The MAMBO experiment

Rachele Di Salvo

INFN-Sezione di Roma “Tor Vergata”

MAMiBOnn

- **Prosecution of the experimental activity in Mainz (DAPHNE, GDH,GDHN, CTT) at MAMI accelerator (tagged photon beam E_γ =0.05÷1.6GeV)**
  (CB@MAMI Collaboration)

- **New scientific line in Bonn at ELSA accelerator (tagged photon beam E_γ =0.3÷2.9 GeV and significant polarization degree up to 1.8GeV) based on the BGO-Ball of the former GRAAL experiment**
  (BGO-OD Collaboration)

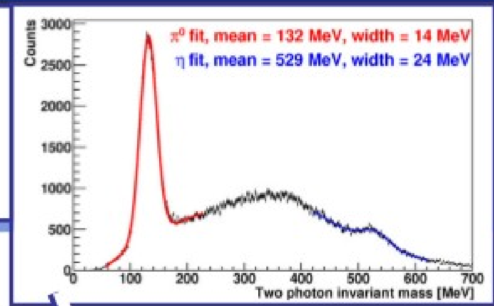
- **Sezioni INFN : CT (Me), ISS, LNF, PV, RM2, TO**

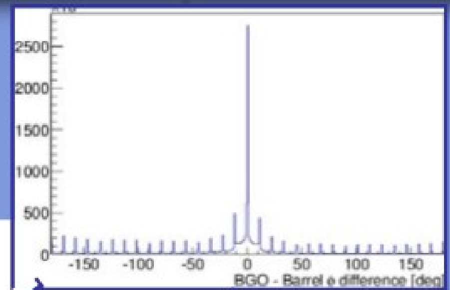
Italian Spokeperson: Rachele Di Salvo

CENTRAL REGION AND TAGGING SYSTEM

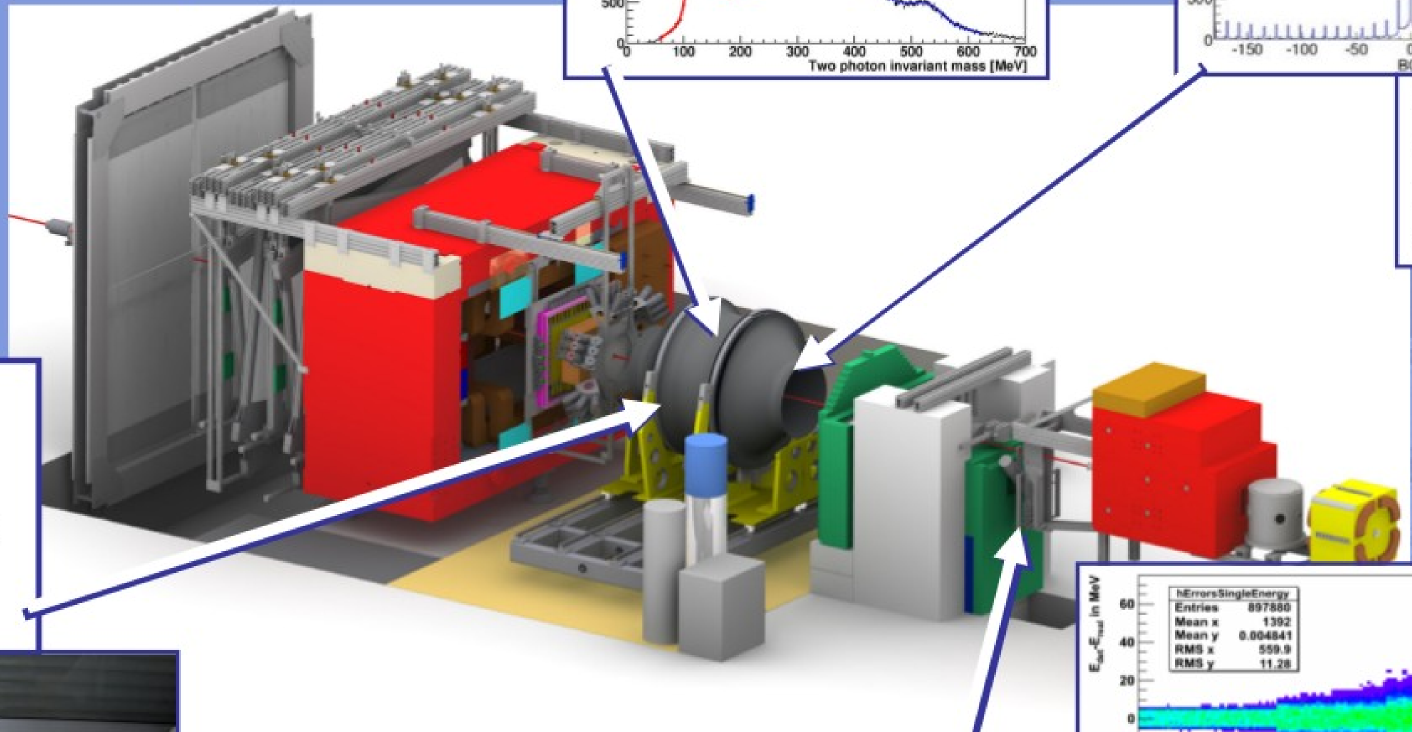
$Bi_4Ge_3O_{12}$
= Bismuth germanate

BGO calorimeter
480 crystals, $0.9\times4\pi$
$\theta_{lab}=25°\ldots155°$,
trigger logic, sADC

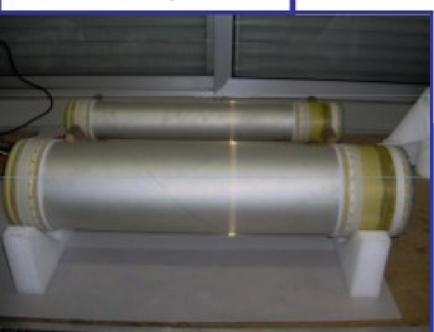




32 strip
scintillator
Barrel,
charge id

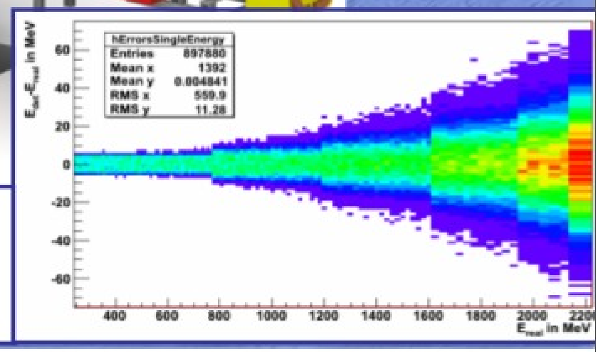


MWPC
inner tracking
2 layers,
$\theta_{lab}=8°\ldots163°$,
$\Delta\varphi = 2°$,
$\Delta z = 300\mu m$



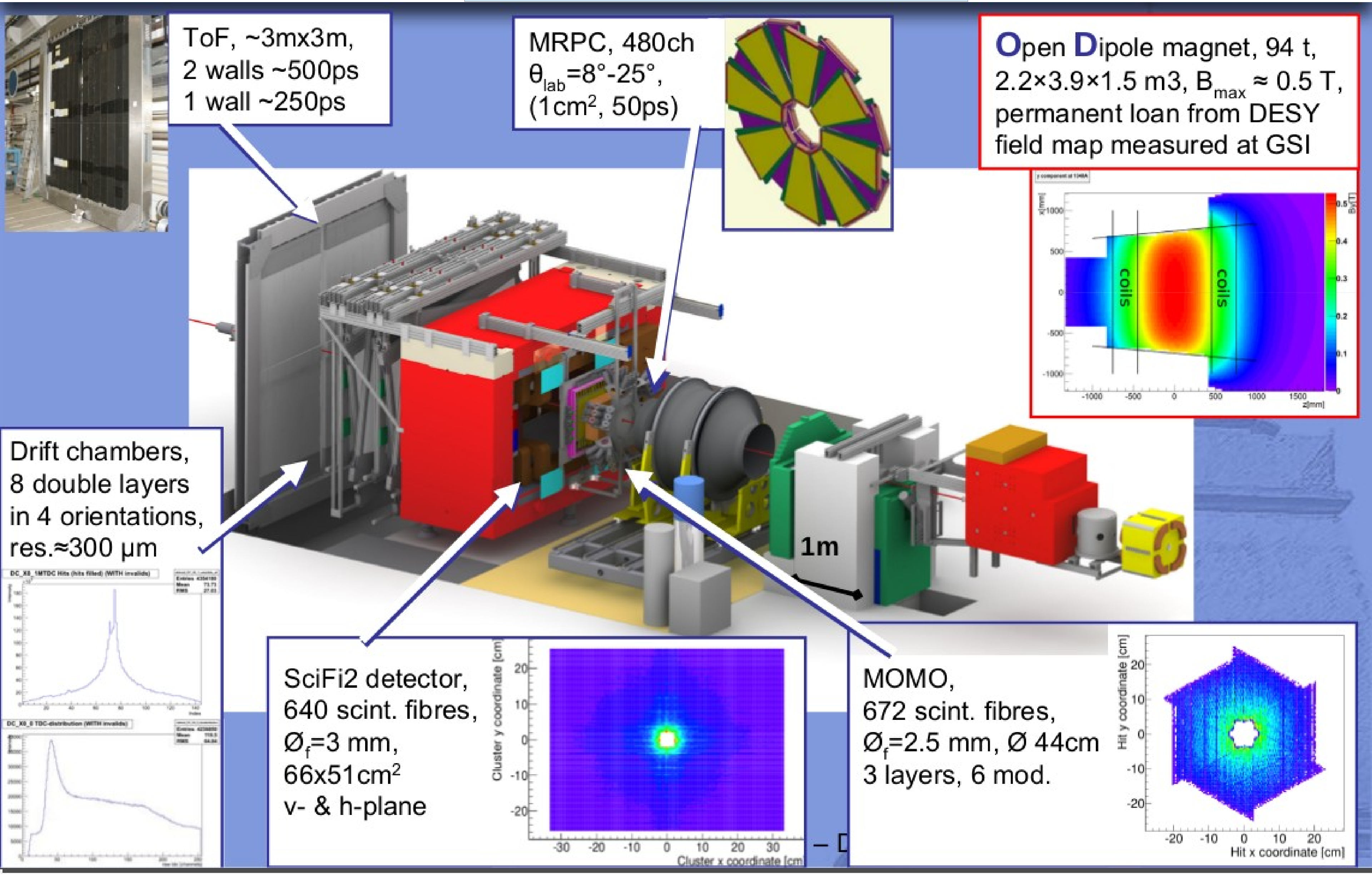
Target system
LH_2, LD_2

Tagging system
120 scintillator bars,
10%…90% E_{beam}

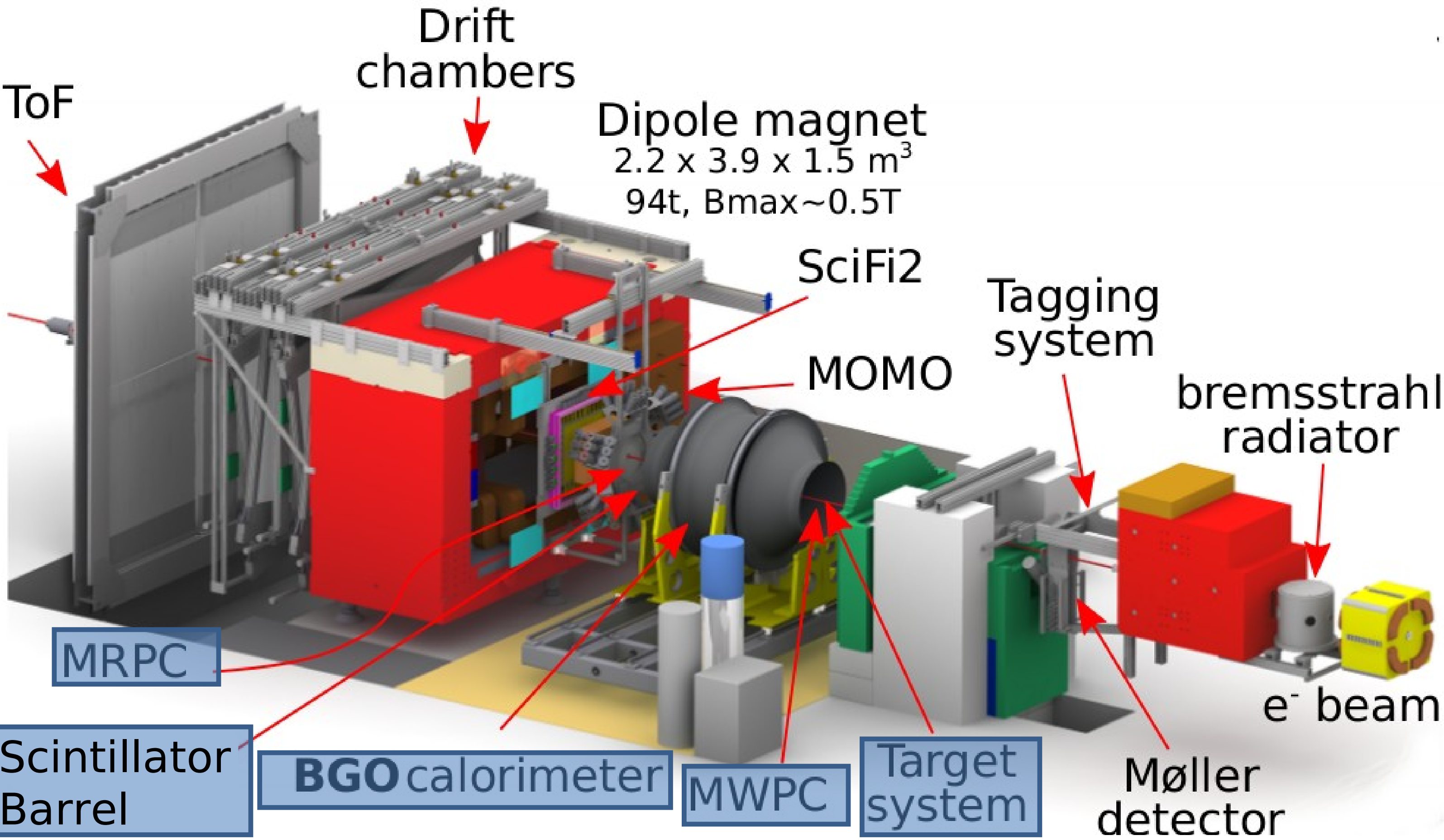


→ tools for lin. and circ. pol. beams in preparation

FORWARD REGION



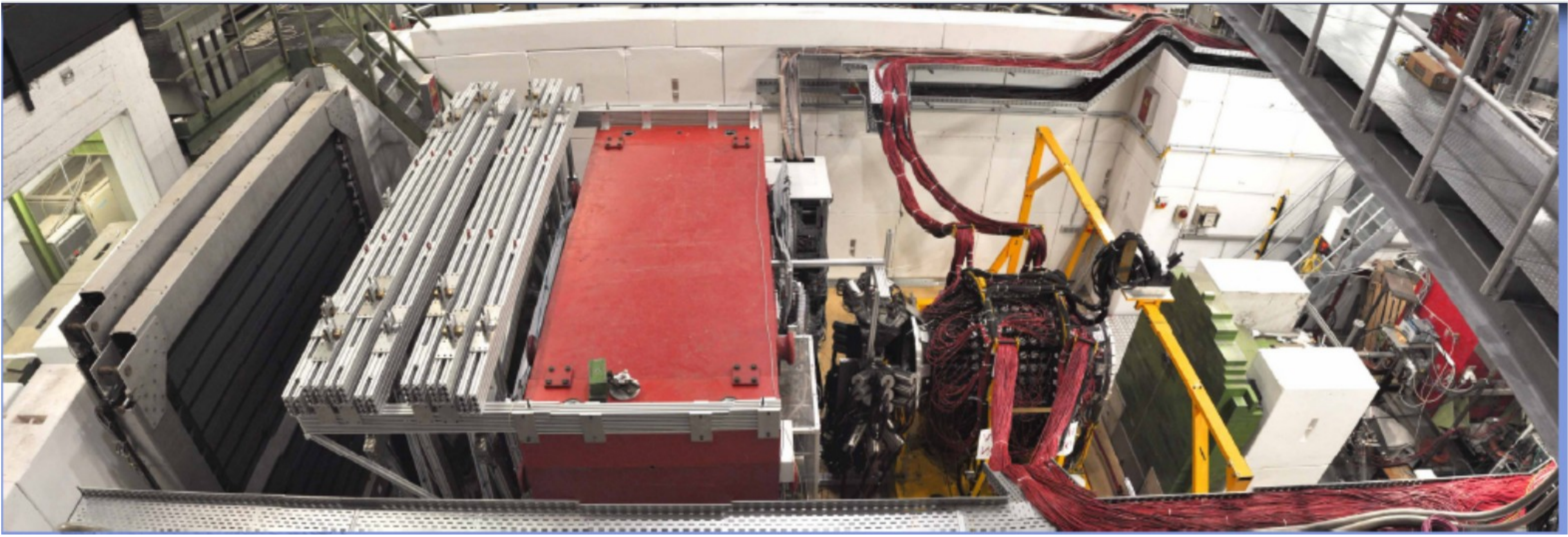
BGO-OD (BGO-Open Dipole)



INFN responsibilities

BGO Calorimeter, Barrel, Target ==> **Successful Commissioning in Feb./March and May/June 2012**

BGO-OD (BGO-Open Dipole)



Daniel Elsner

BGO-OD DETECTOR FEATURES

Detector is optimized for:
- forward region: charged particle identification and momentum resolution

- central region: photon detection with good energy and angular resolution; charged particle tracking and identification; energy measurement for protons; neutron detection

- mixed charged and neutral final state detection

- has trigger capabilities (trigger on the energy sum deposited in BGO)

- open trigger (many channels can simultaneously be acquired)

- good time resolution of signals in the BGO calorimeter

BGO-OD Bonn: Main physics objectives

(higher nucleon excitation energies)

Systematic investigation of the photoproduction of mesons off the nucleon for the study of the excitation spectrum of the nucleon. The underlying mechanisms must still be considered as poorly understood. Improved experiments will shed new light on the low-energy hadronic aspects of the strong interaction. In particular asymmetry observables can help to disentangle the contribution of the different resonances.

