Double-Polarization Observables in Pion-Photoproduction from Polarized HD at LEGS

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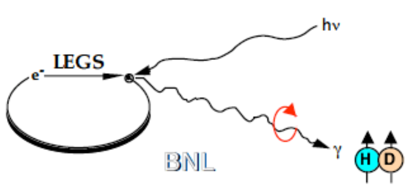
(for the LEGS-Spin Collaboration)

- overview of HD target production at LEGS
- the Fall'04 and Spring'05 production runs with calorimeter
- preliminary results
- schedule for 2nd phase experiments with Time Projection Chamber



NSTAR'05, Tallahassee, Oct 12,2005

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37 people from

10 institutions in

3 countries

Post-Docs (NSF)
Grad Students
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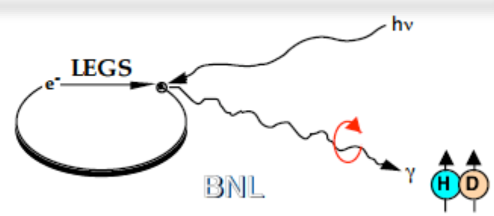
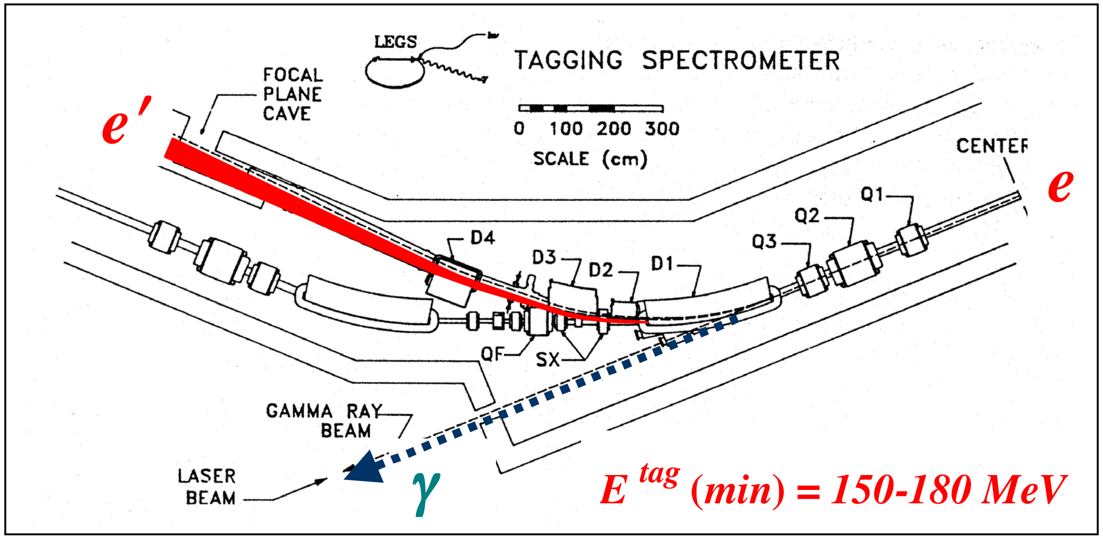
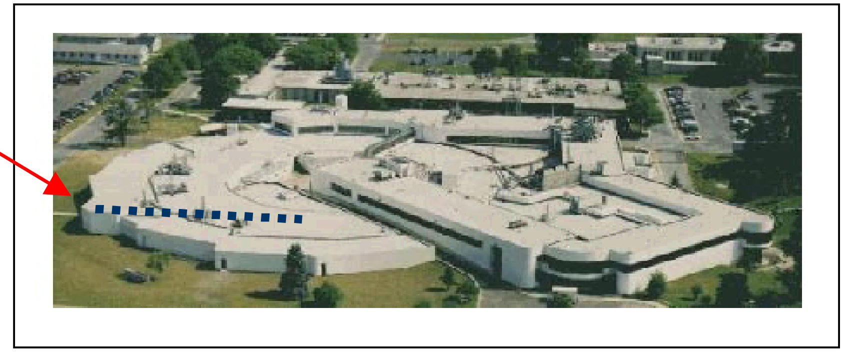


LSC list May'05

Laser-Electron-Gamma-Source (LEGS)



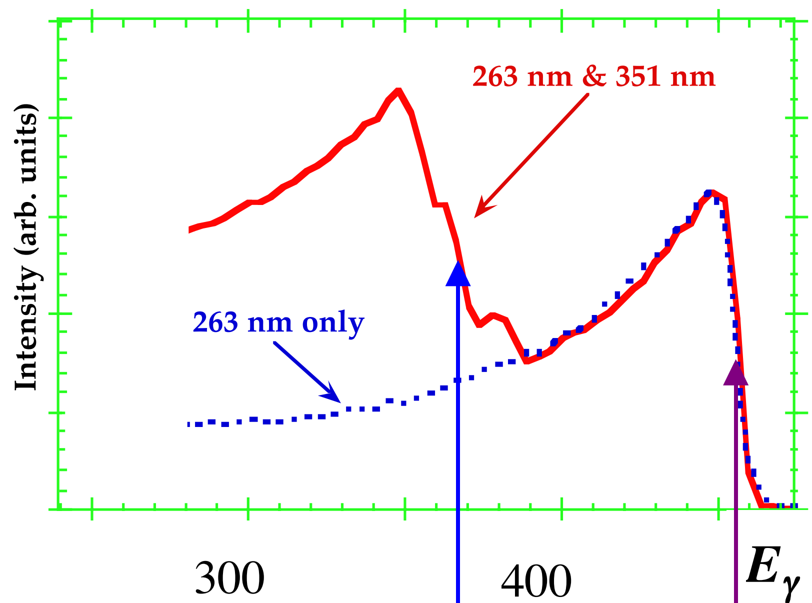


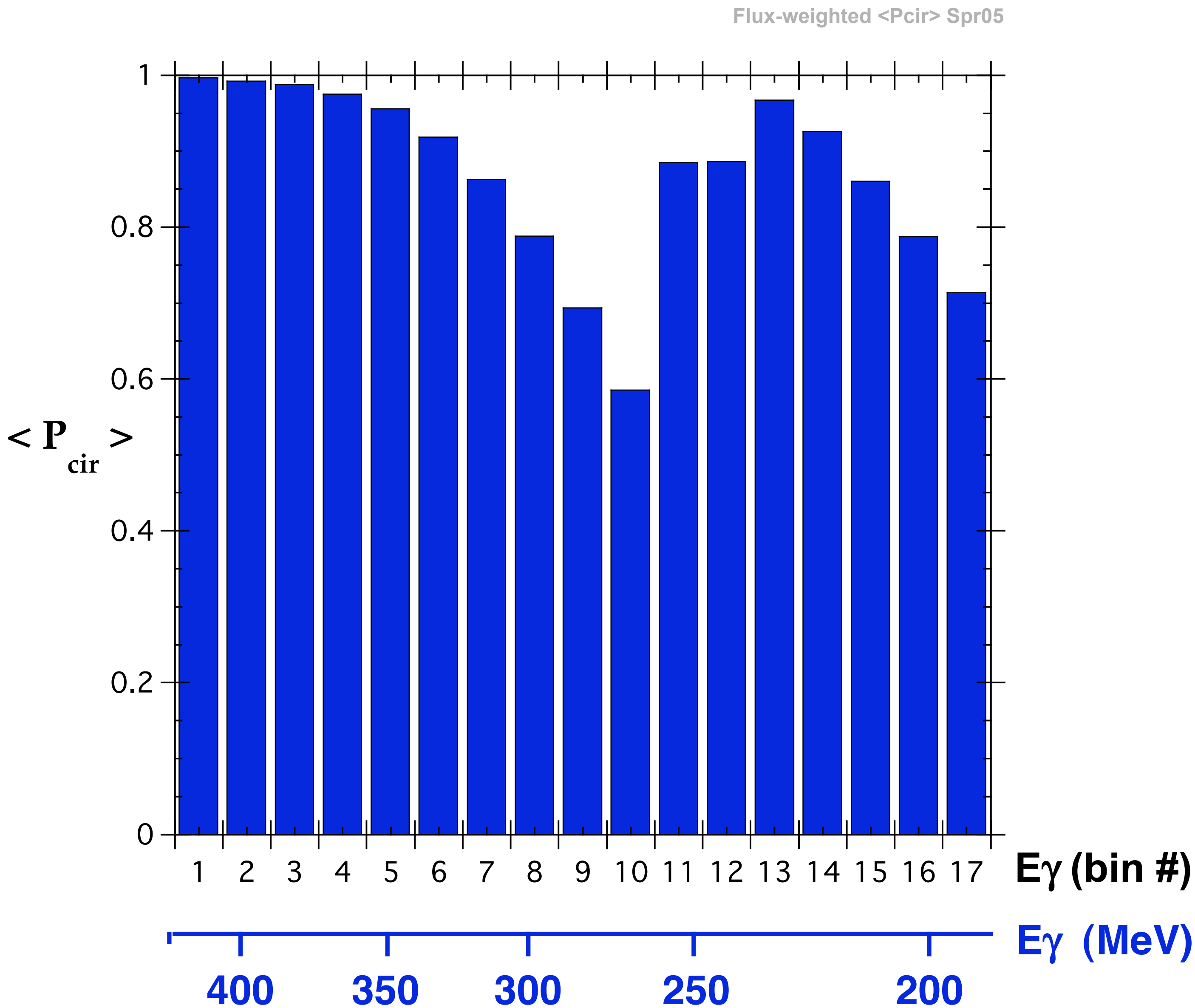
NSLS $E_e = 2.8$ *GeV*

γ beam energy determined by e′ tagging

$E_\gamma = E_e - E_{e'}$, $\Delta E_\gamma = 3$ MeV

	4ω Nd-YLF ring laser	Ar-Ion laser			
λ(nm)	263	300	351	488	515
E_γ (*max*)	*471 MeV*	*421 MeV*	*368 MeV*	*275 MeV*	*262 MeV*




