Measurement of $\gamma d \rightarrow \pi^- pp$ and $\gamma d \rightarrow \pi^+ \pi^- np$ reactions with tagged photons

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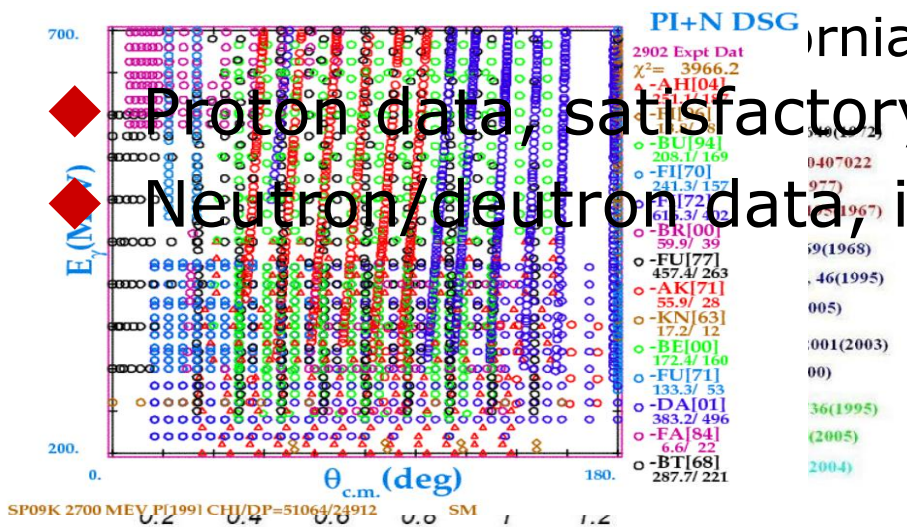
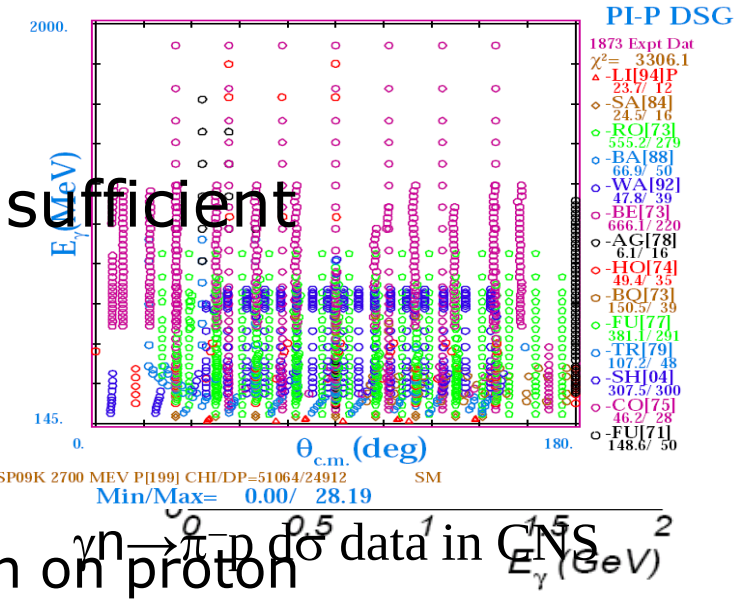
- Introduction of pion photoproduction
- Experimental setups
- Analysis and results
- Summary

Introduction of pion photoproduction

For pion photoproduction: ISI, 1st perturbative approx. and all the physics processes→FSI;

- Best lab for study interaction among meson, N and N*;
- Standard way of study EM resonance coupling;
- …





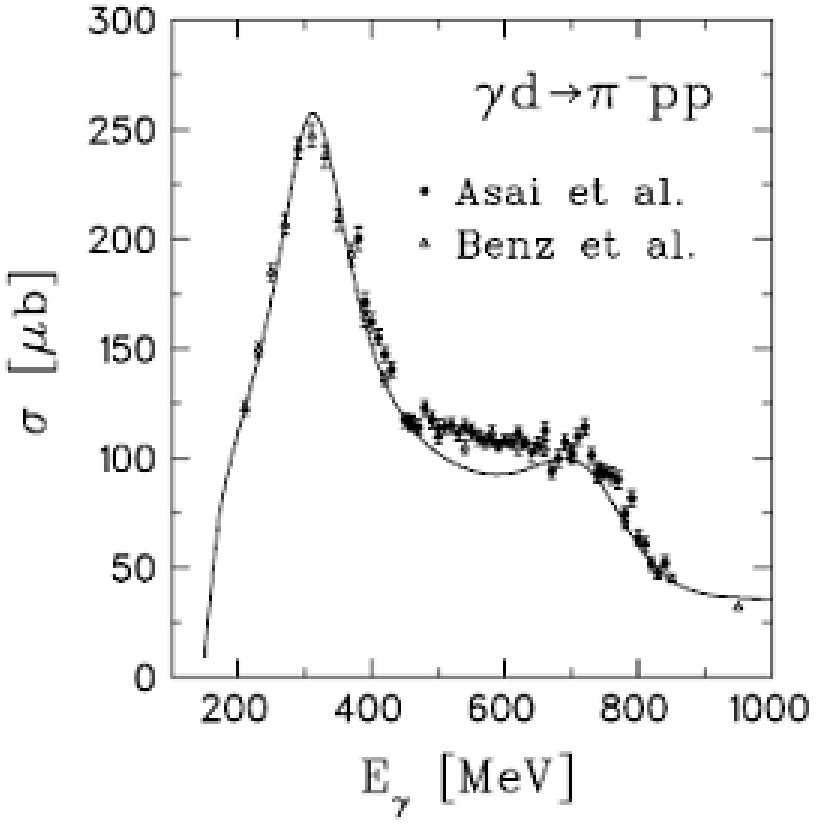
- Proton data, satisfactory
- Neutron/deutron data, insufficient