- $\gamma N \rightarrow N\eta$ $\gamma N \rightarrow N\eta'$ scalar mesons
- $\gamma N \rightarrow N\omega$ $\gamma N \rightarrow N\phi$ vector mesons
- $\gamma N \rightarrow K\Lambda\ (\Sigma)$ strange mesons

Joint PAC of MAMI and ELSA Dec. 6th-7th

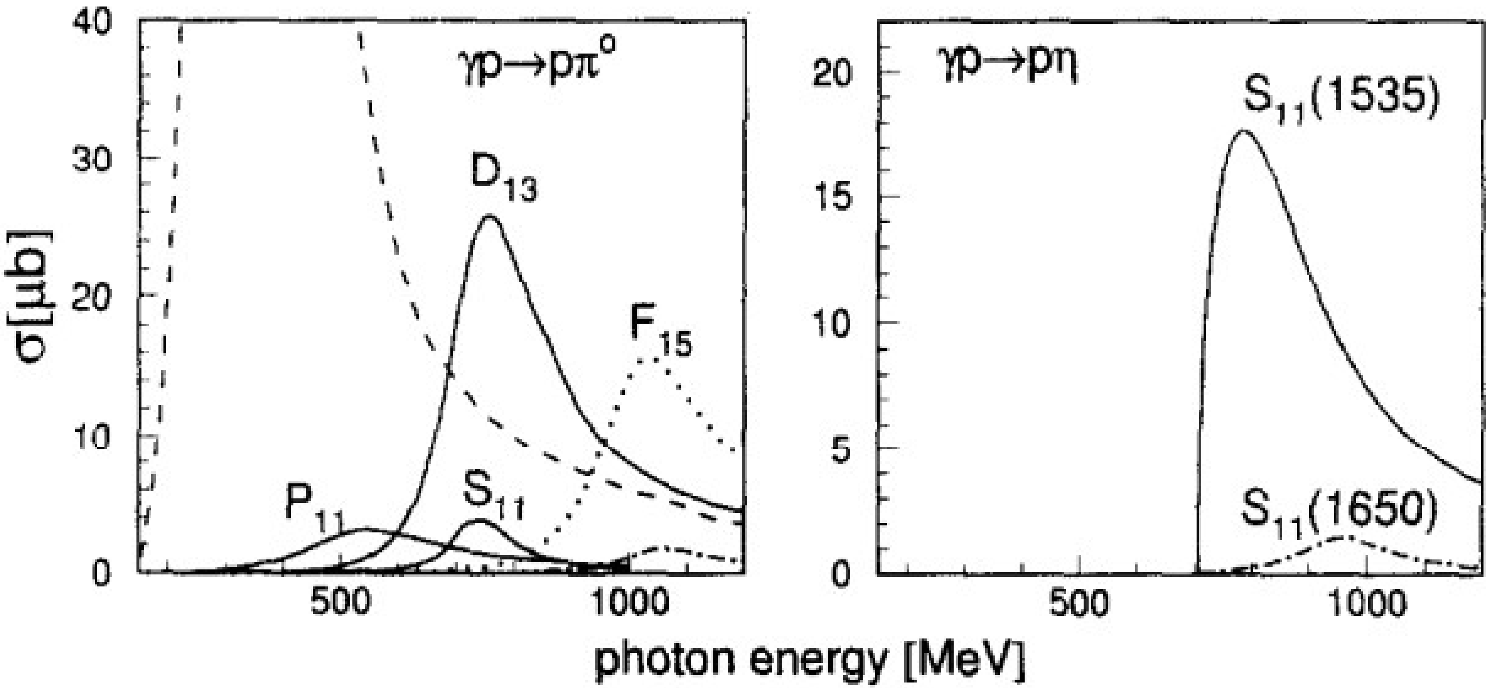
- After more than 50 years of $\gamma N \rightarrow N\pi$ our knowledge of the nucleon resonances is far from being satisfactory

Main reasons:
(i) too few observables have been measured
(ii) too few data on the neutron (e.m. interactions do not conserve isospin)
(iii) resonances can decay into $N\pi\pi$, $N\eta$, ... (coupled channel approach needed)

What is needed:
==> Single and double polarization asymmetries
==> III and IV Resonance Regions
==> Data on neutron

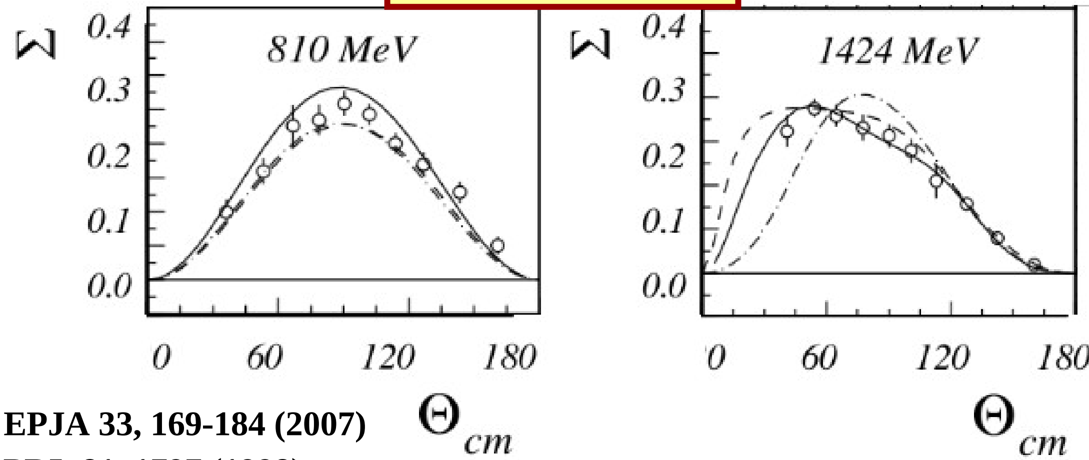
η, η', ω = ISOSPIN FILTERS

Isoscalar mesons allow to access only N*(I=1/2) resonances and this simplifies the interpretation of the data.



From B.Krusche, Prog. Part. Nucl. Phys. 51 (2003), 399-485

$\vec{\gamma}\, p \to \eta\, p$



Low energy: Σ=0 if only $S_{11}(1535)$ contributes

Interf $S_{11}(1535)$-$D_{13}(1520)$ ($\sin^2\theta_\eta^{cm}$ behav.)

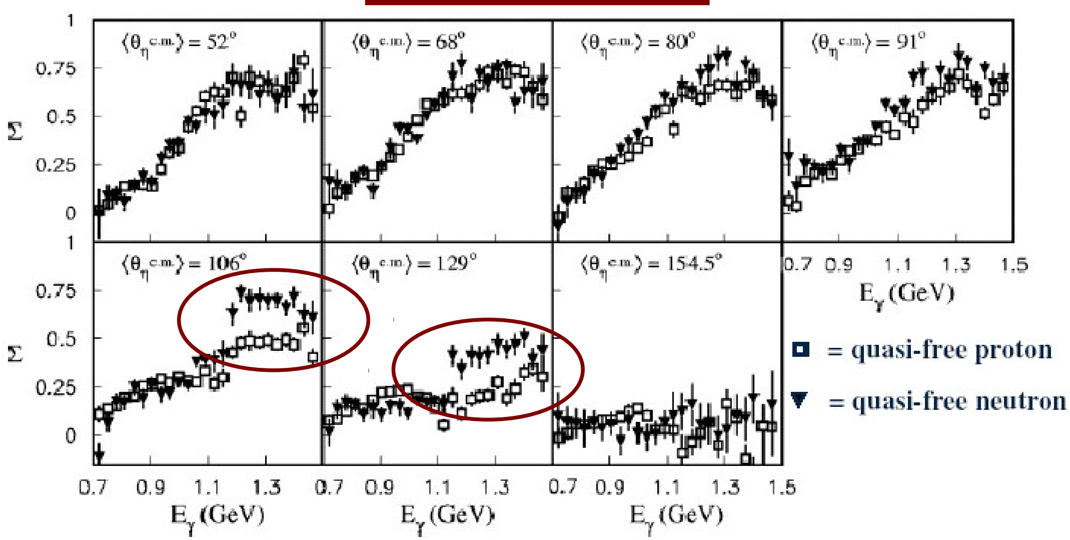
High energy: interference $S_{11}(1535)$-$F_{15}(1680)$ (peak at forward angles)

$$\Sigma = -\frac{q^{CM}}{2\,k_\gamma^{CM}} \frac{3\,\sin^2\theta\;\mathrm{Re}\left[E_{0+}\left(E_{2-}+M_{2-}\right)\right]}{\left(d\sigma/d\Omega\right)_{UNP}}$$

Higher multipoles expansion $\cos\theta(E_{3-},+M_{3-})$

EPJA 33, 169-184 (2007)
PRL 81, 1797 (1998)

$\vec{\gamma}\, N \to \eta\, N$

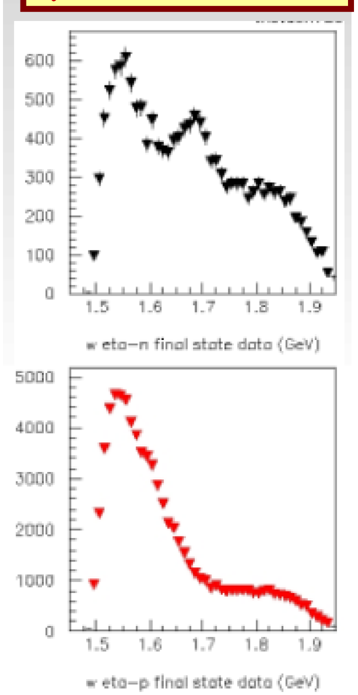


Phys.Rev C 78, 015203 (2008)
*Eur.Phys. J. A 32, 311 (2007)
*Phys. Lett. B650, 172 (2007)

⇒ Including a narrow resonance $P_{11}(1670)$ resonance into a traditional isobar model*

⇒ Interference $S_{11}(1650)$-$P_{11}(1710)$ (Giessen model)**

$\gamma\, N \to \eta\, N$

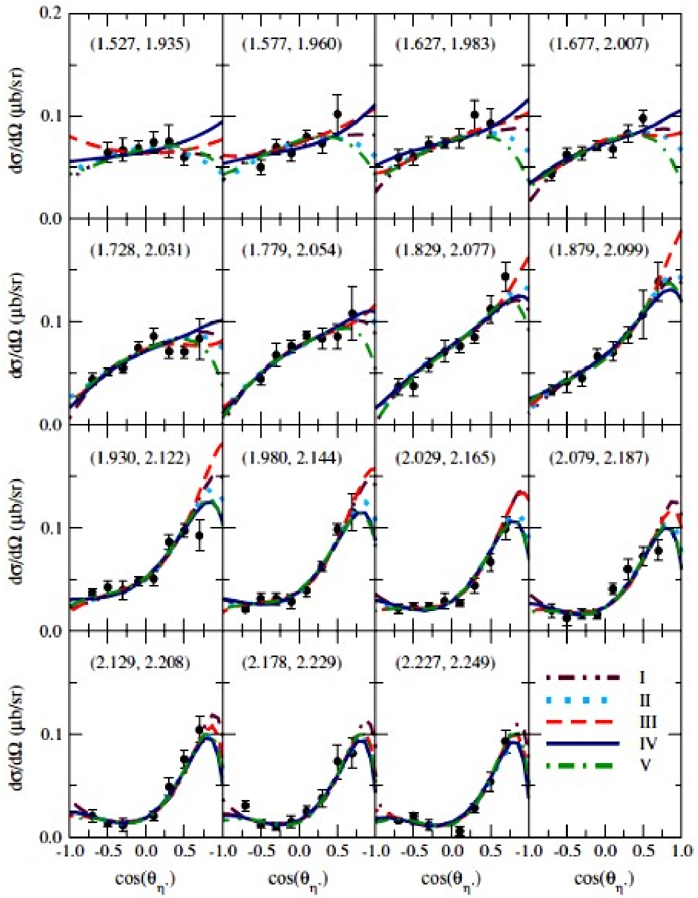


Different behaviour proton-neutron at E_γ>1GeV. Differences will be further explored at BGO-OD.

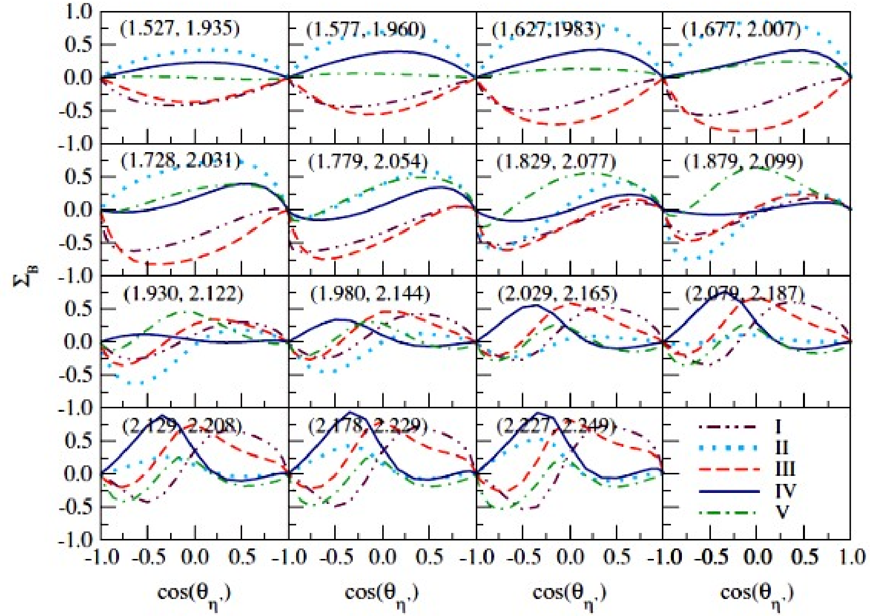
A. Fantini

η' PHOTOPRODUCTION

Recent precise data are available on total and diff. x-sections from CLAS and ELSA-CB. Inclusion of different set of resonances in the models provides similar predictions for x-sect. but very different for the beam asym. Σ will be measured for the first time at ELSA.



$$d\sigma/d\Omega \sim H_1^2 + H_2^2 + H_3^2 + H_4^2$$
$$\Sigma \sim \mathrm{Re}\,(H_1H_4^* - H_2H_3^*)$$
$$T \sim \mathrm{Im}\,(H_1H_2^* - H_3H_4^*)$$
$$P \sim \mathrm{Re}\,(H_1H_3^* - H_2H_4^*)$$

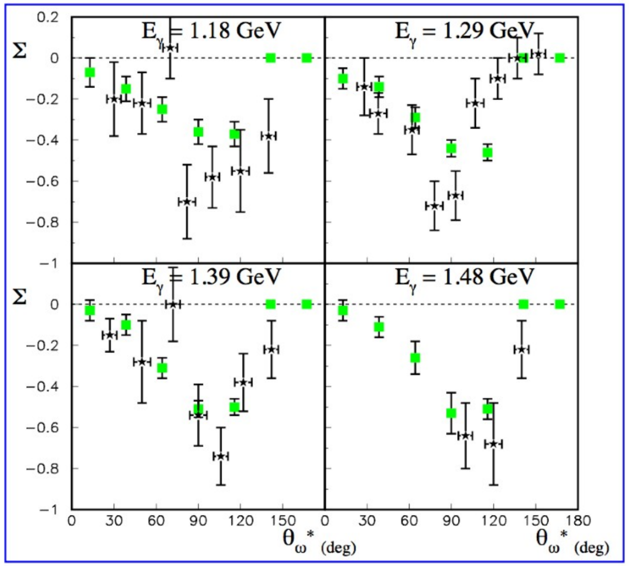


I = P11 , S11 , P13 and D13
II= inclusion of an extra D13 (2085)
III= inclusion of higher mass P11 and S11
IV=P13 is removed from the fit
V=all resonances (W,Γ from PDG)

G. Mandaglio

ω PHOTOPRODUCTION

$\vec{\gamma} + p \longrightarrow \omega + p$: beam asymmetry (1/2)



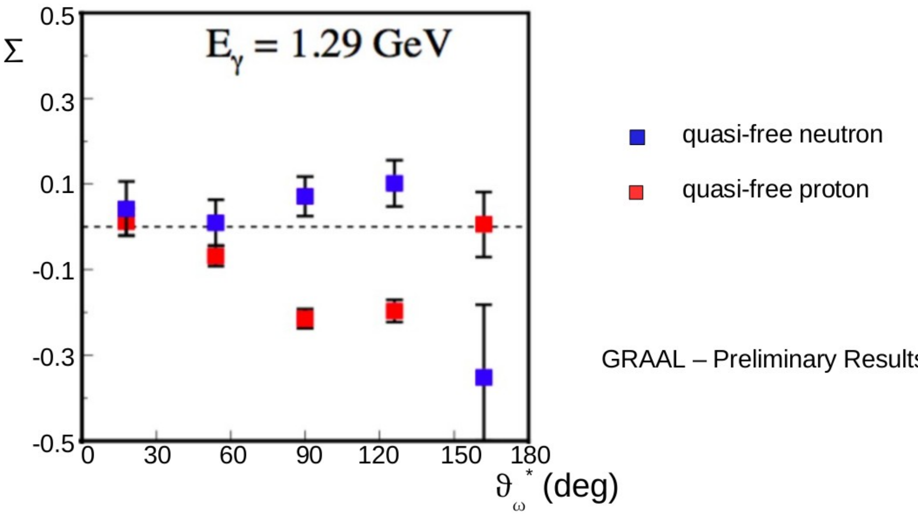
★ CBELSA/TAPS
F.Klein et al.
Phys. Rev. D 78,
117101 (2008)

$P_{13}(1720)$

GRAAL
A.Ajaka et al.
Phys. Rev. Lett. 96,
132003 (2006)

$P_{13}(1720)$

$\vec{\gamma} + n \longrightarrow \omega + n$: beam asymmetry



V. Vegna

The asymmetry on the neutron will be further explored at BGO-OD

ϕ PHOTOPRODUCTION

$\vec{\gamma} + p \rightarrow \phi + p$: s-channel?

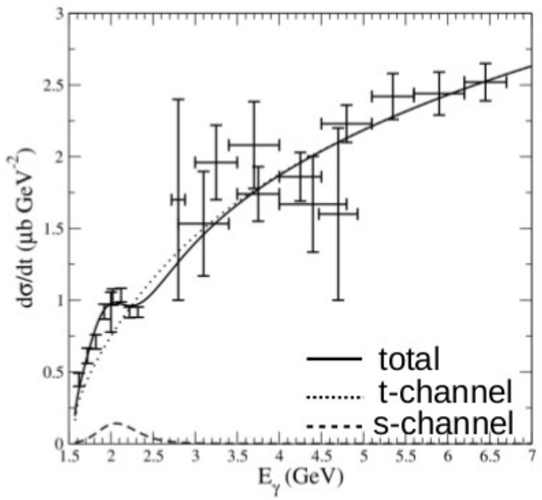
A. Kiswandhi et al., Physics Letters B 691 (2010) 214-218

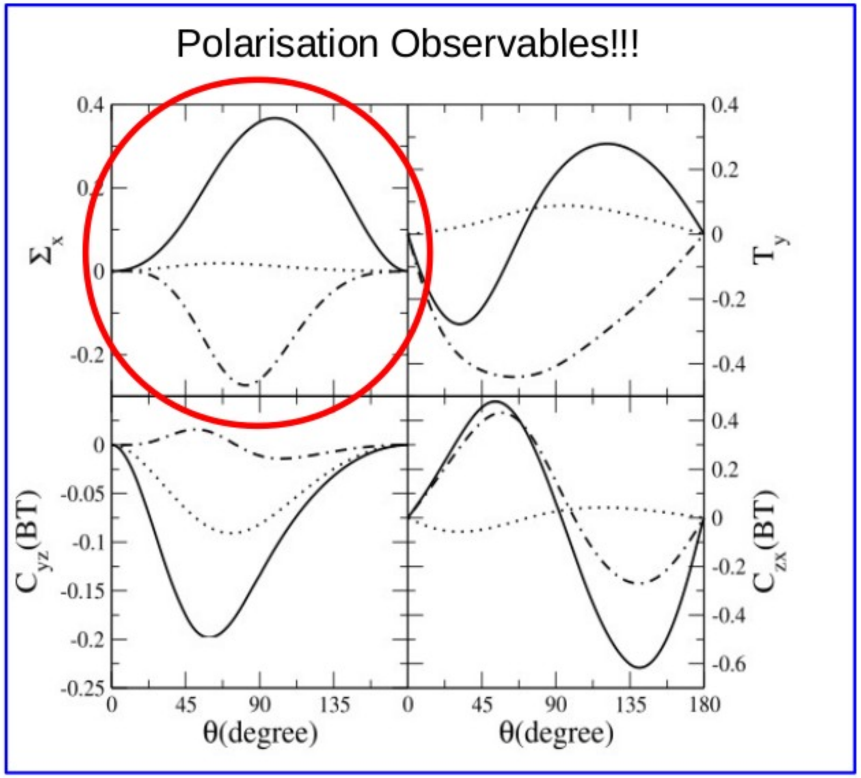
t-channel exchange: Pomeron + PSE

+

resonant intermediate state:

- strange content ($s\bar{s}uud$)
- W = 2.1 GeV;
- J = 3/2
- P = ?