Flux-weighted <Pcir> Spr05
1
0.8
0.6
0.4
0.2
0
$< P_{cir} >$
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Eγ (bin #)
400 350 300 250 200
Eγ (MeV)

Polarized cross sections and asymmetries:

- *flip between 6 γ-beam polarization states:* *R-circular, 0º Linear, +45º Linear; L-circular, 90º Linear, –45º Linear*

(H) For **Hydrogen** polarization $P_z = P^V$ defined as +1 when spin is along z,

- there are three asymmetries: Σ , G **and** E :

$$\frac{d\sigma}{d\Omega}(\theta,\phi;E_\gamma) = \frac{d\sigma_o}{d\Omega}(\theta;E_\gamma)\cdot\left\{\begin{array}{l} 1 + P_\gamma^L \cdot \left[\ \Sigma(\theta;E_\gamma)\ \right]\cdot \cos 2\phi \\ + P_\gamma^L \cdot P_H^V \cdot G(\theta;E_\gamma)\cdot \sin 2\phi \\ - P_\gamma^C \cdot P_H^V \cdot E(\theta;E_\gamma) \end{array}\right\}$$

GDH

(D) For **Deuterium** with vector polarization $P^V{}_D$ along γ-beam, and tensor polarization $P^V{}_T$,

- there are three vector asymmetries: $\tilde{\Sigma}$, $\tilde{G}$ **and** $\tilde{E}$;
- and there are 2 tensor asymmetries: $T^L{}_{20}$ and $T^0{}_{20}$:

$$\frac{d\sigma}{d\Omega}(\theta,\phi;E_\gamma) = \frac{d\sigma_o}{d\Omega}(\theta;E_\gamma)\cdot\left\{\begin{array}{l} 1 + P_\gamma^L \cdot \left[\tilde{\Sigma}(\theta;E_\gamma) + \tfrac{1}{\sqrt{2}} P_D^T \cdot T_{20}^L(\theta;E_\gamma)\right]\cdot \cos 2\phi \\ + P_\gamma^L \cdot P_D^V \cdot \tilde{G}(\theta;E_\gamma)\cdot \sin 2\phi \\ - P_\gamma^C \cdot P_D^V \cdot \tilde{E}(\theta;E_\gamma) + \tfrac{1}{\sqrt{2}} P_D^T \cdot T_{20}^0(\theta;E_\gamma) \end{array}\right\}$$

Separating $\vec{H}$ and $\vec{D}$ data with spin flip - *example, π^o production*

Run A: $\vec{H}\cdot\vec{D}$ **with parallel spins**

$$\sigma^A_{\overleftarrow{\gamma}_L} = \sigma\left[\vec{p}(\overleftarrow{\gamma},\pi^o)\right] + \sigma\left[\vec{D}(\overleftarrow{\gamma},\pi^o)\right]$$

$$\sigma^A_{\vec{\gamma}_R} = \sigma\left[\vec{p}(\vec{\gamma},\pi^o)\right] + \sigma\left[\vec{D}(\vec{\gamma},\pi^o)\right]$$

Run B: $\overleftarrow{H}\cdot\vec{D}$ **with anti-parallel spins**

$$\sigma^B_{\overleftarrow{\gamma}_L} = \sigma\left[\overleftarrow{p}(\overleftarrow{\gamma},\pi^o)\right] + \sigma\left[\vec{D}(\overleftarrow{\gamma},\pi^o)\right]$$

$$\sigma^B_{\vec{\gamma}_R} = \sigma\left[\overleftarrow{p}(\vec{\gamma},\pi^o)\right] + \sigma\left[\vec{D}(\vec{\gamma},\pi^o)\right]$$

$$\Rightarrow \quad \Delta\sigma(p) = \left(\sigma_{3/2} - \sigma_{1/2}\right)_p = \left[\sigma^B_{\vec{\gamma}_R} - \sigma^A_{\vec{\gamma}_R}\right] + \left[\sigma^A_{\overleftarrow{\gamma}_L} - \sigma^B_{\overleftarrow{\gamma}_L}\right] \quad \textit{from } \gamma p \rightarrow \pi^o p$$

$$\Delta\sigma(D) = \left(\sigma_{3/2} - \sigma_{1/2}\right)_D = \left[\sigma^A_{\overleftarrow{\gamma}_L} - \sigma^B_{\vec{\gamma}_R}\right] + \left[\sigma^B_{\overleftarrow{\gamma}_L} - \sigma^A_{\vec{\gamma}_R}\right] \quad \textit{from } \gamma D \rightarrow \pi^o X$$

- *similarily, runs with different P_D separate Vector and Tensor D-observables*

- *in general, one fits out different observables from runs with different polarizations*

Physics from $\vec{H}\cdot\vec{D}$ measurements:

$$\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^o)\Rightarrow\begin{cases}\vec{D}(\vec{\gamma},\pi^o)np+\vec{D}(\vec{\gamma},\pi^o)D\\ \vec{p}(\vec{\gamma},\pi^o)\end{cases}$$

$\vec{p}(\vec{\gamma},\pi^o)$ → *GDH(p)*

$$\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^+n)\Rightarrow\begin{cases}\vec{p}(\vec{\gamma},\pi^+)\\ \vec{D}(\vec{\gamma},\pi^+n)n\end{cases}$$

$\vec{p}(\vec{\gamma},\pi^+)$ → *GDH(p)*

$\vec{D}(\vec{\gamma},\pi^+n)n$ → *compare to free p*
w, w/o ϕ-cut $\Rightarrow$ *binding effects*

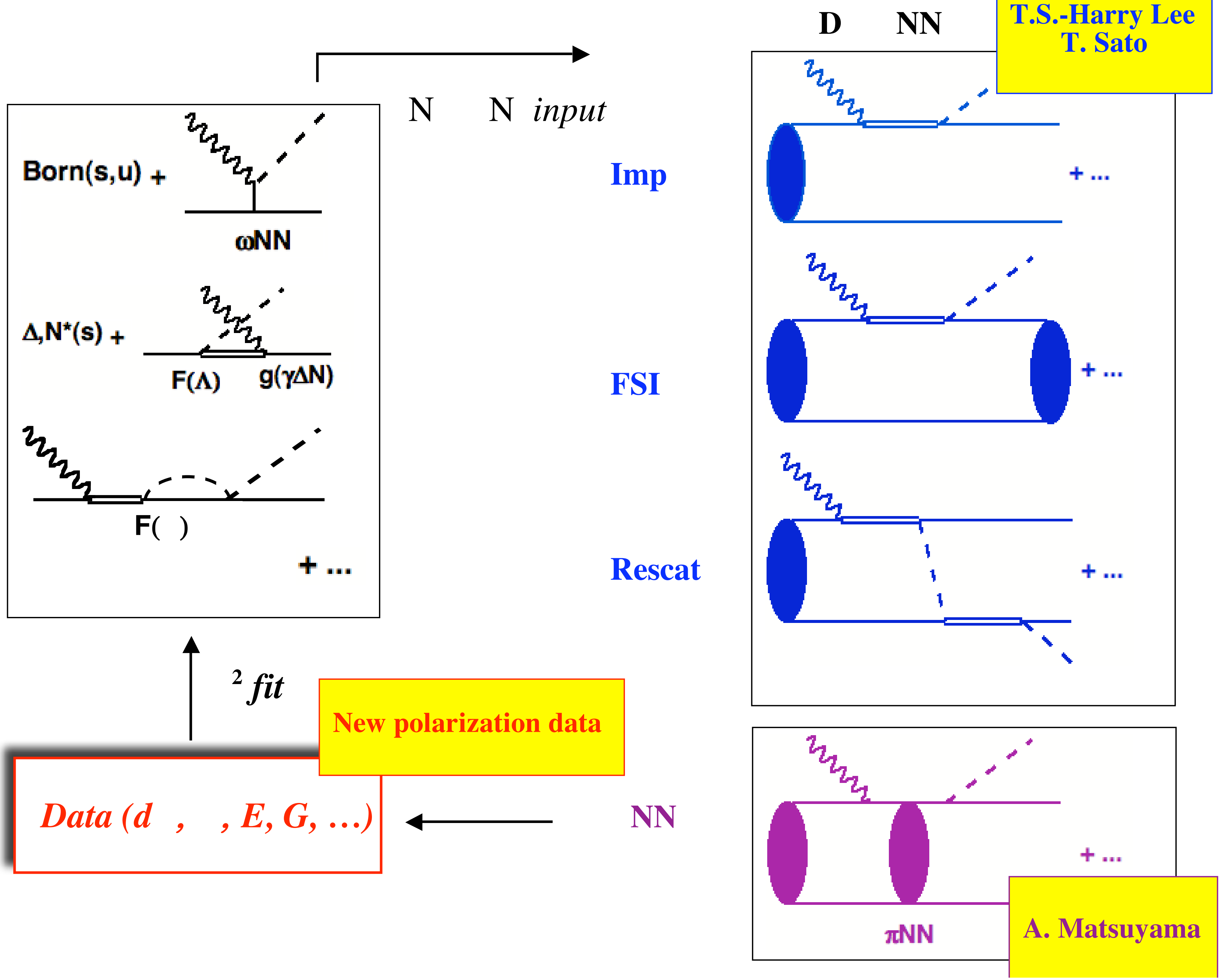
$\vec{D}(\vec{\gamma},\pi^o n)p$ → *compare to cal. w, w/o ϕ-cut*
$\Rightarrow$ $\vec{n}(\vec{\gamma},\pi^o)$

