Strange Quark Contribution to Nucleon Electroweak Form Factors in G^0 Experiment

EINN 2007
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Outline

G^0 Collaboration : Spokesperson: Doug Beck (UIUC)

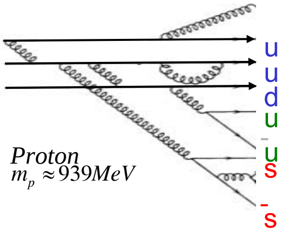
Caltech, Carnegie-Mellon, William&Mary, Hampton, IPN-Orsay, LPSC-Grenoble, JLab, Kentucky, LaTech, NMSU, TRIUMF, U Con, UIUC, U Manitoba, U Maryland, U Mass, UNBC, VPI, Yerevan

1. Physics Motivation
2. G^0 Forward Angle
3. G^0 Backward Angle
    1. Setup
    2. Data Analysis

Conclusion

Strange Quark

- QCD : nucleon = valence quarks + sea quarks + gluons



➡ Valence quarks : $m_u \sim m_d < 4\text{-}8\ MeV/c^2$

➡ *u* and *d* quarks from the sea

➡ *s* quarks : lightest quarks only in the sea

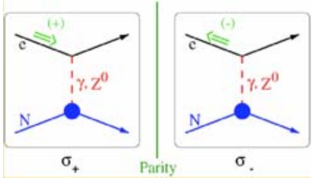
- Strange *s* quark contribute to global properties of the nucleon :
  - Momentum : ~4% (Deep Inelastic Scattering)
  - Mass : ~ 0 to 30% (π-N)
  - Spin : ~ 0 to -10% (Polarized DIS)

- How does *s* quark contribute to electromagnetic properties of the nucleon?

Parity Violating Asymmetries Measurement

- Accessing weak interaction cross section :

$$\sigma_{el} \propto \left| M_\gamma + M_Z \right|^2 \quad \text{but} \quad \frac{M_\gamma}{M_Z} \approx 10^5$$



- **Parity violating asymmetries** only see interference terms and involve EM and weak form factors :

$$A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \propto \frac{2M_\gamma M_Z}{\left|M_\gamma\right|^2} \propto \frac{A_E + A_M + A_A}{2\sigma_{unpol}} \qquad \begin{cases} A_E = \varepsilon . G_E^Z . G_E^\gamma \\ A_M = \tau . G_M^Z . G_M^\gamma \\ A_A = -(1 - 4\sin^2\theta_W)\varepsilon' . G_A^e . G_M^\gamma \end{cases}$$

- Combining
  - two kinematics : e^- scattering angles
  - two targets : LH2,LD2

  gives three linear combinations of EM and weak form factors

$$\begin{cases} A_{PV}^{proton} (\theta \approx 5°, 10°) \\ A_{PV}^{proton} (\theta \approx 110°) \\ A_{PV}^{neutron} (\theta \approx 110°) \end{cases} \rightarrow \begin{cases} G_E^s(Q^2) \\ G_M^s(Q^2) \\ G_A^e(Q^2) \end{cases}$$

Jefferson Lab Facility

CEBAF facility, Jefferson Lab., Virginia

- CEBAF accelerator :
  - two LINACs, 0.6 GeV
  - Up to 6 GeV
- Beam polarization up to ~85%
- Helicity flips :
  - 30Hz (main power effects)
  - Pseudo-random **Quartet** structure (+--+), (-++-)
  - Mechanical Helicity flip every 24h (IHWP)
- Special features for G^0:
  - Special beam time structure (32ns)
  - Very low energy (362 MeV)

G^0 Forward Angle

Nov 2003 - May 2004

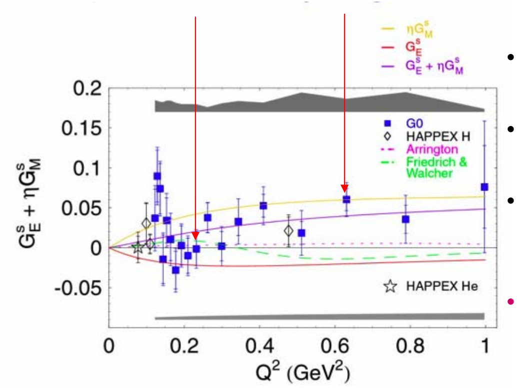
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Hydrogen target
- Electron □beam energy of 3 GeV
- Detection of recoiling proton between 50º and 80º.
- Large Q^2 range :

  0.12 to 1.0 $(GeV/c)^2$
- 8 octants of 16 scintillators (FPDs), each with a fixed Q^2
- Background separation by time of flight measurement (special beam structure of 32 ns).

