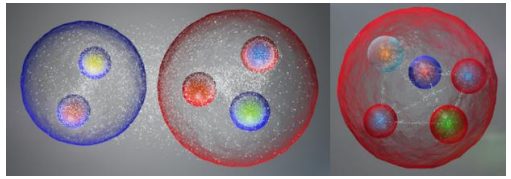
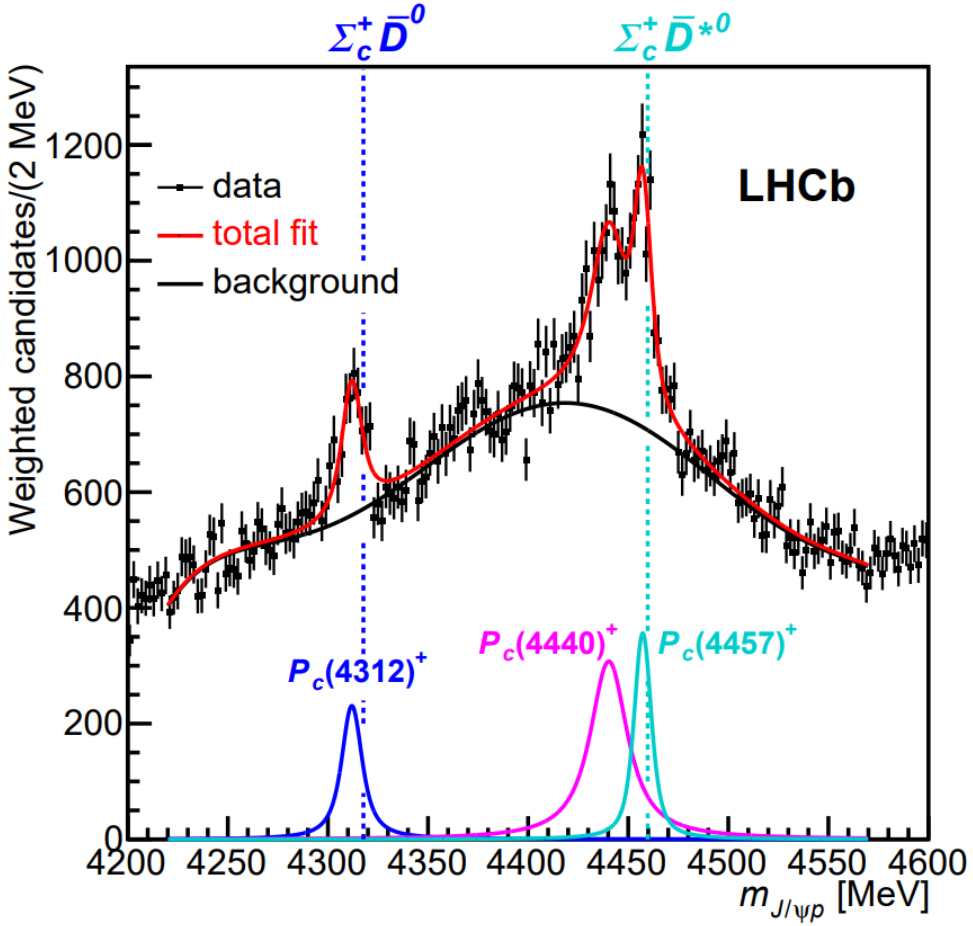
J/ψ Production in $\pi^- p$ Reaction near Threshold

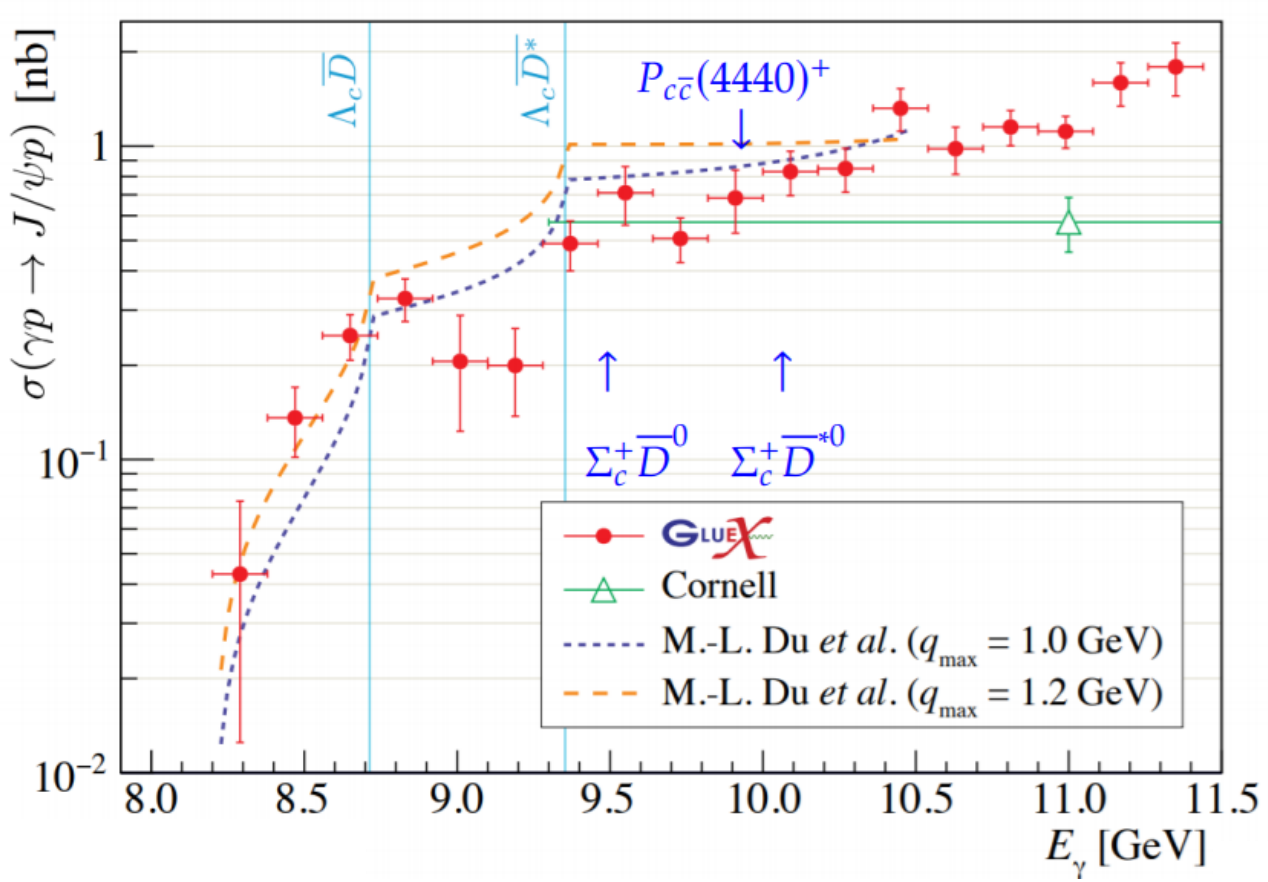
Sun Young Ryu
(RCNP, The University of Osaka)

RCNP
大阪大学 核物理研究センター

$J/\psi p$ from Λ_b Decays and Photoproduction







- LHCb observed three hidden-charm pentaquarks decaying into $J/\psi p$ in the Λ_b decays.