$\vec{D}(\vec{\gamma},\pi^- p)p$ - - - → *limited coverage w calorimeter*

$\vec{D}(\vec{\gamma},p)n$

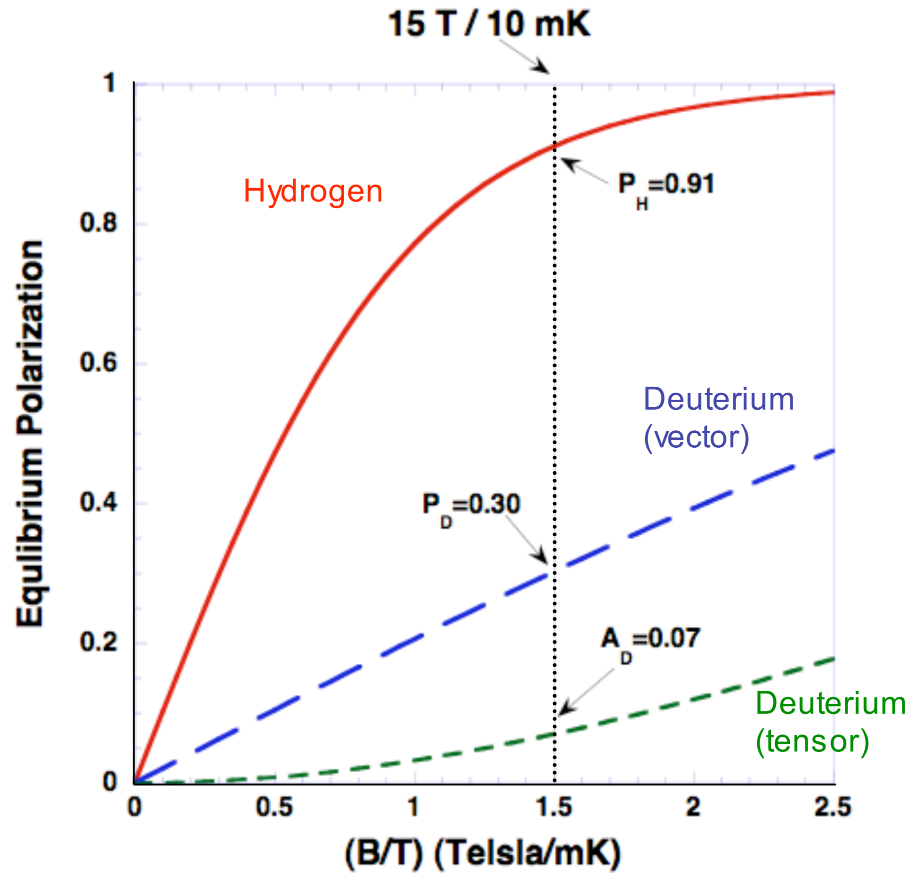
$\vec{D}(\vec{\gamma},\pi^-)$ *and* $\vec{D}(\vec{\gamma},\pi^- p)$ *TPC'2006* *compare to cal.* $\Rightarrow$ *GDH(n)*
w, w/o ϕ-cut $\vec{n}(\vec{\gamma},\pi^-)$

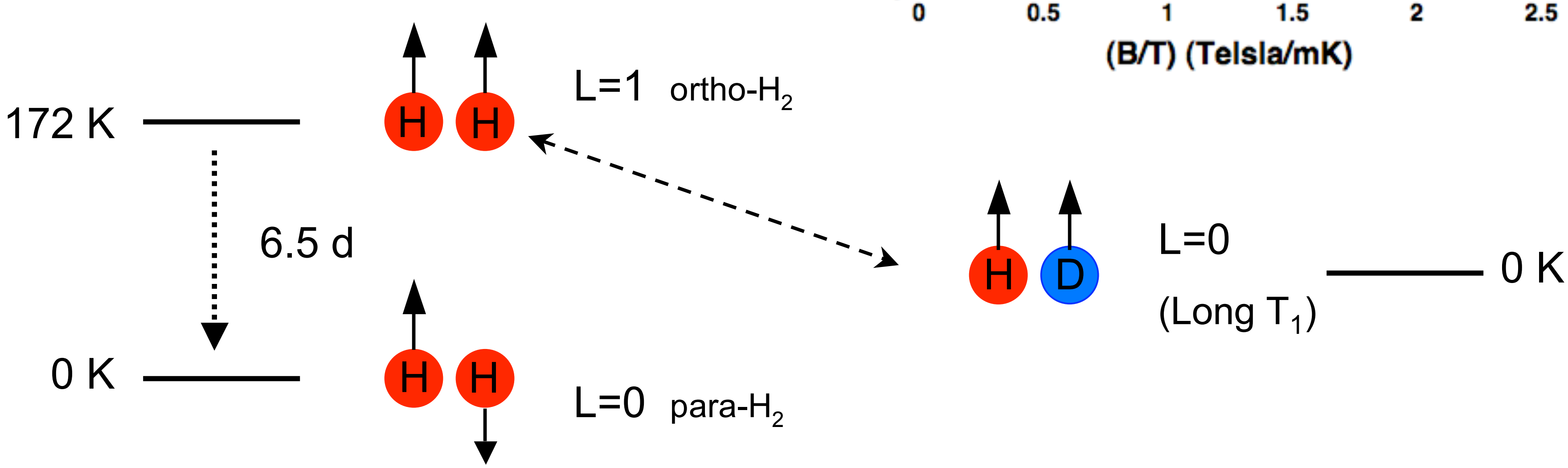
A *campaign* to determine the +n multipoles

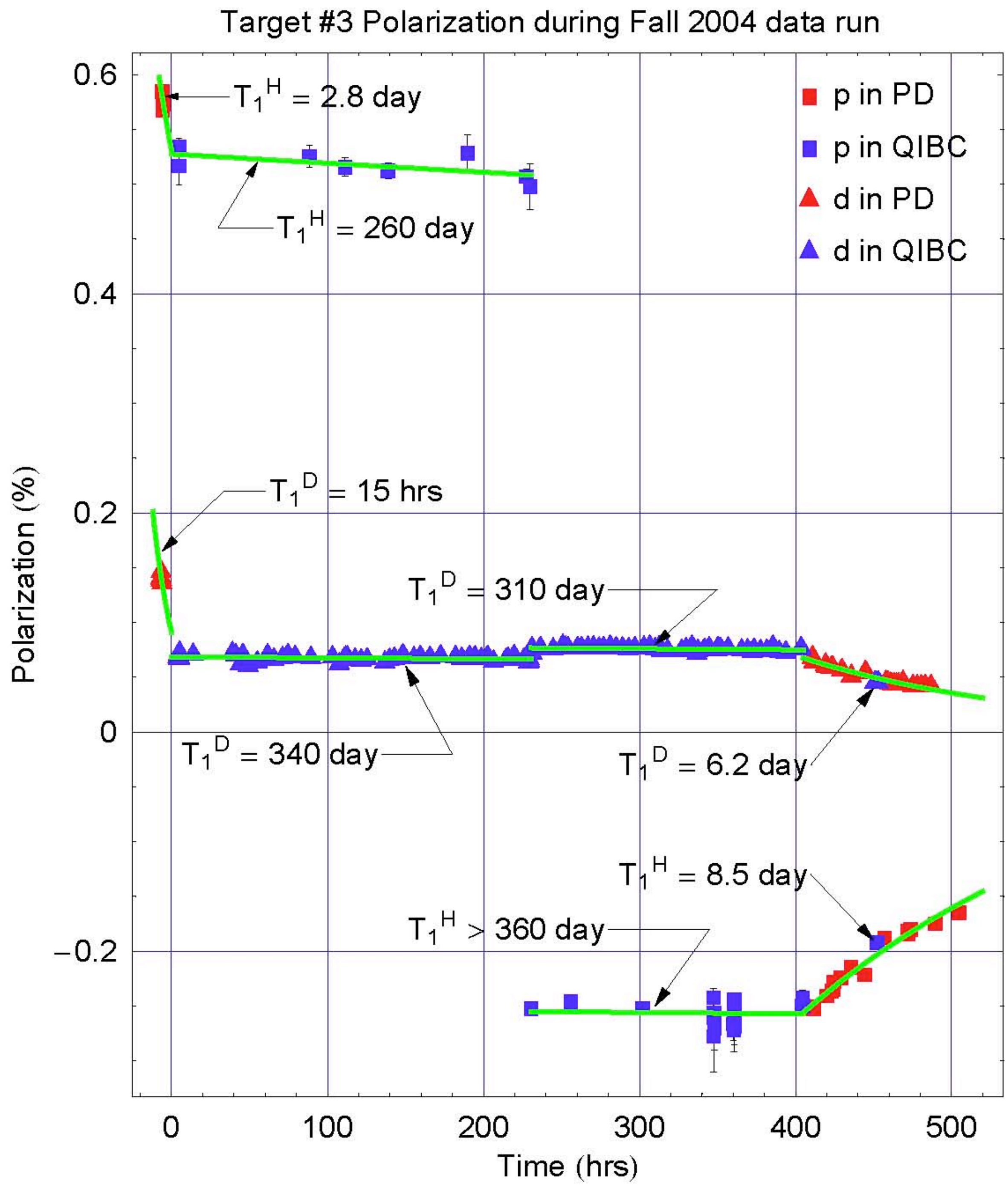


HD Target Polarization

- align spins with high B (15 tesla) and low T (~12 mK)
- L=0 for HD ➔ long T_1
- use spin-exchange with small concentration of o-H_2 (and p-D_2) to polarize HD
- wait for L=1 H_2 and D_2 to decay

