Measurement of the parity violating asymmetry of Pion photoproduction near the Δ resonance

09-06-2009

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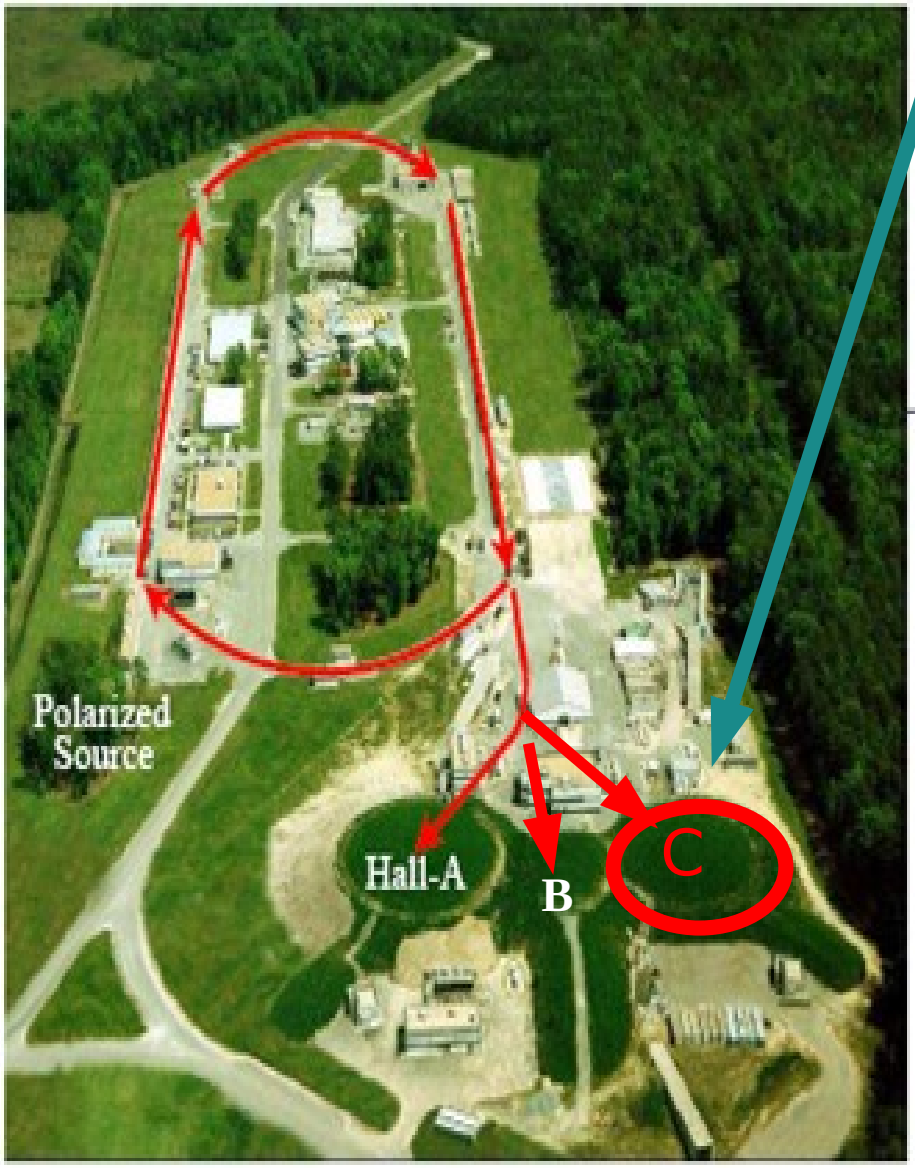
For the G0 Collaboration

CAP Congress 2009

The G0 Experiment

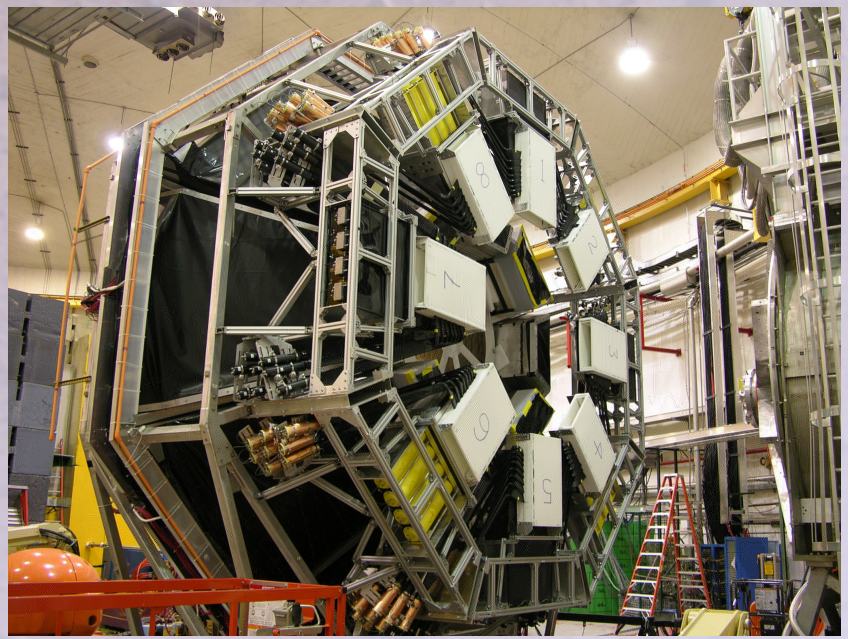
Jefferson Lab Accelerator (Virginia, US)



G0 Experiment :