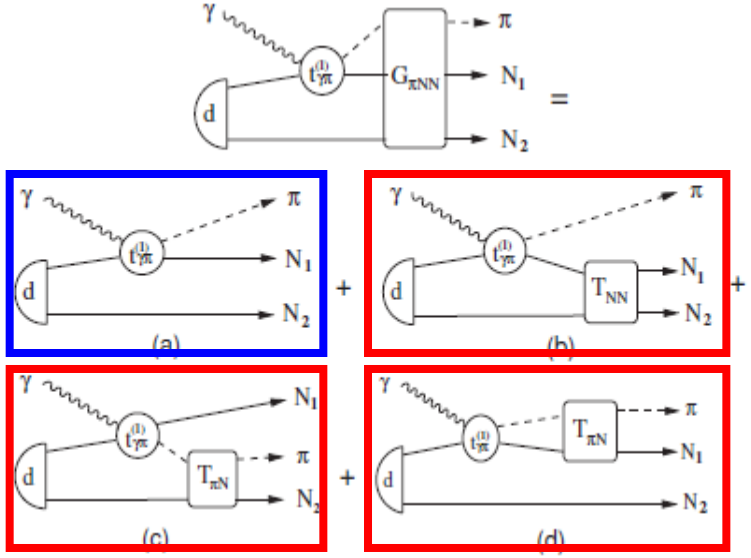
γp→π⁺n dσ data in CNS

γn→π⁻p dσ data in CNS

Photoproduction on proton

Motivation: γd→π⁻pp

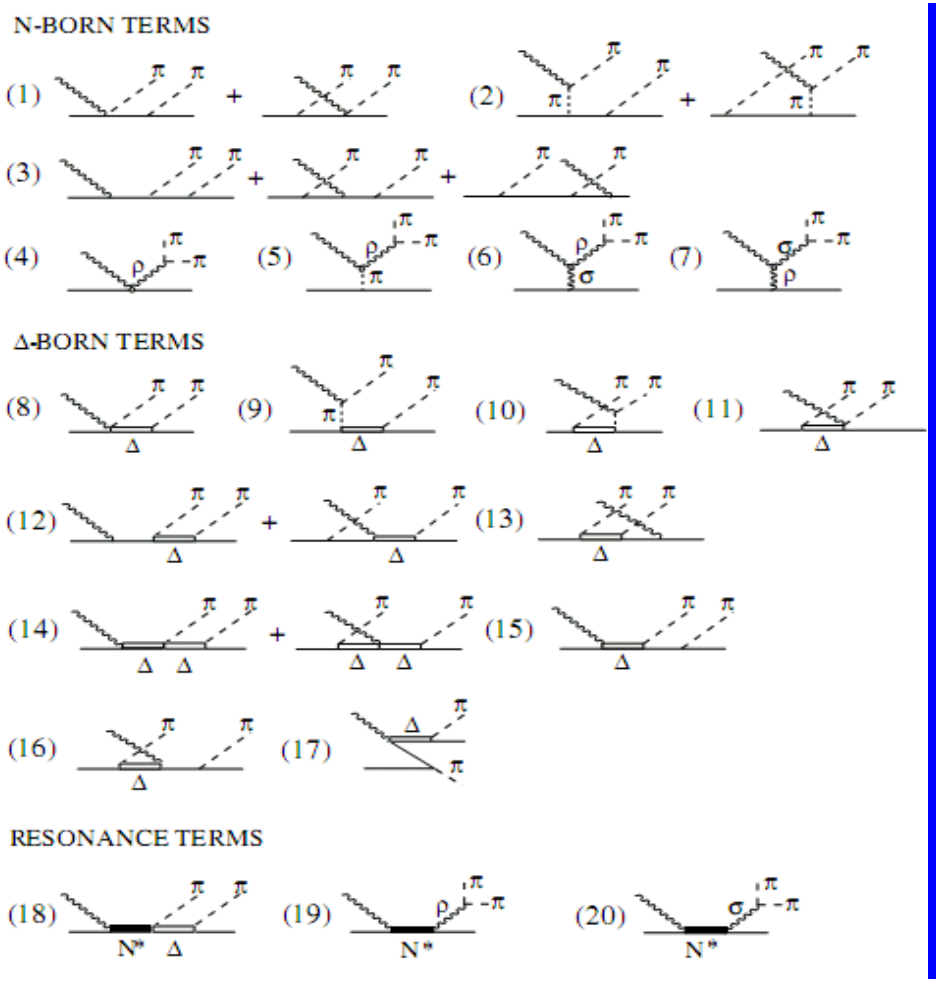




Impulse approximation

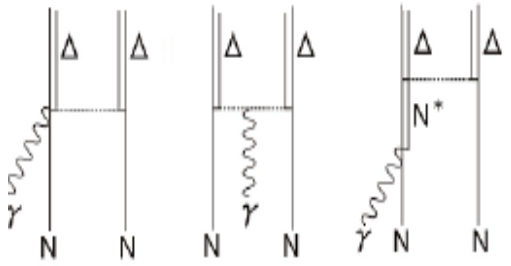
NN and πN rescattering

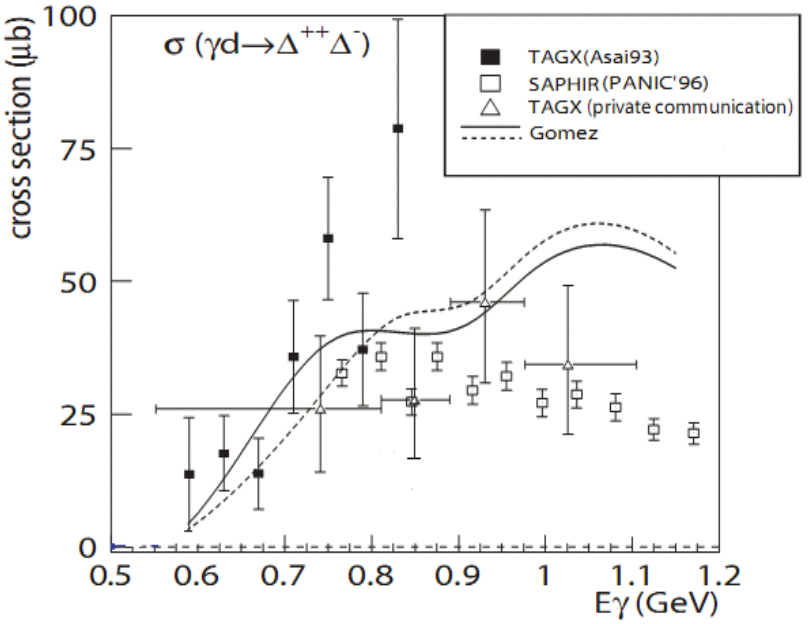
Motivation: Study of $\gamma d \rightarrow \pi^+\pi^- np$ reaction



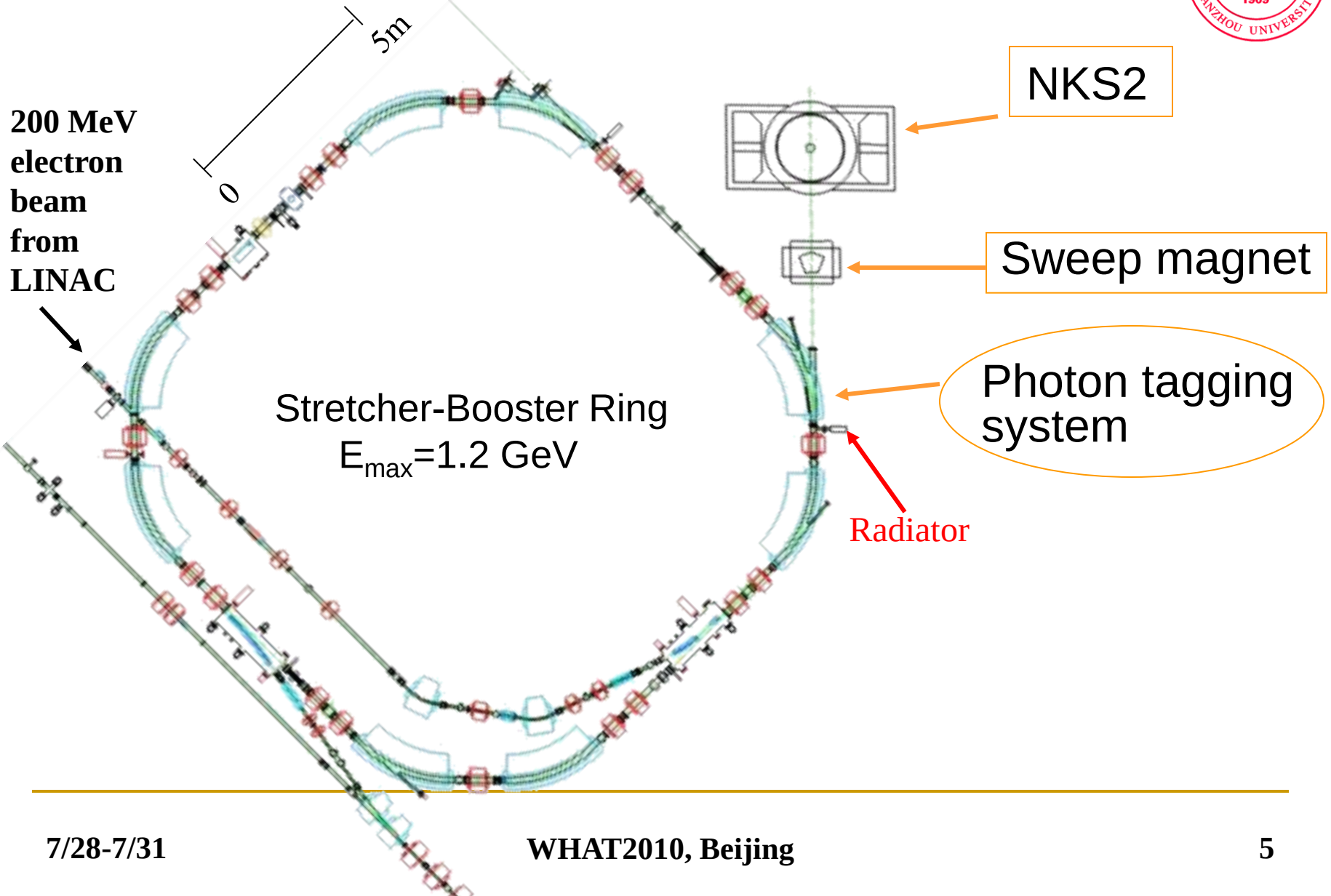
Δ^{++} (uuu)