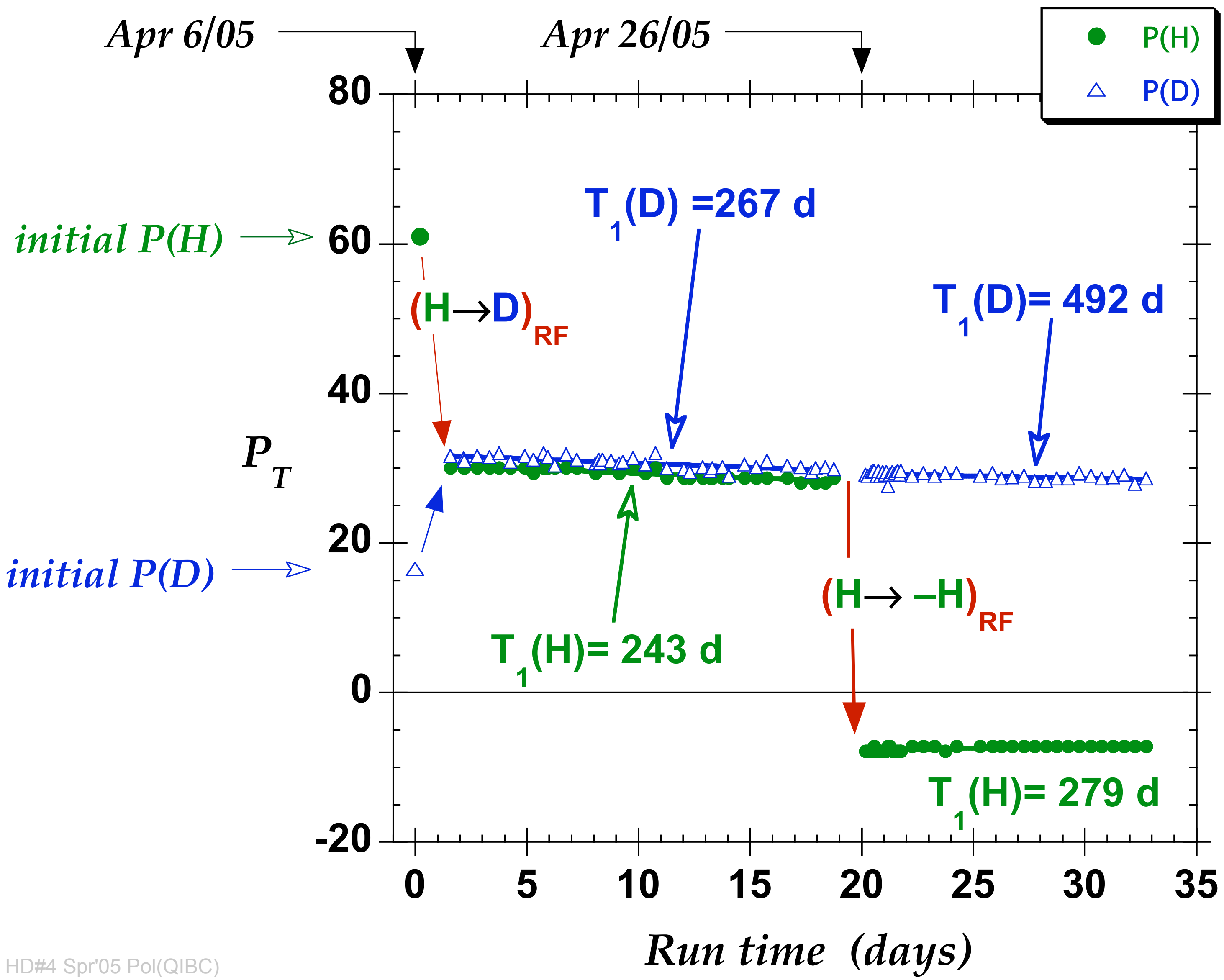


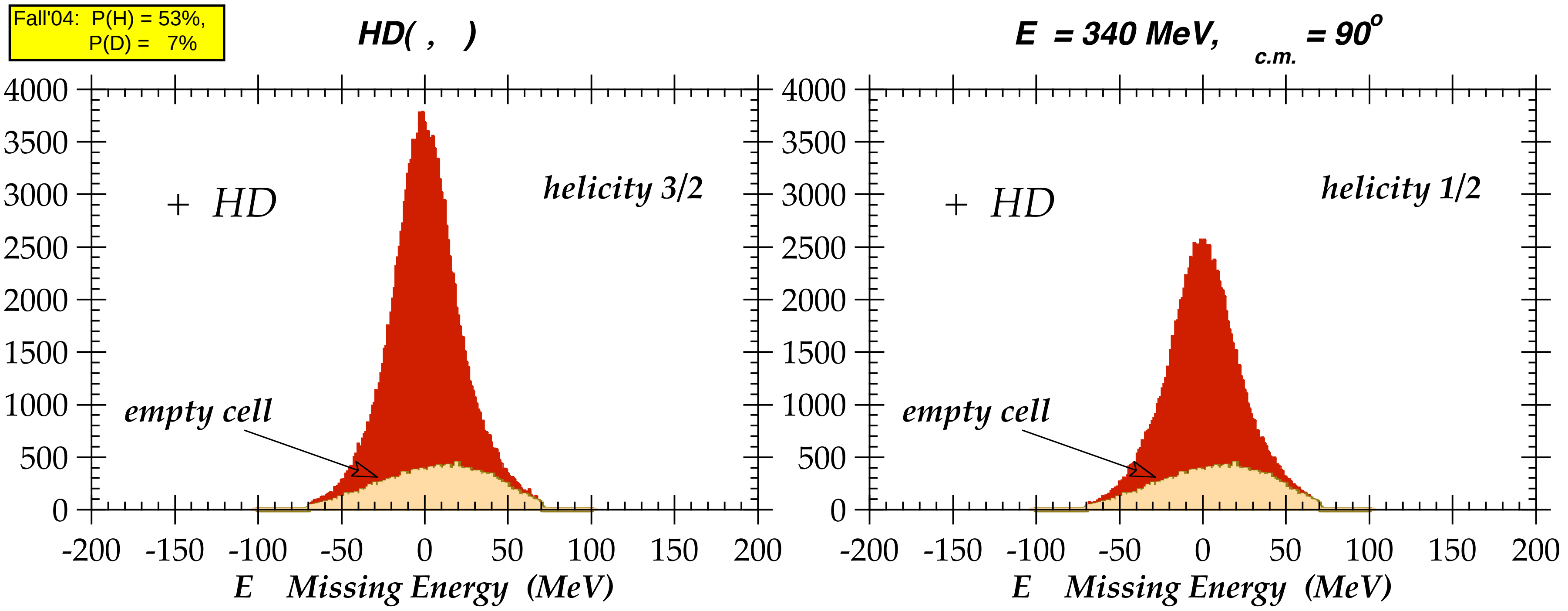




Target #3 Polarization during Fall 2004 data run
Polarization (%)
Time (hrs)
0.6
0.4
0.2
0
−0.2
0
100
200
300
400
500
p in PD
p in QIBC
d in PD
d in QIBC
T_1^H = 2.8 day
T_1^H = 260 day
T_1^D = 15 hrs
T_1^D = 310 day
T_1^D = 340 day
T_1^D = 6.2 day
T_1^H = 8.5 day
T_1^H > 360 day