- PV experiment of e-N scattering, momentum transfer from 0.1 to 1GeV^2

- Backward angle running occurred in 2006 - 2007



G0 Physics overview

- Parity violating electron scattering (Lh2 and Ld2)
  - Strange quark contributions to electromagnetic form factors
  - **Axial-vector N-Δ transition form factor**
  - **Weak interaction contribution to pion photoproduction**
  - Transverse beam spin asymmetries

PV inelastic electron scattering asymmetry

- Use PV inelastic e-N scattering to access the Axial FF
  - for $e+p \rightarrow e' + \Delta^+$

Δ : excited state of the nucleon

$$A_{inel} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\left[\Delta^{\pi}_{(1)} + \Delta^{\pi}_{(2)} + \Delta^{\pi}_{(3)}\right]$$

$$\Delta_{(3)} = 2(1-4\sin^2\theta_W)F(Q^2,s)(neutral\ current)$$
$$+\Delta^{a}_{(3)}(anapole)$$
$$+\Delta^{\pi}_{(3)}(Siegert)$$

"Siegert" term dominates at low Q^2, giving potentially large theory uncertainty to $G_A^{N\Delta}$ extraction.

M.J. Musolf, T.W. Donnelly, J. Dubach, S.J. Pollock, S. Kowalski, and E.J. Beise, Phys. Rep. **239**, 1 (1994)

Siegert term and Pion photoproduction, dΔ

- Asymmetry of the Siegert term

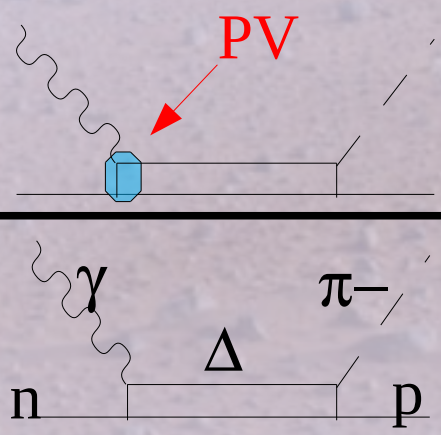
Not known

$$A_{LR}[\Delta^{\pi}_{(3)}(Siegert)] = -\frac{2d_{\Delta}}{C_3^V}\frac{\delta}{\Lambda_\chi}P(Q^2,s)$$

C_3^V : Dominant N->Δ vector transition FF

- **Pion photoproduction asymmetry on the Δ**

$A_\gamma^{\pm} \approx$



$$\approx \frac{-2d_{\Delta}^{\pm}}{C_3^V}\frac{M_N}{\Lambda_\chi} + \ldots \approx 10^{-8}$$

(Natural scale)

Small but.... $A_\gamma^{\pm} \approx 1.3\text{x}10^{-6}$ Zhu et *al*, PRL 87 (2001) 201802

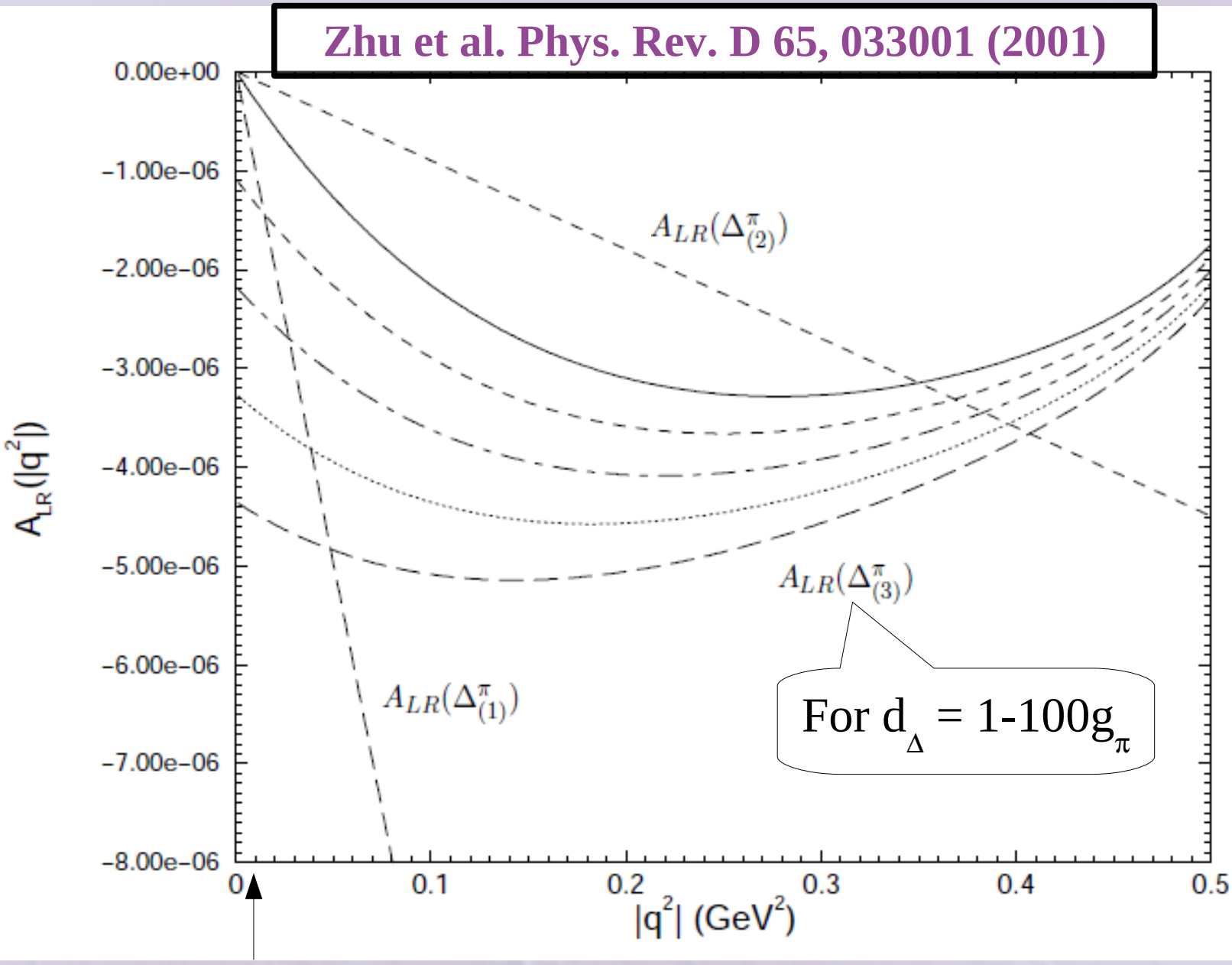
In fact : $0 < |A_\gamma^{\pm}| < 5\,ppm$ (G0 statistical sensitivity ~1 ppm)