Predictions at Eγ = 2 GeV

P=-

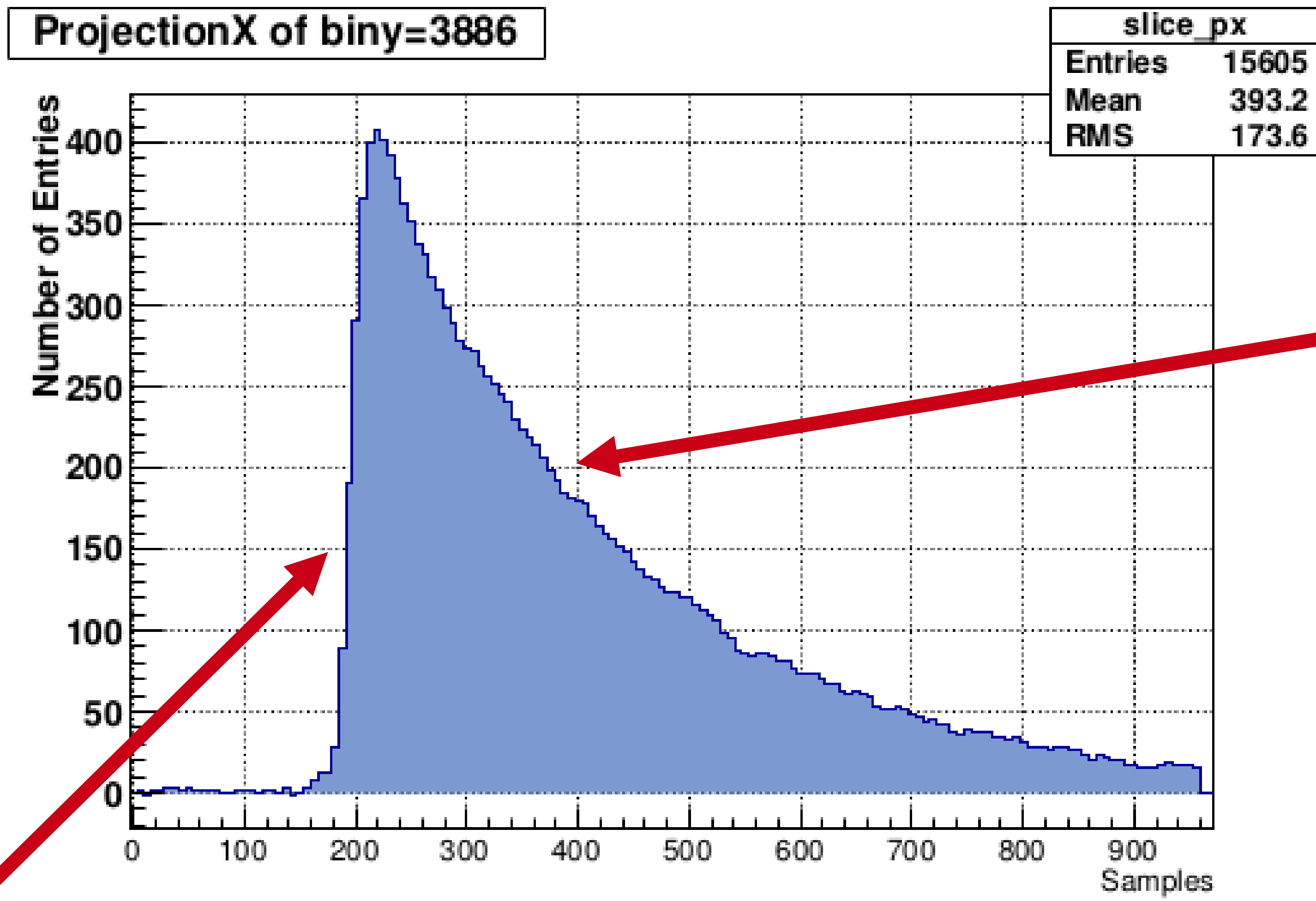
P=+

no resonance

V. Vegna

Asymmetry on the proton and the neutron will be further explored at BGO-OD

BGO crystal read-out is performed with Sampling ADCs@160MHz (6.25ns) which allow to reconstruct the starting time of the signal and its main parameters: time and amplitude of the first maximum and mimimum (and of all following relative mamima and minima), total integral of the signal, partial integrals.

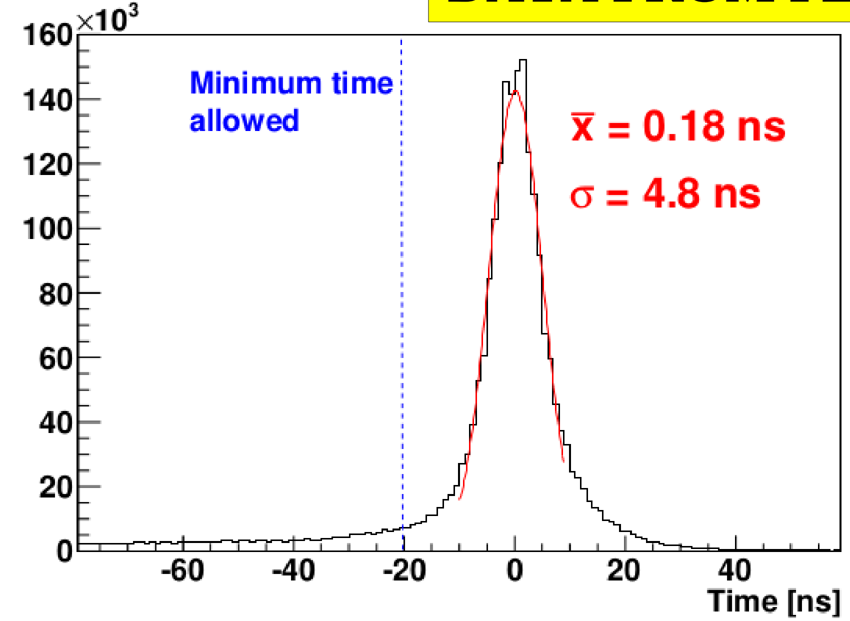


Decay time ≈ 300 ns

Fast rising edge ≈ 20 ns

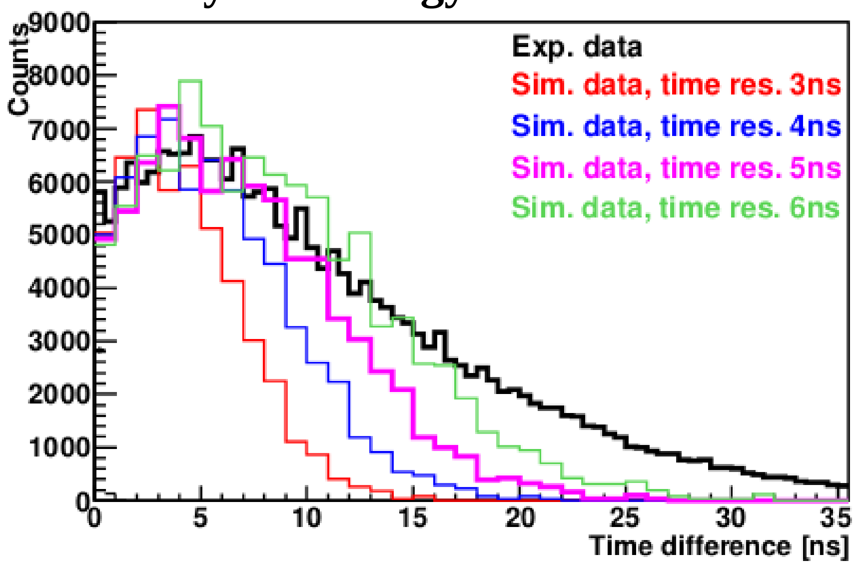
Sampled BGO signal in a 1000 ns window during data taking

DATA FROM FEB.-MARCH 2012

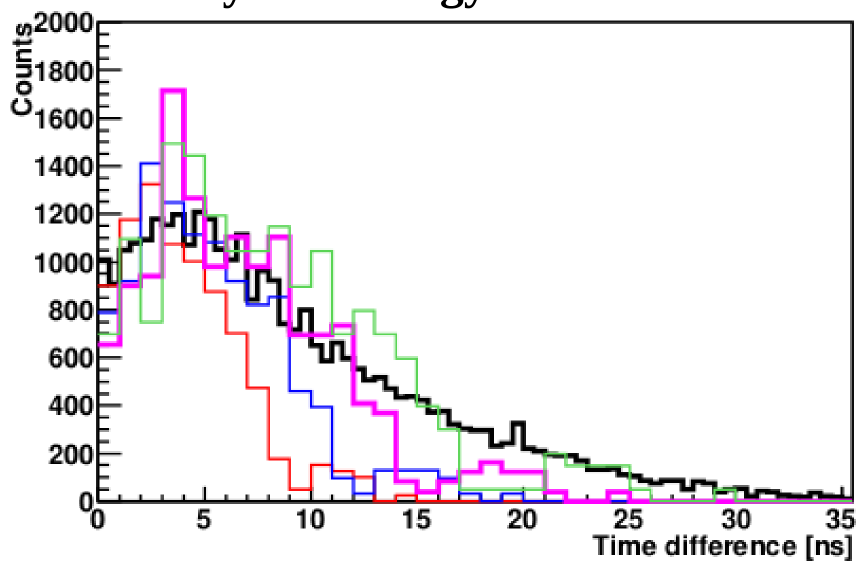


Signal start time distribution of all BGO crystals

Crystals energy 0-100 MeV



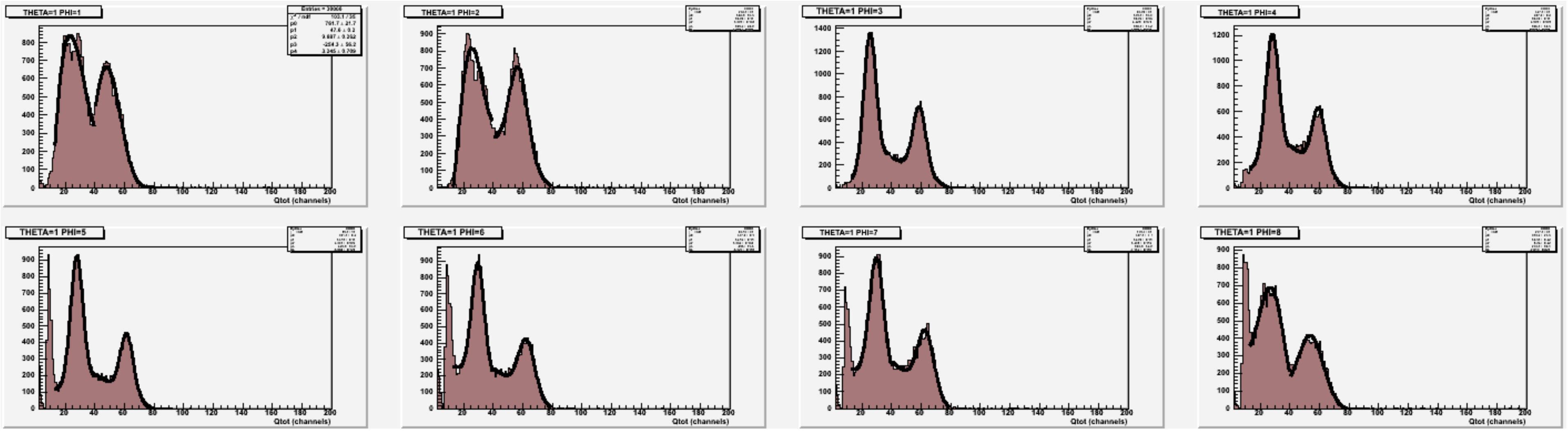
Crystals energy 100-200 MeV



Time difference between crystals in a photon cluster

BGO Crystals are calibrated with a 22Na source.

01 March 2012: Beginning of data taking

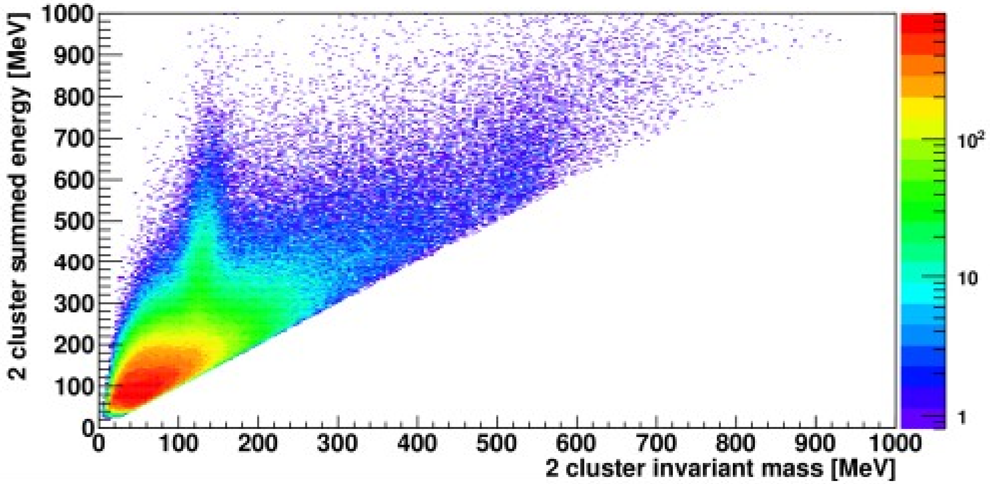


DATA FROM FEB.-MARCH 2012

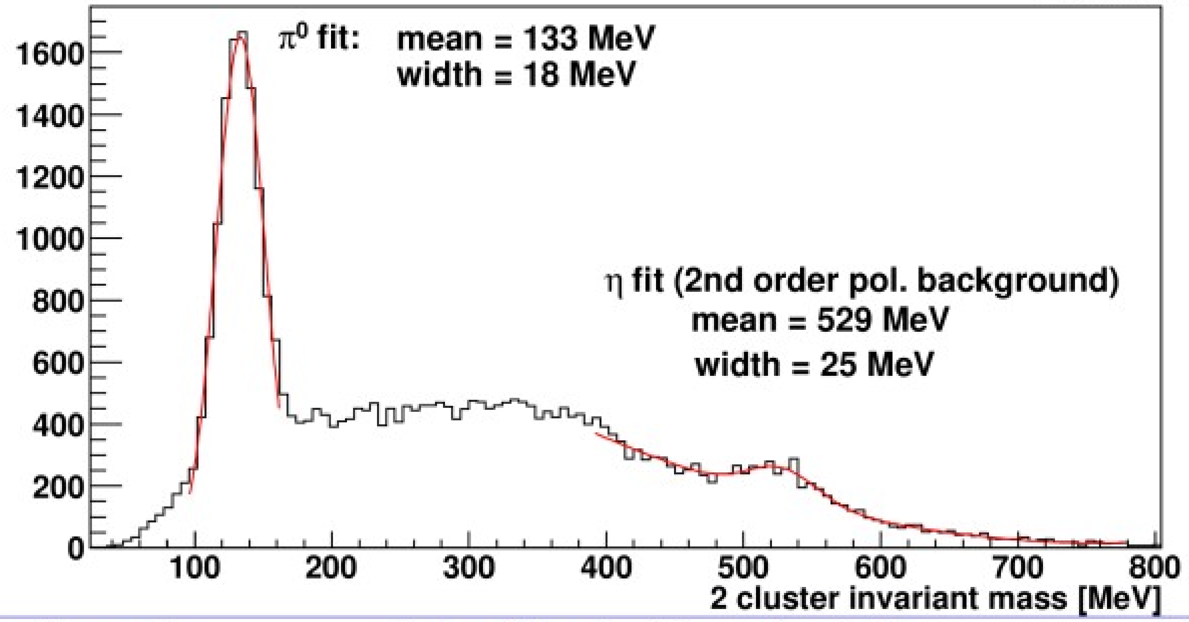
Reconstruction of π^0 and η masses

Each cluster contains at least 3 crystals (reject protons – no charged particle ID)

Summed energy of clusters > 400 MeV



Runs:
6839,
6340,
6841,
6857,
6873,
6877,
6881,
6886,
6888,
6890



Tom Jude

DATA FROM FEB.-MARCH 2012

Identification of the proton in the BGO

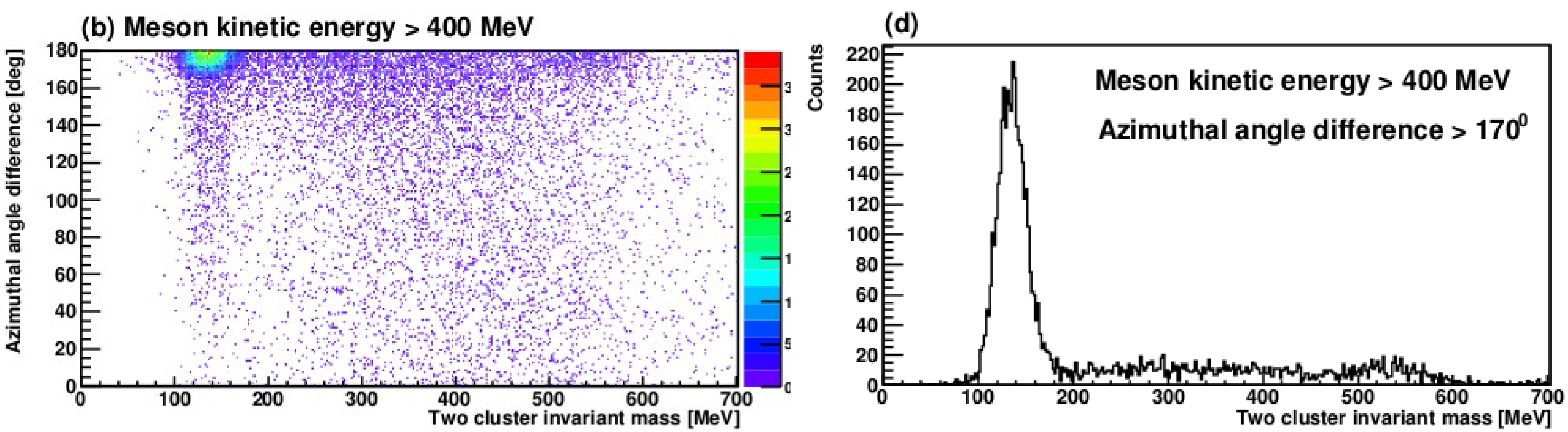
Identify 3 clusters in the BGO

2 clusters with at least 3 crystals (π^0 decay photons)

1 cluster with less than 3 crystals (proton)