HD#4 Spring'05 Running Cycle



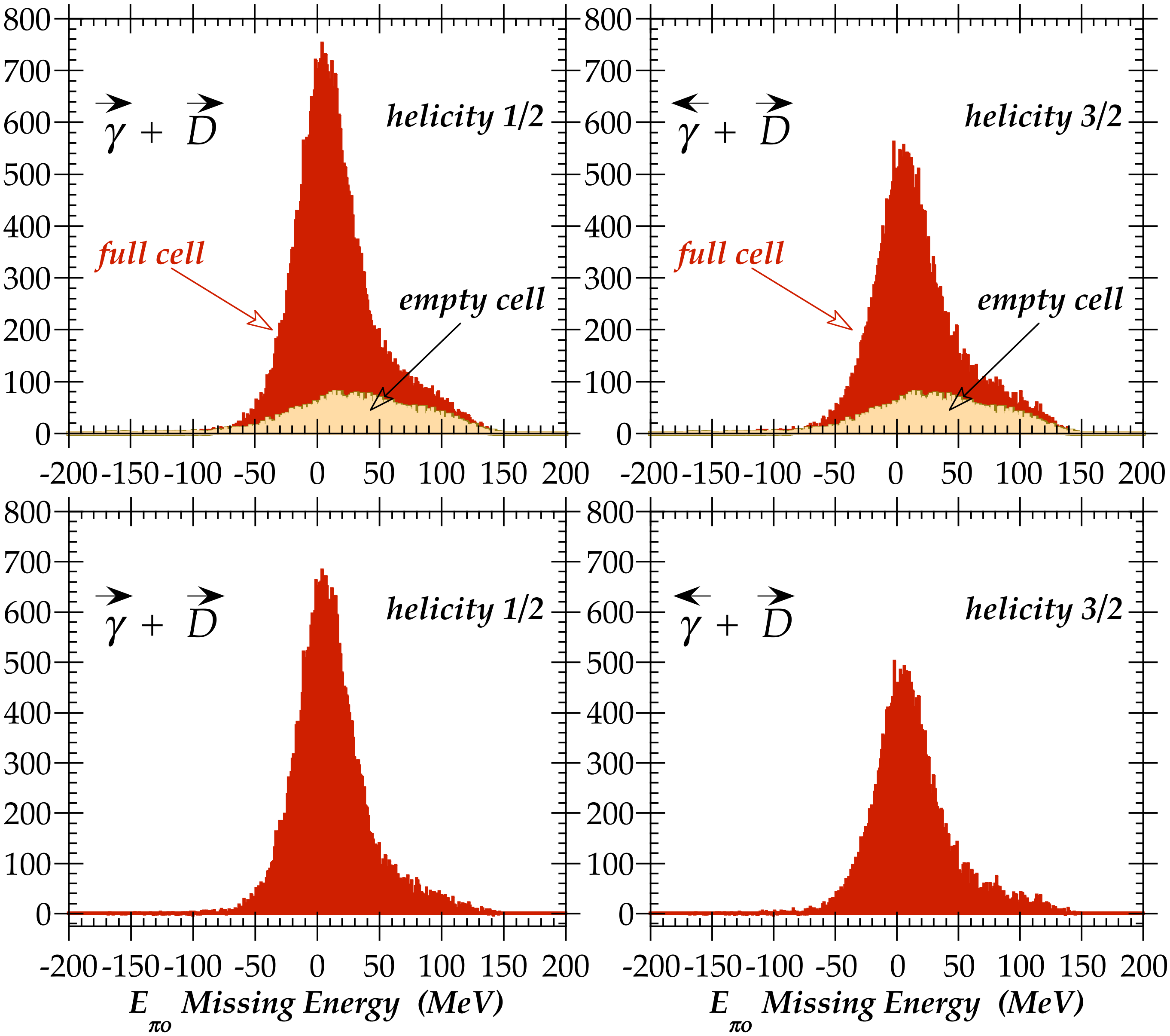


Fall'04: P(H) = 53%,
P(D) = 7%
HD(,)
E = 340 MeV,
c.m.
= 90o
4000
3500
3000
2500
2000
1500
1000
500
0
+ HD
helicity 3/2
empty cell
-200
-150
-100
-50
0
50
100
150
200
E Missing Energy (MeV)
+ HD
helicity 1/2
empty cell
E Missing Energy (MeV)

LEGS production run #2, deepUV-1 (Spring'05)

$D(\gamma,\pi^o n)$ $P_\gamma = 92\%$ $P_D = 31\%$

$E\gamma = 341$ MeV $\theta_{cm}(\pi^o n) = 105^o$



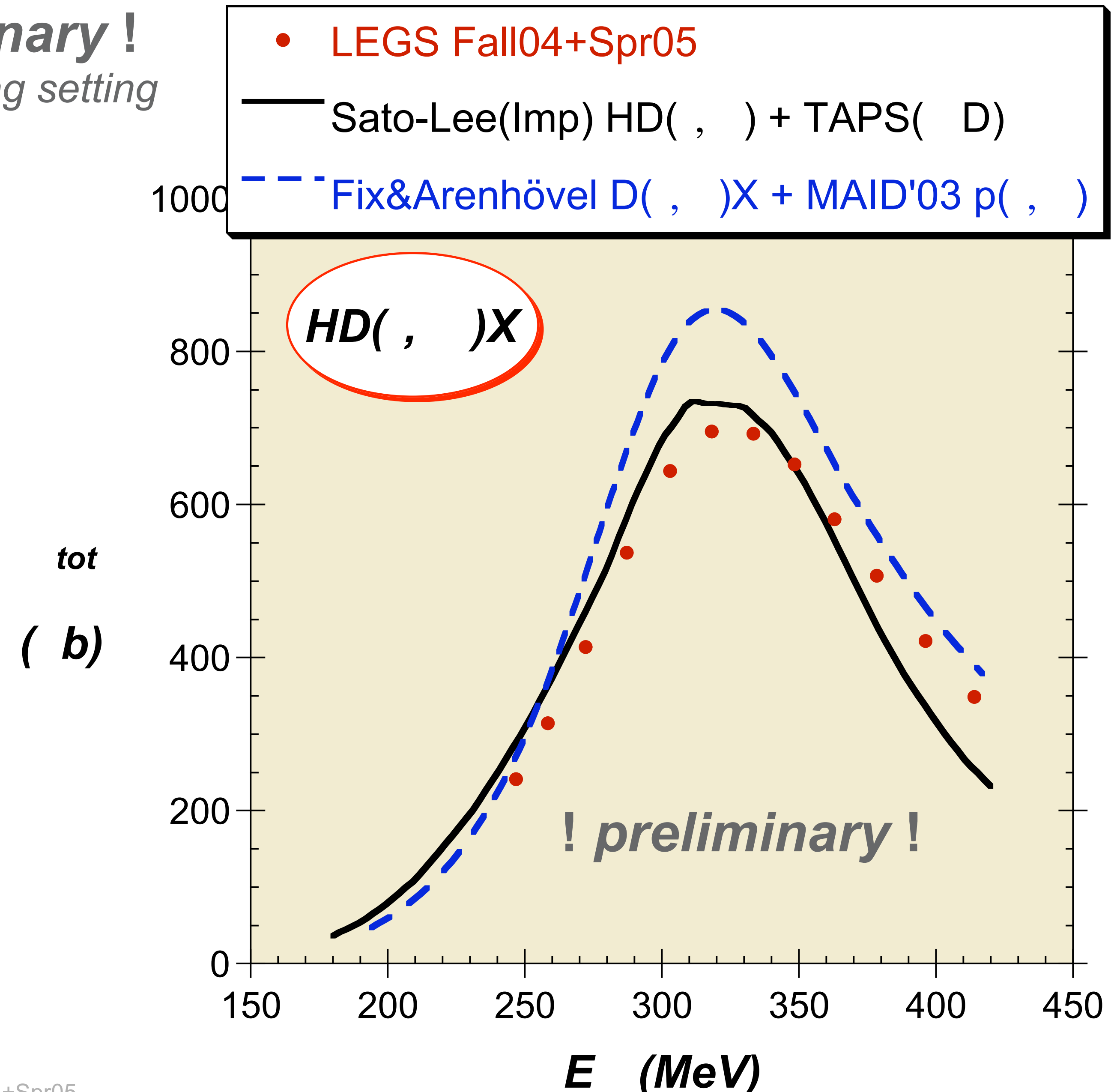
- target cell and Al wires contain the only unpolarizable nucleons;

- background is sampled in runs with an empty cell

D(g,pi0n)341MeV105 full&empty_FS

! *preliminary* !