Why an extraction of dΔ is interesting?

- To do a better job on the extraction of the Axial N-Δ form factor.

- Additional validation of the Resonance Saturation model
  - Successfully solves puzzle in Hyperon decays (Λ(uds) -> n γ)
  - Predicts values of the order of a few ppm's for dΔ

Prediction for dΔ

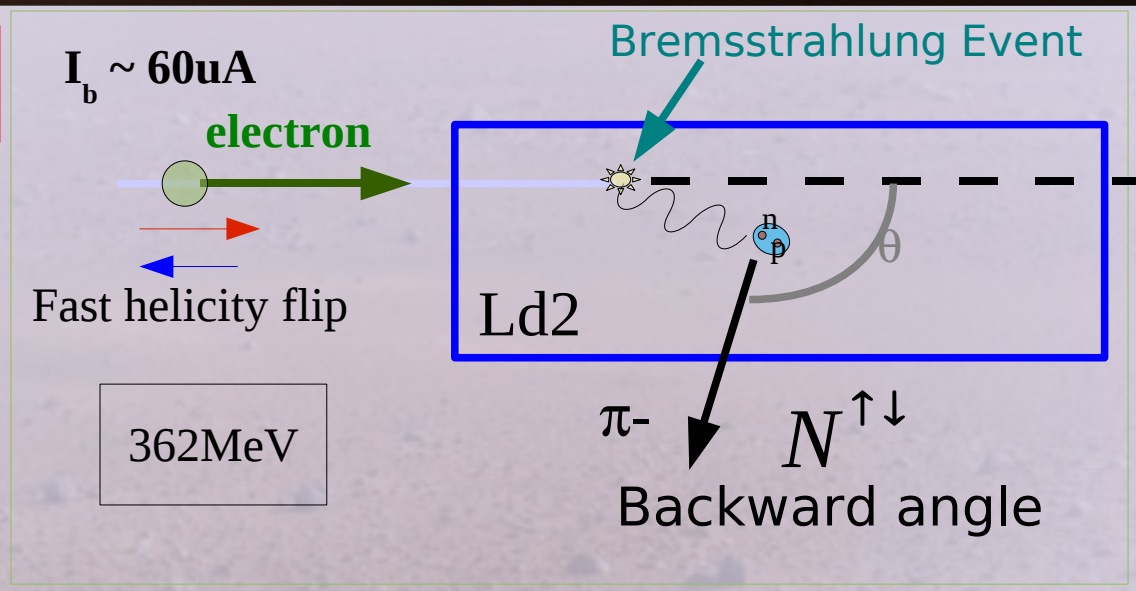


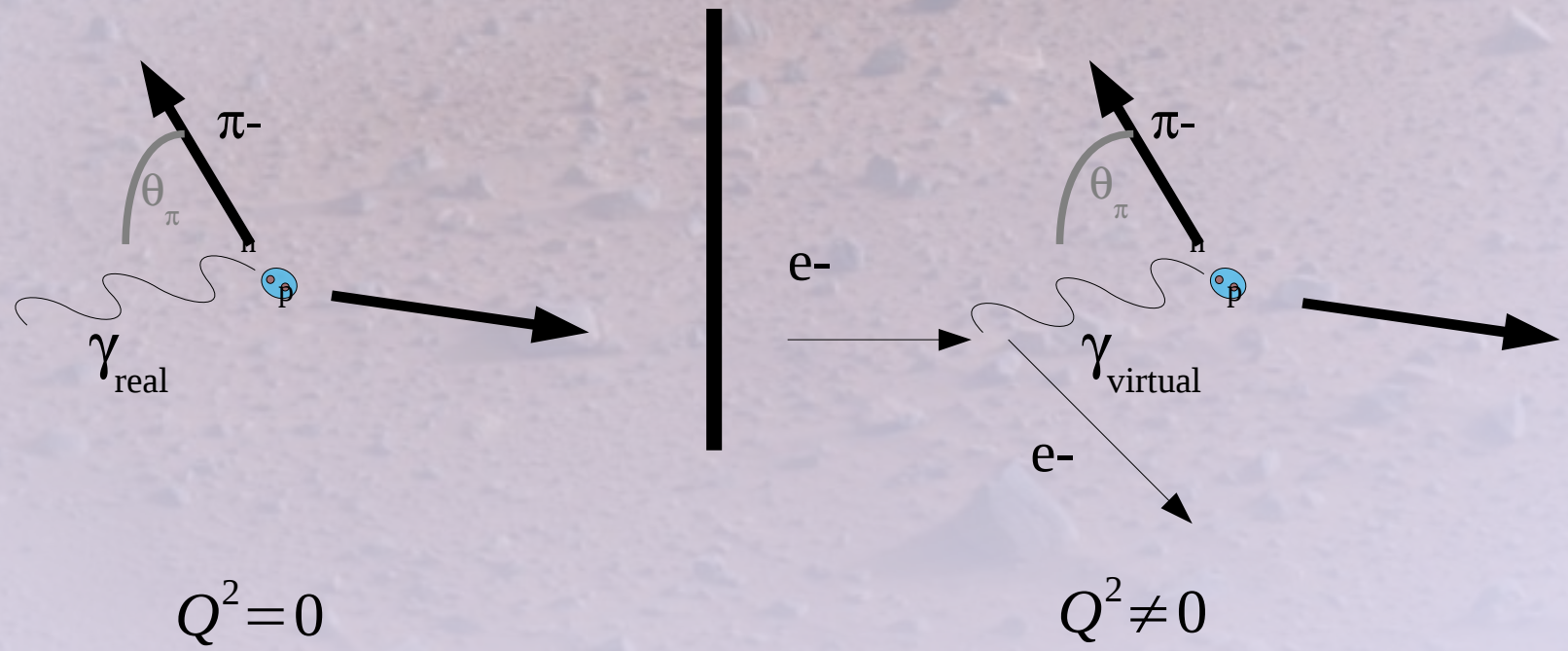
Pion photoproduction

$$\gamma + n \rightarrow \Delta^0 \rightarrow p + \pi^-$$

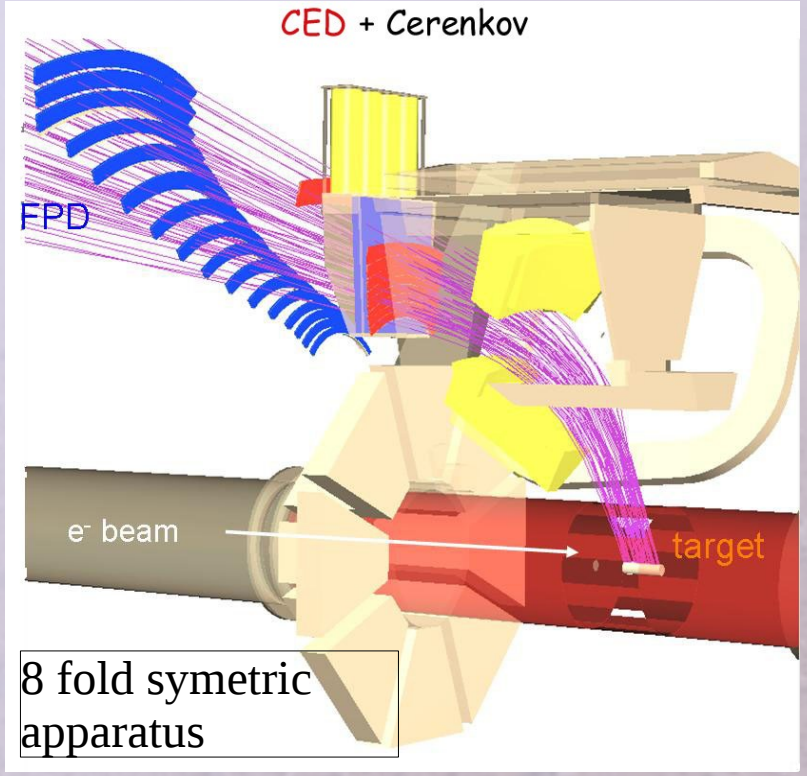
Asymmetry : A_γ