Δ^{-} (ddd)

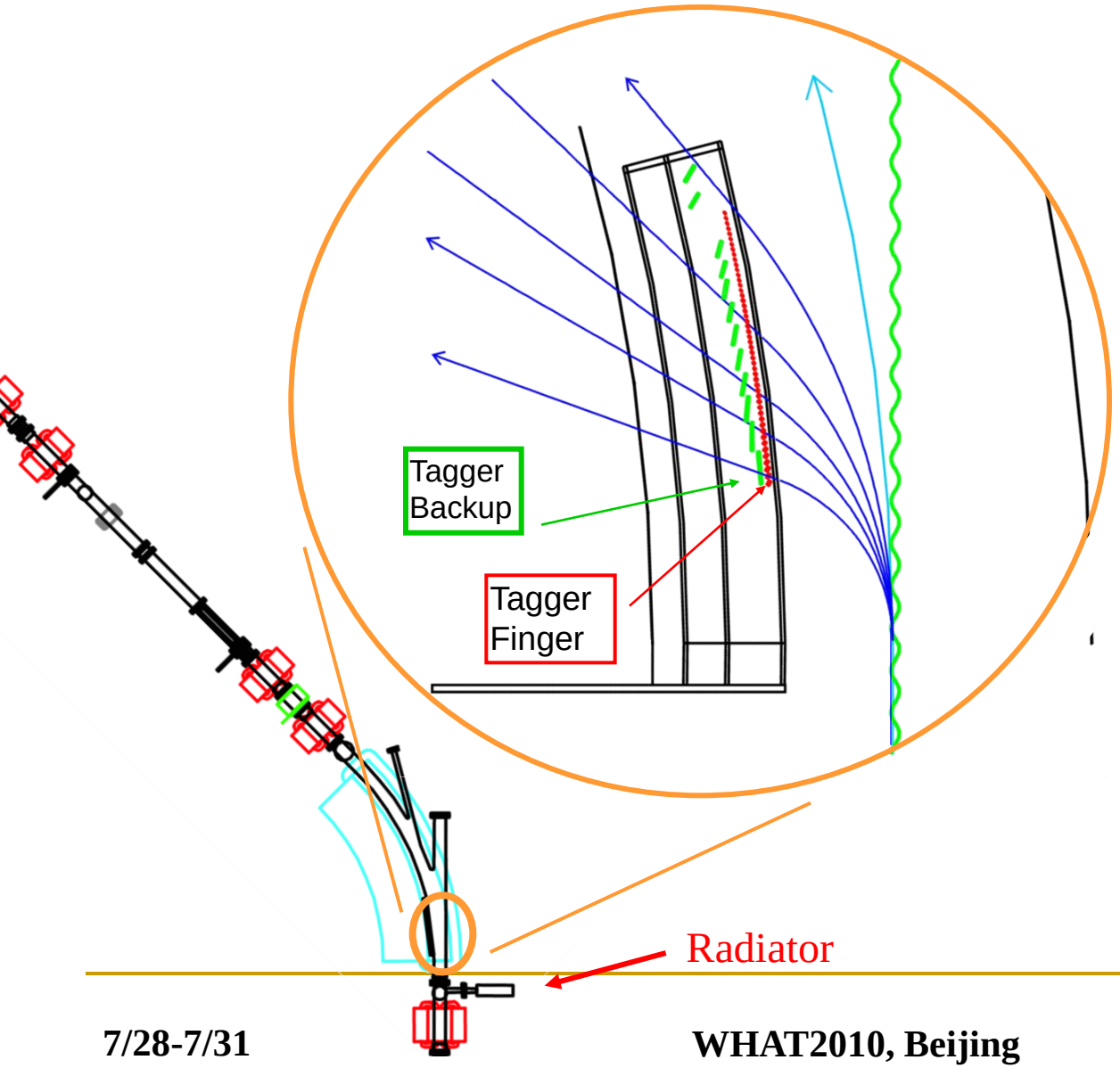




Tagged Photon Beam at LNS-Tohoku



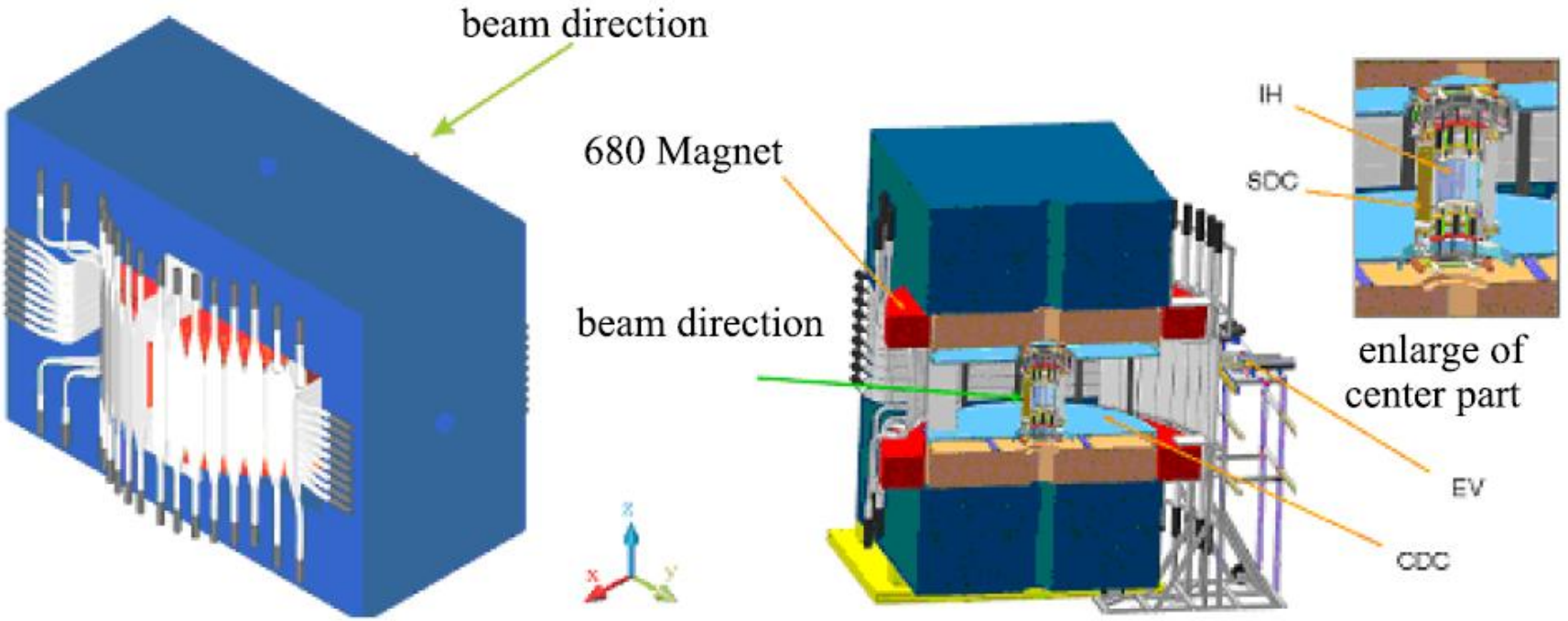
Photon Tagging System



- Photon beam
- Electron beam on carbon fiber
- Tagged by scattering electron
- E_γ=0.8-1.1 GeV from 1.2 GeV mood electron beam mode
- 6 MeV coverage per tagging counter

Schematic View of NKS2

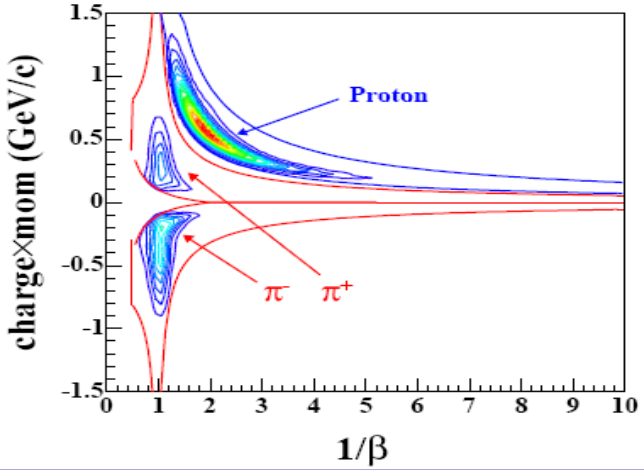
Solid angle ~ π sr; D~0.42 T; θ(Lab): -165°~165°

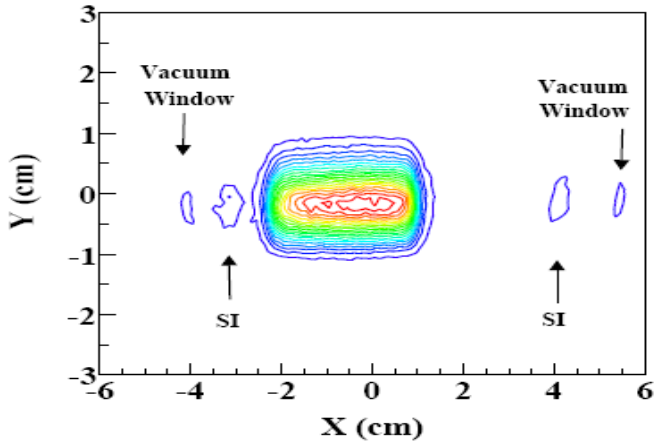


$$MT = (SUMOR \otimes (IH \geq 2)) \otimes (OH \geq 2) \otimes \overline{EV}.$$