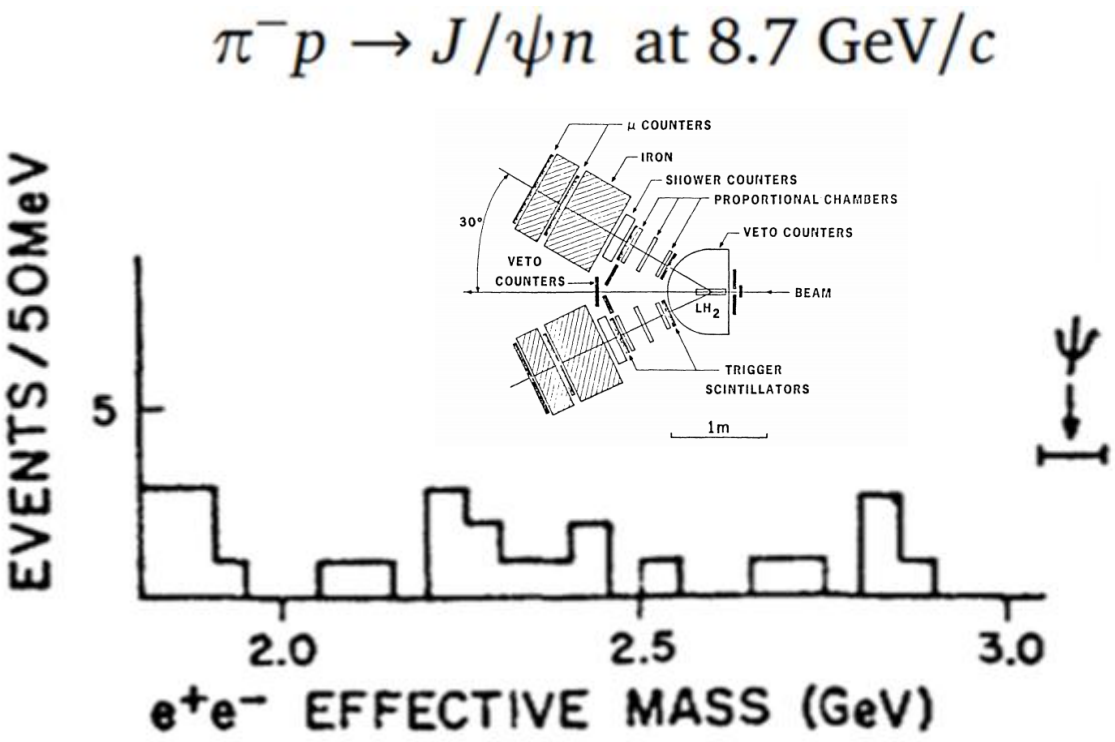
R. Aaij et al., Phys. Rev. L 122, 222001 (2019)

- GlueX measured J/ψ photoproduction cross sections near threshold and showed just upper limits for hidden-charm pentaquarks.

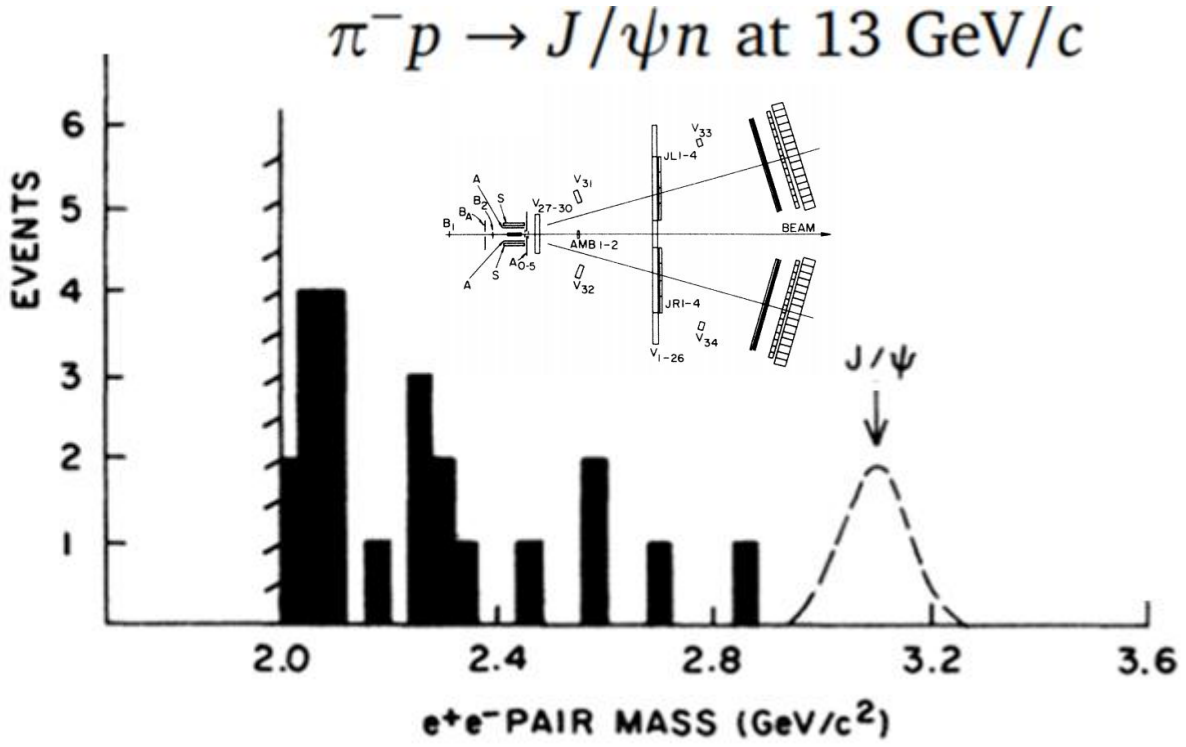
Phys. Rev. C 108, 025201 (2023)

Past Experiments for J/ψ Production in $\pi^- p$ Reaction

K. Jenkins *et al.*, Phys. Rev. D17, 52 (1978).

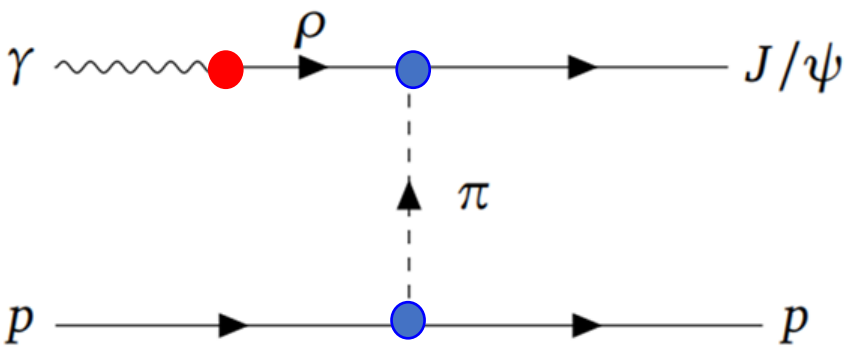


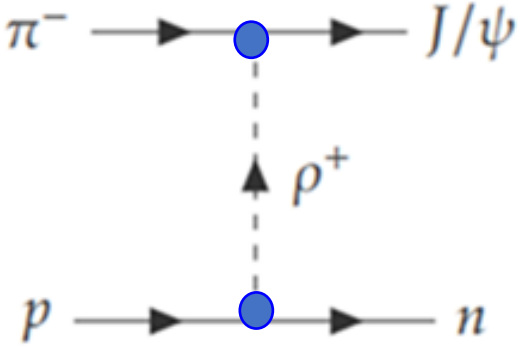
I.-H. Chiang *et al.*, Phys. Rev. D34, 1619 (1986).



