t region where t-channel production is suppressed

- Enhancing the resonant production of J/ψ through Pc $(4450)^+$ decay

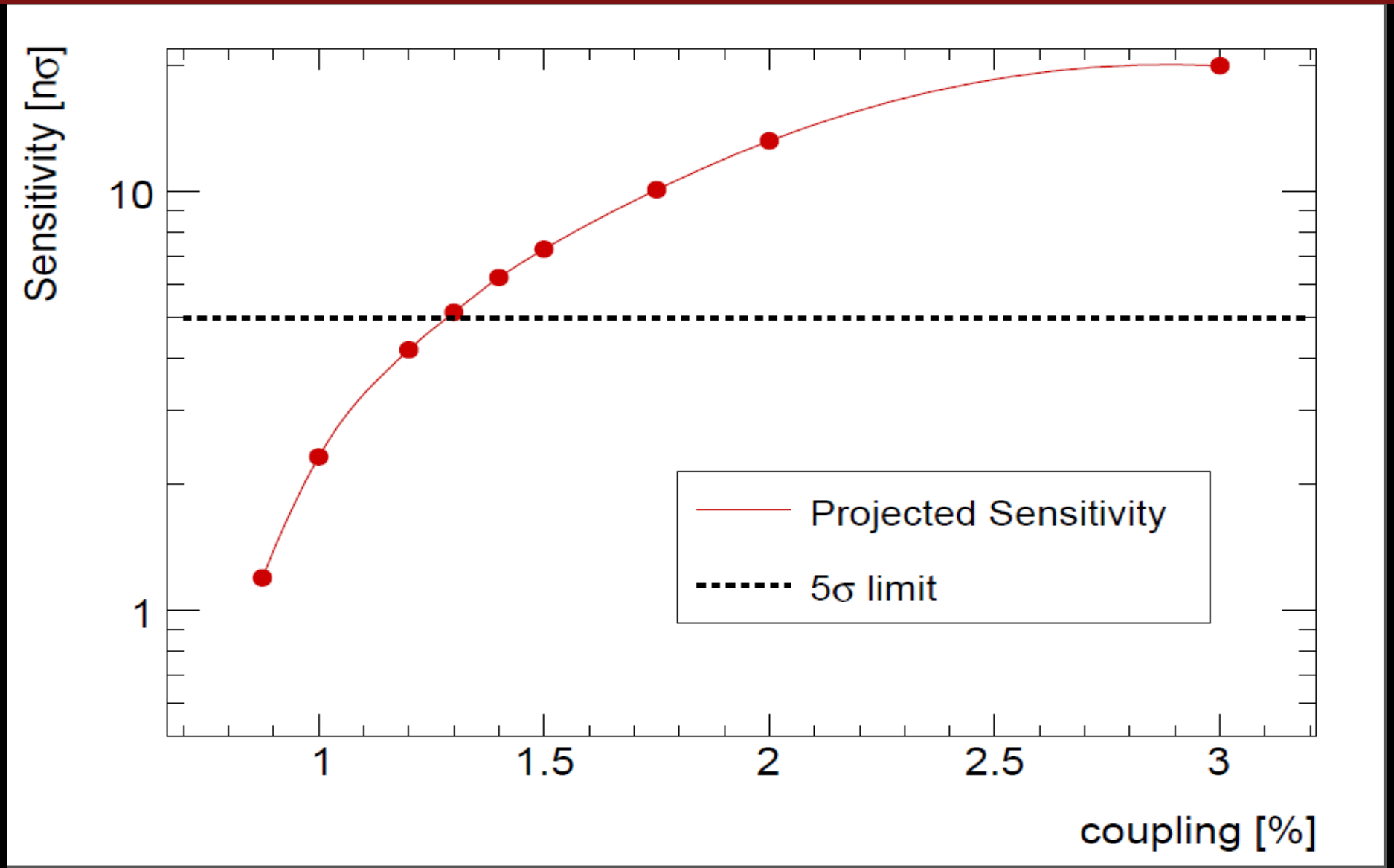
Projected results for resonant Pc channel