Analysis

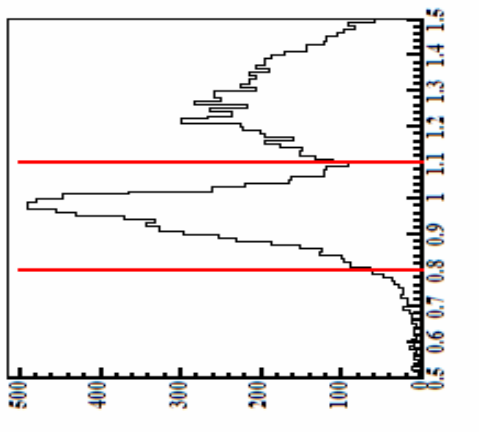
- Time selection → suppress accidental coincidence
- Track selection → suppress noisy of Drift Chamber
- Vertex position → target region select
- Particle Identify
- ‣π⁻]

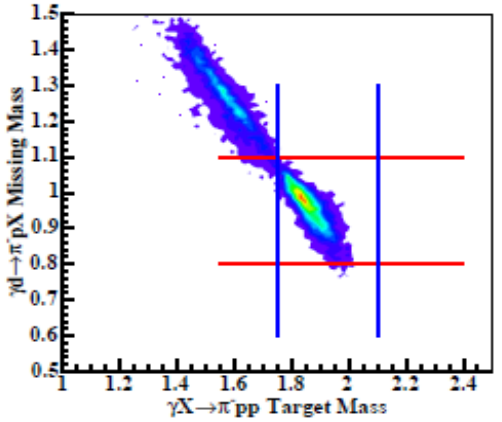




p~0.7 GeV/c: p(π)<1.3%, π(p)<0.3%

Channel selection of $\gamma d \rightarrow \pi^- pp$



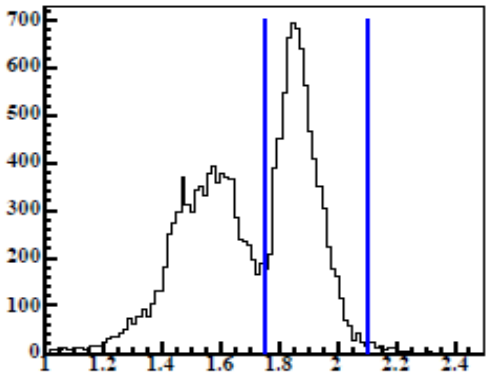


For reconstructed $\gamma d \rightarrow \pi^- pX$ mass $M_{missing}$,

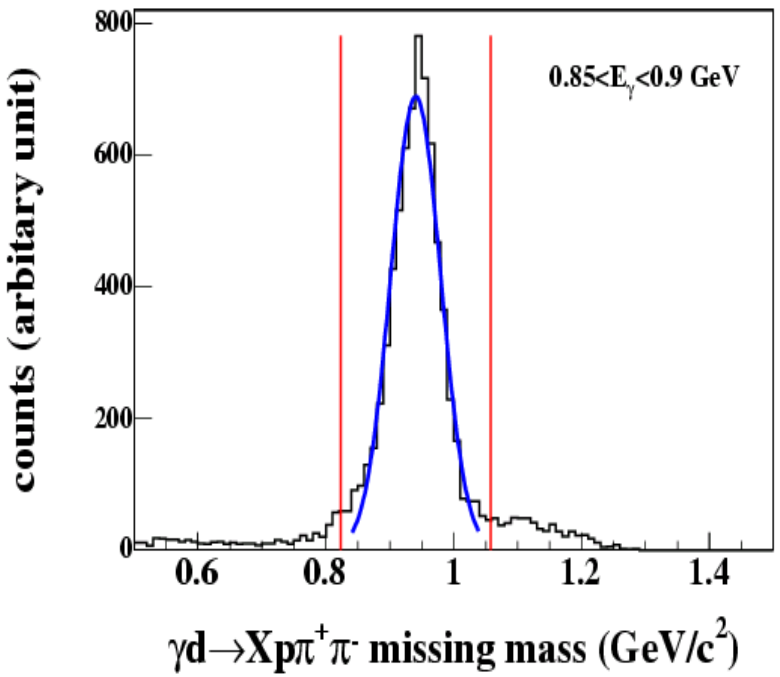
$0.8 < M_{missing} < 1.1$ (GeV/c^2);