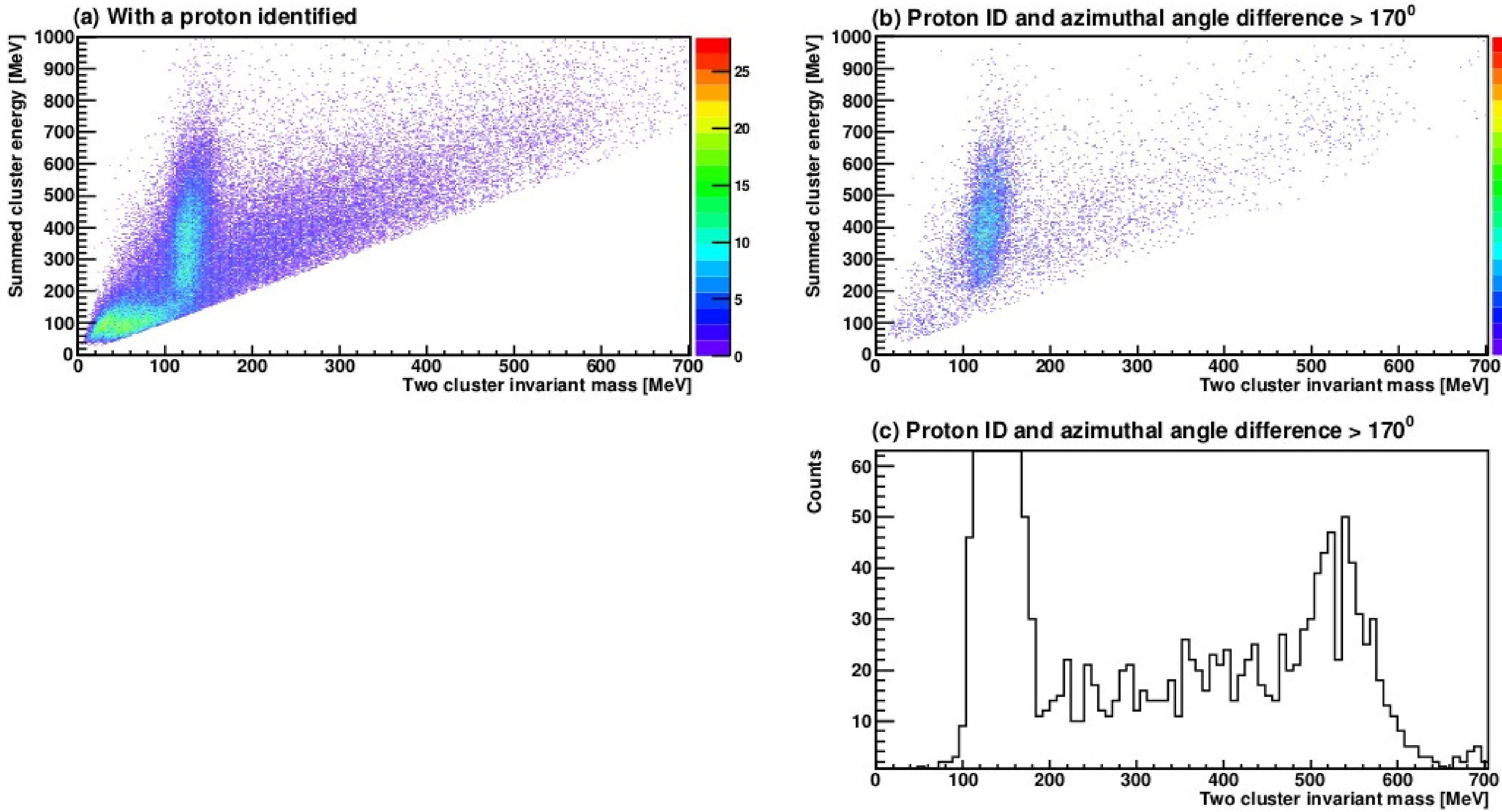
Select events where reconstructed proton and π^0 are back to back in azimuthal angle

Require p0 cluster energy > 400 MeV



Tom Jude

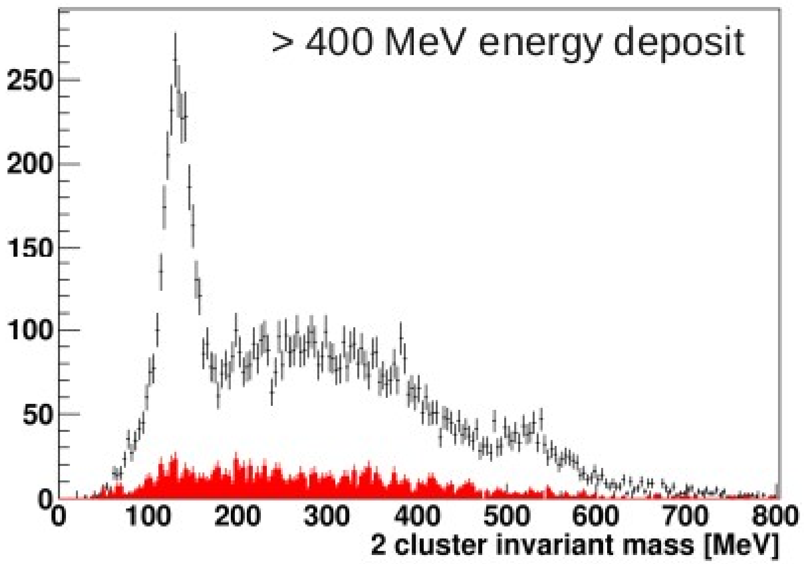
DATA FROM FEB.-MARCH 2012

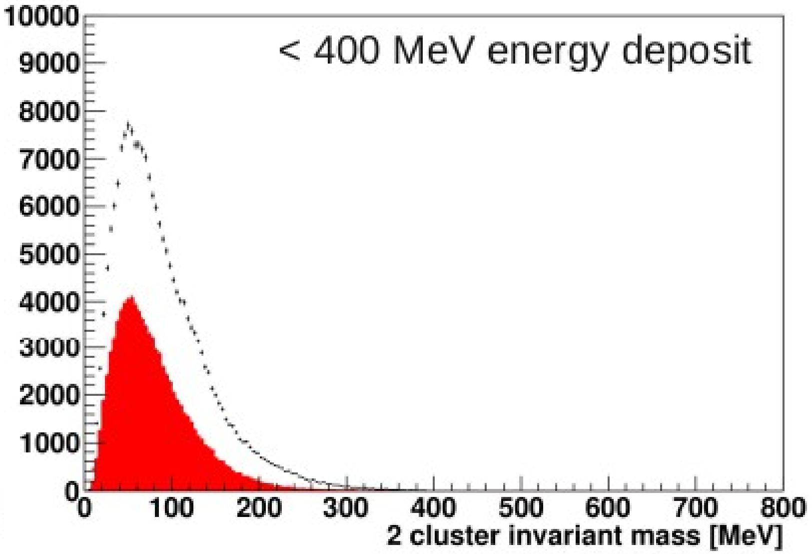


Tom Jude

Comparison with empty target data

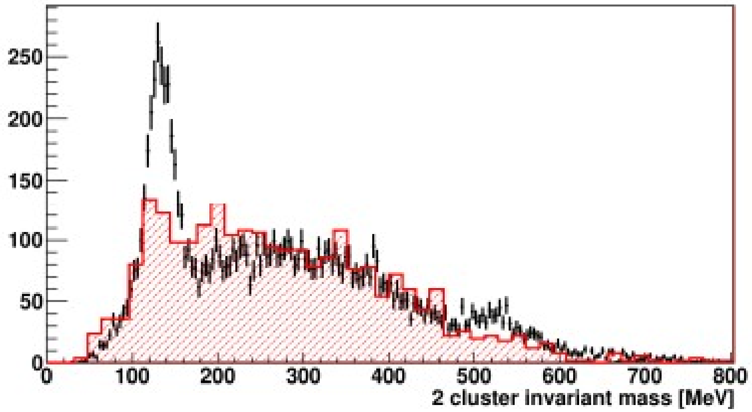
Black points, full target (run 6873), red shaded points, empty target (6833)





Approximately the same amount of events in Full and empty target runs

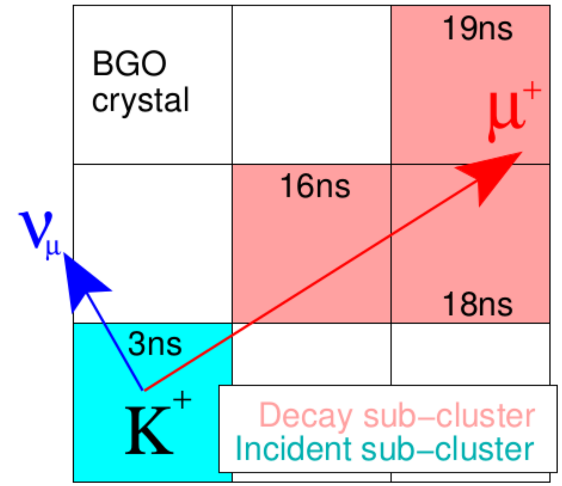
Scaled empty target by eye:

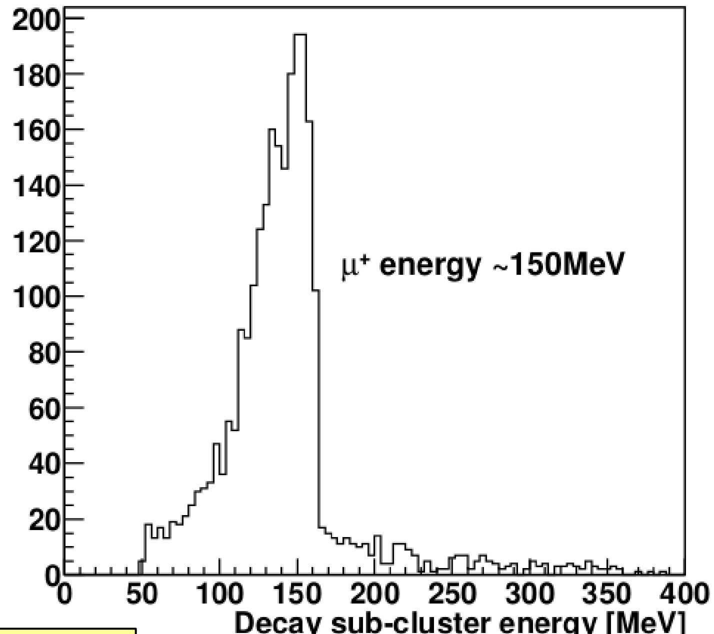


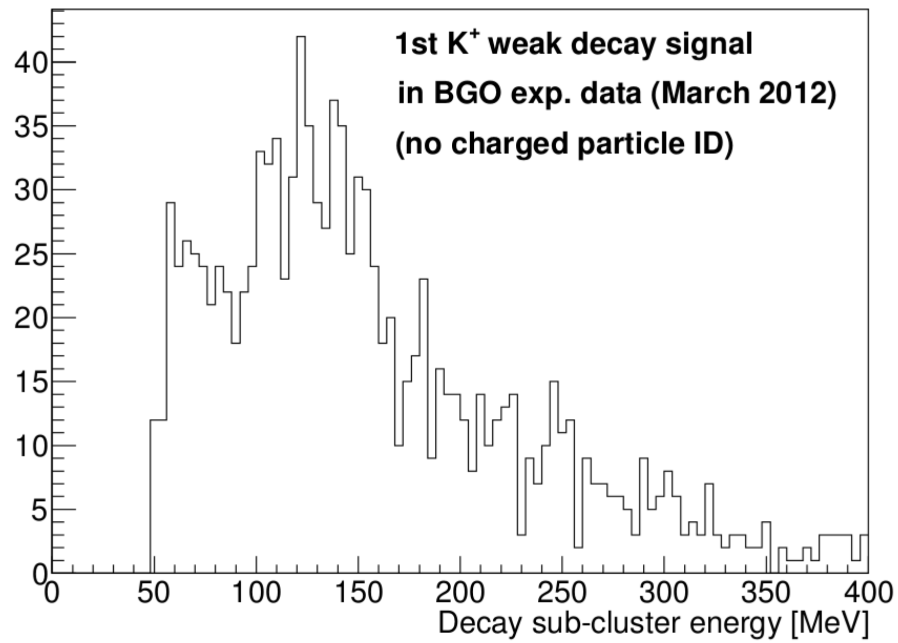
Tom Jude

DATA FROM FEB.-MARCH 2012

The good time resolution on the BGO signals will allow not only background rejection in clusterization algorithms but also a new method for the K+ identification from the time delay between the signal released by the K+ and the delayed signal released by the decay product ($K^+ \rightarrow \mu^+ \nu_\mu$).







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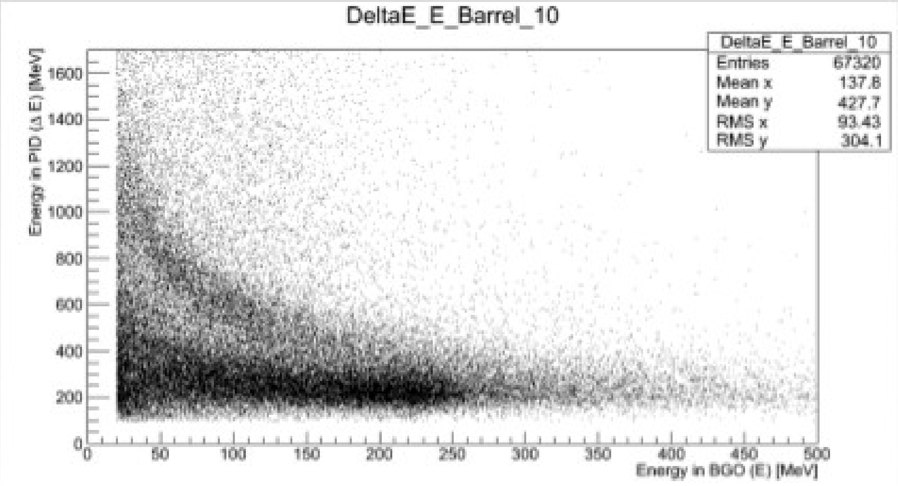
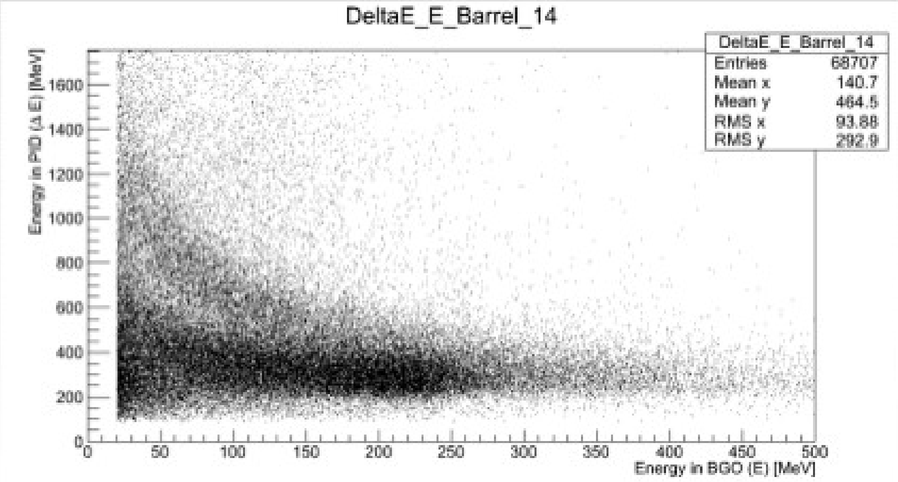
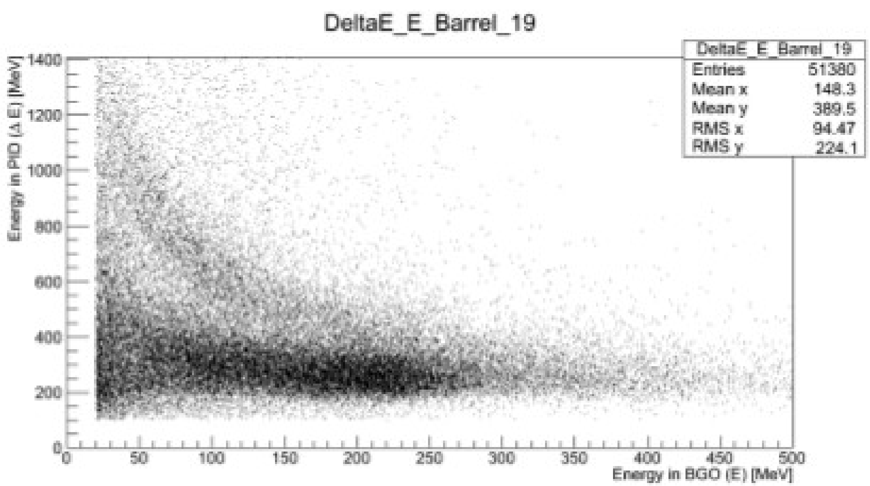
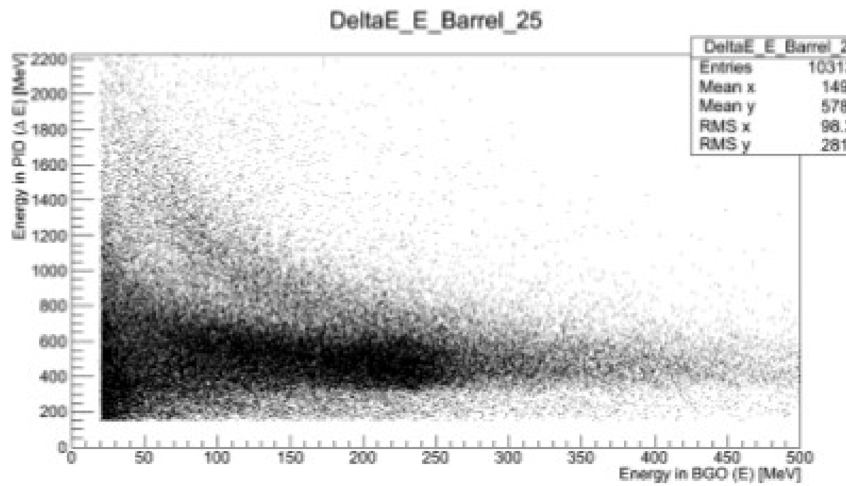
ΔE_{BAR} vs. E_{BGO}
Data taking June2012









4π Photon Spectrometer @ MAMI

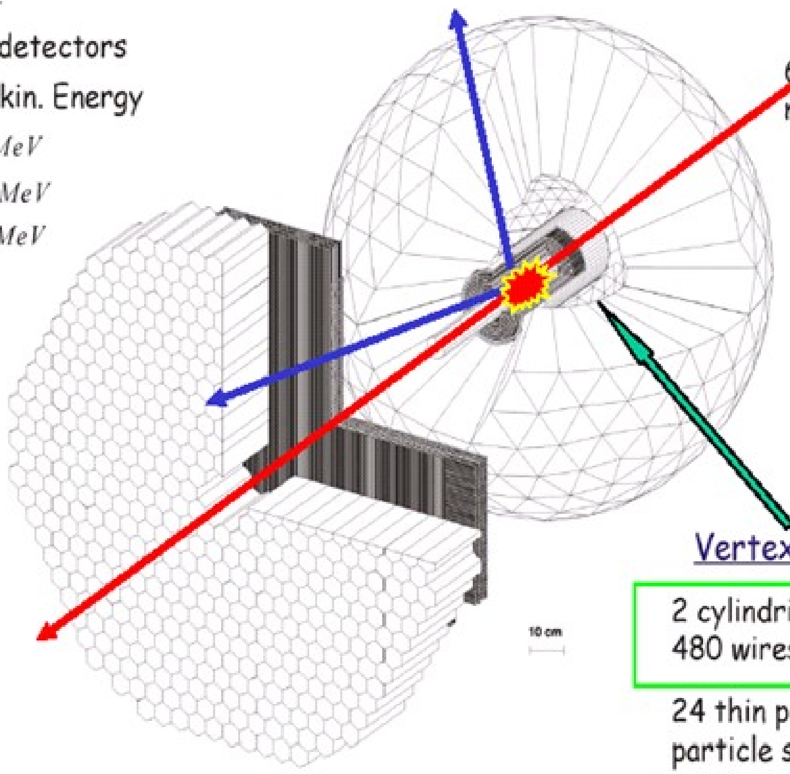
TAPS:

510 BaF_2-detectors
maximum kin. Energy

$\pi^{\pm}: 180\ MeV$

$K^{\pm}: 280\ MeV$

$p: 360\ MeV$



Crystal Ball:

672 NaI-detectors
maximum kin. energy

$\mu^{\pm}: 233\ MeV$

$\pi^{\pm}: 240\ MeV$

$K^{\pm}: 341\ MeV$

$p: 425\ MeV$

Vertex Detectors:

2 cylindrical wire chambers
480 wires, 320 strips

24 thin plastic counters
particle separation

MWPC
2 cylindrical layers (PAVIA)

CB@MAMI: Main physics objectives

(mainly involving low cross sections and/or precision measurements)

- **Threshold meson production:** (test of LET/ ChPT):

  Strangeness ($\gamma N \rightarrow \Lambda K$)

  π^0 photoproduction at threshold

Ambiguity free amplitude analysis of meson photoproduction

Requires Double polarization measurements:

$\gamma N \rightarrow N\pi(\pi)$; $N\eta$ (ρ,…) channels

- Rare η, η' decays **Tests of fundamental symmetries (C,CP,CPT…)**

In medium properties of hadrons & nuclear physics:

Meson photo production on nuclei

Observables for $\gamma N \rightarrow N\pi$ photoproduction

Photon polarization		Target polarization			Recoil nucleon polarization			Target and Recoil polarizations			
		X	Y	Z(beam)	X'	Y'	Z'	X' X	X' Z	Z' X	Z' Z
unpolarized	σ	-	T	-	-	P	-	T_x	L_x	T_z	L_z
linear	Σ	H	(-P)	G	O_x	(-T)	O_x	$(-L_z)$	(T_z)	(L_x)	$(-T_x)$
Circular	-	F	-	E	C_x	-	C_z	-	-	-	-

1 unpolarized measurement

3 single polarization measurements

12 double polarization measurements

Performed or planned experiments at Mainz

The measurement of 7 (8) (properly chosen) observables is necessary to **unambiguously** (in a model independent way) determine the scattering amplitudes ("complete analysis")

First measurement of the F observable

- γ p -> pπ^0 channel

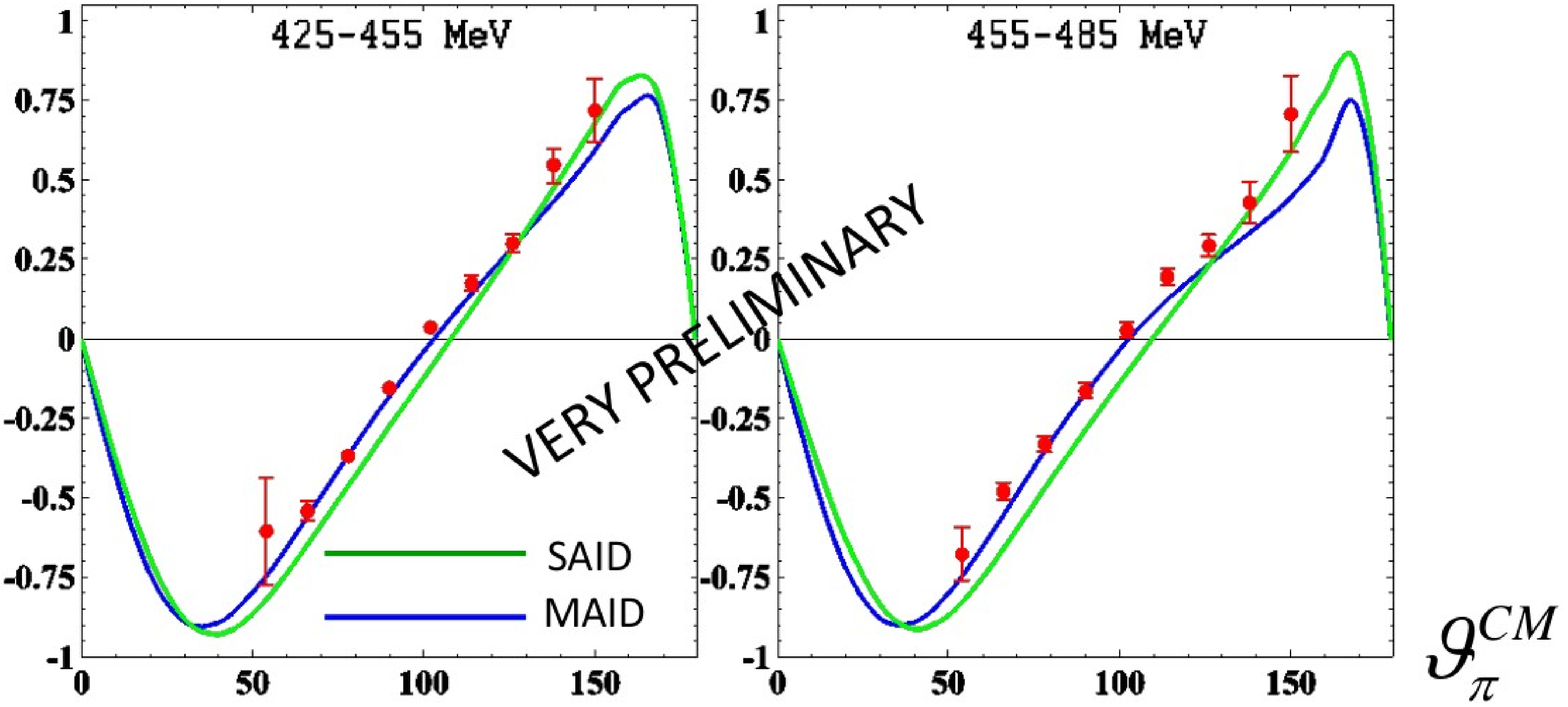
- Circular polarized photon beam
- Transverse polarized target

- Photon energy range : 420 -1020 MeV

$$\left.\frac{d\sigma}{d\Omega}\right|_{POLAR} = \left.\frac{d\sigma}{d\Omega}\right|_{UNPOL} \cdot \Big[1 \quad - p_{lin}^{\gamma}\Sigma\cos(2\varphi)$$
$$- p_x^T p_{lin}^{\gamma} H \sin(2\varphi) + p_x^T p_{circ}^{\gamma} \boxed{F}$$
$$- p_y^T \boxed{T} - p_x^T p_{lin}^{\gamma} P\cos(2\varphi)$$
$$- p_z^T p_{lin}^{\gamma} G\sin(2\varphi) + p_z^T p_{circ}^{\gamma} E\Big]$$

F Asymmetry

$\gamma\, p \to p\,\pi^0$



$$F \approx -\sin(\vartheta)\cos(\vartheta)\left|M_{1+}\right|^2$$

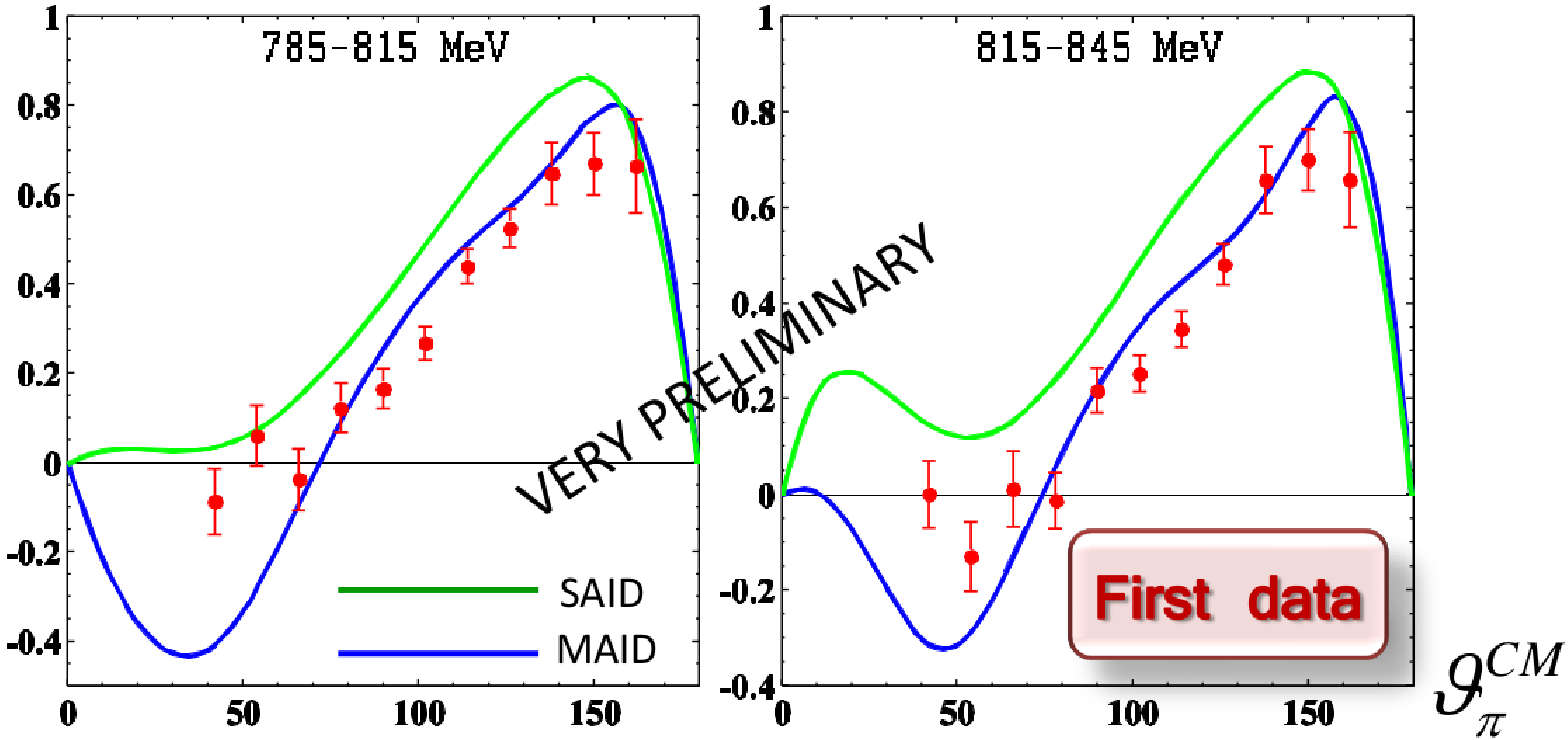
Δ(1232) strongly dominates

- **ONLY STATISTICAL errors**

First data

F Asymmetry

$\gamma p \rightarrow p \pi^0$



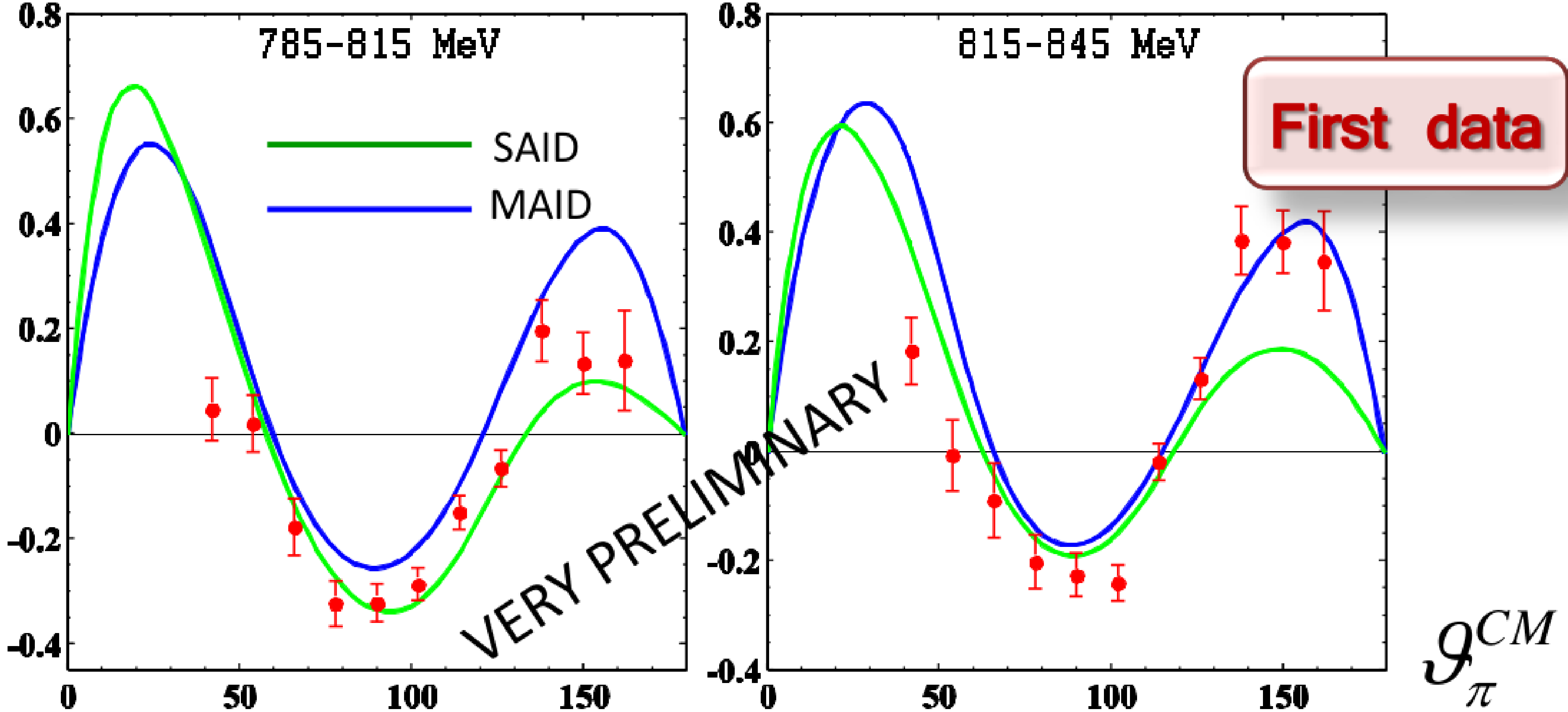
$$F \approx -\sin(\vartheta)\cos(\vartheta)\left(\left|E_{2-}\right|^2 - 3\left|M_{2-}\right|^2 + E_{0+}^*(E_{2-} + M_{2-}) - 2E_{2-}^* M_{2-}\right)$$

- ONLY STATISTICAL errors

Main contribution due to $D_{13}(1520)$ excitation

T Asymmetry

$\gamma p \to p \pi^0$



$$T \approx \mathrm{Im}\left(E_{0+}^{*}(E_{2-}+M_{2-})-6E_{2-}^{*}M_{2-}\right)$$

Strong D–wave contribution from D_{13} (1520)

- ONLY statistical errors

Experiments with polarised neutrons

- **No Free neutron target available**
- Model dependent results from nuclear targets
- Our experimental goal: to have a "small" and "realiable" model dependence
- Two different (and complementary) targets

  =) **deuteron** (data from Mainz –Bonn)

  =) **^{3}He** **(no data up to now)**

- Measurement of partial channels like

$$\boxed{\begin{array}{l} \vec{\gamma}\vec{d} \rightarrow \pi^0 np \\ \vec{\gamma}\vec{d} \rightarrow \pi^- pp \\ \vec{\gamma}\,{}^3\vec{He} \rightarrow \pi^0 ppn \end{array}}$$

Experiments with polarised neutrons

n p

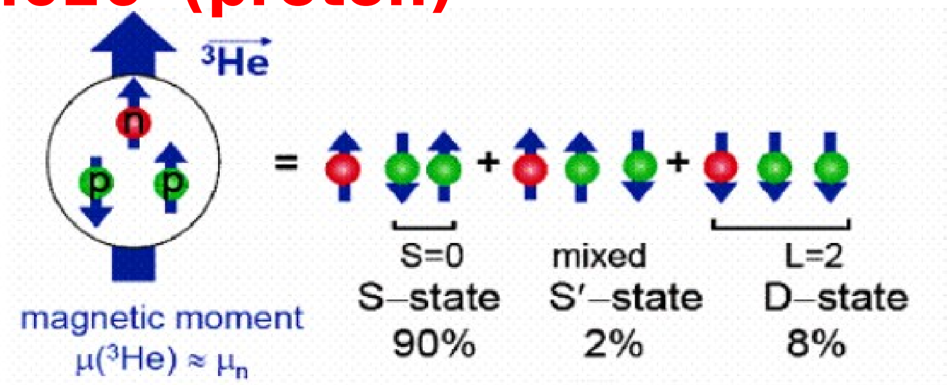
- **^{2}H:** $\mu \sim \mu_p + \mu_n \Rightarrow \uparrow\uparrow$

deuteron ~ 0.93•(neutron)+0.93•(proton)

n p p

^{3}He: $\mu \sim \mu_n \Rightarrow$ $\uparrow\uparrow\downarrow$ (S-state with ~ 90% prob.)

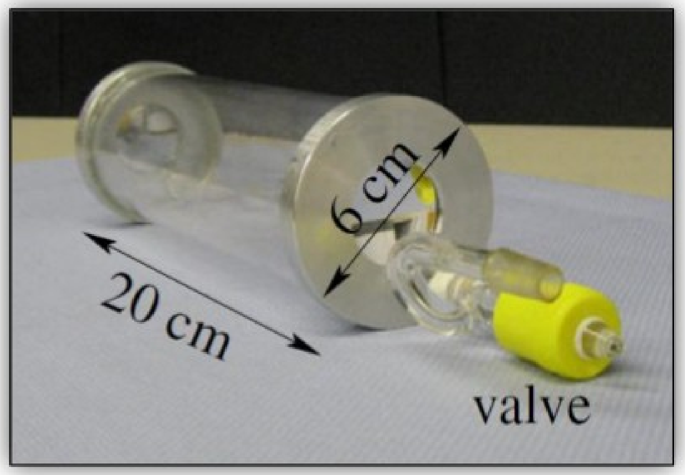
^{3}He ~ 0.87•(neutron)-0.026•(proton)



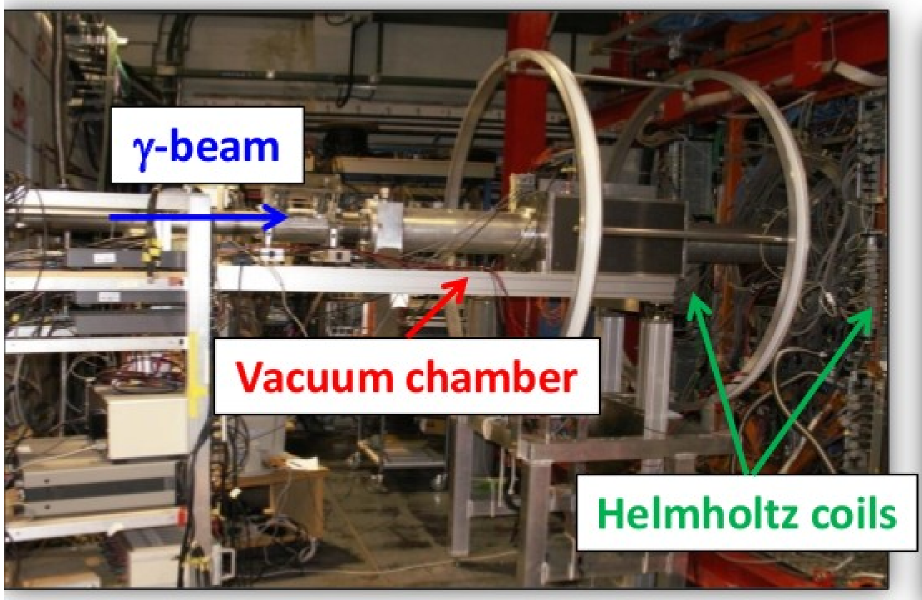
- **Polarised 3He is the best substitute of a free polarised neutron**