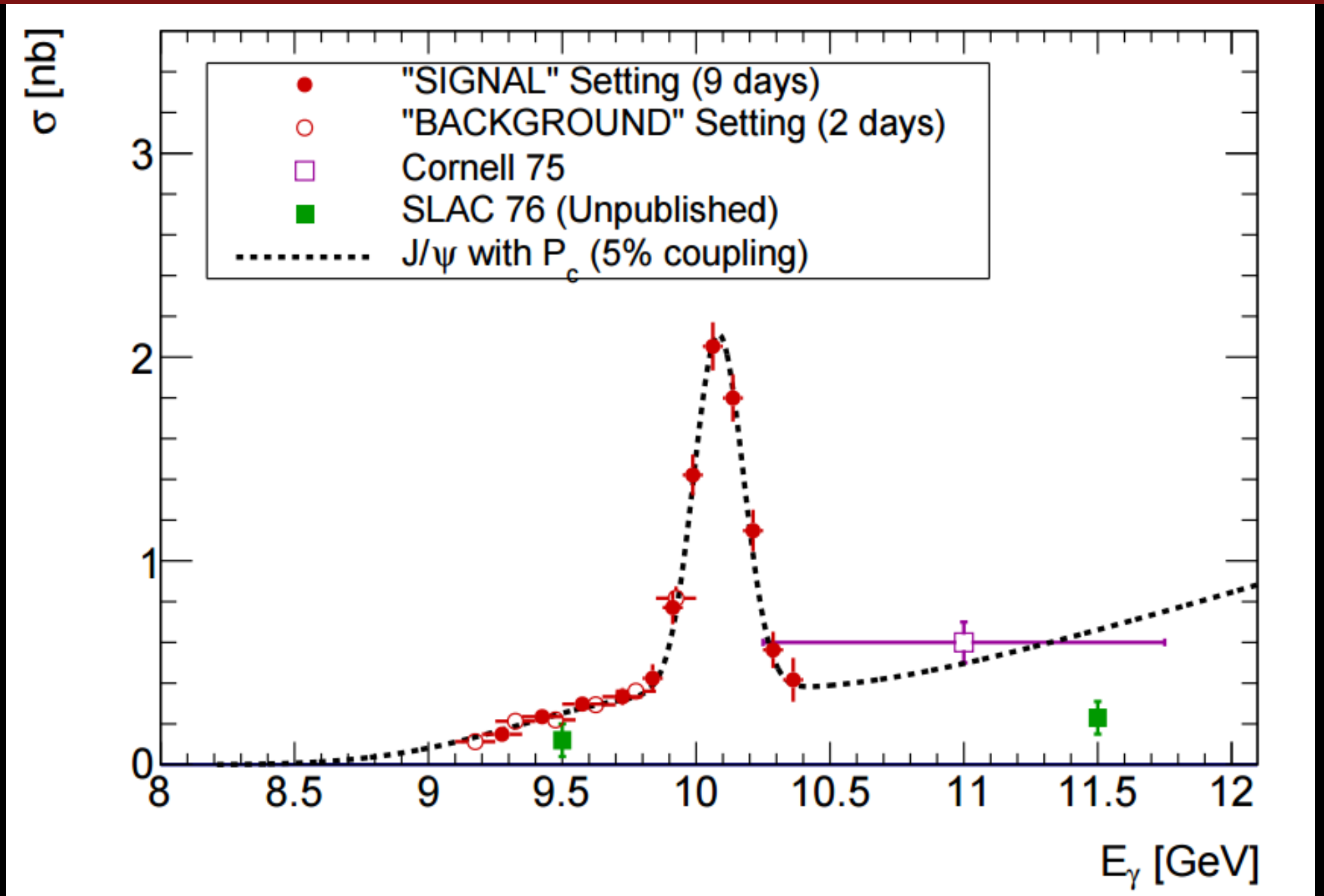
Projected results for t-channel process



Sensitivity for discovery



Projected Impact on the world data of J/ψ photoproduction



Summary

- The result of the experiment will either identify the LHCb exotic resonant as a ‘resonance’ or reject its existence
- t-channel J/ψ background study will enhance our knowledge near threshold region