- To date, there have been no observations of exclusive J/ψ production events in the $\pi^- p$ reaction. Only upper limits for the process $\pi^- p \to J/\psi n$ have been estimated by two old experiments, which are 1.3 nb at 8.75 GeV/c and 127 pb at 13 GeV/c (90% CL).

Photoproduction and Pion-induced Production Reactions

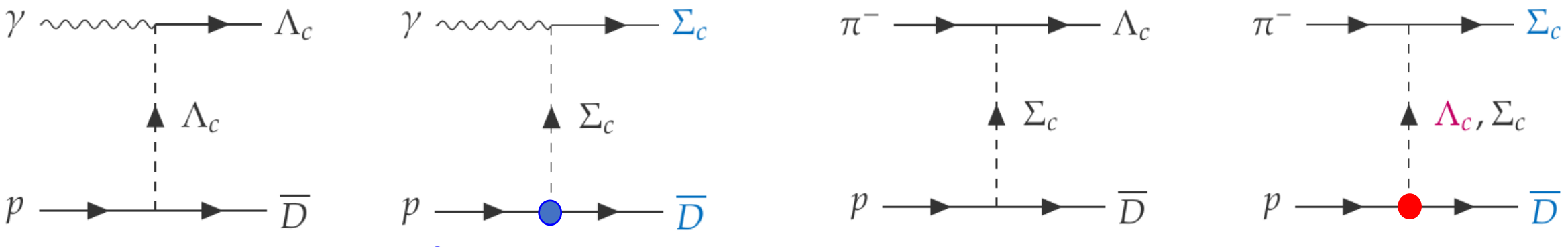




- Photocoupling to vector meson suppresses J/ψ production in photoproduction, compared to the hadron-induced production reaction.

- Photoproduction cross section at 8.75 GeV from GlueX is approximately 0.3 nb, while the upper limit for the pion-induced reaction cross section at 90% CL is 1.2 nb.

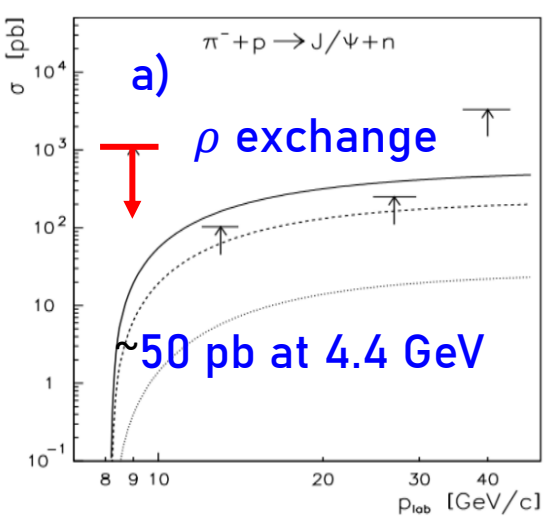
Photoproduction and Pion-induced Production Reactions

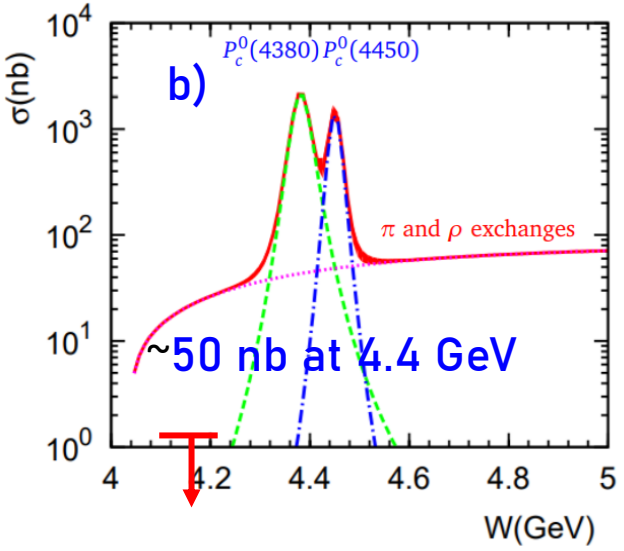


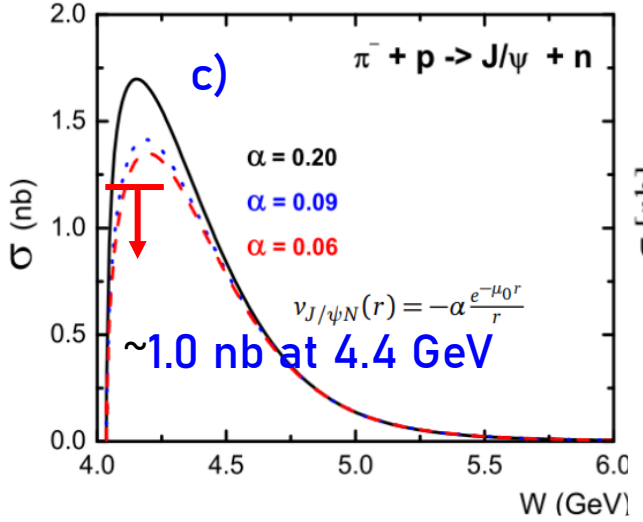
- $P_{c\bar{c}}$ states strongly couple to $\Sigma_c^{(*)}\overline{D}^{(*)}$ channels, while they couple weakly to $\Lambda_c^{(*)}\overline{D}^{(*)}$ channels.