G^0 Forward Angle

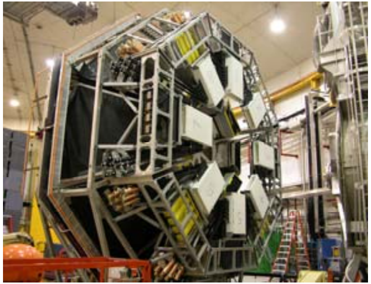
Nov 2003 - May 2004



- 700 hrs of data taking : 101 C.
- 18 Q^2 measurements
- Good agreement with other experiments (HAPPEx and PVA4)
- Data disagrees with the no-strange hypothesis at the 89% confidence level

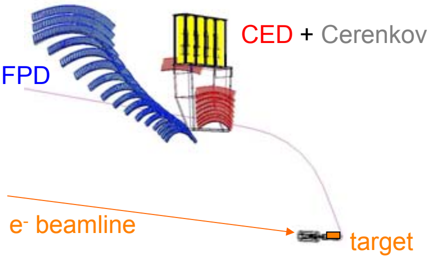
$G^s{}_E + \eta G^s{}_M$.
Grey bands indicate systematics.

G^0 Backward Angle



- Hydrogen and deuterium targets
- Electron beam energy of :
  - 362 MeV : Q^2=0.23 $(GeV/c)^2$
  - 687 MeV : Q^2=0.62 $(GeV/c)^2$
- Detection of scattered electrons between 100º and 130º.

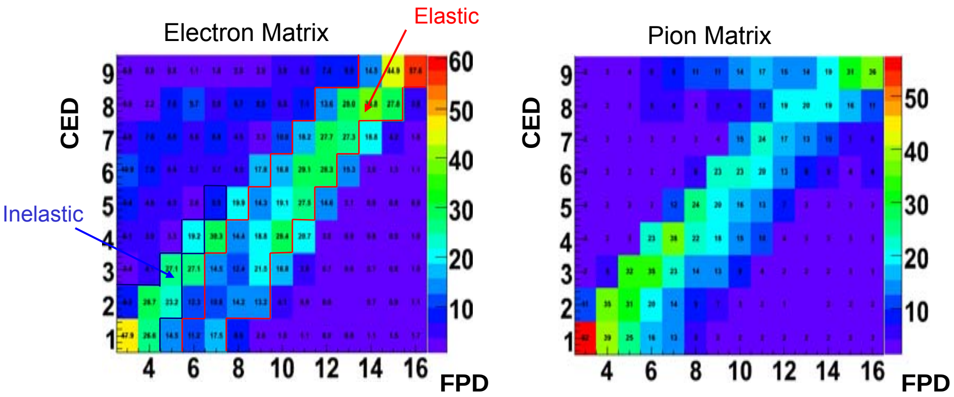
Backward Angle Configuration



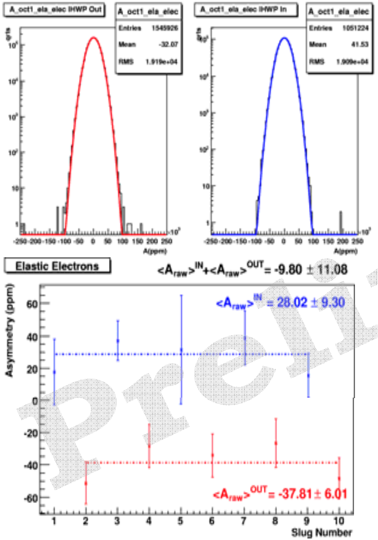
- Particle detection and identification :
  - 16 Focal Plan Detectors
  - 9 Cryostat Exit Detectors
  - ➡ elastic and inelastic electron separation
  - Additional Čerenkov detectors
  - ➡ electron and pion separation