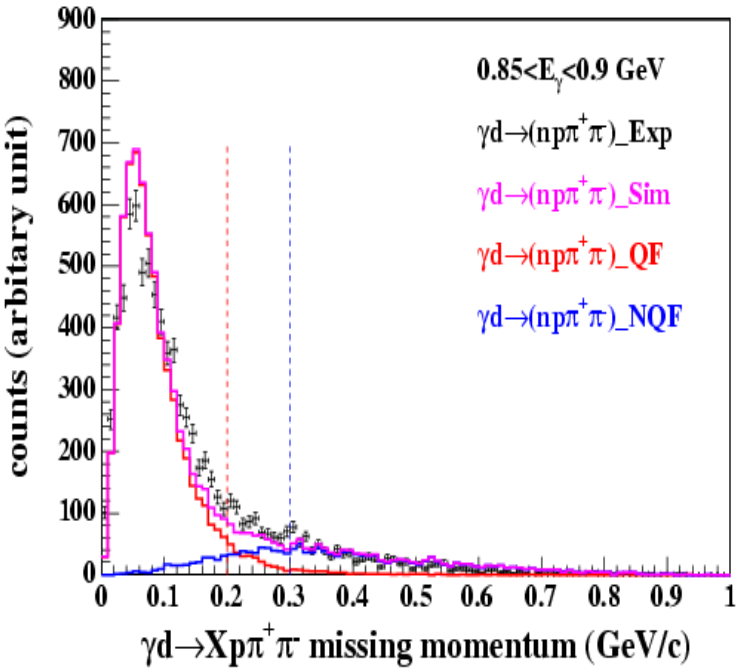
For reconstructed $\gamma X \rightarrow \pi^- pp$ mass M_{target} ,

$1.75 < M_{target} < 2.1$ (GeV/c^2);



Channel selection of $\gamma d \rightarrow np\pi^+\pi^-$





$m_x \sim m_{peak} \pm 3\sigma$;

P_x<0.2 GeV/c: quasi-free;

P_x>0.3 GeV/c: non-quasi-free process;

Data Analysis

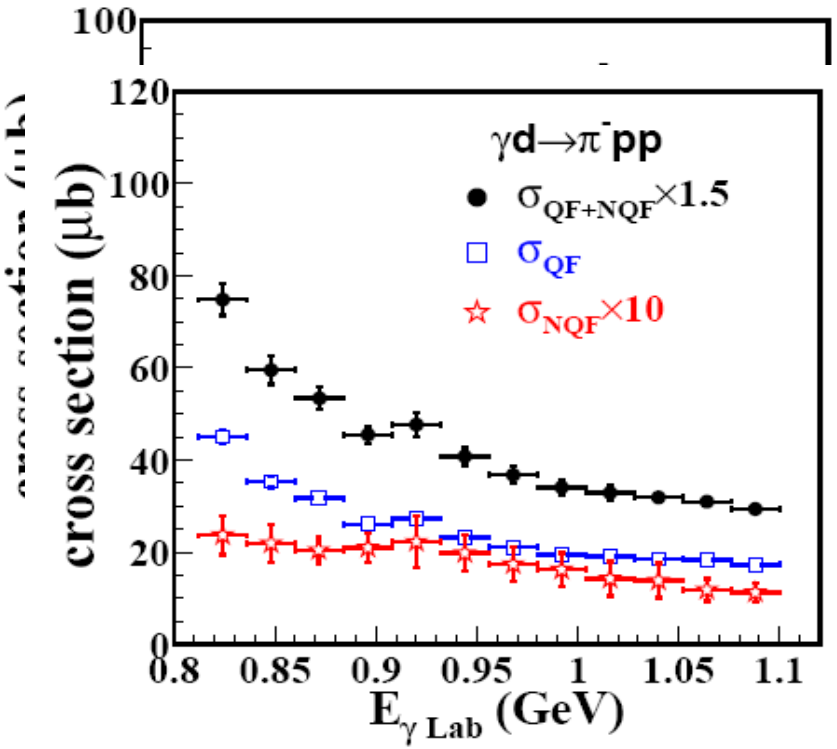
Total cross section:

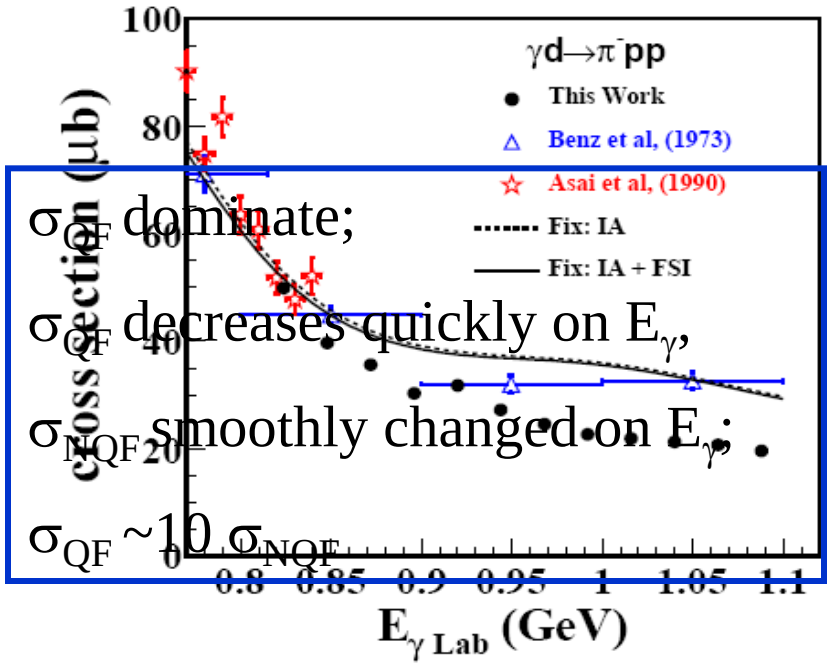
$$\sigma(E) = \frac{N_{Yield}(E)}{N_{\gamma}(E) N_{Target} \varepsilon_{Ana}(E) \varepsilon_{DAQ} \varepsilon_{Track}}$$

Differential cross section:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{N_{Yield}(E,\theta)}{N_{\gamma}(E) N_{Target} \varepsilon_{Ana}(E,\theta) \varepsilon_{DAQ} \varepsilon_{Track} d\Omega}$$

Total cross section of $\gamma d \rightarrow \pi^- pp$





σ_{QF} dominate;