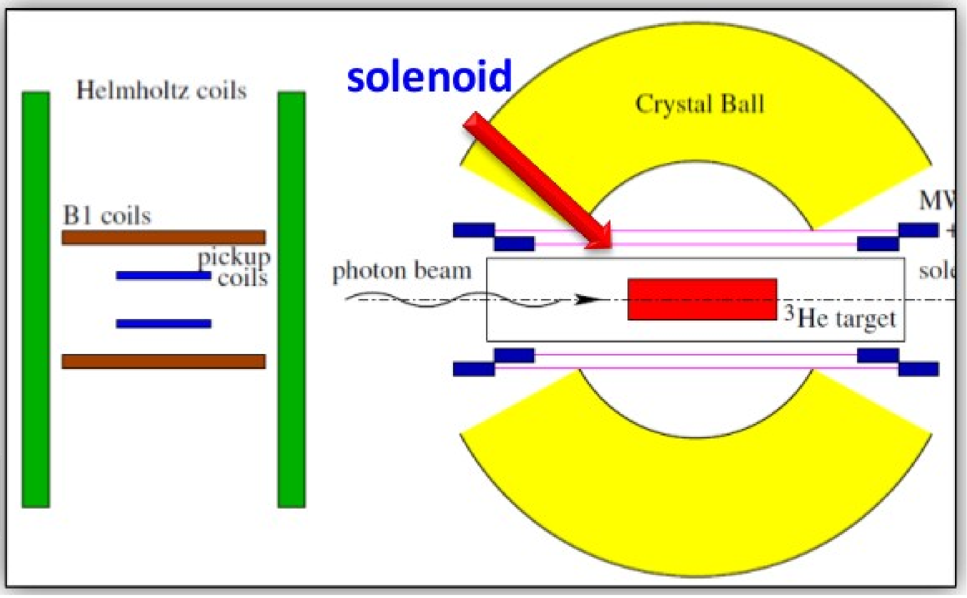
Polarised ^{3}He gas target

- Cylindrical cell **(gas polarised via MEOP)**
  - Length: 20 cm
  - diameter: 6 cm
- Made of quartz glass (thickness: 2 mm)
- Titanium entrance and exit windows (50 μm)
  - provide the necessary gas tightness (4 bar)
  - give long relaxation time (~20 hrs) of the gas polarisation
- ^{3}He polarisation measurements carried out via NMR technique; field provided by Helmholtz coils



in collaboration with PI, Mainz

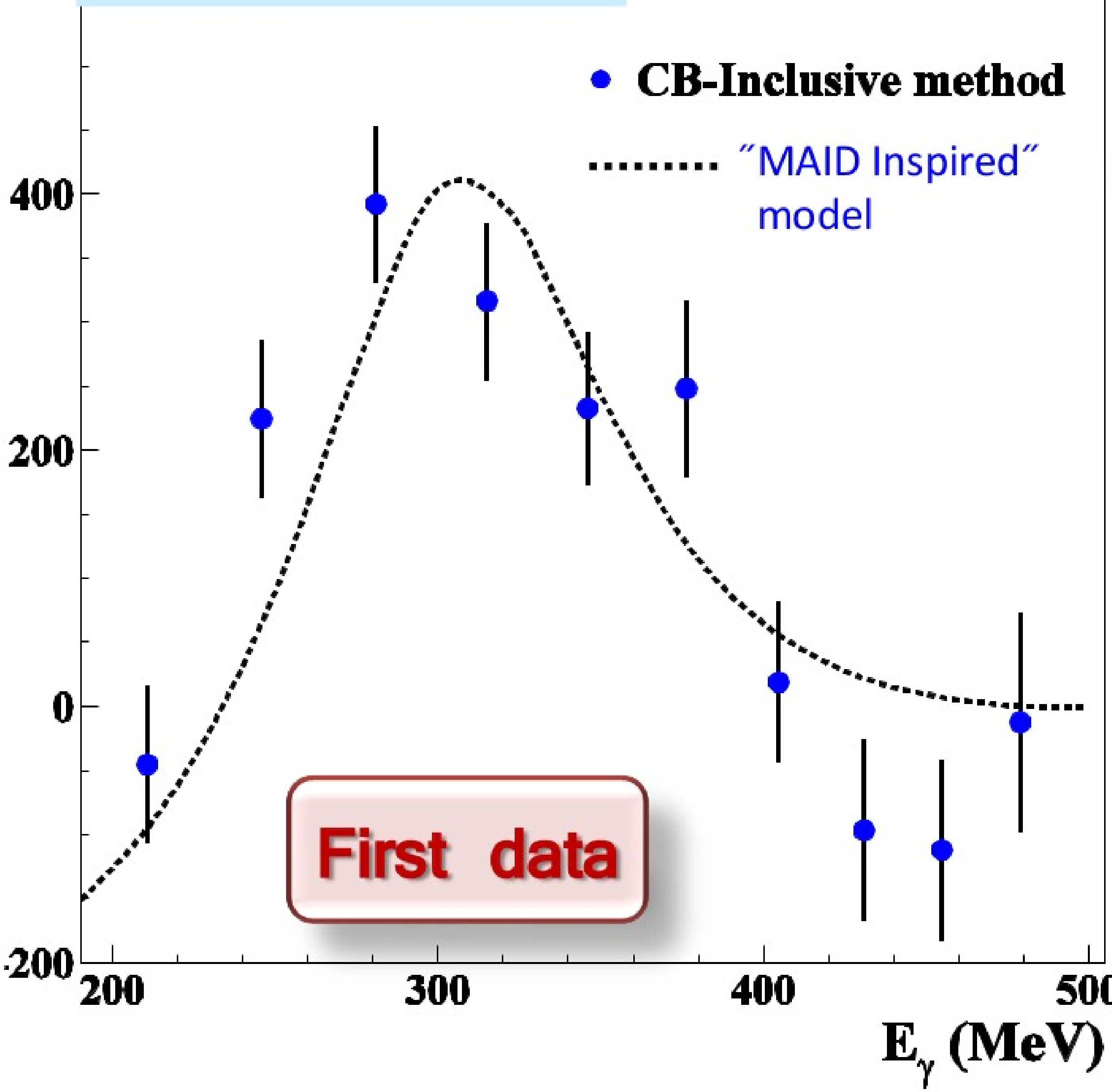




$$\vec{\gamma}\,{}^3\vec{He} \rightarrow X$$

Polarised data

$$\Delta\sigma = \sigma_p - \sigma_a \ (\mu b)$$



"Inclusive" analysis method

(NO partial channel separation)

- Extrapolation from quasi-free pion production and MAID cross sections
- Extrapolation from Schwamb model for ppn

- Extrapolation from quasi-free pion production and MAID cross sections
- **Model: Prediction based on MAID**

$$\boxed{\Delta\sigma = 0.87\cdot\Delta\sigma_n - 0.05\cdot\Delta\sigma_p}$$

Effective nucleon polariz. (due to S/D waves)

CONCLUSIONS

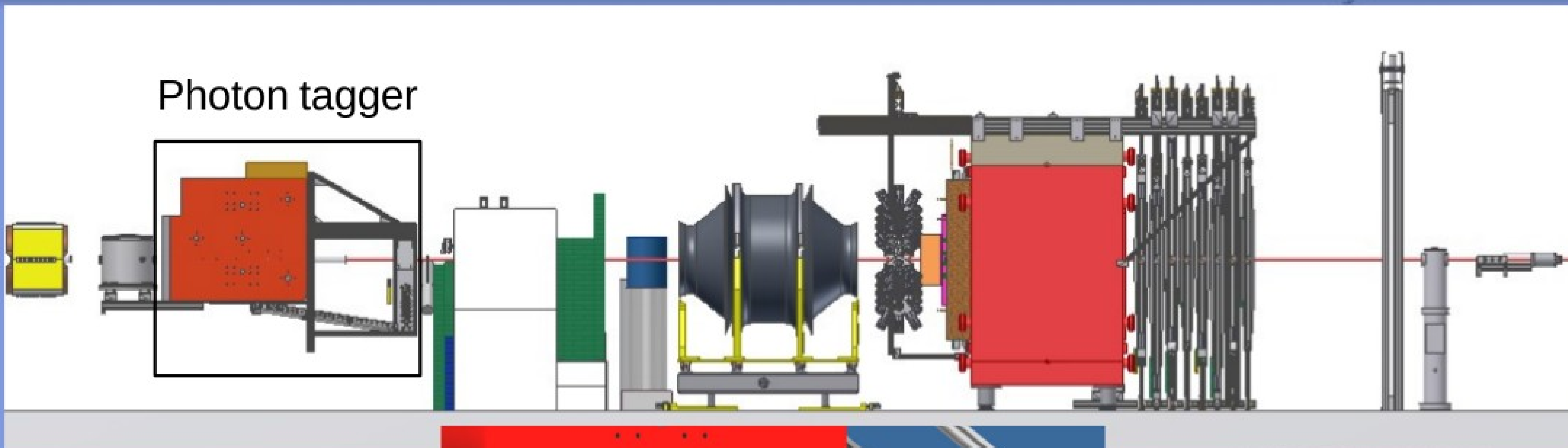
- **CB@MAMI Collaboration** is continuing a very fruitful physics program based on double polarization measurements with a high intensity and high energy resolution tagged beam up to energies of 1.6 GeV

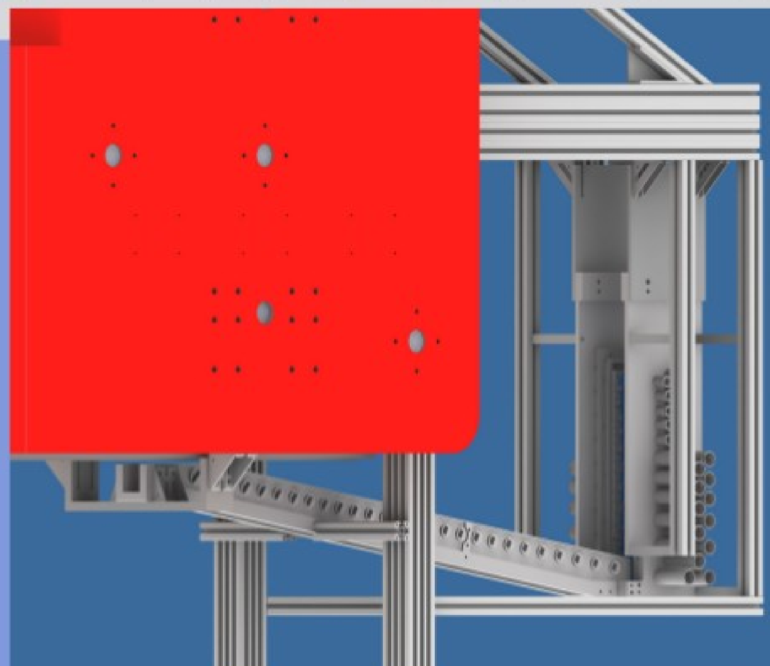
- **BGO-OD Collaboration** has successfully completed its first part of commissioning and will be ready soon to take data in a complementary energy region (up to 2.9 GeV) with a linearly polarized beam and will start an interesting program of scalar, vector and strange meson photoproduction on the proton (first) and on the neutron (after).

THANKS FOR YOUR ATTENTION!

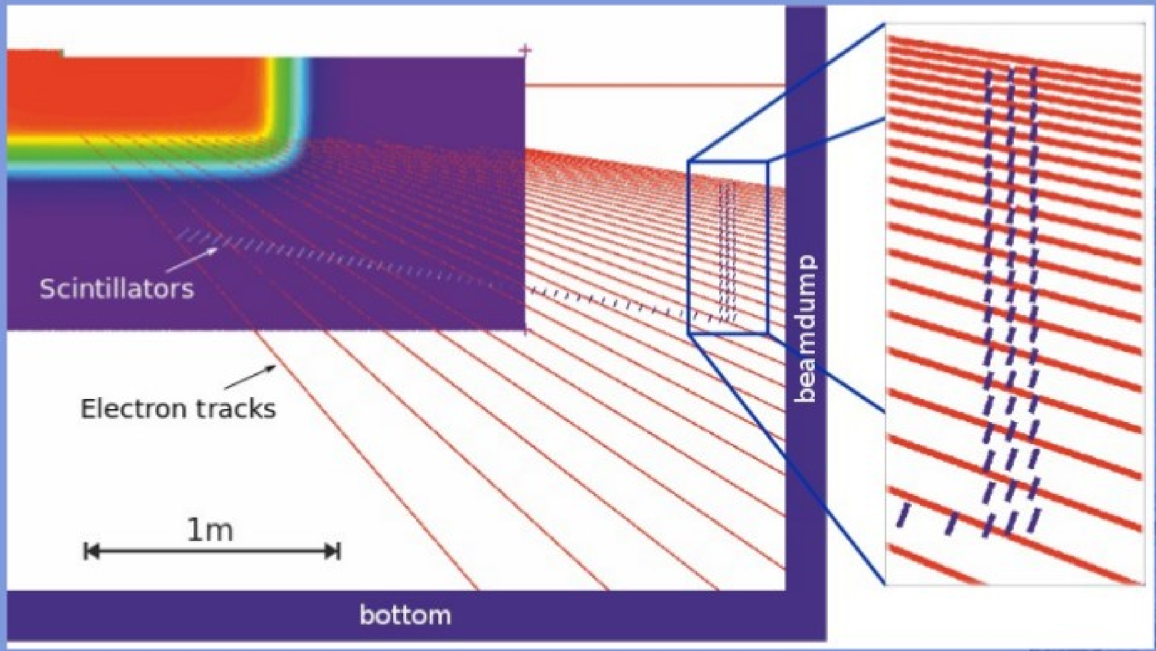
BACKUP SLIDES

BGO-OD Experiment





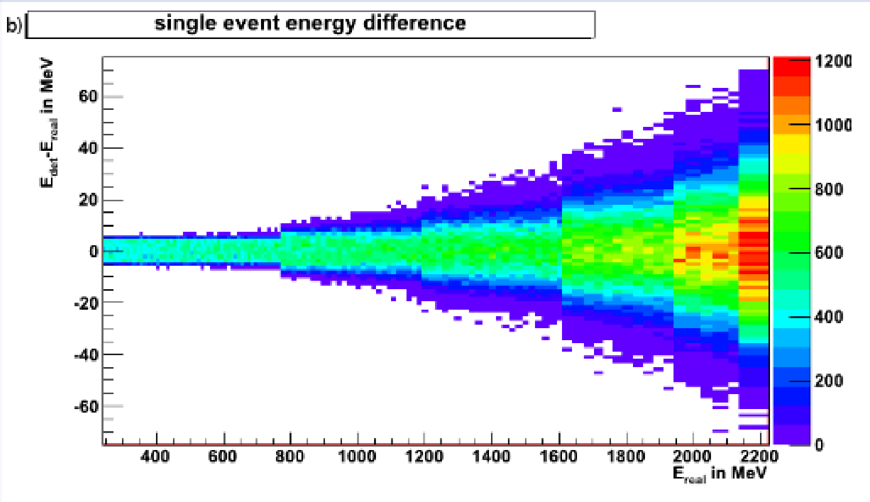
Tagger design

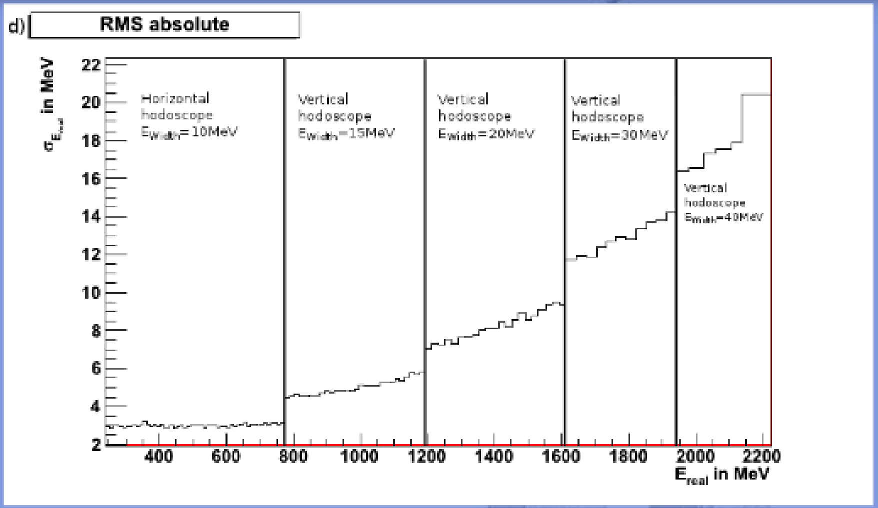


Siebke, G. Design of the BGO-OD Tagging System and Test of a Detector Prototype, Physikalisches Institut Bonn, 2010

- Tagging hodoscope split into horizontal (covers 10-32% E_0) and vertical part (covers 32-90% E_0)
- 120 plastic scintillators (54 horizontal, 66 vertical), adjacent scintillators overlap by 55%, trigger on coincidence

Energy resolution



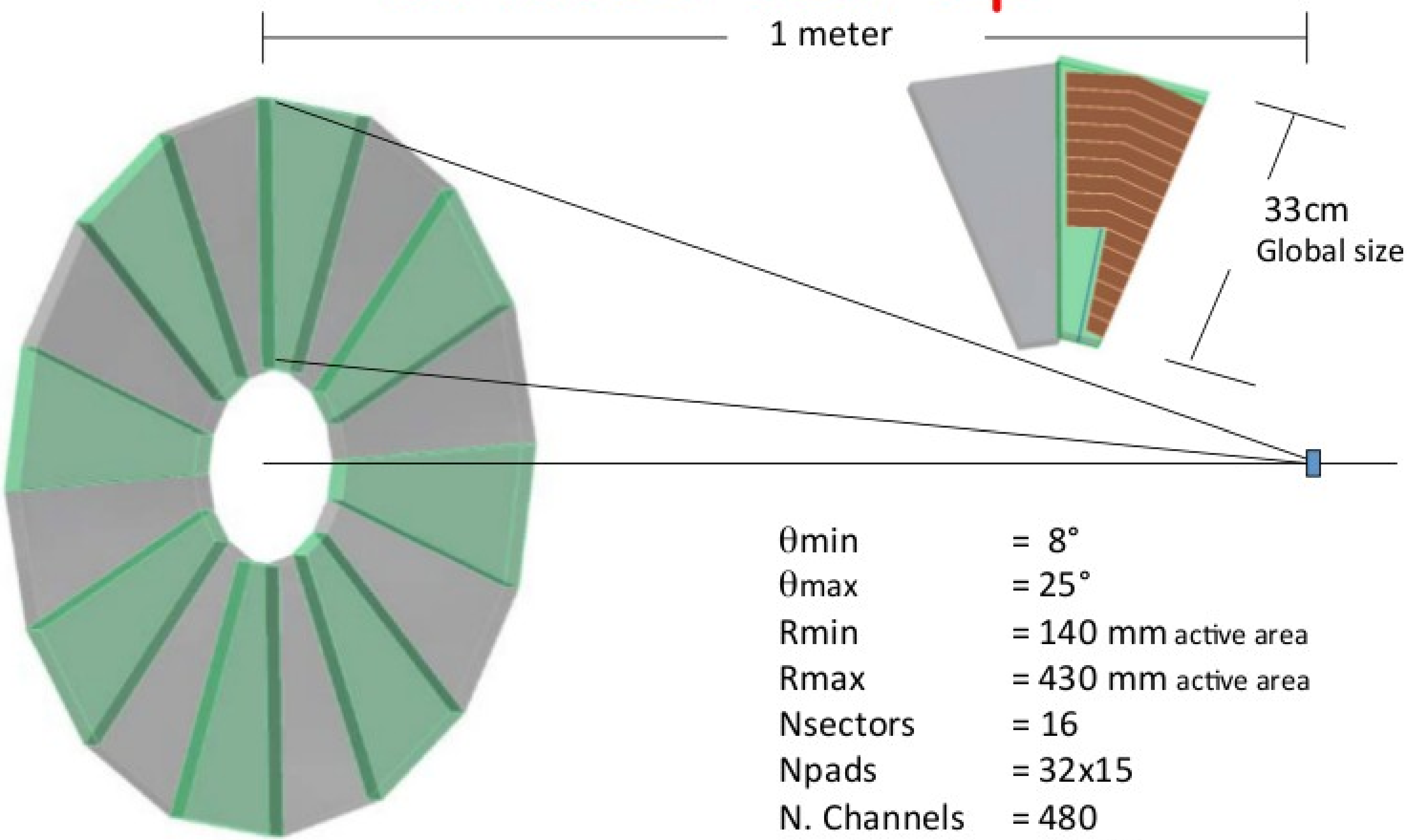


E_0 = 2400 MeV					
Energy range	240 MeV to 768 MeV	768 MeV to 1176 MeV	1176 MeV to 1608 MeV	1608 MeV to 1944 MeV	1944 MeV to 2160 MeV
Energy width	10 MeV	15 MeV	20 MeV	30 MeV	40 MeV
Energy range	10%E_0 to 32%E_0	32%E_0 to 49%E_0	49%E_0 to 67%E_0	67%E_0 to 81%E_0	81%E_0 to 90%E_0
Energy width	0.4% E_0	0.6% E_0	0.8% E_0	1.3% E_0	1.7% E_0