$$A_{exp} = \frac{N^{\uparrow}_{exp} - N^{\downarrow}_{exp}}{N^{\uparrow}_{exp} + N^{\downarrow}_{exp}}$$

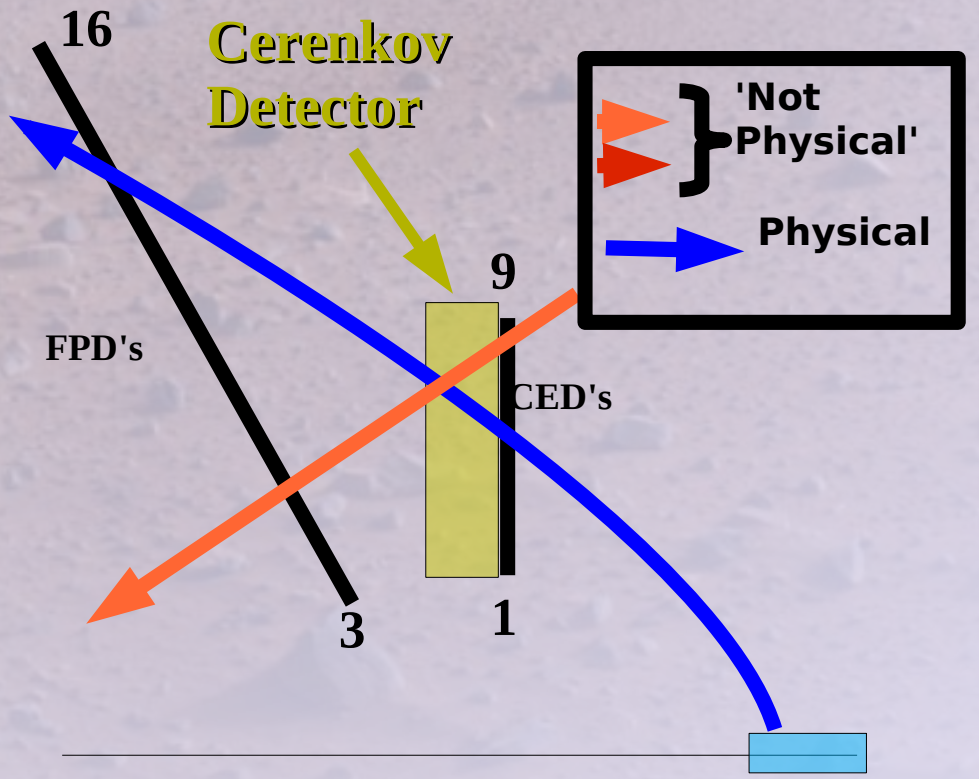




Backward angle scattering configuration



- Coincidences between CED's and FPD's
  -> Elastic/Inelastic separation for the electrons
- Additional coincidence with Cerenkov detectors
  -> Particle ID determination
    -> Electrons produce a coinc
    -> Pions do not produce a coinc



Notice that a correlation between CED and FPD element number gives a crude kinematic selection for events.