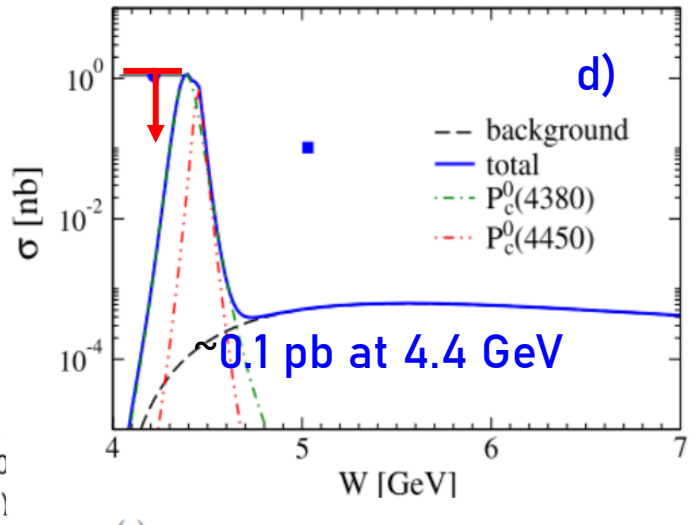
- Due to the relation in coupling constants, where $g_{\Lambda_c N\bar{D}} \gg g_{\Sigma_c N\bar{D}}$, the $P_{c\bar{c}}$ states may be suppressed in photoproduction but could be produced in $\pi^- p$ reactions.

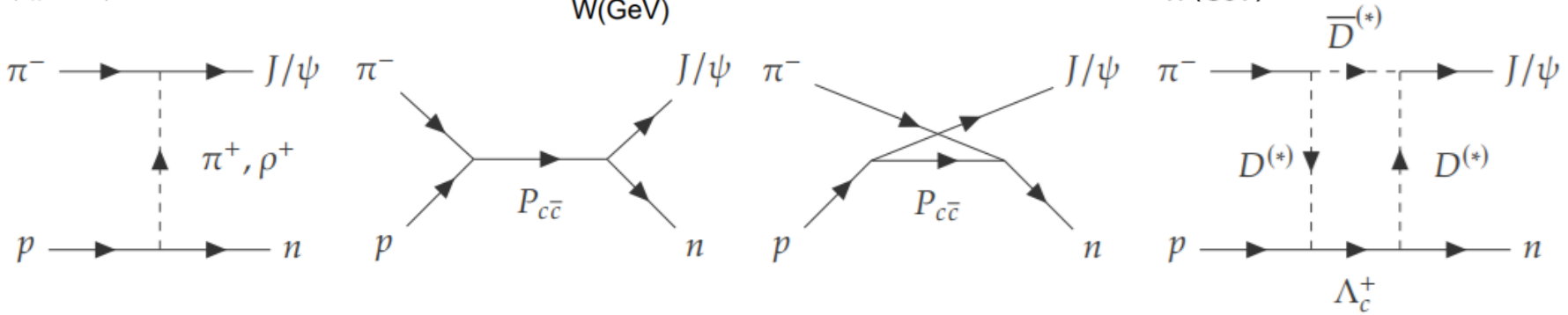
Theoretical Predictions for J/ψ Production Cross sections