σ_{QF} decreases quickly on E_γ,

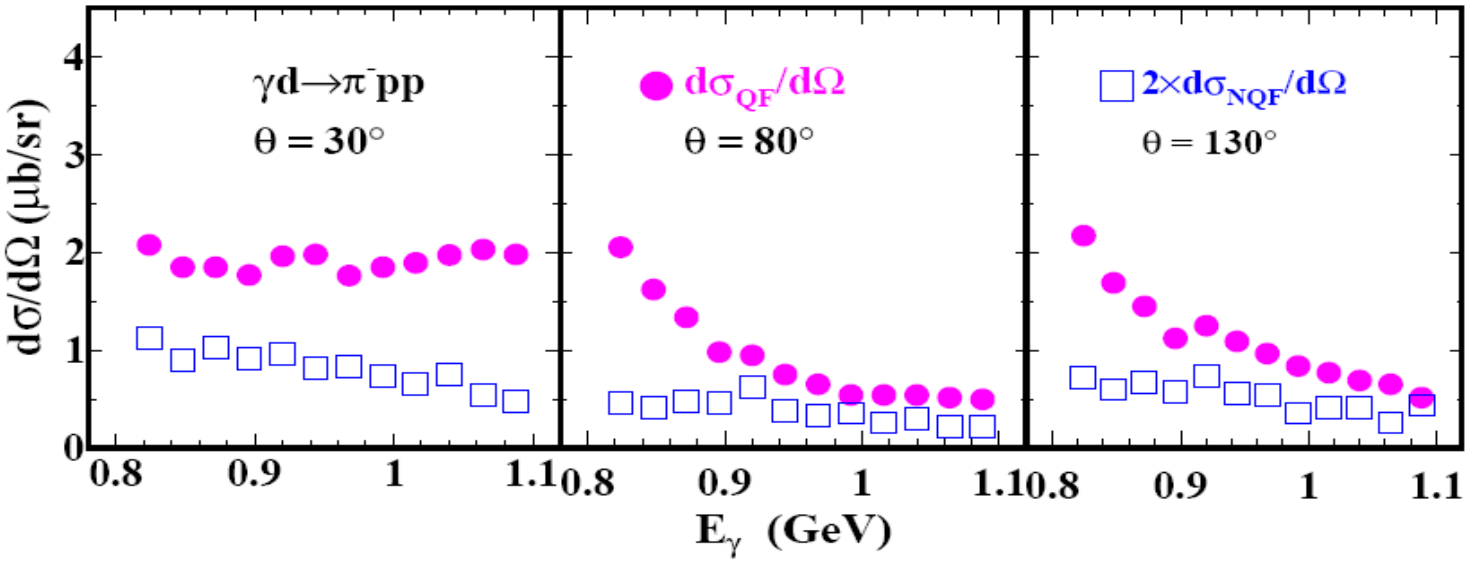
σ_{NQF} smoothly changed on E_γ;

$\sigma_{QF} \sim 10\ \sigma_{NQF}$

E>0.95, $\sigma_{QF} < \sigma(\gamma n \rightarrow p\pi^-)$

Theo. > Exp.

Differential cross section of $\gamma d \rightarrow \pi^- pp$



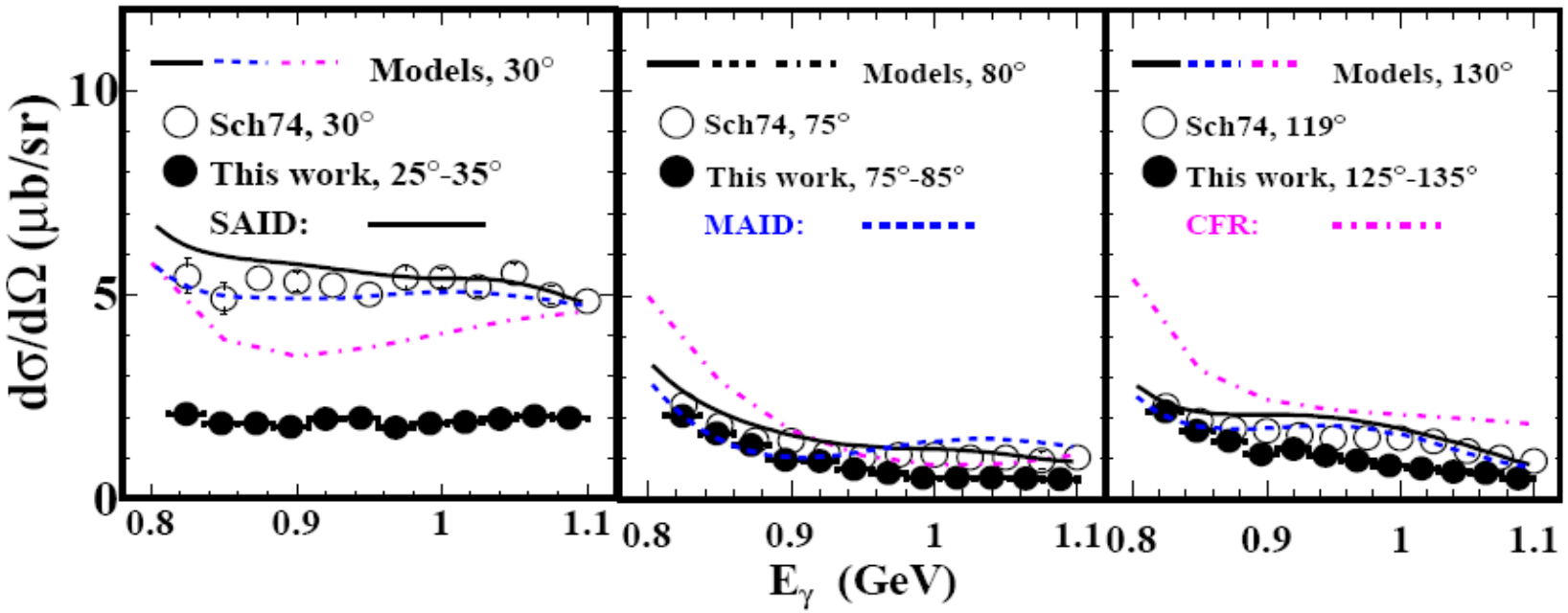
$d\sigma/d\Omega(\gamma d \rightarrow \pi^- pp)$ dominate in the forward angle;

$d\sigma_{QF}/d\Omega$ flat in the forward angle region on E_γ,

and decrease steeply on E_γ otherwise;