This work is supported by the Department Of Energy through grant DE-FG02-94ER4084

Backup Slides

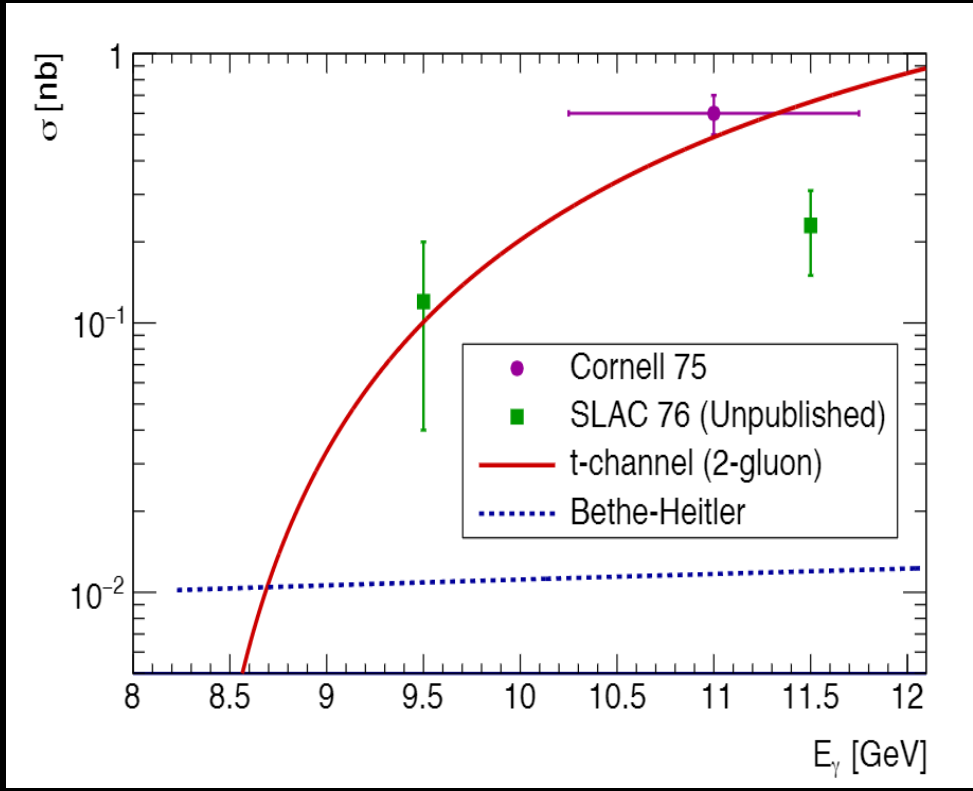
Spectrometer Settings

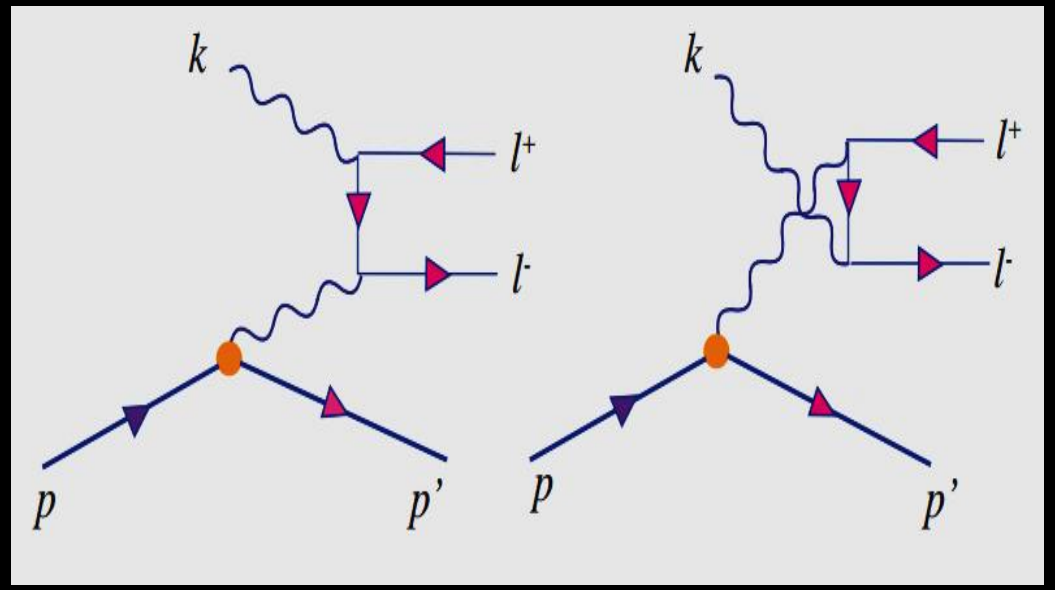
	HMS		SHMS		Acceptance	
Setting	p GeV/c	θ	p GeV/c	θ	t-channel %	$P_c(4450)$ %
#1	3.25	34.5°	4.5	13.0°	0.0004	0.003
#2	4.75	20.0°	4.25	20.0°	0.01	0.003

Bethe Heitler pair production

$$\gamma p \rightarrow e^+ e^- p$$

- Based on calculations of Pauk and Vanderhaeghen within the acceptance of our Pc (4450)$^+$ mass centered spectrometer settings
- Constant background 10 times smaller than t-channel J/ψ production which can be calculated and controlled for





Background: Single $e^{\pm}$, single $\pi^{\pm}$ and accidental coincidence rate

CTEQ5 and F1F209

electron rate estimation in HMS

EPC and a background program from E94-010 experiment at JLab

positron rate estimation in SHMS

Wiser

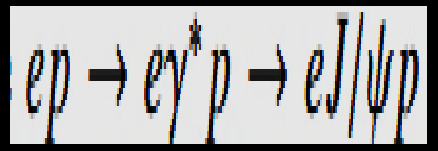
single π^+ / π^-

Single Rates

	HMS		SHMS	
Setting	e^- (kHz)	π^- (kHz)	e^+ (kHz)	π^+ (kHz)
#1	6.9×10^{-3}	7.5×10^{-2}	6.5×10^{-4}	1.95×10^{2}
#2	9.7×10^{-1}	2.2×10^{0}	7.5×10^{-4}	10.5×10^{0}

- Accidental coincidence rate between HMS and SHMS ~ 10^{-5} Hz for 50 ns trigger window → negligible!
- Pion rejection > 10^3 (combined Cherenkov and calorimeter)