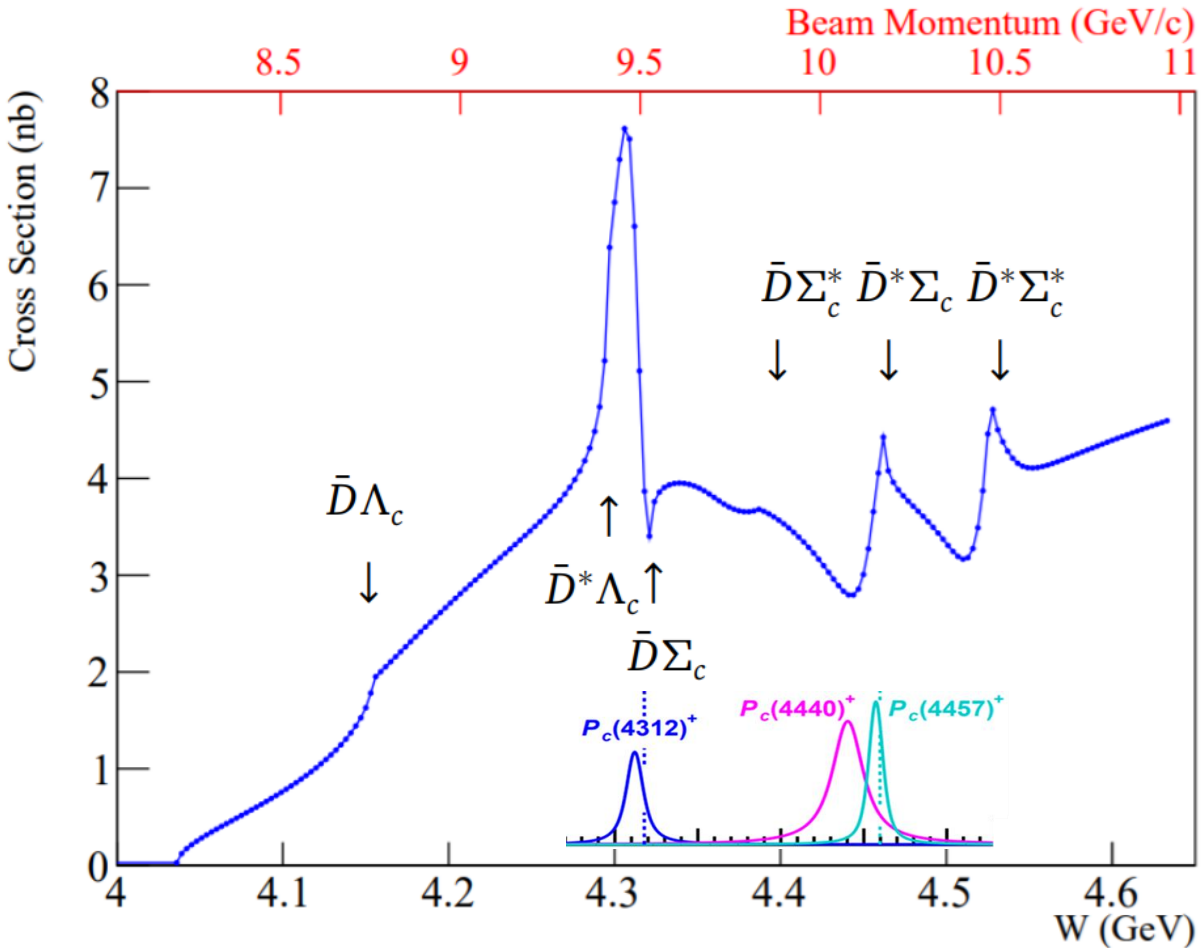




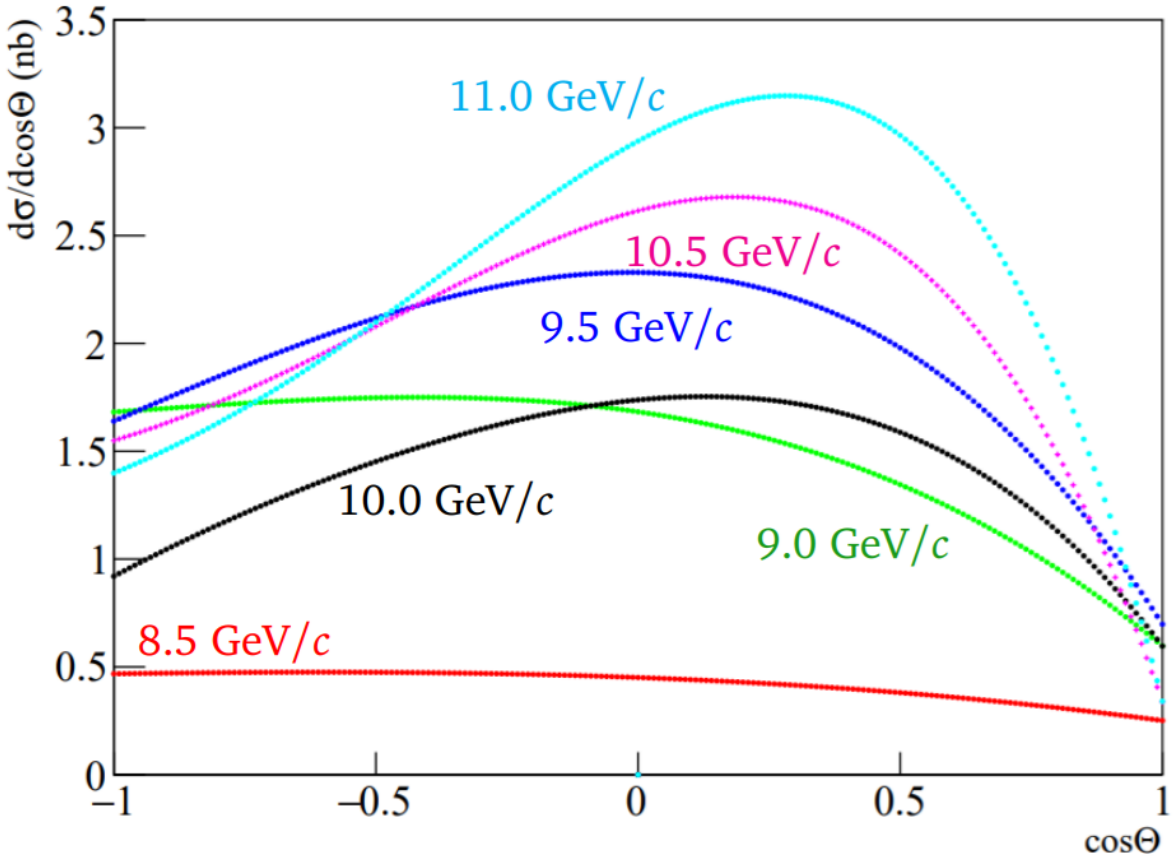
- Theoretical estimates for the J/ψ production cross section vary largely with different considerations of the upper limits (⊤) : from 0.1 pb to 50 nb.

a) A. Sibirtsev and K. Tsushima, nucl-th/9810029
b) Q.-F. Lü *et al.*, Phys. Rev. D 93, 034009 (2016).
c) J.-J. Wu and T.-S. H. Lee, Phys. Rev. C 88, 015205 (2013).
d) S.-H. Kim, H.-Ch. Kim and A. Hosaka, Phys. Lett. B 763, 358 (2016).

J/ψ Production Cross Sections near Threshold

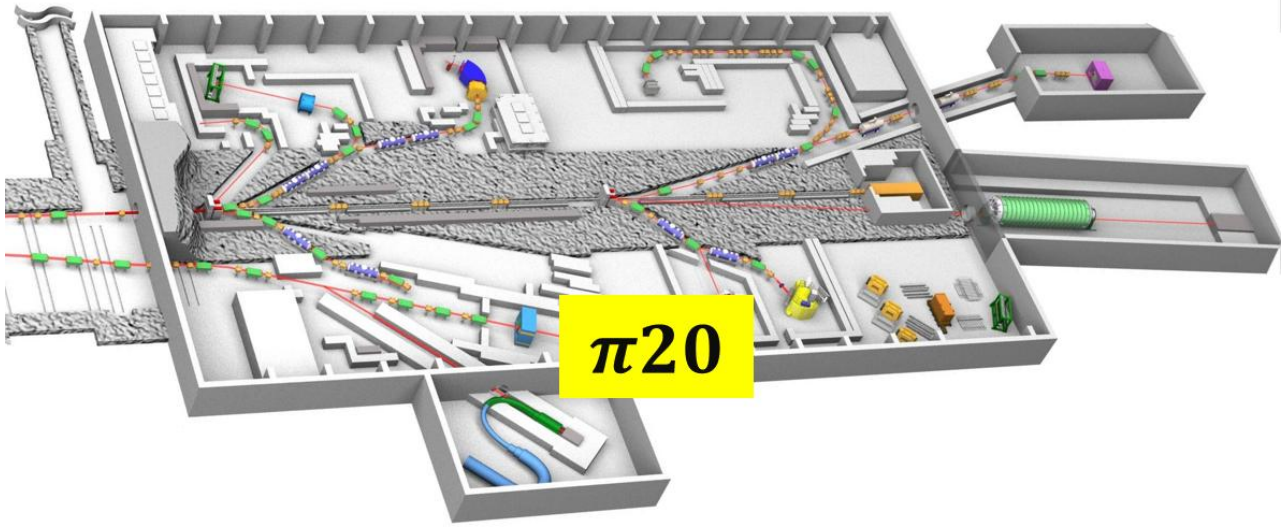


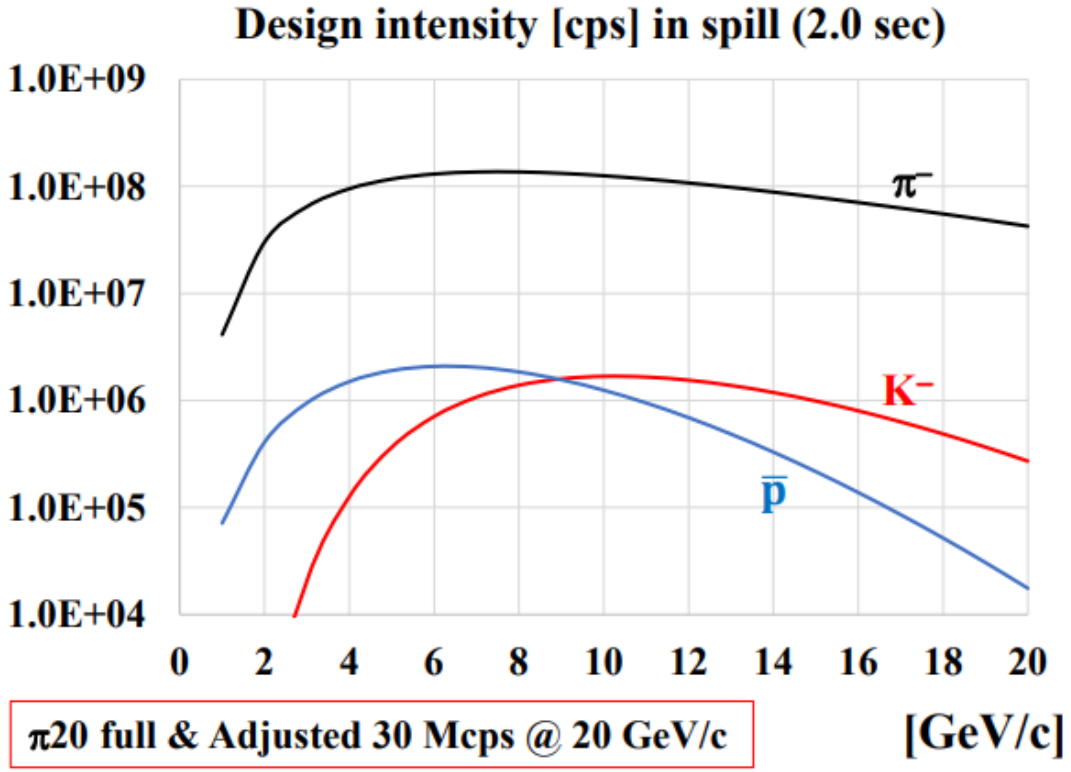
S. Clymton, S. Y. Ryu, J.K. Ahn, H. Ch. Kim in preparation