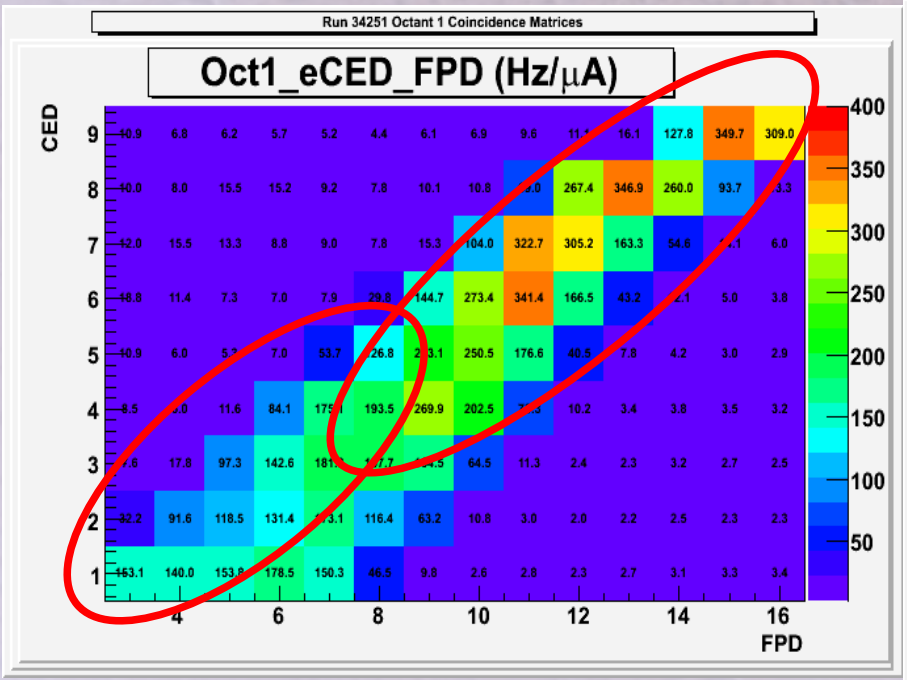
CED – FPD Coincidence matrix

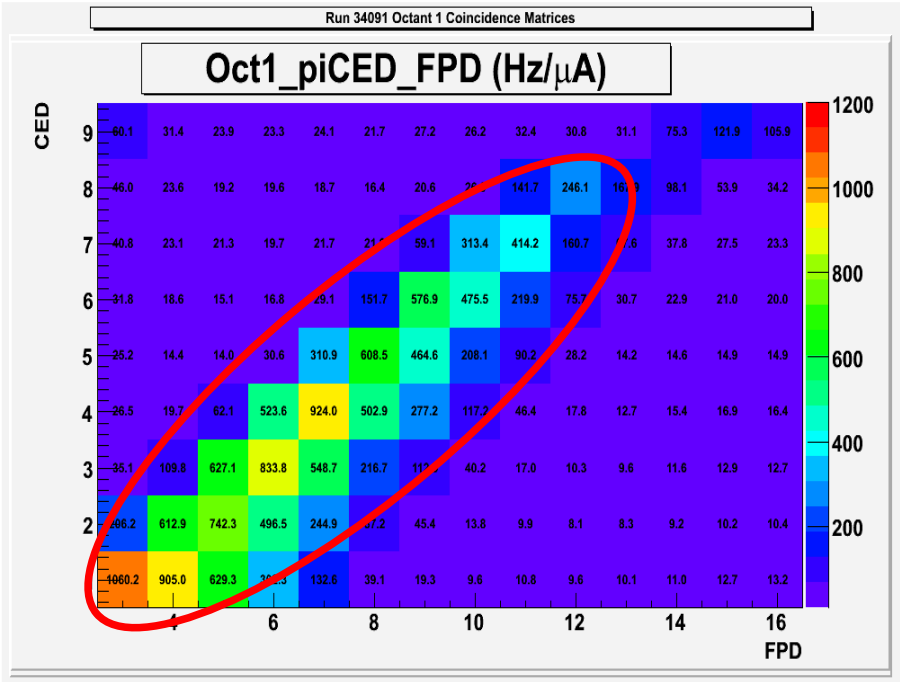
G0 LD2 Data at 362 MeV

Coincidence Signals

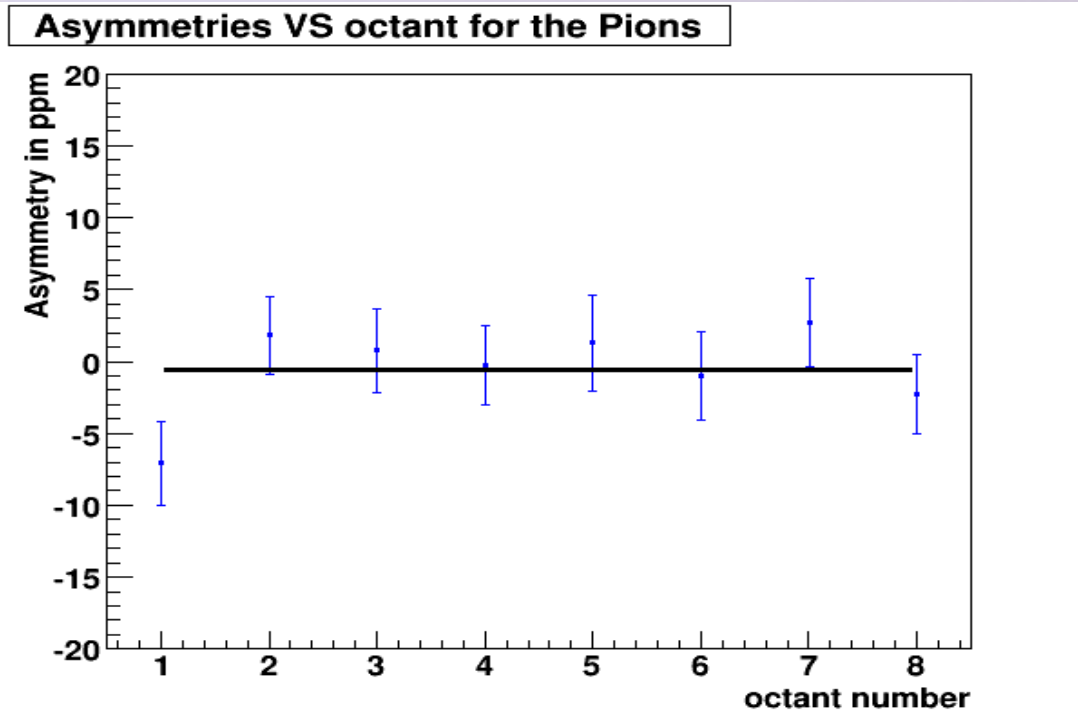
Cerenkov → Electron matrix