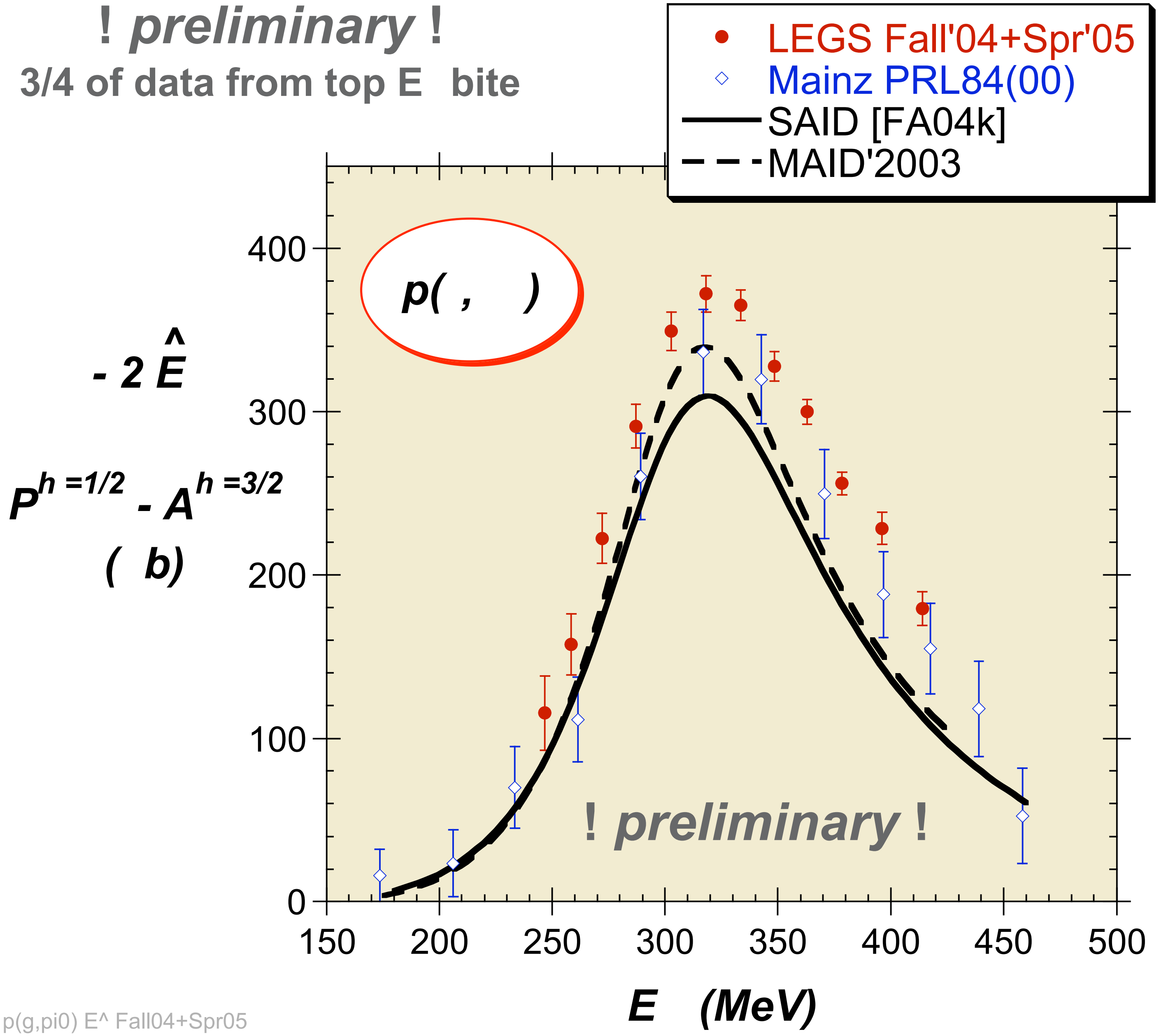
3/4 of High tag setting



XSC HD(g,pi0)X Fall04+Spr05

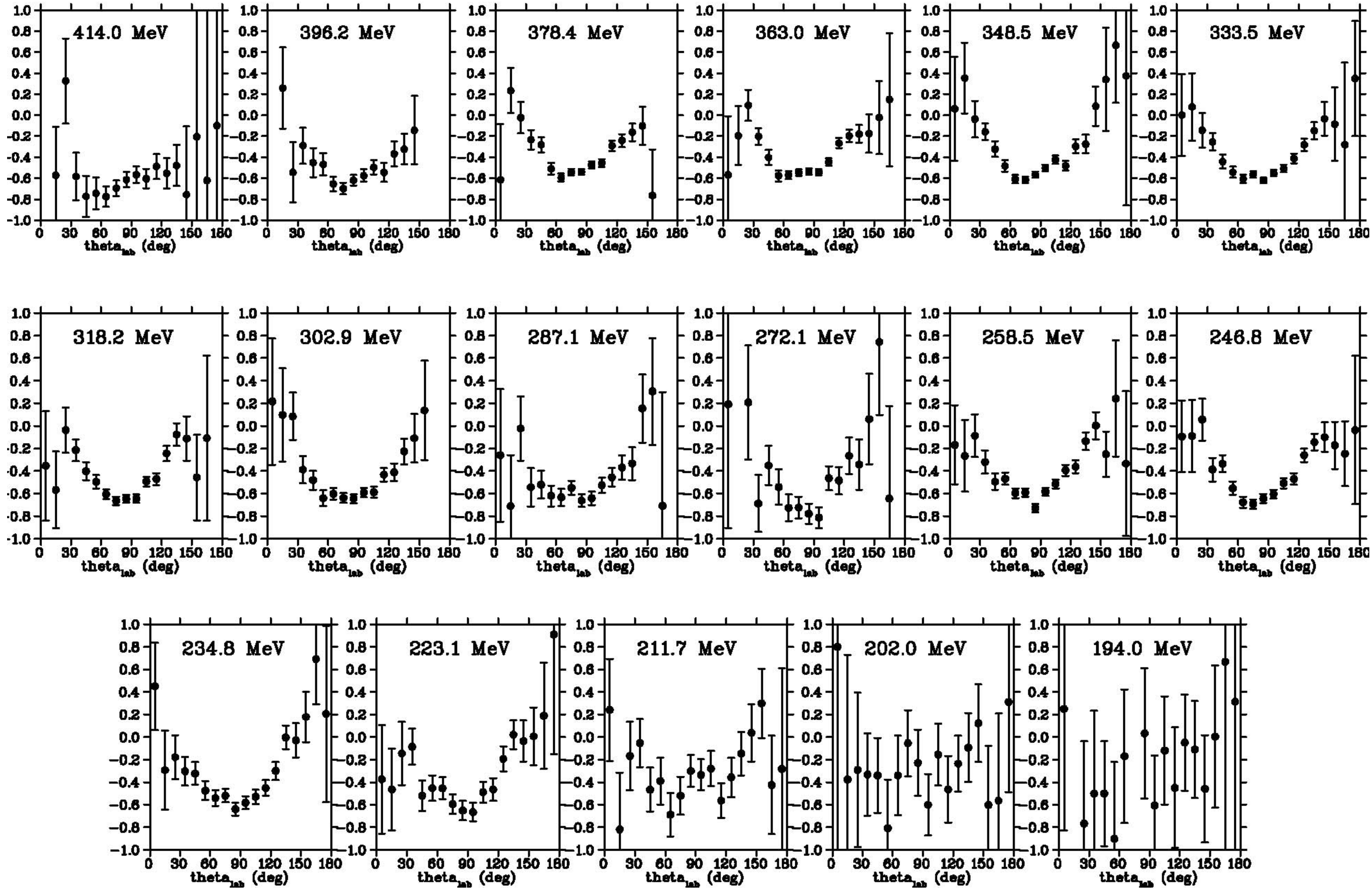
! *preliminary* !