Background from lepto-production and $\gamma p \longrightarrow J/\psi p\pi$



50 µA electron beam at 11 GeV

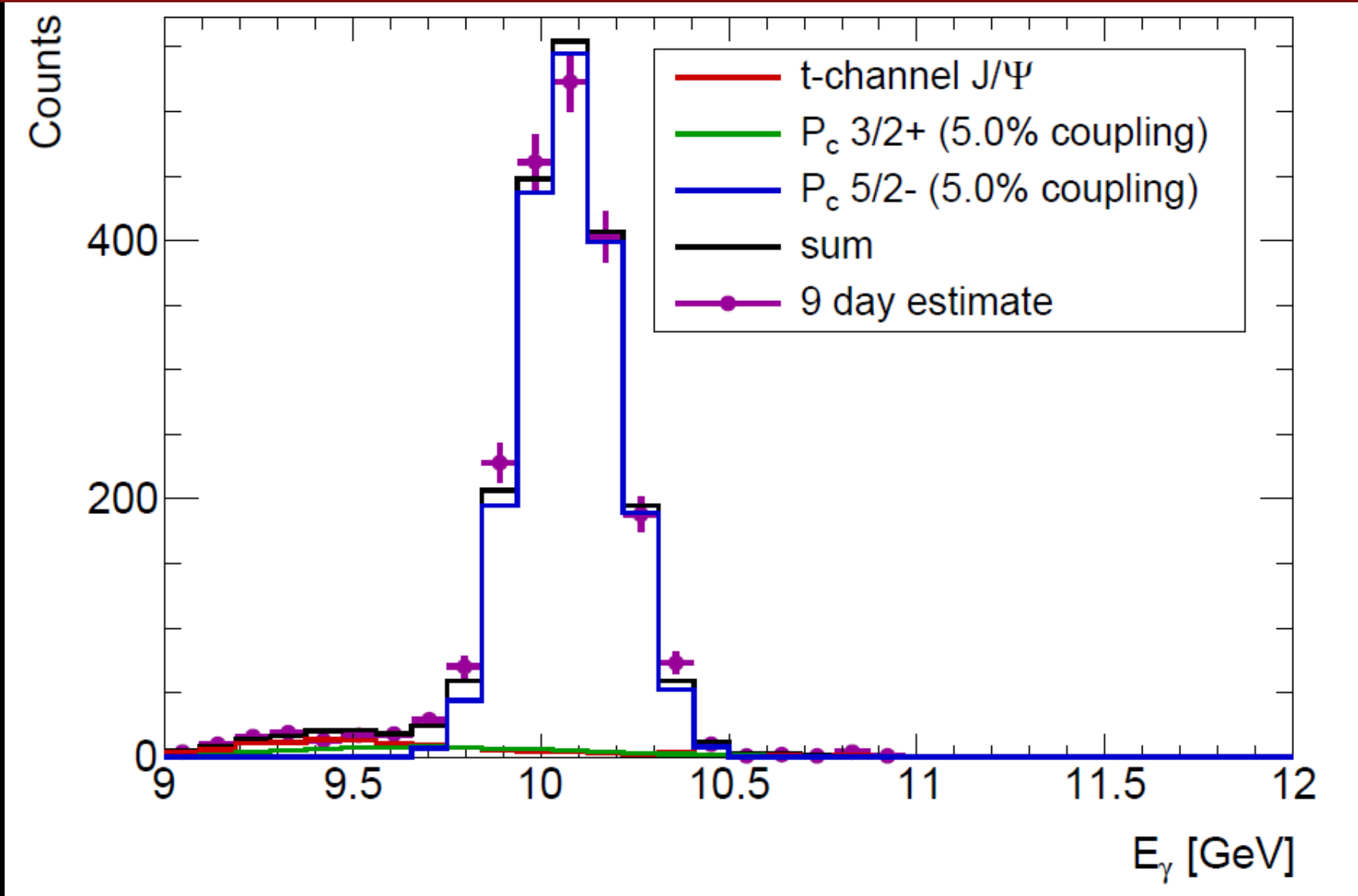
- Only quasi-real photons up to $Q^2 \sim 0.01$ have an impact ⟶ small enhancement of the count rates
- Contribution will be verified by a measurement without a radiator.
- Photons with higher virtuality are highly suppressed
  - the virtual photon flux drops with Q^2
  - higher Q^2 ⟶ lower W^2