G^0 Backward Angle

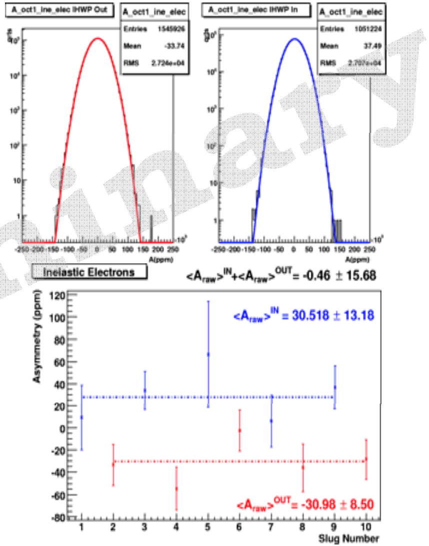
"electron" and "pion" CED-FPD correlation matrices (LD2)



G^0 Backward Angle : Data Quality



IN
OUT



Elastic electrons ***Inelastic electrons***

G^0 Backward Angle Data Analysis

Blinding Factor

LH2, LD2 Raw Asymmetries, A_{meas}

Instrumental & Beam corrections:

Electronics Dead time/Randoms

Helicity correlated beam properties

Beam polarization

Background corrections:

Dilution Factors

Background from target

Pion Contamination

Unblinding

LD2 A_{phys}

LH2 A_{phys}

Previous experiments

$G_E^s + \eta G_M^s$

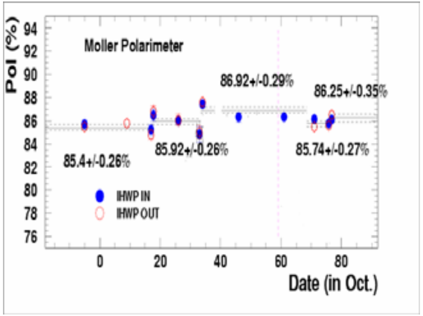
Q^2

$G_e^s \; G_m^s \; G_A^e$

Capuano, Coppens, Ellis, Mammei, Muether, Schaub, Versteegen

G^0 Backward Angle : Beam Specifications

Beam Parameter	Achieved (IN-OUT)/2	"Specs"
Charge asymmetry	0.09 +/- 0.08	2 ppm
x position difference	-19 +/- 3	40 nm
y position difference	-17 +/- 2	40 nm
x angle difference	-0.8 +/- 0.2	4 nrad
y angle difference	0.0 +/- 0.1	4 nrad
Energy difference	2.5 +/- 0.5	34 eV
Beam halo (out 6 mm)	< 0.3 x 10^{-6}	10^{-6}



Measured Polarity

- Beam parameters specifications were set to assure:

$$A_{P_i}^{false} \leq 5\% \, \Delta A_{stat}^{meas}$$

- Helicity correlated beam properties

  ⇨ false asymmetry

Correction : linear regression

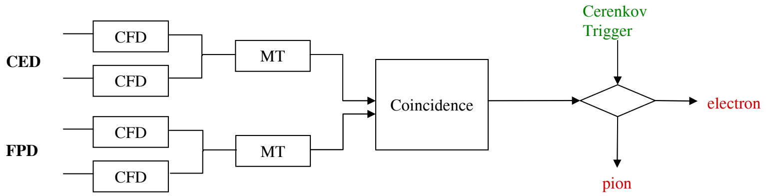
$$A_{cor} = A_{meas} - \sum_i \frac{1}{2Y} \frac{\partial Y}{\partial P_i} \Delta P_i$$

85% polarization has been reached routinely using superlattice GaAs cathodes.

Suleiman, Bailey, Schaub, Pitt, Gaskell, Horn, Mammei

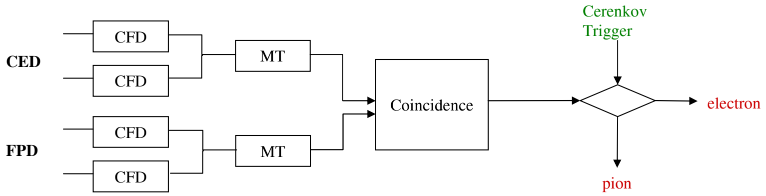
G^0 Backward Angle Data Analysis

Dead Time and Contamination Corrections :

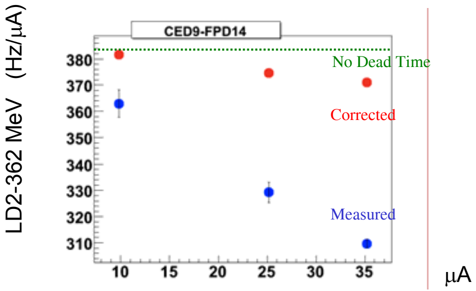


G^0 Backward Angle Data Analysis

Dead Time and Contamination Corrections :