$d\sigma_{NQF}/d\Omega$ does not depend much on E_γ

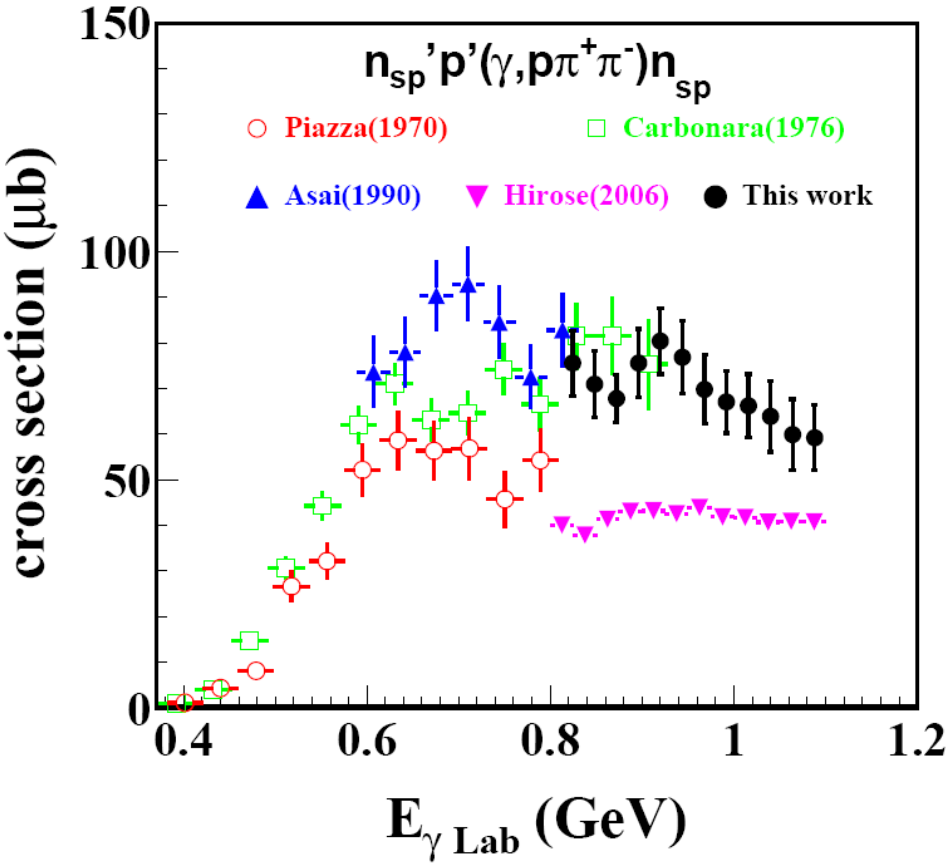
Differential cross section of $\gamma d \rightarrow \pi^- pp$



Deuteron effects are significant in the forward angle region;

Divergence of theo. exist esp. forward/backward angle region.

Total cross section of $\gamma d \rightarrow n_{sp} p \pi^+ \pi^-$

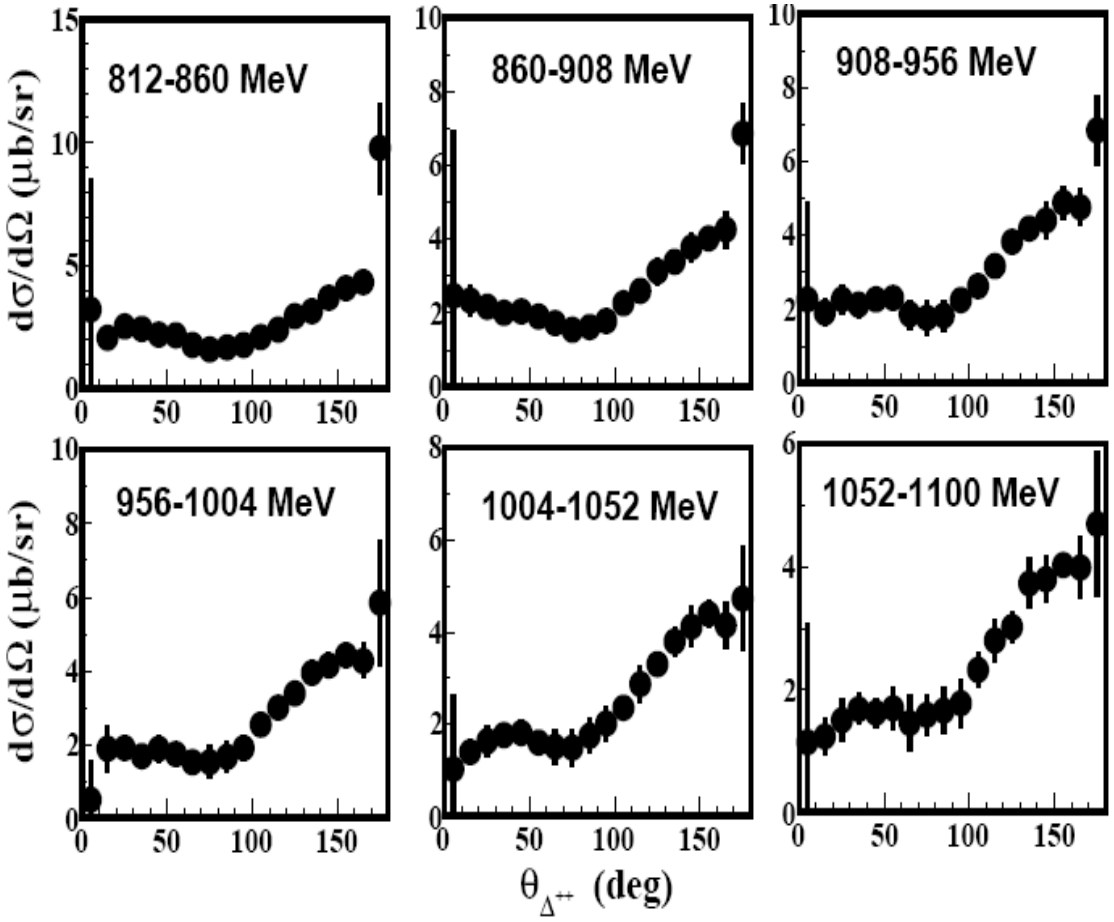


$\gamma p \rightarrow$ $\Delta^{++}\pi^-$, $\Delta^0\pi^+$, $p\rho^0$, $N^*\pi$, 3BPS $\rightarrow p\pi^+\pi^-$

This work, Max.;

Hirose; ratio fit by IM

Differential cross section of $\gamma d \rightarrow n_{sp}\Delta^{++}\pi^{-}$



Maximum limit;

$\Delta^{++}\pi^{-}$ CM frame

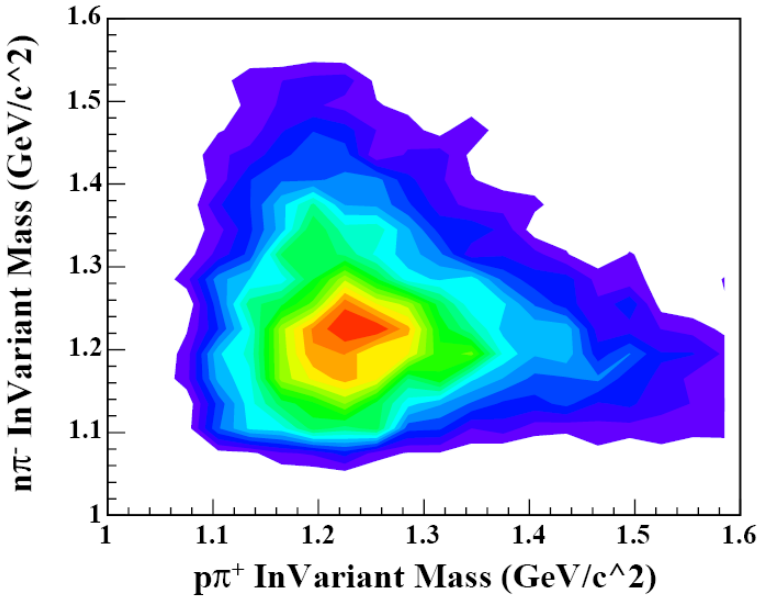
Backward favor distribution;