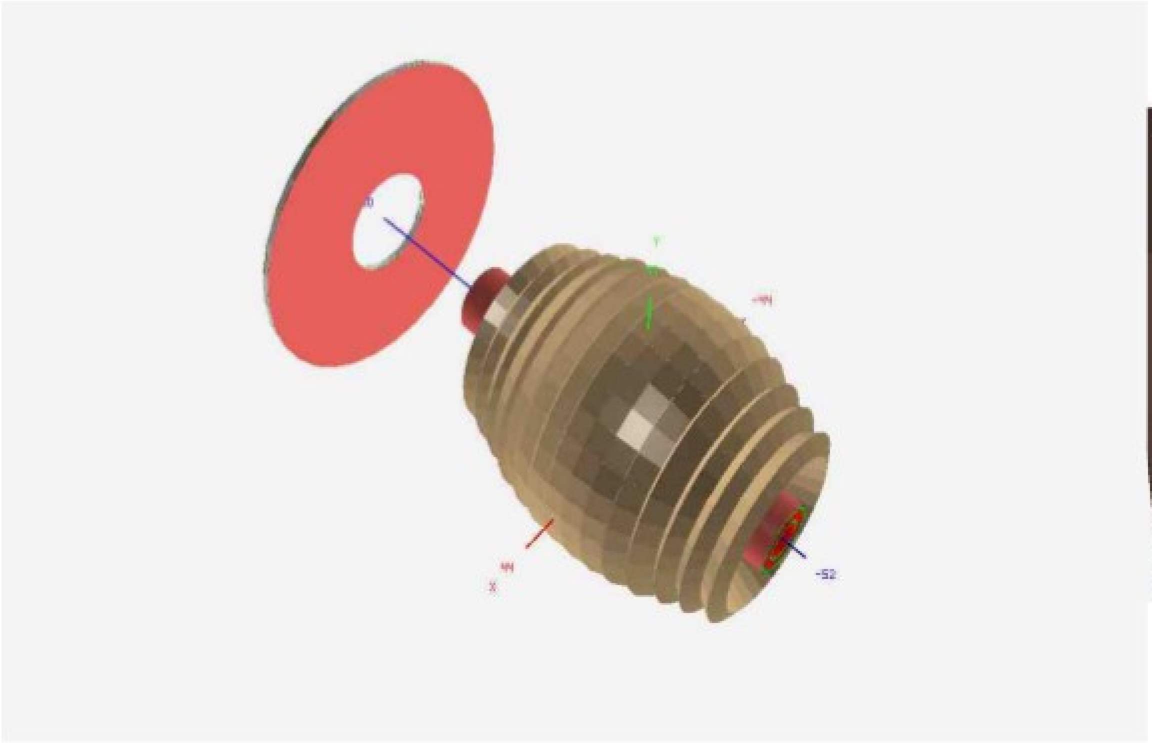
MRPC

(Multigap Resistive Plate Chamber)

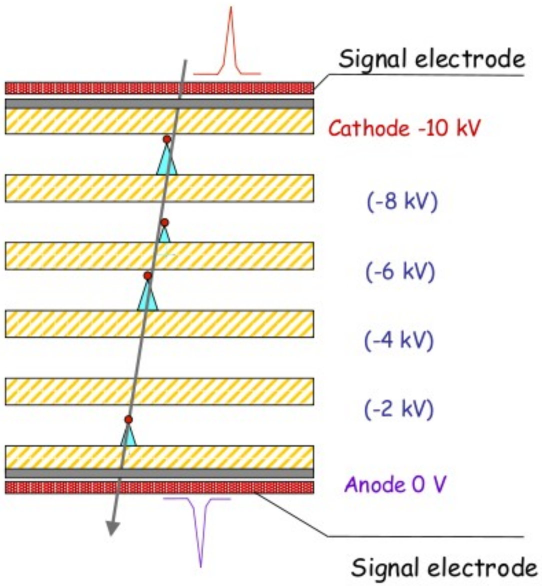
MAMBO Set-Up



MRPC on Geant4 (Thanks to G. Mandaglio)



MRPC working principle



Stack of equally-spaced resistive plates with voltage applied to external surfaces (all internal plates electrically floating)

Pickup electrodes on external surfaces (resistive plates transparent to fast signal)

Internal plates take correct voltage - initially due to electrostatics but kept at correct voltage by flow of electrons and positive ions - feedback principle that dictates equal gain in all gas gaps

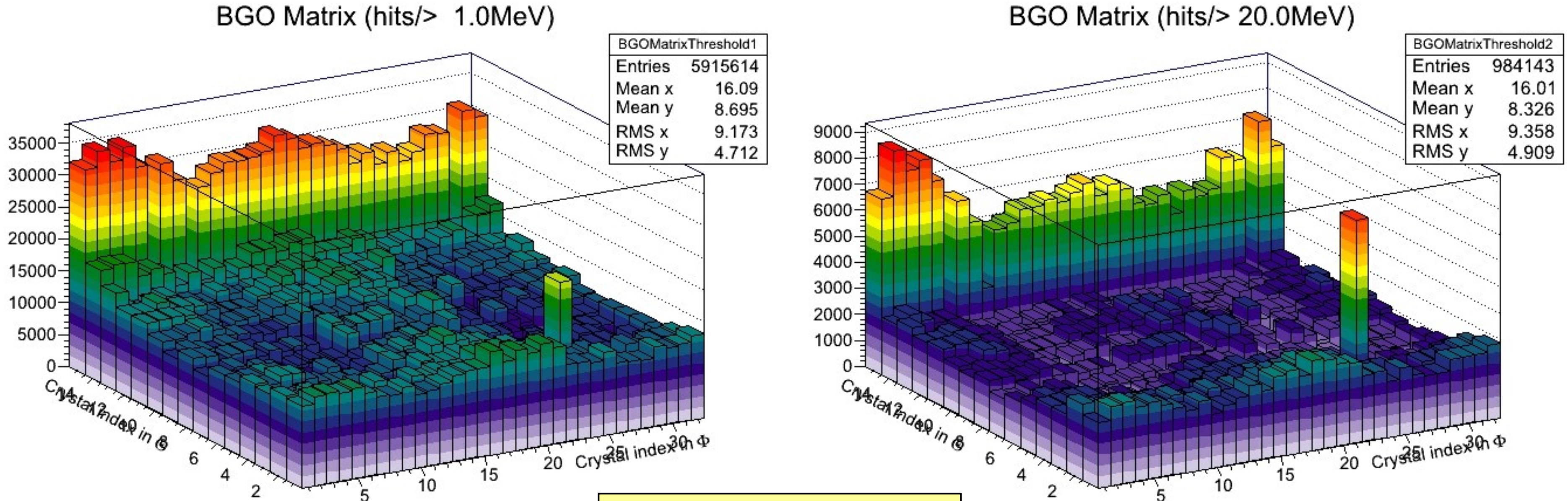
stack

e:

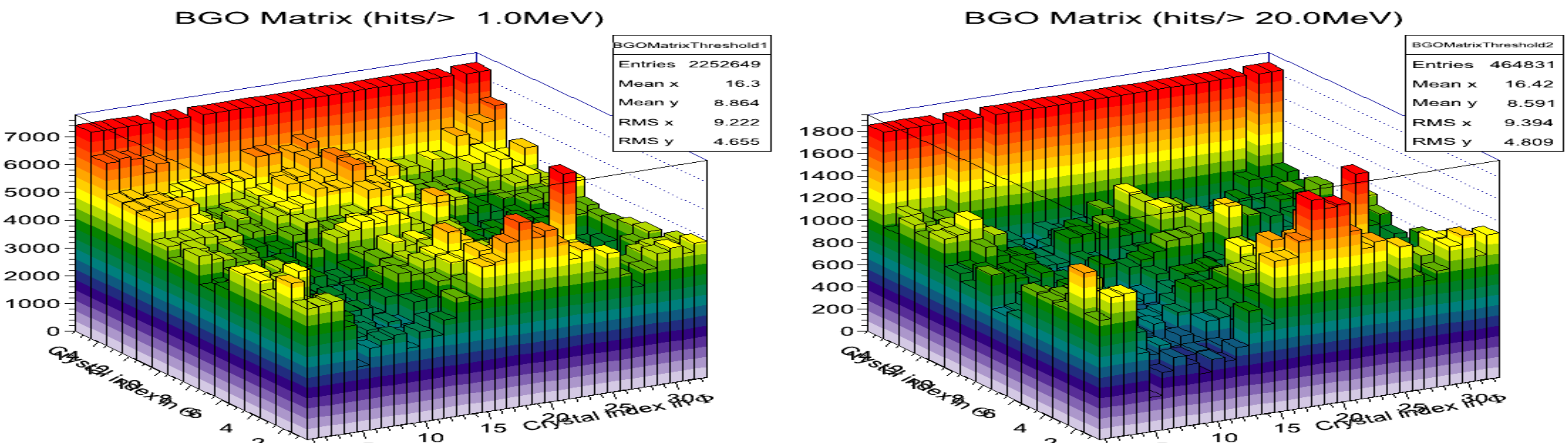
wo stacks

$_2$ + 3 % C_4H_{10} + 1 % SF_6

Honeycomb
Glue
PCB
Mylar
Glass (??)
Fishing Line
Pin
Nino Chip

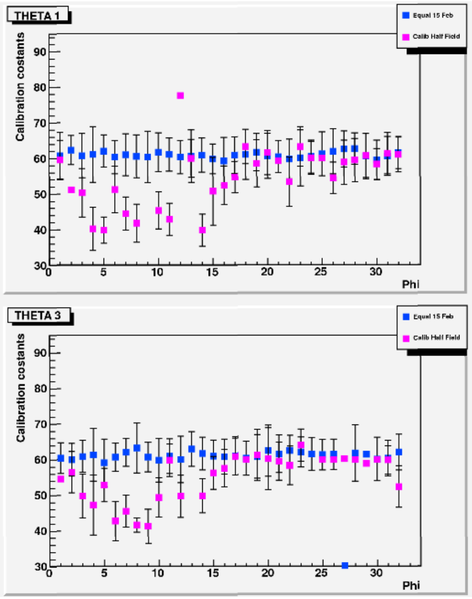


No field

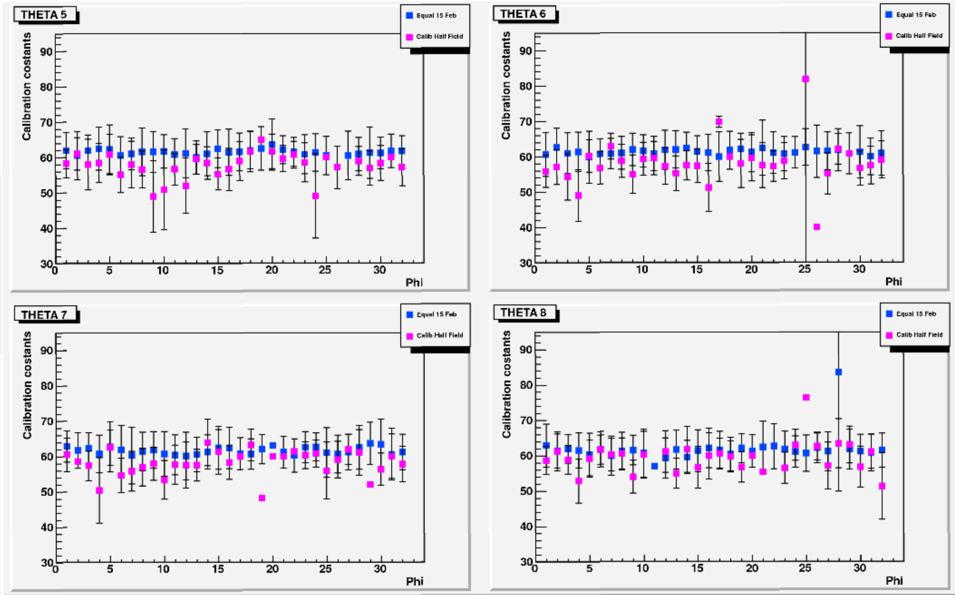


Magnetic field – 0.168 T

FIELD IMPACT ON CALIB. CONSTANTS – 2012, FEB. 15Th – MARCH 2nd : THETA 1÷4

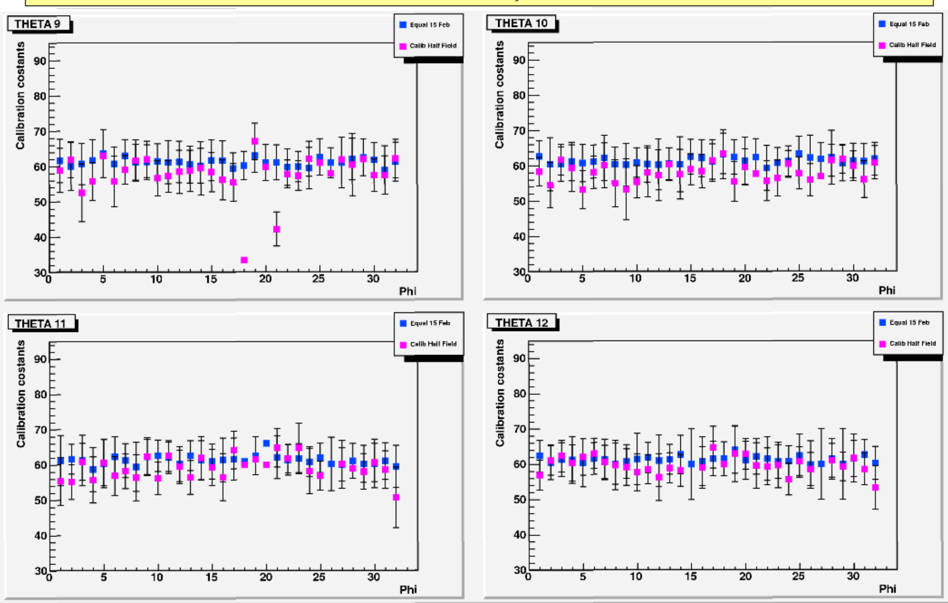


FIELD IMPACT ON CALIB. CONSTANTS – 2012, FEB. 15Th – MARCH 2nd : THETA 5÷8

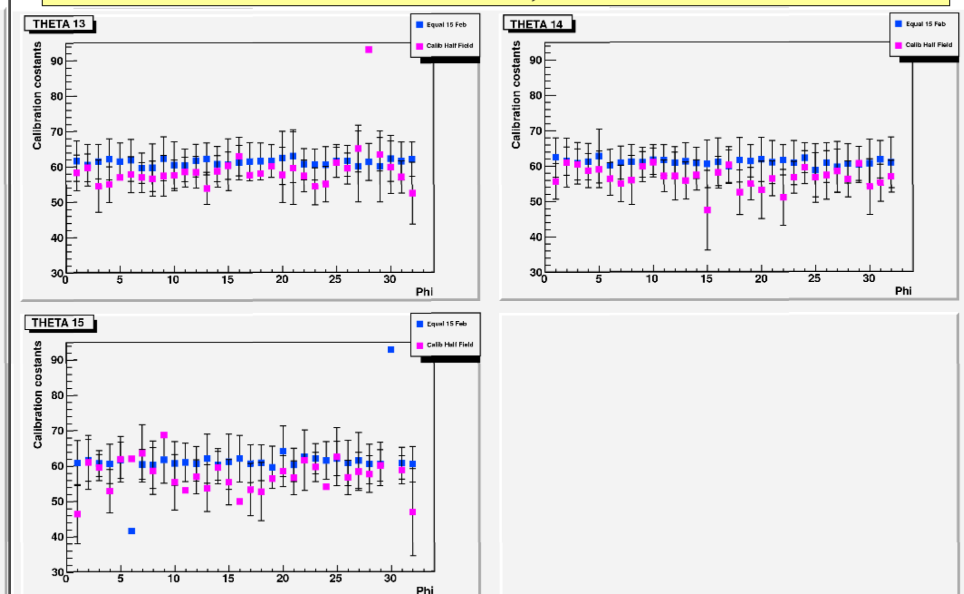


Blue squares: calib. 2012, Feb 15th
Pink squares: calib. 2012, March 2nd magnetic field 0.168 T

FIELD IMPACT ON CALIB. CONSTANTS – 2012, FEB. 15Th – MARCH 2nd : THETA 9÷12



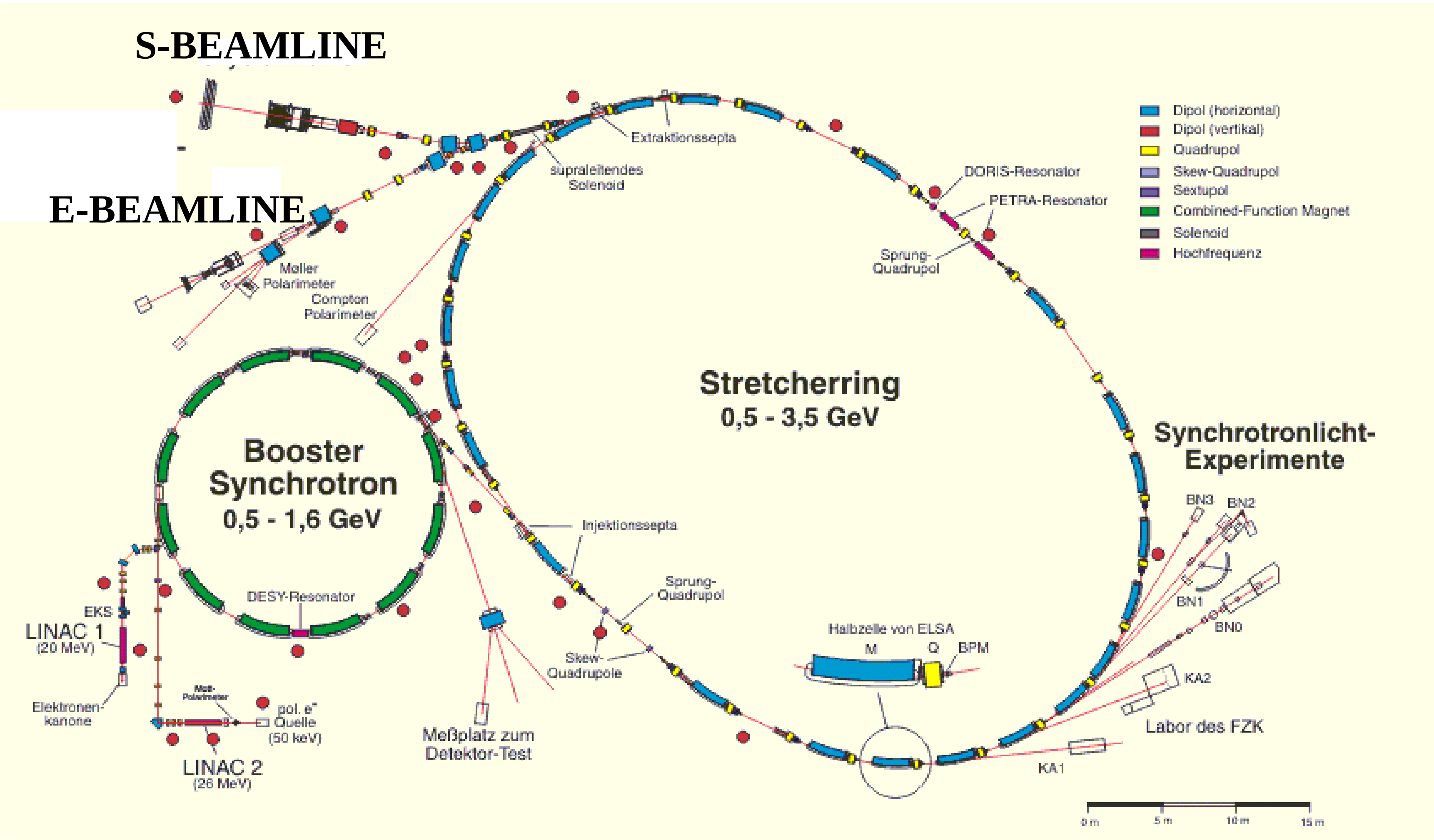
FIELD IMPACT ON CALIB. CONSTANTS – 2012, FEB. 15Th – MARCH 2nd : THETA 13÷15