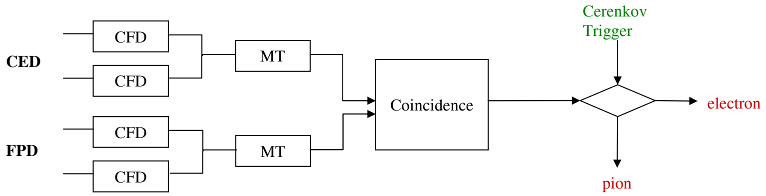
Electron Measured-Corrected Yield



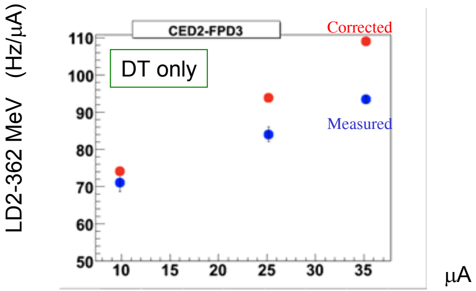
- Modeling the electronics allowed for the correction of the following bias :
  - CED-FPD coincidence electronics **dead time**

G^0 Backward Angle Data Analysis

Dead Time and Contamination Corrections :



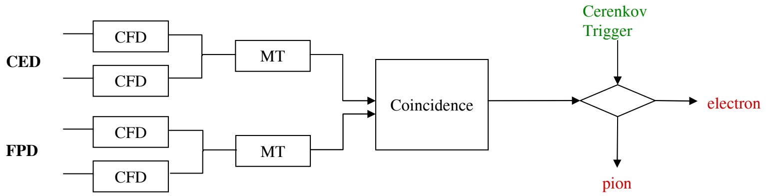
Electron Measured-Corrected Yield



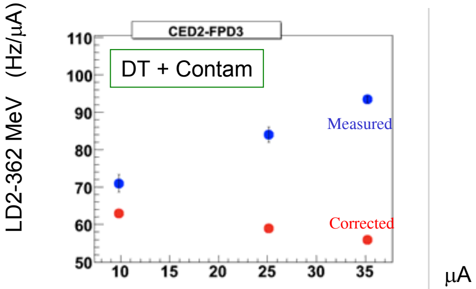
- Modeling the electronics allowed for the correction of the following bias :
  - CED-FPD coincidence electronics **dead time**
  - Electron, resp. pion, **contamination** due to Čerenkov electronics dead time and randoms

G^0 Backward Angle Data Analysis

Dead Time and Contamination Corrections :



Electron Measured-Corrected Yield



- Modeling the electronics allowed for the correction of the following bias :
  - CED-FPD coincidence electronics **dead time**
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Conclusion

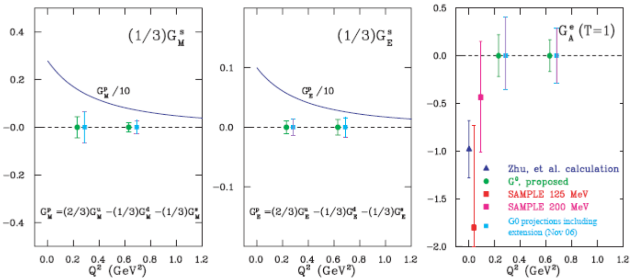
- G^0 Backward Angle data taking completed : (84% polarization)

Q^2 $(GeV/c)^2$	0.23	0.62
Hydrogen	90C	100C
Deuterium	65C	45C

vs 170 C proposed at 75% polarization

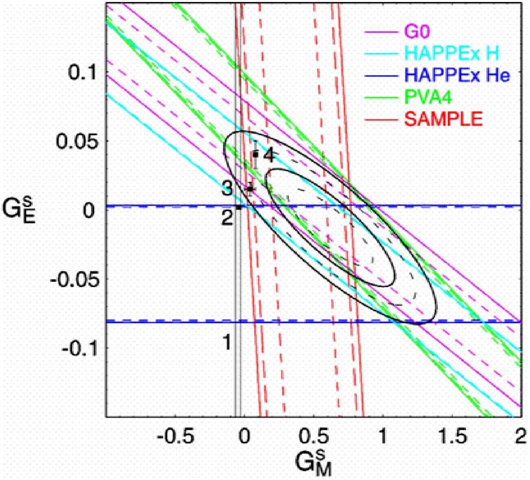
- Ongoing analysis for thorough study of systematics
- Combined Forward and Backward results will provide a clean separation of G_E^s, G_M^s, and G_A^e at Q^2 of 0.23 and 0.6 $(GeV/c)^2$