Total cross section of $\gamma d \rightarrow \Delta^{++}\Delta^{-}$

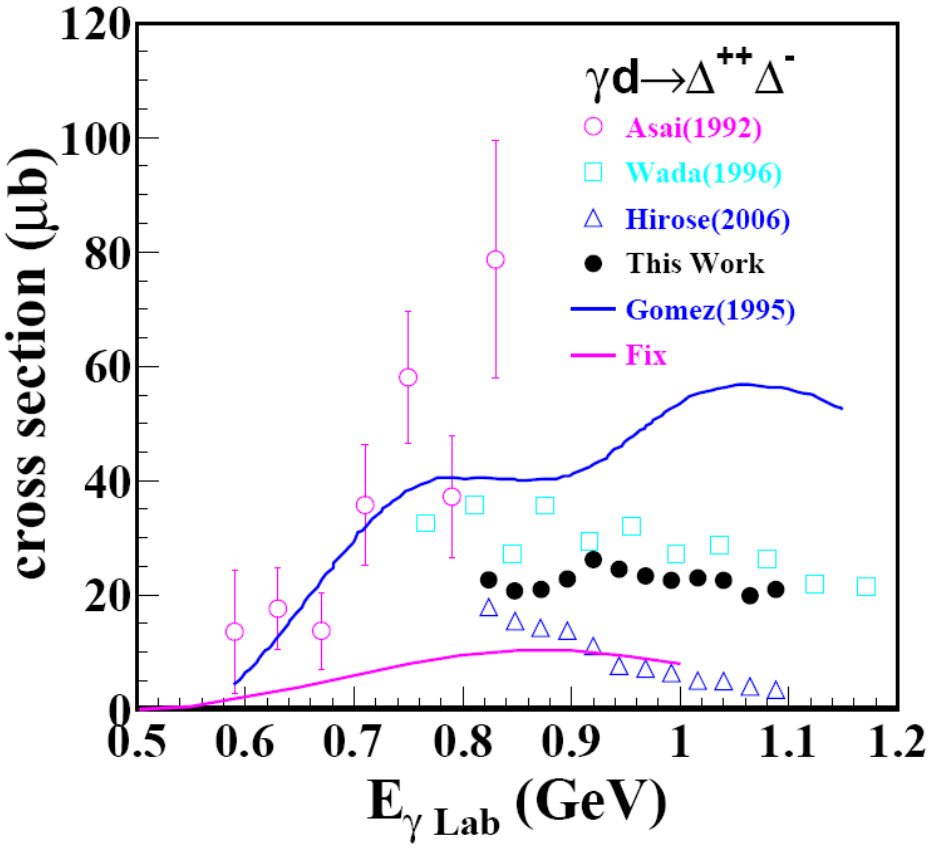
If select p_n>0.3 GeV/c,

$\gamma d \rightarrow \Delta^{++}\Delta^{-}$/4BPS

$\rightarrow np\pi^{+}\pi^{-}$



Total cross section of $\gamma d \rightarrow \Delta^{++}\Delta^{-}$



This work Max. limit;

Hirose, ratio by fit IM;

Fix, preliminary;

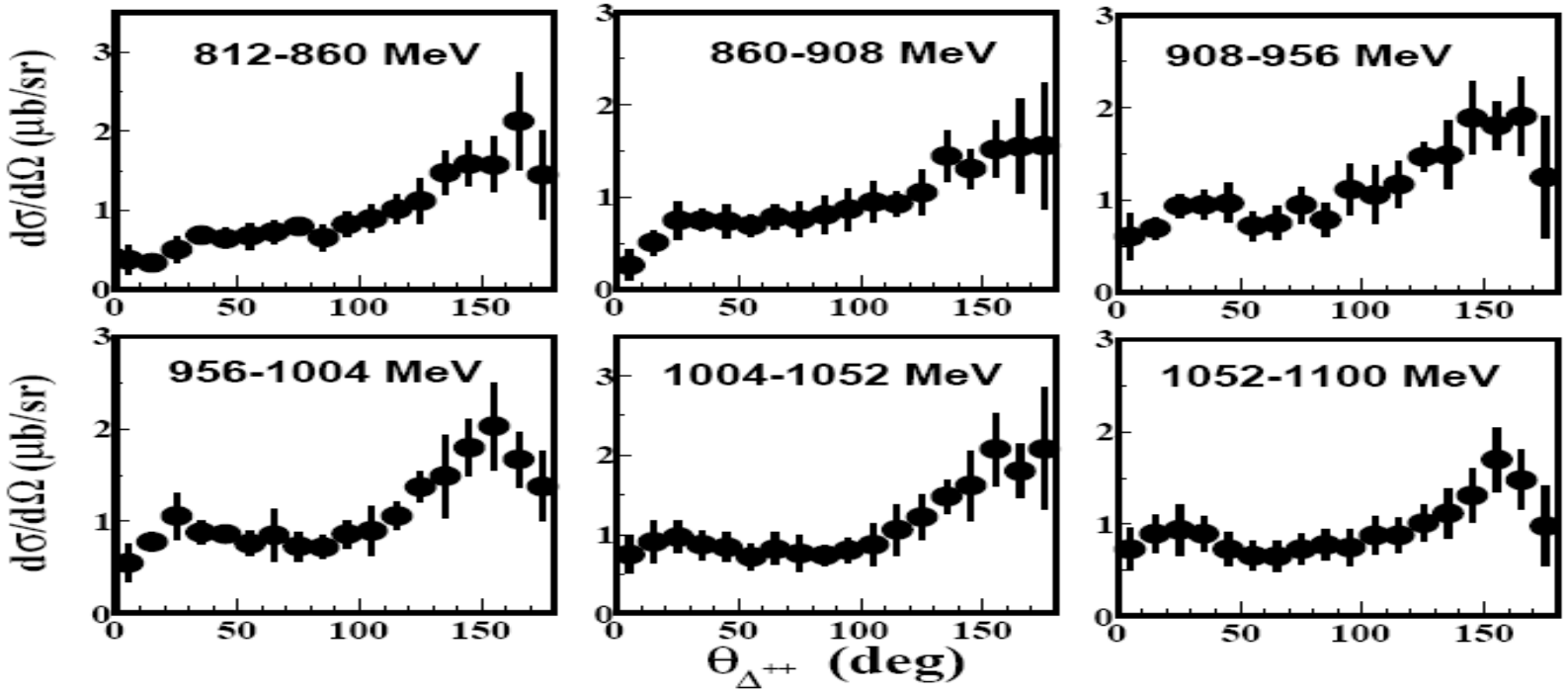
Asai and Wada bigger;

Wada ~ this work Max.

Gomez >> A. Fix

Branch ratio!!!

Differential cross section of $\gamma d \rightarrow \Delta^{++}\Delta^{-}$



Maximum limit, $\Delta^{++}\Delta^{-}$ CM frame

Δ^{++} backward favor distribution

Summary

- $\gamma d \rightarrow \pi^- pp$ and $\gamma d \rightarrow \pi^+ \pi^- np$ were measured with $0.812 < E_\gamma < 1.1$ GeV;
- Differential and total cross section were obtained;
- Non-/ quasi-free process were separated;
- For $\gamma d \rightarrow \pi^- pp$, $\sigma_{QF} \sim 10\ \sigma_{NQF}$; $d\sigma_{NQF}/d\Omega$ does not depend much on E_γ; deuteron effects are significant in the forward angle region;
- for $\gamma d \rightarrow \pi^+ \pi^- np$, Δ^{++} has backward favor distribution;
- Need find a better branch ratio fitting method;
- Theo. study need improve to fit Exp. data;
- NKS2 upgrade for larger acceptance and better resolution, new Exp. with $0.6 < E_\gamma < 0.9$ GeV is approved.

Collaboration List

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