t-channel cross section drops
the available phase space shrinks rapidly

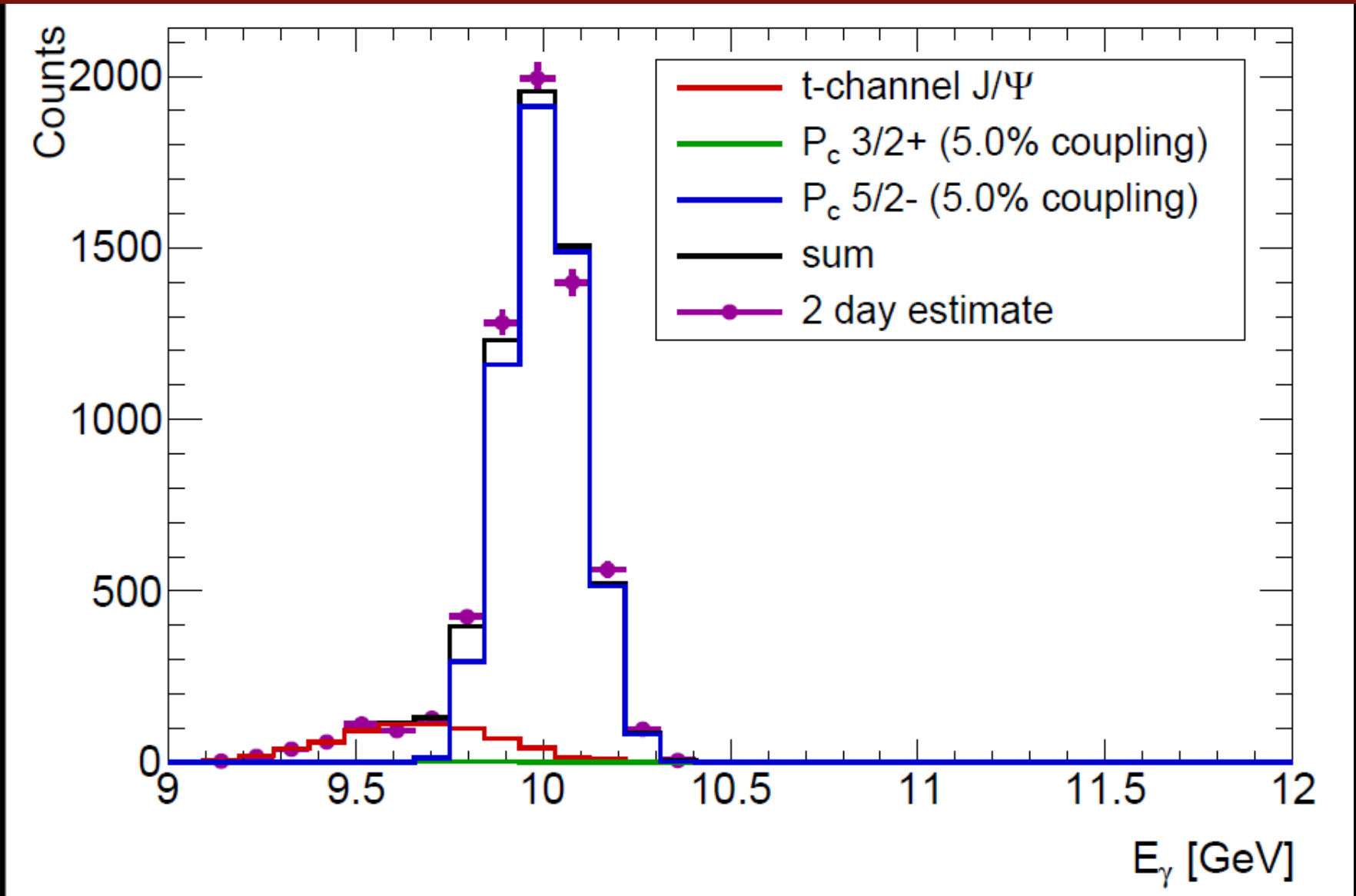
$\gamma p \longrightarrow J/\psi p\pi$

- The inelastic channel of J/ψ production
- An additional final state pion is produced but not detected
- Possible contamination in the kinematic region of resonant pentaquark channel
- The cross section of inelastic channels < 30% of the elastic channels (at high energies)
- Dominant contribution:
  - the resonant channel $\gamma p \longrightarrow J/\psi\Delta$