Expected G^0 Experiment Uncertainties



Thank you for your attention

World Data at $Q^2 = 0.1$ GeV^2 (pre-HAPPEX '05)

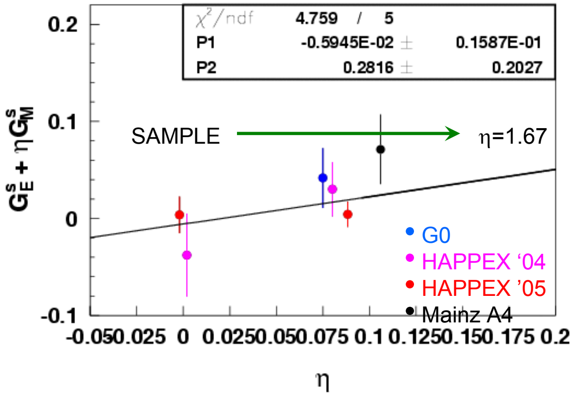


- G0 results (extrapolated to Q^2=0.1 GeV^2) combined with world data:

  G_E^s = -0.103 +/- 0.28
  G_M^s = 0.62 +/- 0.31

- 2 σ deviation of G_M^s from zero

World Data at Q^2=0.1 GeV^2 "Rosenbluth Plot"



$$\eta = \frac{\tau G_M^p}{\varepsilon G_E^p}$$

- Post-HAPPEX '05

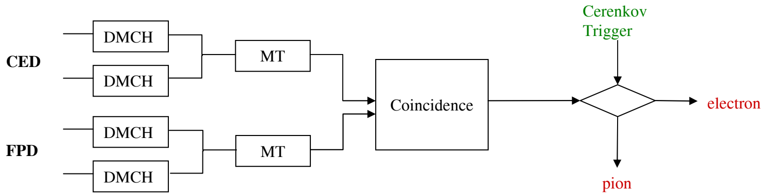
  G_E^s = 0.006 +/- 0.016
  G_M^s = 0.28 +/- 0.20

- New HAPPEX results yield smaller G_M^s
- Even with this shift in the central value, world data still remarkably consistent

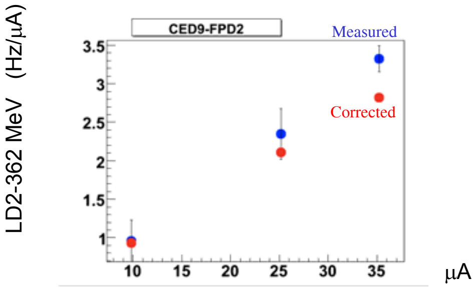
Thanks to Kent Paschke for plot, and Dave Gaskell

G^0 Backward Angle Data Analysis

Dead Time and Contamination Corrections :