- A full coupled-channel calculation predicts J/ψ production cross sections to exhibit intriguing structures near the open-charm meson-baryon mass thresholds. (No $P_{c\bar{c}}$ states are explicitly included).

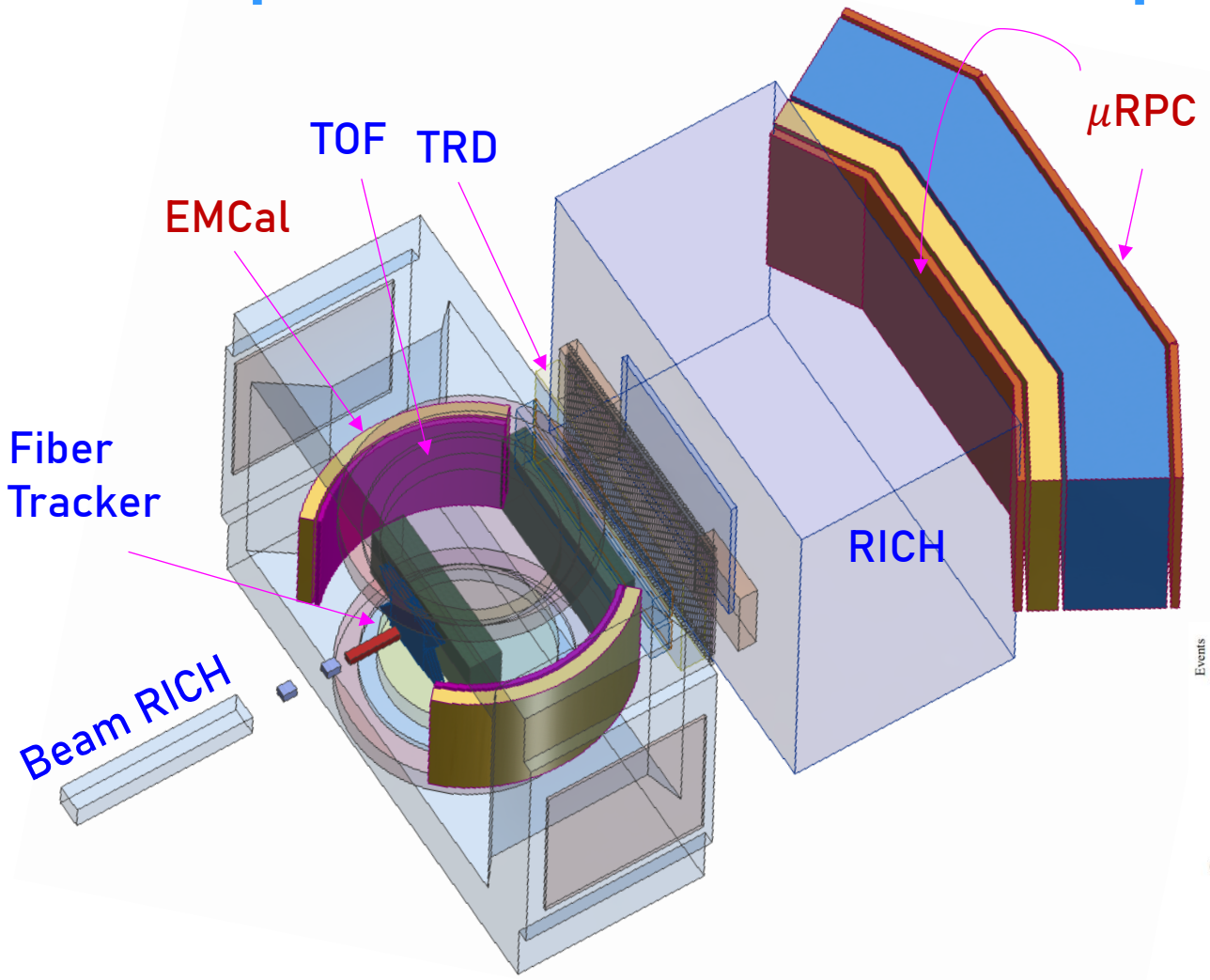
High-intensity Pion Beam in the π20 Beam Line