3/4 of data from top E bite

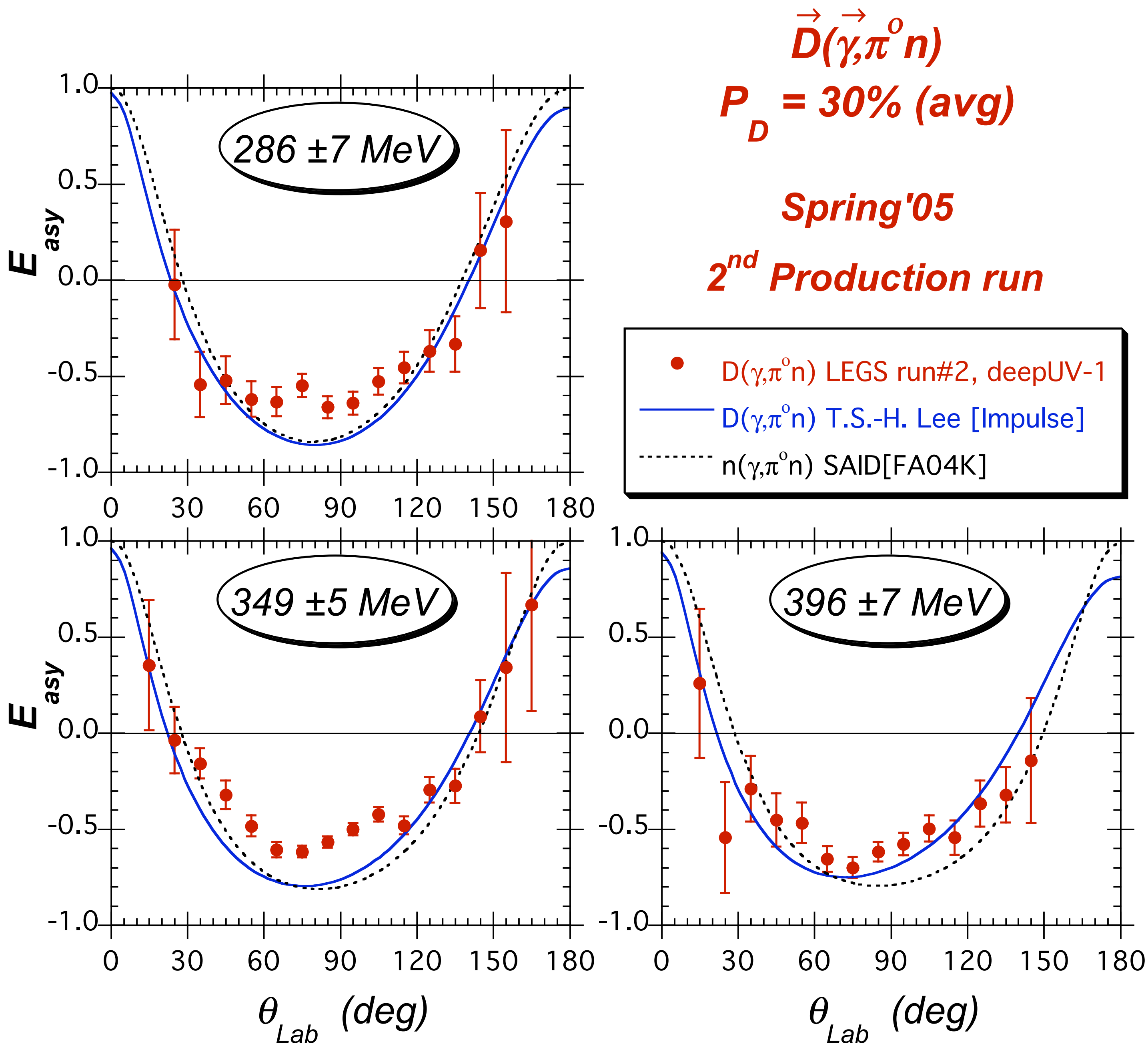


p(g,pi0) E^ Fall04+Spr05

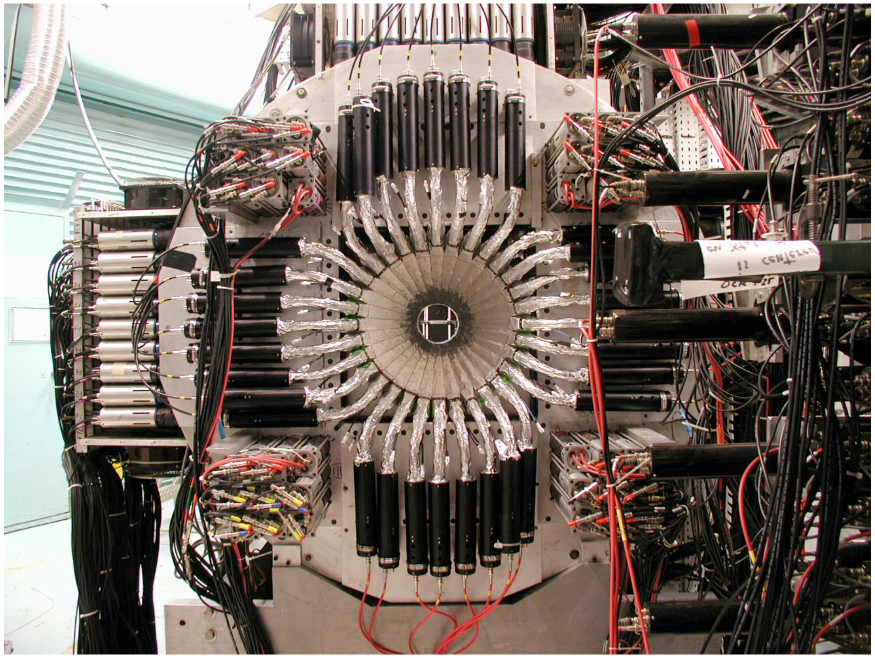
-Very preliminary - $\vec{D}(\vec{\gamma},\pi^{\circ}n)$ **E_{asy}**