$\overline{\text{Cerenkov}}$ → Pion matrix





Preliminary results



Preliminary unblinded results :

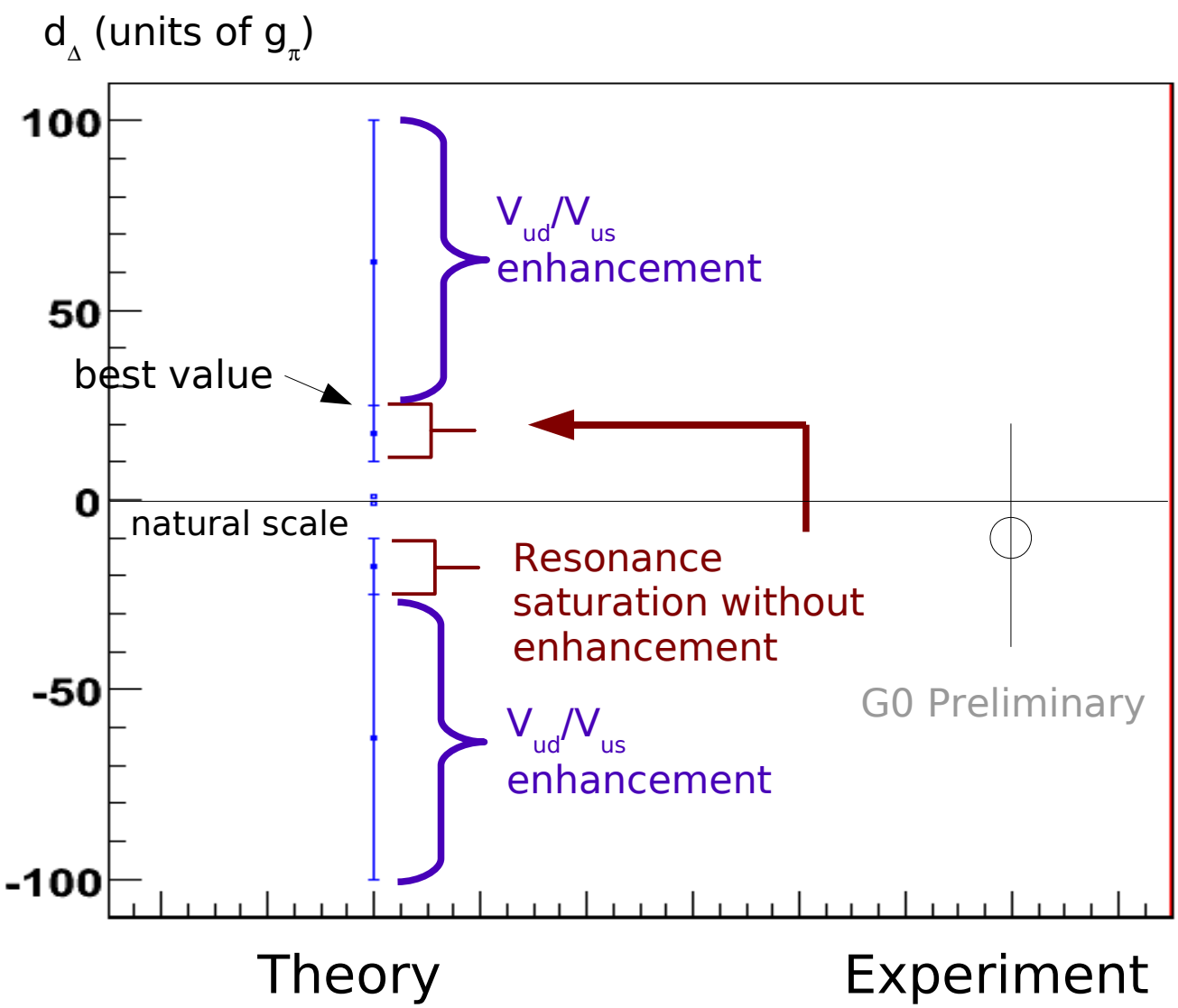
A_{π} (Out-In) = -0.56 +- 1.03 ppm

In+Out = 3.84 +- 2.15 ppm

Systematic errors related to the experiment :