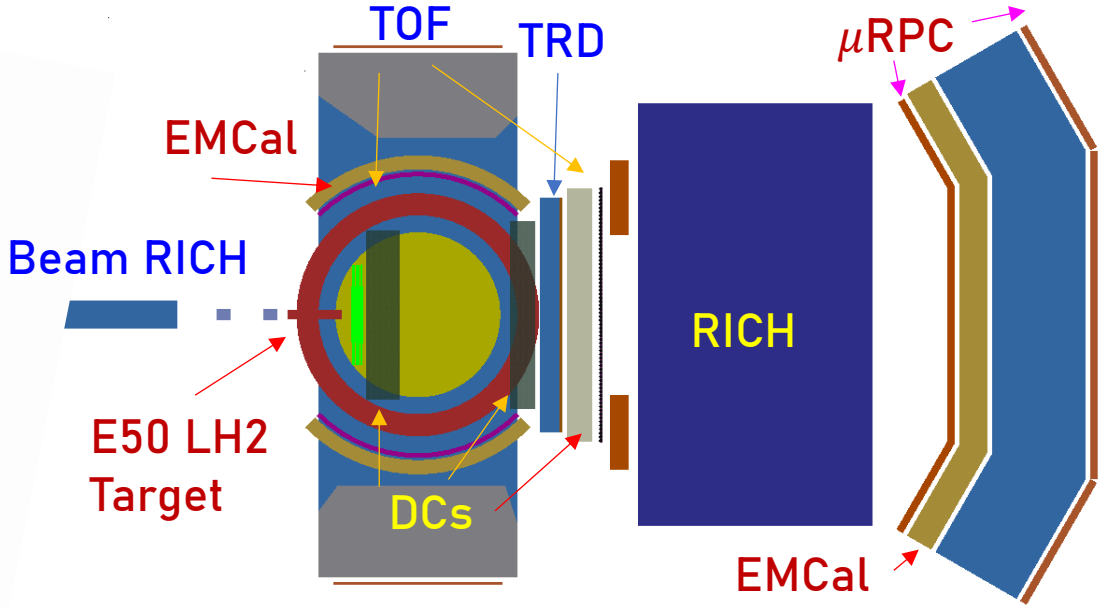


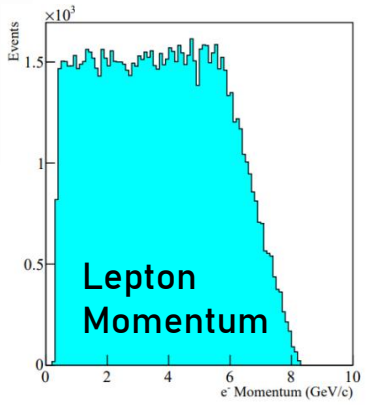


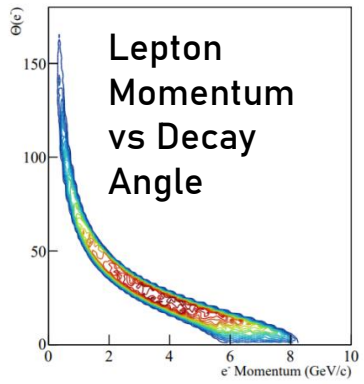
- The π20 beam line will deliver high-intensity π- beam with 100 M counts/spill in the range of 8 to 11 GeV/c. (2.5×10^7Hz for 2 s spill duration)
- The proposed measurement (P111) will follow the E50 run with a successful operation of this π20 beam line using a 15kW-loss production target.

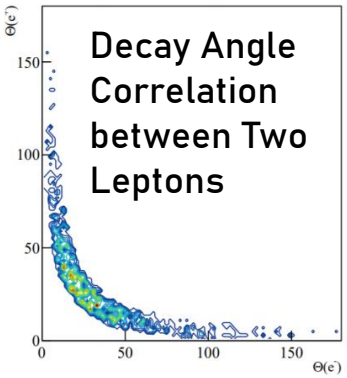
P111 Spectrometer (E50++ Spectrometer)