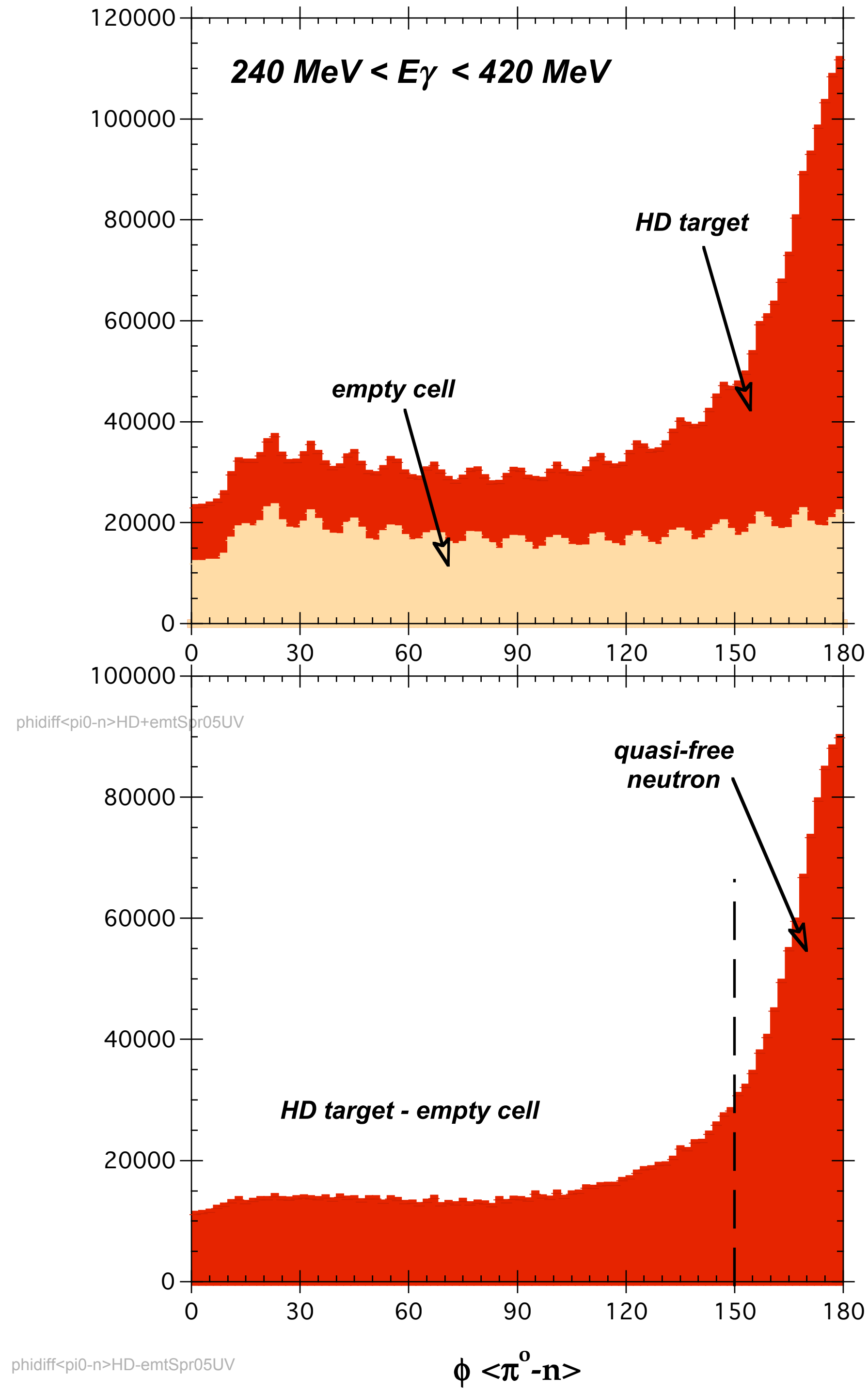
- very preliminary -



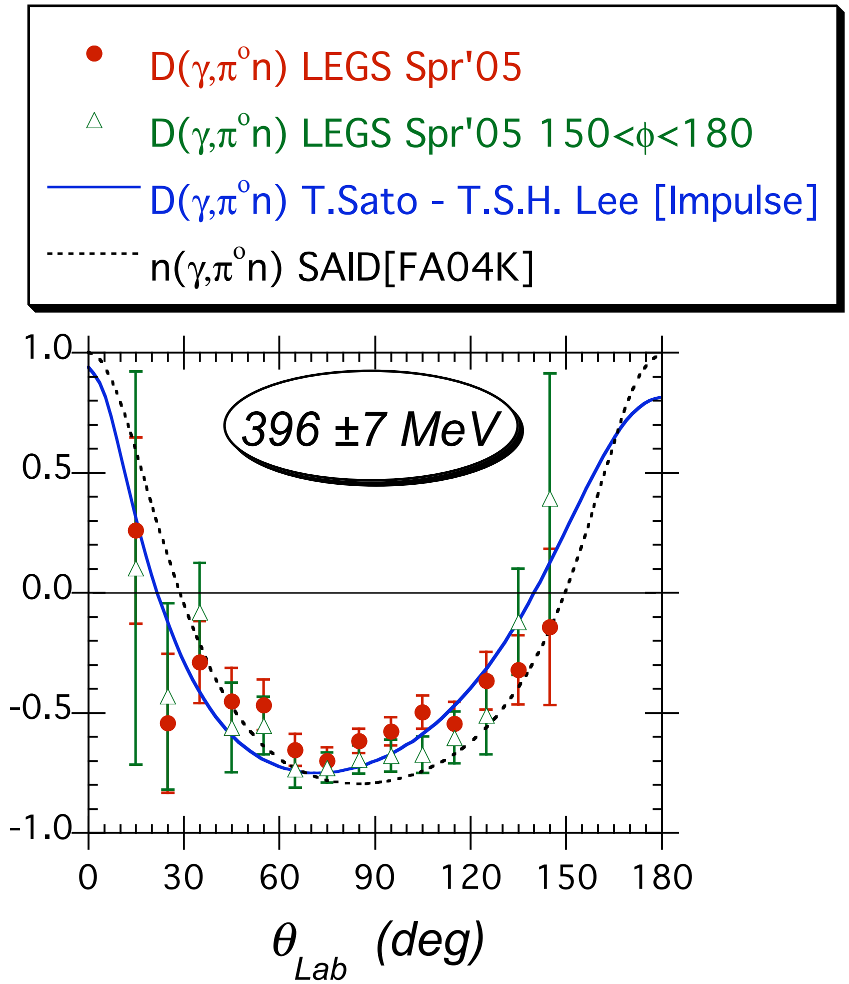
$D(\gamma,\pi^o n)p$

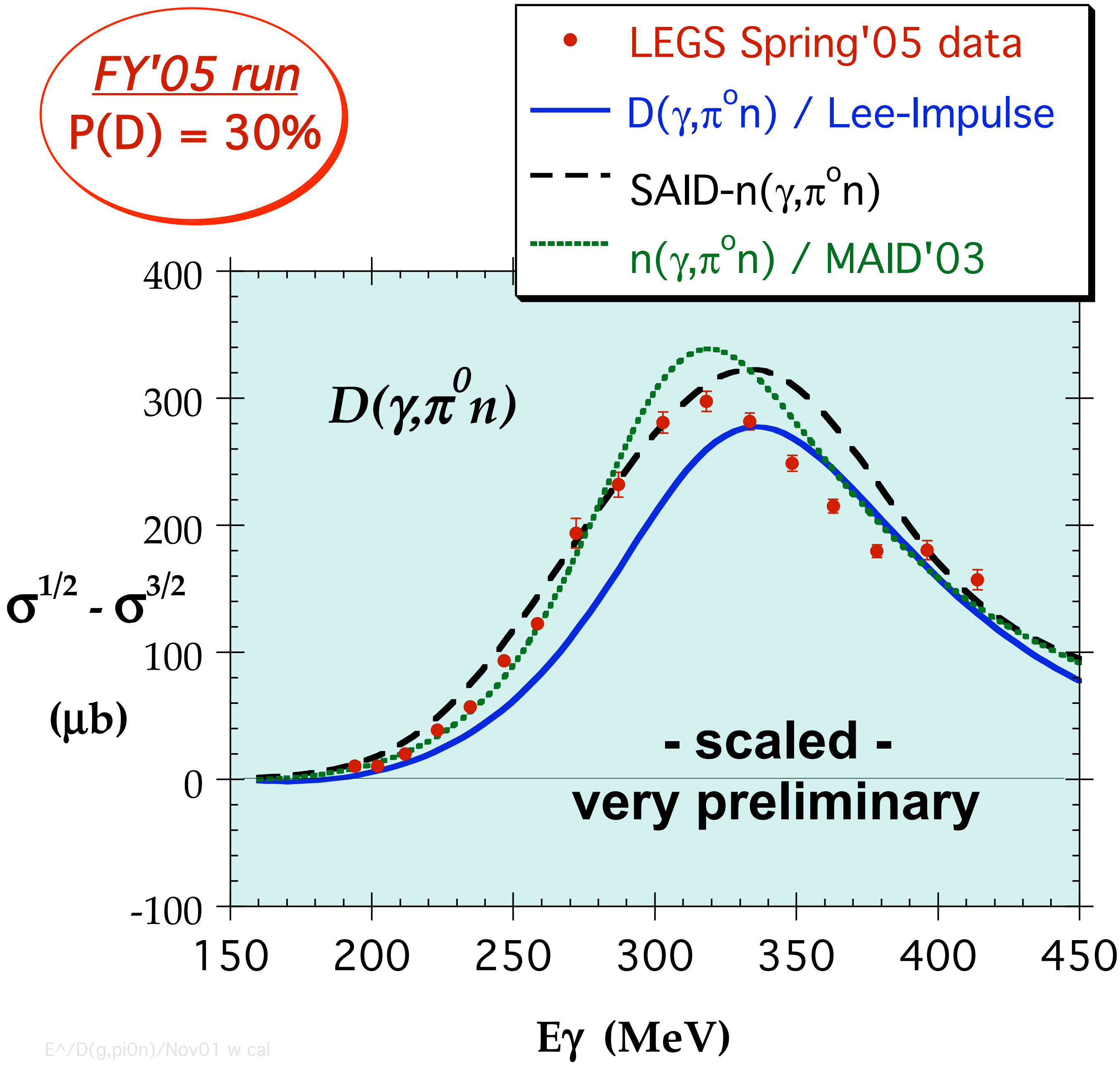


neutron-barrel
(U Roma-II)



$\vec{D}(\vec{\gamma},\pi^o n)$ P_D = 30% (avg)



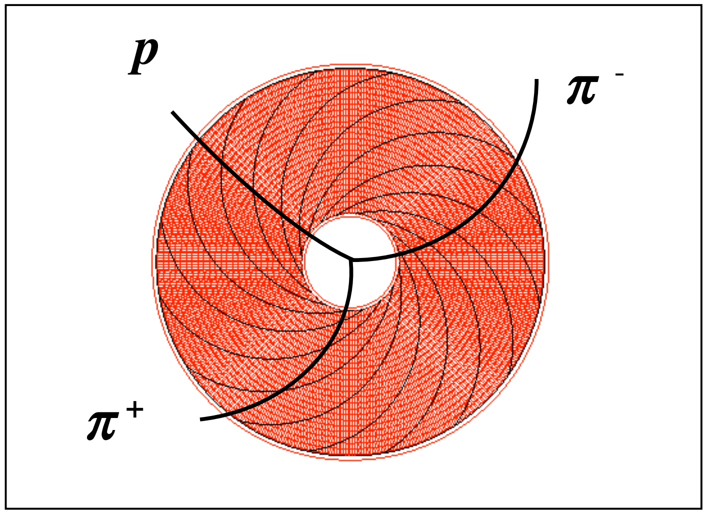


FY'05 run
P(D) = 30%
LEGS Spring'05 data
D(γ,π°n) / Lee-Impulse
SAID-n(γ,π°n)
n(γ,π°n) / MAID'03
D(γ,π⁰n)
σ1/2 - σ3/2
(μb)
400
300
200
100
0
-100
150
200
250
300
350
400
450
- scaled -
very preliminary
Eγ (MeV)
E^/D(g,pi0n)/Nov01 w cal

Central tracking with magnetic analysis in a Time-Projection Chamber

- isolate *neutron* reactions:

$$\gamma + n \rightarrow \pi^- p$$

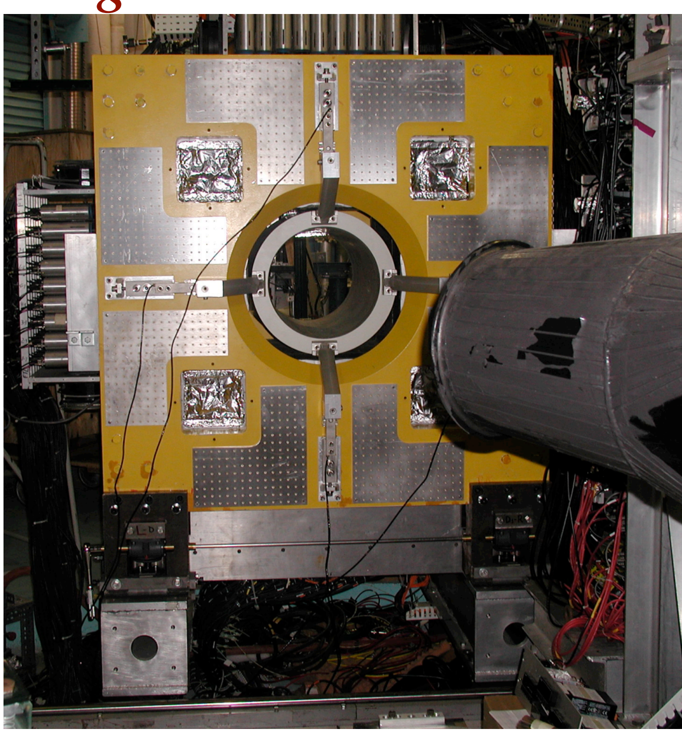


separate

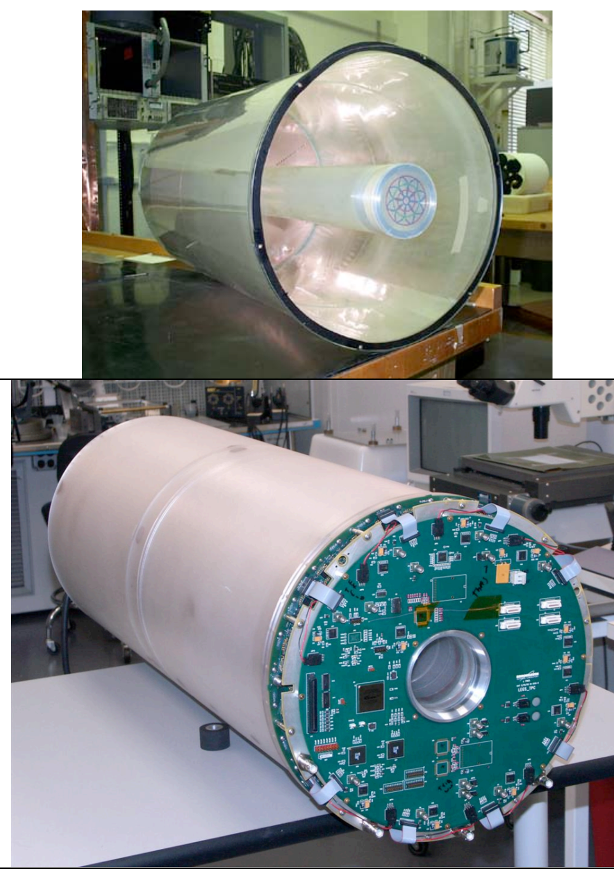
$D(\gamma, \pi^- p)$ from $D(\gamma, \pi^+ n)$

measure the $\pi^\pm$ *charge*

Large-bore 2 tesla solenoid



TPC



Experiment schedule - through 2006 :

- ✓ Fall'04: $\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^o)$ to extract $\vec{H}(\vec{\gamma},\pi^o)$ and $\vec{H}(\vec{\gamma},\pi^+)$
- ✓ FY'05: $\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^o)$ to extract $\vec{D}(\vec{\gamma},\pi^o)$
- Sept'05-Jan'06: install Time-Projection-Chamber
- Feb'06 -Apr'06: $H_2(\gamma,\pi^+)$, $D_2(\gamma,\pi^\pm)$ calibrations
- May'06 -June'06: $\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^\pm)$ - run 1
- Aug'06 -Sept'06: $\vec{H}\cdot\vec{D}(\vec{\gamma},\pi^\pm)$ - run 2

extract: $\vec{D}(\vec{\gamma},\pi^-)$, $\vec{D}(\vec{\gamma},\pi^+)$, $\vec{H}(\vec{\gamma},\pi^+)$

- Oct'06: expected end of LEGS experiments

Extras