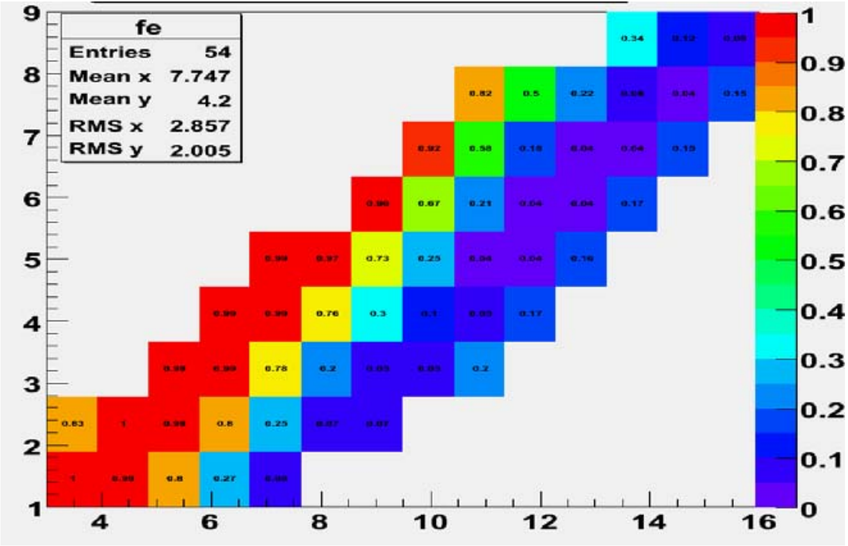


Octant 1 - Measured-Corrected Yield



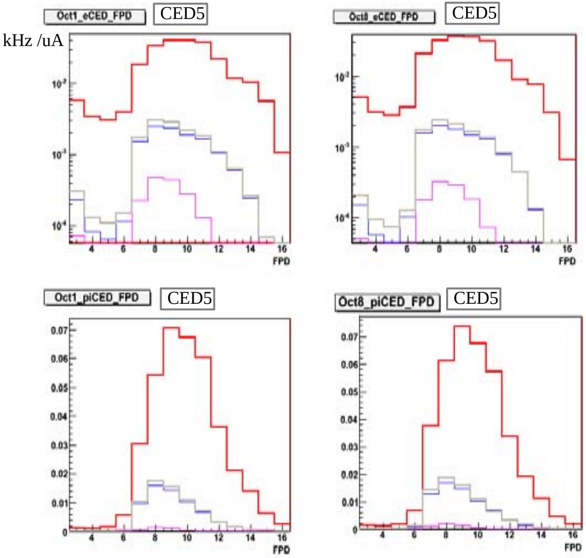
- Modeling the electronics allowed for the correction of the following bias :
  - CED-FPD coincidence electronics **dead time**
  - CED-FPD coincidence **randoms**

Physics contamination : Dilution factors



Contamination by Target Al windows

Counting rates for on CED as a function of FPD number (in kHz/uA) :



<u>contamination :</u>

~4% @362 and 687MeV

<u>Al data Asymmetries :</u>

@362MeV :

Elastic : -18 +- 29ppm

Inelastic : 21 +- 41ppm

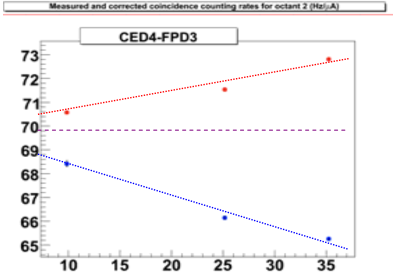
@687MeV :

Elastic : -48+- 72ppm

Inelastic : - 2 +- 41ppm

- **LH2 @ 687 MeV**
- **Total Al windows**
- **Entrance + Vacuum Window**
- **Exit Window**

Dead Time Correction Procedure



First Step Correction

- Corrects CEDxFPD coincidences from dead time, CED-FPD randoms and MT multihits effects
- Results :

  "Residual Dead time" : residual slope in yields vs beam current, after DT, MH **and** random corrections

	All Octants (elastic locus)		All Octants (inelastic locus)	
	To be corrected	Residual	To be corrected	Residual
LH2 362 MeV 60 µA	7%	2.1%	8.7%	4.5%
LH2 687 MeV 60 µA	5.9%	3.6%	8.9%	5.9%
LD2 362 MeV 35 µA	14.5%	3.5%	27%	3.5%
LH2 687 MeV 30 µA	10%	1.2%	13%	1.8%

(see Philippe's Addendum to Dead Time Report)

⇨ Residual Dead Time in elastic locus is between 1 and 4 %

Cerenkov Efficiency

- 31 MHz data, separate pions from electrons.

- Maud, Alex; Analysis of 31 MHz data, independent analysis

LD2 NOV 2006 687 MeV Multiplicite 3 (Old PMTs)

oct	eff
1	53.95 +- 0.85
2	42.92 +- 0.94
3	44.31 +- 1.14
4	26.36 +- 0.51
5	31.23 +- 1.36
6	42.63 +- 0.60
7	30.32 +- 0.98
8	36.98 +- 0.62

LD2 JANV 2007 360 MeV Multipilicte 2 (New PMTs)

1	86.32 +- 0.07
2	80.51 +- 0.04
3	81.97 +- 0.24
4	69.42 +- 0.04
5	76.21 +- 0.05
6	85.18 +- 0.03
7	72.83 +- 0.08
8	79.89 +- 0.04

- 362 MeV LD2, Mult2