Projected results for resonant Pc channel



Projected results for t-channel process

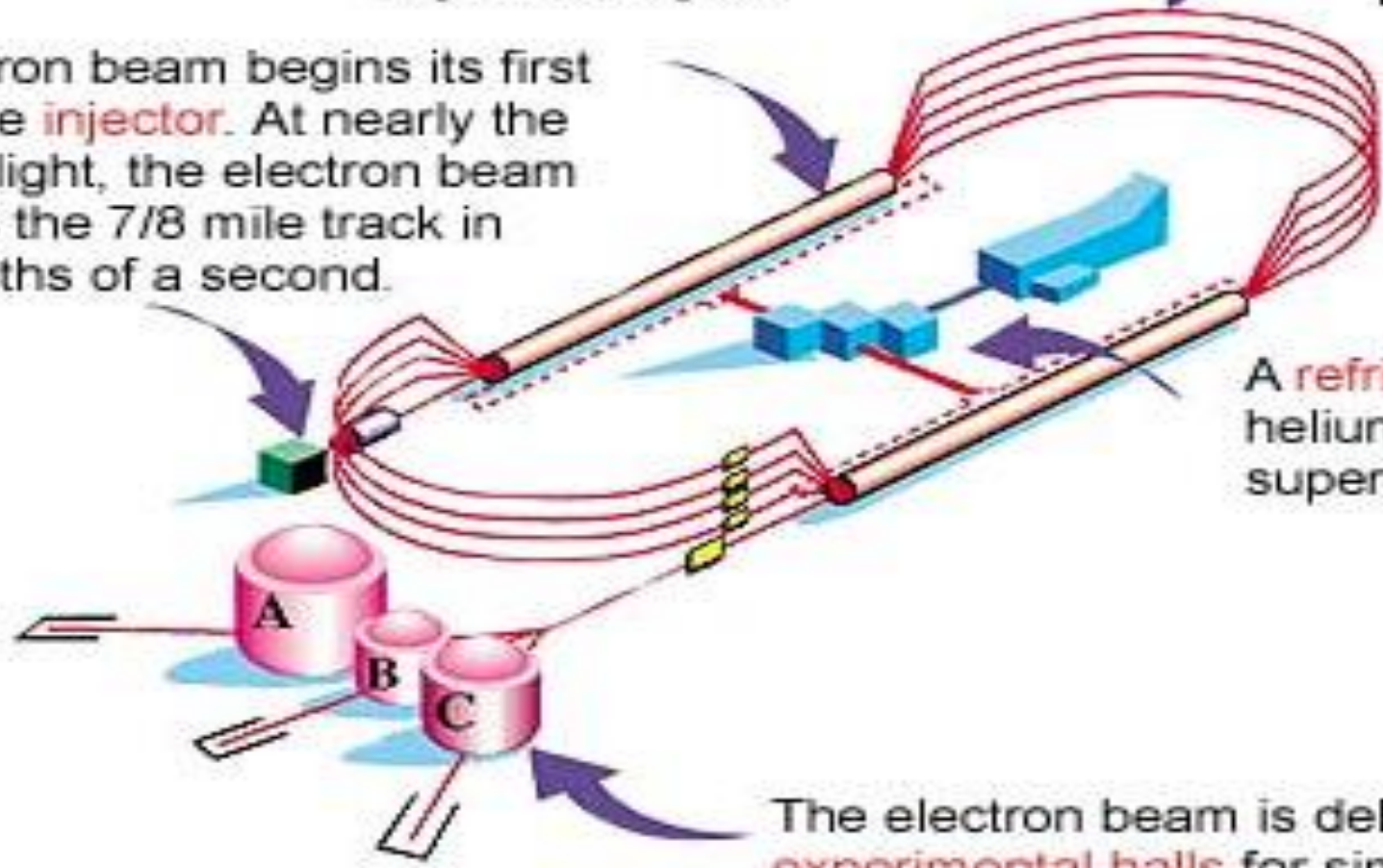


HOW CEBAF WORKS

Each linear accelerator uses superconducting technology to drive electrons to higher and higher energies.

Magnets in the arcs steer the electron beam from one straight section of the tunnel to the next for up to five orbits.

The electron beam begins its first orbit at the injector. At nearly the speed of light, the electron beam circulates the 7/8 mile track in 24 millionths of a second.



A refrigeration plant provides liquid helium for ultra-low-temperature, superconducting operation.

The electron beam is delivered to the experimental halls for simultaneous research by three teams of physicists.