Beam correlated Effects :	< 0.05 ppm
Deadtime/random Corrections :	~0.4 ppm
Background Corrections :	~0.1 ppm
Transverse correction :	~0.12 ppm
Beam polarization :	~0.15 ppm
non-zero Q2,photon depolarization	In progress

Conclusion


d_Δ (units of g_π)
100
50
0
-50
-100
best value
natural scale
V_{ud}/V_{us} enhancement
Resonance saturation without enhancement
V_{ud}/V_{us} enhancement
G0 Preliminary
Theory
Experiment

G0 Collaboration

The G0 Collaboration :

G0 Spokesperson: Doug Beck (UIUC)
N-D Spokesperson: Steve Wells (LaTech), Neven Simicevic (LaTech)

California Institute of Technology, Carnegie-Mellon University, College of William and Mary,
Grinnell College, IPN Orsay, JLab, LPSC Grenoble, Louisiana Tech. Univ, New Mexico State
University, Ohio University, TRIUMF, University of Illinois, University of Kentucky, University of Manitoba, University of Maryland, University of Winnipeg, Virginia Tech, Yerevan Physics
Institute, University of Zagreb, University of Northern British Columbia

Analysis Coordinator: Fatiha Benmokhtar (CM)

Thesis Students:
Carissa Capuano (W&M), Alexandre Coppens (Manitoba), Colleen Ellis (Maryland) , Juliette Mammei (VaTech), Mathew Muether (UIUC), John Schaub (NMSU), Maud Versteegen (LPSC),
Stephanie Bailey (Ph.D. W&M, Jan ’07)

Backups Slides

Experimental "Physics" Asymmetries

all entries in ppm

Data Set	Asymmetry	Stat	Sys pt	Global
H 362	-11.42	0.84	0.26	0.37
D 362	-17.02	0.79	0.39	0.19
H 687	-46.14	2.36	0.80	0.72
D 687	-55.87	3.22	1.91	0.62

PRELIMINARY – NOT FOR QUOTATION

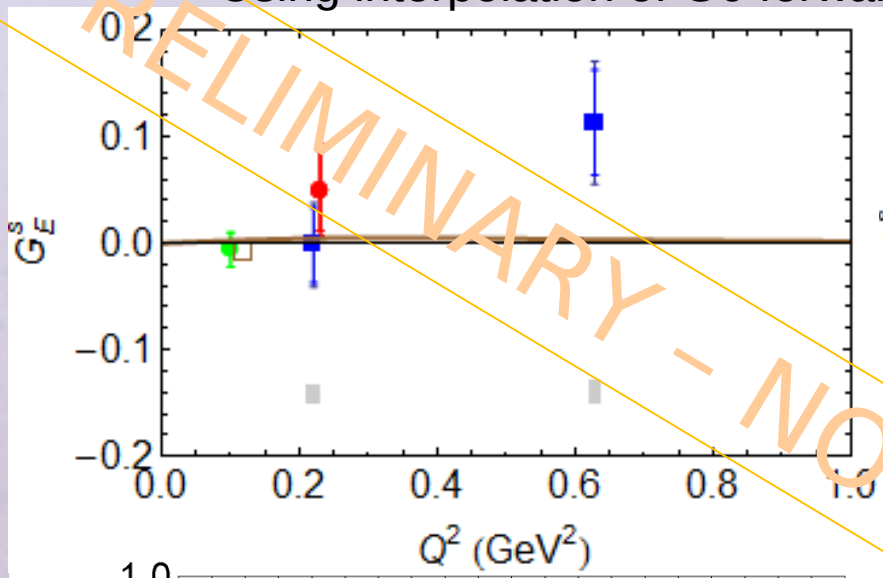
Largest correction is due to the 85% beam polarization

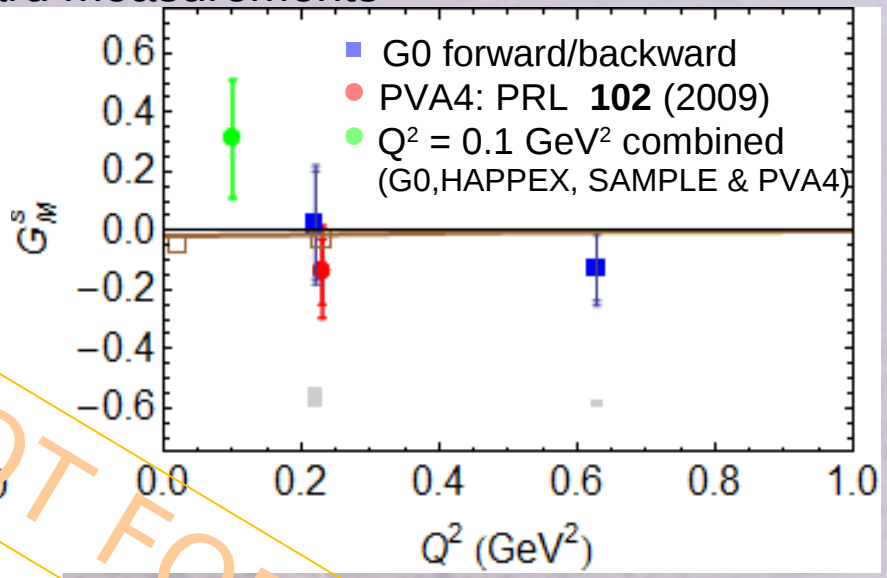
H: systematic uncertainties dominated by beam pol'n