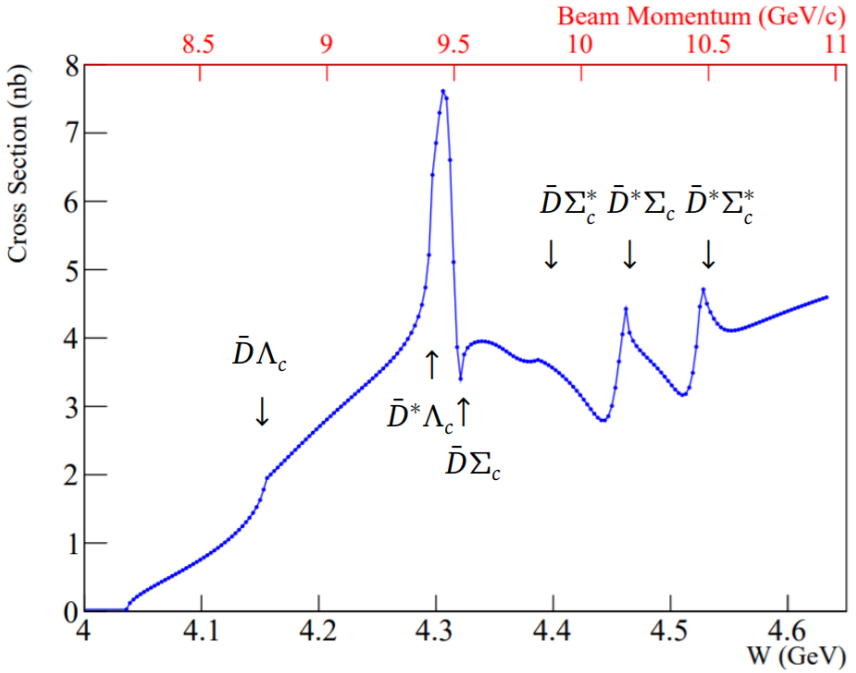


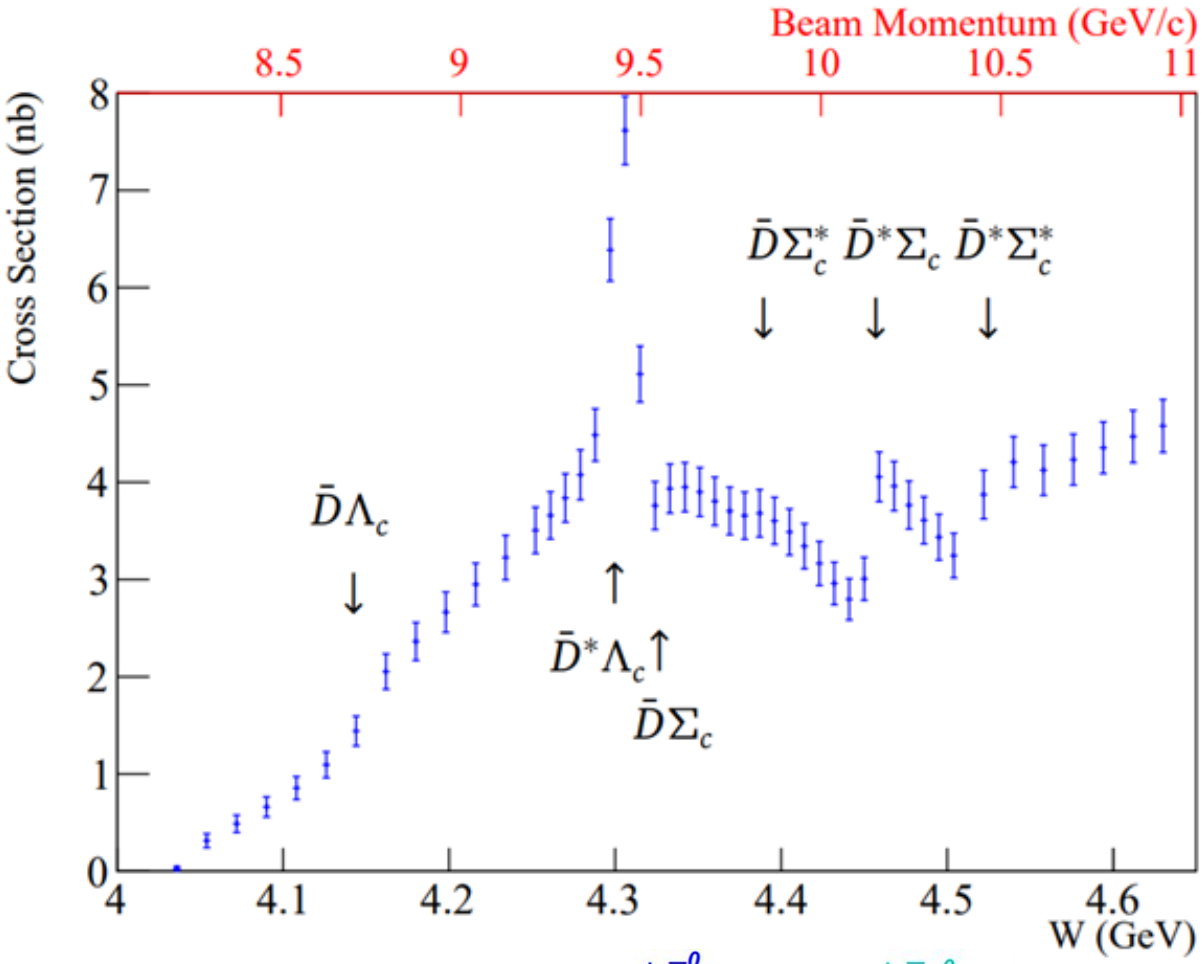


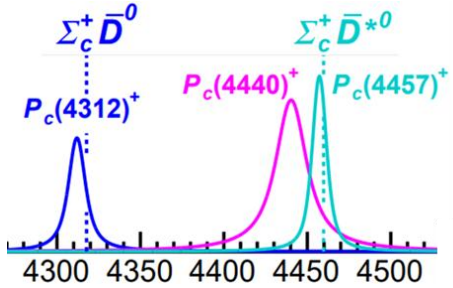
- Detection of the decays $J/\psi \rightarrow e^+e^-$ and $J/\psi \rightarrow \mu^+\mu^-$ needs special lepton PID detectors.
- Three additional detectors will be added to the E50 spectrometer, which are the μRPC, EMcal and the TRD (transition radiation detector).

Expected $J/\psi n$ Mass Spectrum

- Mass region between 4.25 and 4.50 GeV in 10 MeV intervals and other mass regions in 20 MeV intervals : a total of 50 energy bins.
- We expect to collect 62 J/ψ events/nb, or 250 events in a day for 4 nb.





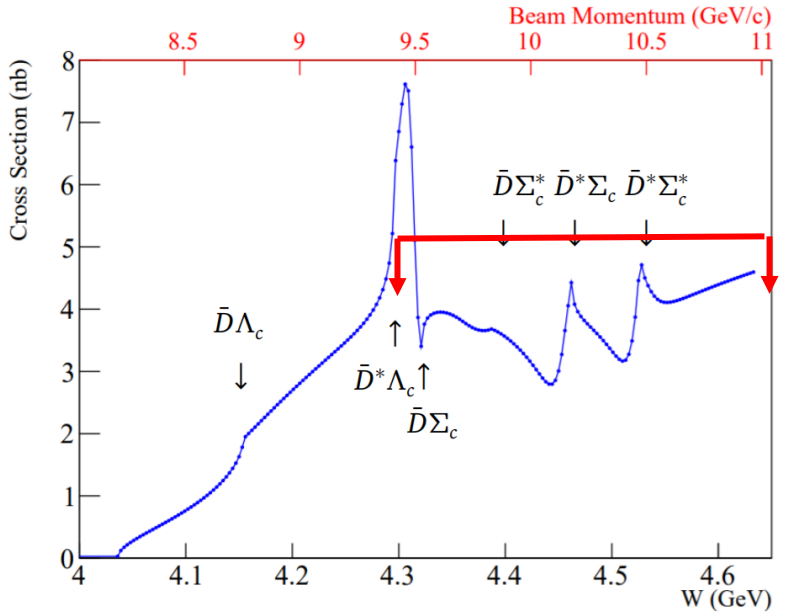


Open Charm Channels

- $D^-\Lambda_c^+ : K^-\pi^+\pi^-K^-\pi^+p$ (9.38%)(6.35%) = 0.6%
- $D^{*-}\Lambda_c^+ : (D^0 \to K^-\pi^+)\pi^-K^-\pi^+p$ (3.945%)(67.7%)(6.35%) = 0.17%
- $D^{*-}(\Lambda_c^+) : (D^0 \to K^-\pi^+)\pi^-$ (3.945%)(67.7%) = 2.67%

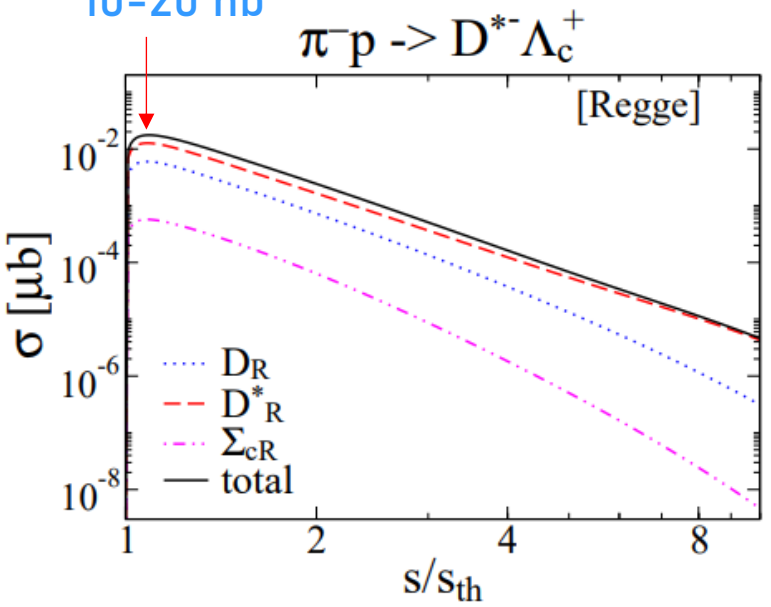
- 6 particle $(2K^-2\pi^+\pi^-p)$ final state : combinatorial background.

- $p(\pi^-, D^{*-})\Lambda_c^+$ reaction can only access the mass region above the $D^{*-}\Lambda_c^+$ mass threshold, and will be measured in this proposed experiment.



$D^-(1869.5)\Lambda_c^+(2286.5) = 4156$
$D^*(2010)^-\Lambda_c^+(2286.5) = 4296.5$

10-20 nb



S.H. Kim et al., Phys. Rev. D92 (2015) 9, 094021

Summary

- We proposed a measurement of J/ψ production cross sections in the $\pi^- p$ reaction from 8.2 to 11.0 GeV/c.

- This study aims to explore the production mechanism, the nature of pentaquarks, and the isospin partners of hidden-charm pentaquarks.

- The measurement will use the E50 detector at the π20 beam line. Additionally, we will incorporate two new detectors, TRD and μRPC, to detect the J/ψ leptonic decays. We will also consider enhancing the detection acceptance with alternative or redundant detection components.

P111 J/ψ Collaboration

- RCNP : S. Y. Ryu (Spokesperson), K. Shirotori, H. Noumi, T. Ishikawa, K. Suzuki, and K. Mizutani
- Korea Univ : J. K. Ahn, D.H. Choi
- KEK : Y. Morino
- George Washington Univ : I. Strakovsky
- JAEA/ASRC : W. S. Jung
- Inha Univ : H.-Ch. Kim
- APCTP : S. Clymton
- Pukyong National Univ : S.-i. Nam
- Soongsil Univ : S. H. Kim

will take shape during the preparation of P111.