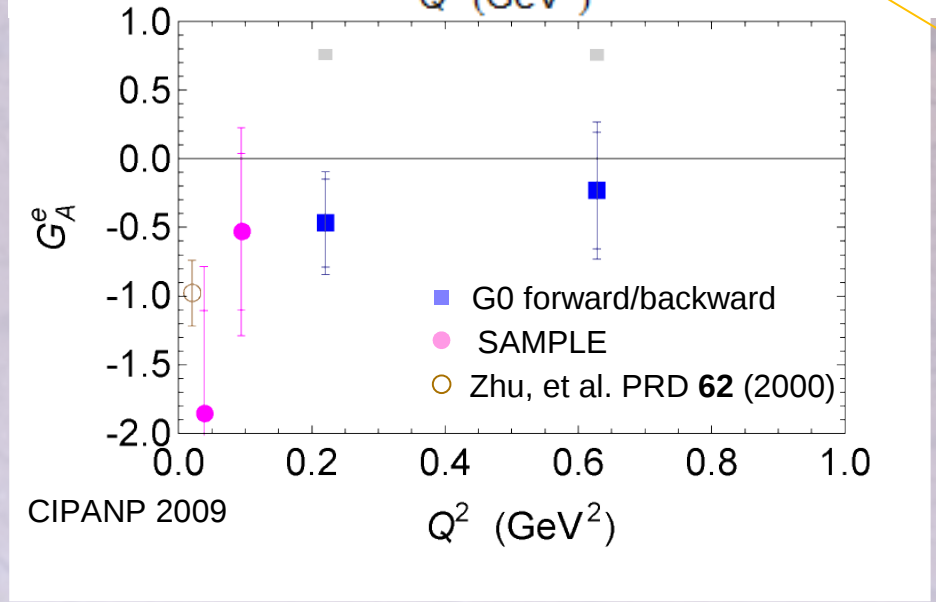
D-687: rate corrections and beam pol'n contribute about equally to the systematic uncertainty

Preliminary results for the form factors

- Using interpolation of G0 forward measurements







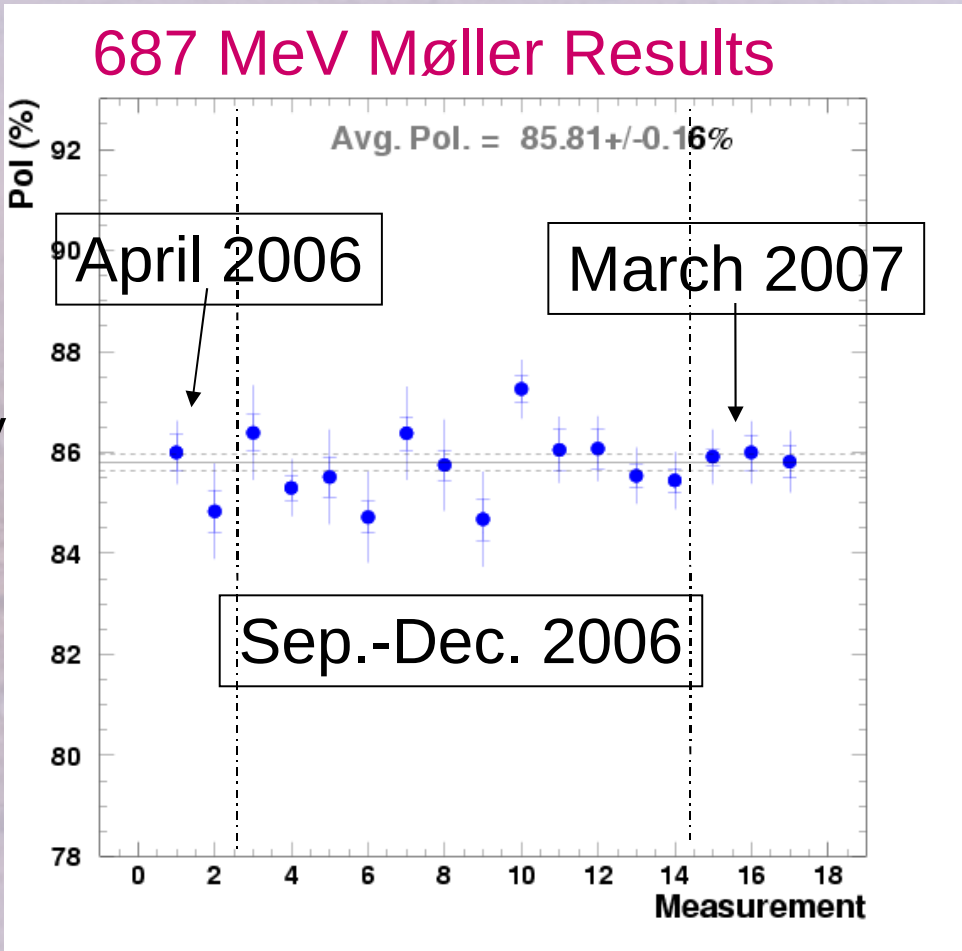
Global uncertainties

Some calculations:
Leinweber, et al. PRL 97 (2006) 022001
Leinweber, et al. PRL 94 (2005) 212001
Wang, et al arXiv:0807.0944 (Q^2 = 0.23 GeV^2)
Doi, et al, arXiv:0903.3232

PRELIMINARY - NOT FOR QUOTATION

Beam polarization

- Measurements of Møller asymmetry at 687 MeV
  - Low energy tune of Møller spectrometer
- Use Mott scattering for 362 MeV measurements
  - Mott asymmetry measured at 5 MeV in injector
  - New work on effect of background improves agreement with Møller



Bottom Lines: P_e(687 MeV) = 85.78 ± 0.07 ± 1.38%

P_e(362 MeV) = ± 2.05%