Blue squares: calib. 2012, Feb 15th
Pink squares: calib. 2012, March 2nd magnetic field 0.168 T

Francesca Curciarello – Veronica De Leo

ELectron Stretcher and Accelerator (ELSA)



The GDH sum rule

- Proposed in 1966 by Gerasimov-Drell-Hearn
- Prediction on the absorption of circularly polarized photons by longitudinally polarized nucleons/nuclei

spin

$$I_{GDH} = \int_{\nu_{thr}}^{\infty} \frac{\sigma_p(E_\gamma) - \sigma_a(E_\gamma)}{\nu}\, d\nu = 4\pi^2 S \frac{e^2}{M^2} k^2$$

Anomalous magnetic moment

$$\nu_{thr} = \begin{cases} \pi \text{ production threshold (nucleon)} \\ \text{photodisintegration threshold (nuclei)} \end{cases}$$

GDH sum rule:

✓ Fundamental check of our knowledge of the γN interaction

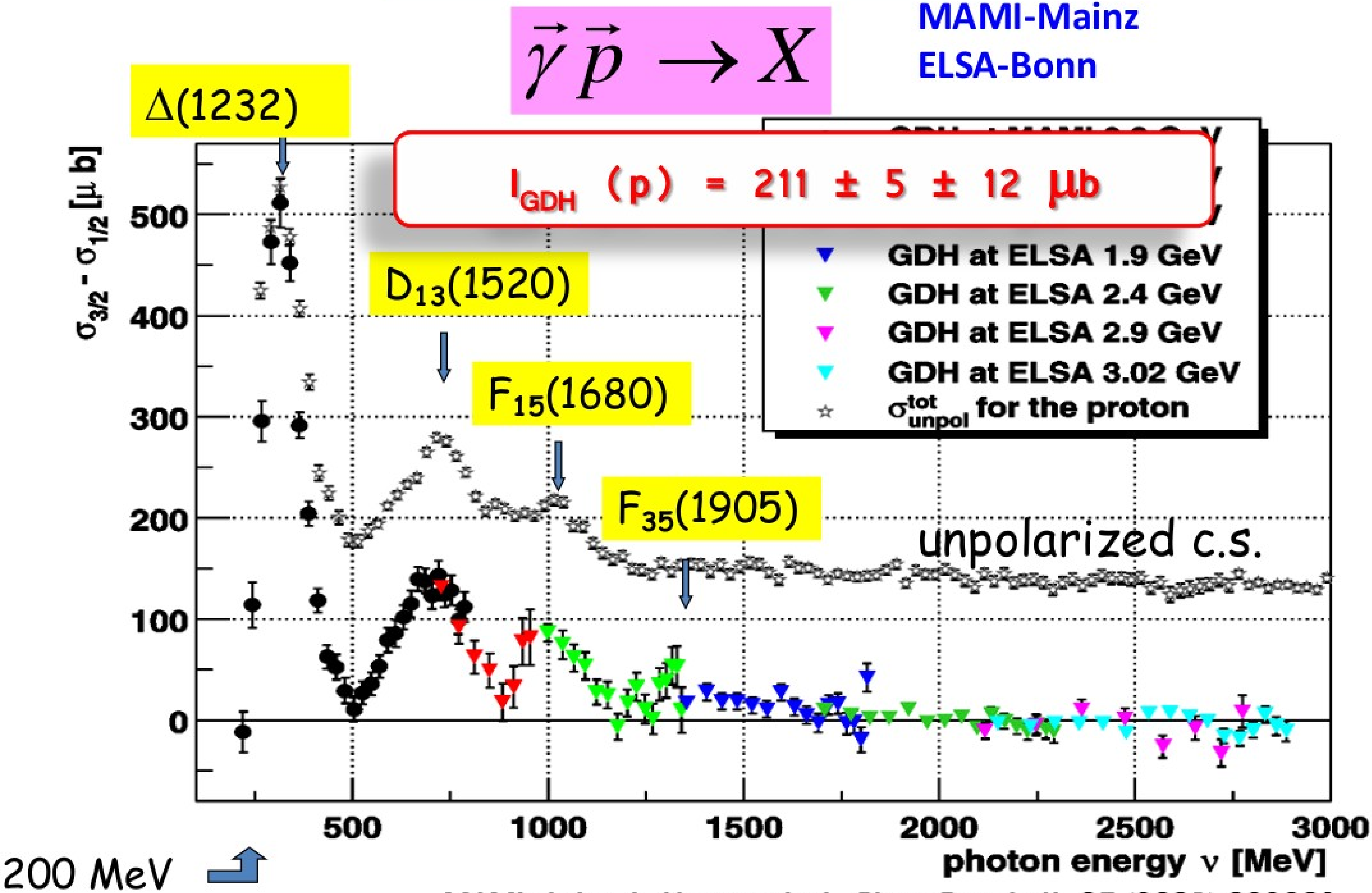
The only "weak" hypothesis is the assumption that **Compton scattering $\gamma N \rightarrow \gamma' N'$ becomes spin independent when $\nu \rightarrow \infty$** *A violation of this assumption can not be easily explained*

✓ Important comparison for photoreaction models

✓ Helicity dependence of partial channels (pion photoproduction) is an essential tool for the study of the baryon resonances (interference terms between different electromagnetic multipoles)

✓ Valid for any system with $\mathbf{k} \neq 0$ (^{2}H, ^{3}He) . "Link" between nuclear and nucleon degrees of freedom

Experimental status



MAMI data: J. Ahrens et al., Phys. Rev. Lett. 87 (2001) 022003
ELSA data: H. Dutz et al., Phys. Rev. Lett 91 (2003) 192001
H. Dutz et al., Phys. Rev. Lett 93 (2004) 032003

GDH sum rule: predictions

Proton	I_{GDH} (μb)	Neutron	I_{GDH} (μb)
$\gamma\, p \rightarrow N\pi$	172 [164]	$\gamma\, n \rightarrow N\pi$	147 [131]
$\gamma\, p \rightarrow N\pi\pi$	94	$\gamma\, n \rightarrow N\pi\pi$	82
$\gamma\, p \rightarrow N\eta$	-8	$\gamma\, n \rightarrow N\eta$	-6
$\gamma\, p \rightarrow K\Lambda\,(\Sigma)$	-4	$\gamma\, n \rightarrow K\,\Lambda(\Sigma)$	2
$\gamma\, p \rightarrow N\rho(\omega)$	0	$\gamma\, n \rightarrow N\rho(\omega)$	2
Regge contrib. (E_γ > 2 Gev)	-14	Regge contrib. (E_γ > 2 Gev)	20
TOTAL	239 [231]	TOTAL	244 [231]
GDH	205	GDH	233

$N\pi$: SAID-FA07K [MAID07] $K\Lambda(\Sigma)$: Sumowidagdo et al., PRC 65,0321002 (02)

$N\eta$: MAID $N\pi\pi$: Fix, Arenhoevel EPJA 25, 114 (2005)

$N\rho$: Zhao et al., PRC 65, 032201 (03) Regge : Bianchi-Thomas , PLB 450,439(99)

First measurement of the F observable

- **γ p -> pπ⁰ channel**

- Circular polarized photon beam
- Transverse polarized target

- **Photon Energy range : 420 -1020 MeV**

$$\frac{d\sigma}{d\Omega}\Big|_{POLAR} = \frac{d\sigma}{d\Omega}\Big|_{UNPOL} \cdot \Big[1 - p^{\gamma}_{lin}\,\Sigma\cos(2\phi)$$

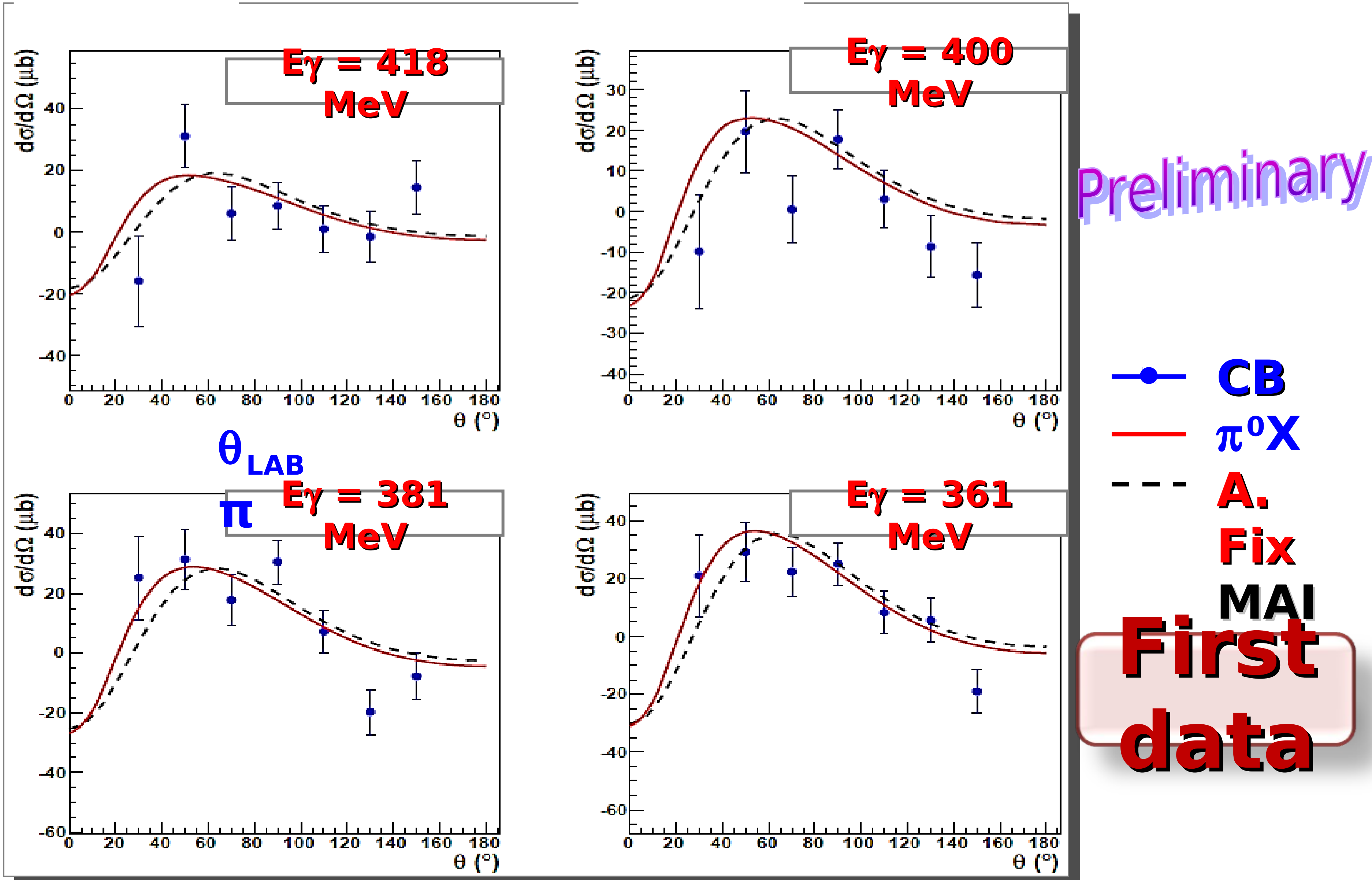
$$- p^{T}_{x}\, p^{\gamma}_{lin}\, H \sin(2\phi) + p^{T}_{x}\, p^{\gamma}_{circ}\, F$$

$$- p^{T}_{y}\, T - p^{T}_{x}\, p^{\gamma}_{lin}\, P\cos(2\phi)$$

$$- p^{T}_{z}\, p^{\gamma}_{lin}\, G \sin(2\phi) + p^{T}_{z}\, p^{\gamma}_{circ}\, E \Big]$$

$$\vec{\gamma}\,{}^3\vec{He} \to \pi^0 X$$

Differential polarised cross section



$\vec{\gamma}\,{}^3\vec{H}e \rightarrow \pi^{\pm} X$

Differential polarised cross section

Eγ = 418 MeV

Eγ = 400 MeV

Preliminary

CB

π^0X

A. Fix

MAID

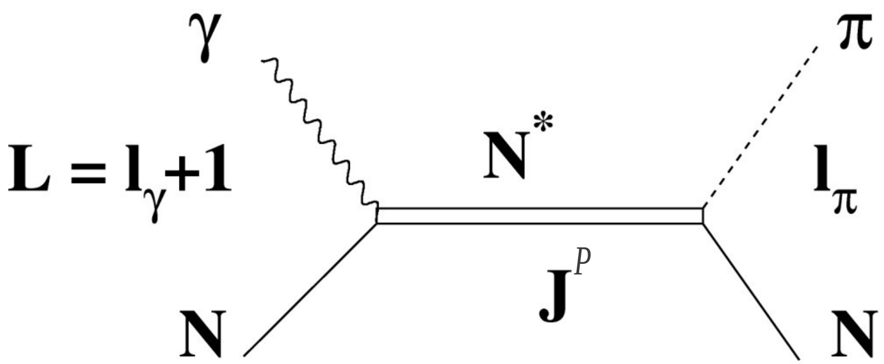
θ_{LAB} π

Eγ = 381 MeV

Eγ = 361 MeV

First data

Connection between resonances and multipoles



$$X_{2I2J}$$

isospin

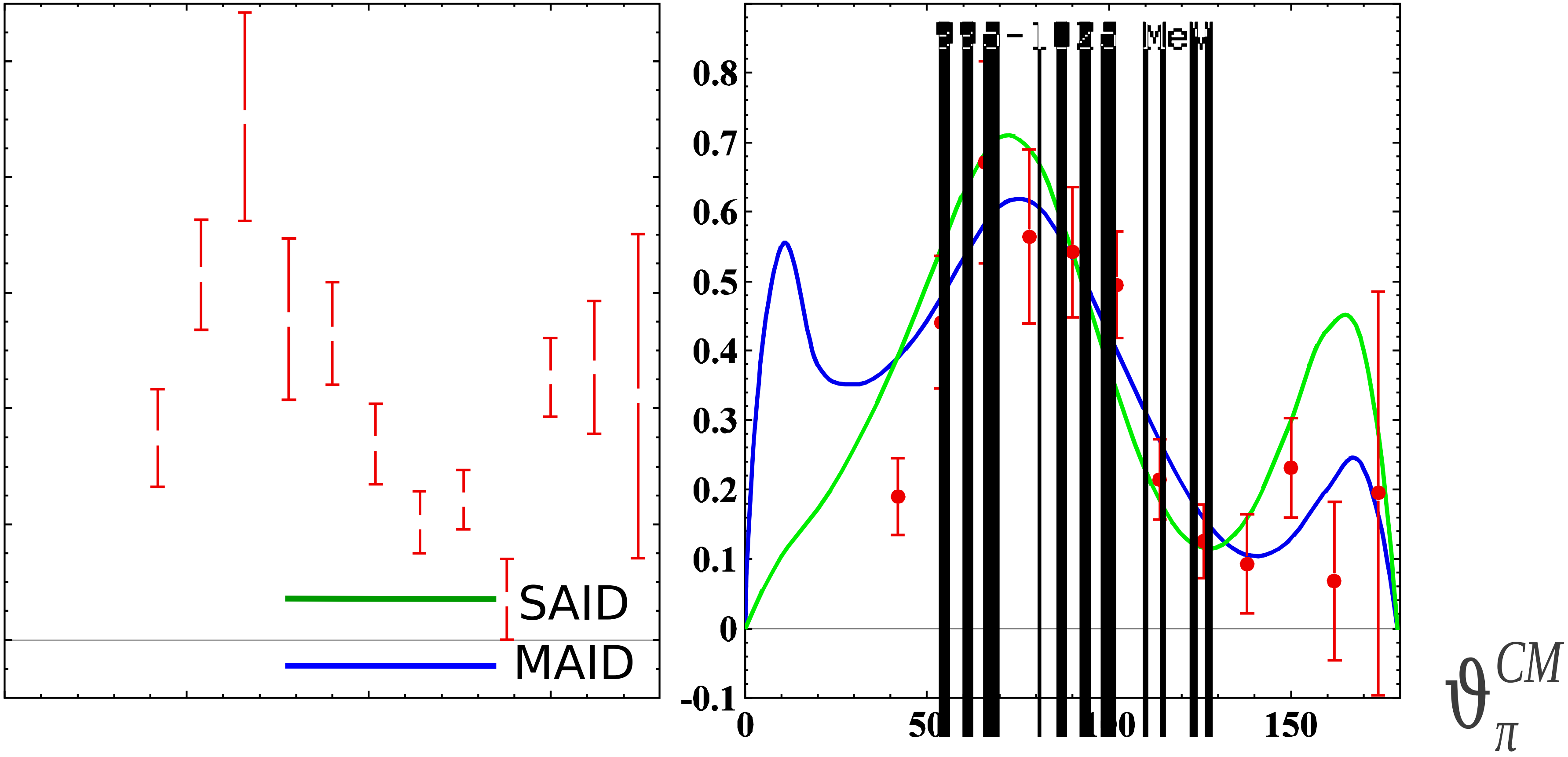
spectroscopic notation

$$X = S(l_\pi = 0); P(l_\pi = 1); \ldots$$

Photon L	Photon Multipole	J	P	Pion l_π	Pion Multipole	Resonance
1	E1	1/2	-	0	E_{0+}	S_{11}
		3/2	-	2	E_{2-}	D_{13}
	M1	1/2	+	1	M_{1-}	P_{11}
		3/2	+	1	M_{1+}	P_{33}
2	E2	3/2	+	1	E_{1+}	P_{33}
		5/2	+	3	E_{3-}	F_{15}
	M2	3/2	-	2	M_{2-}	D_{13}
		5/2	-	2	M_{2+}	D_{15}

F Asymmetry

$\gamma p \rightarrow p\pi^0$

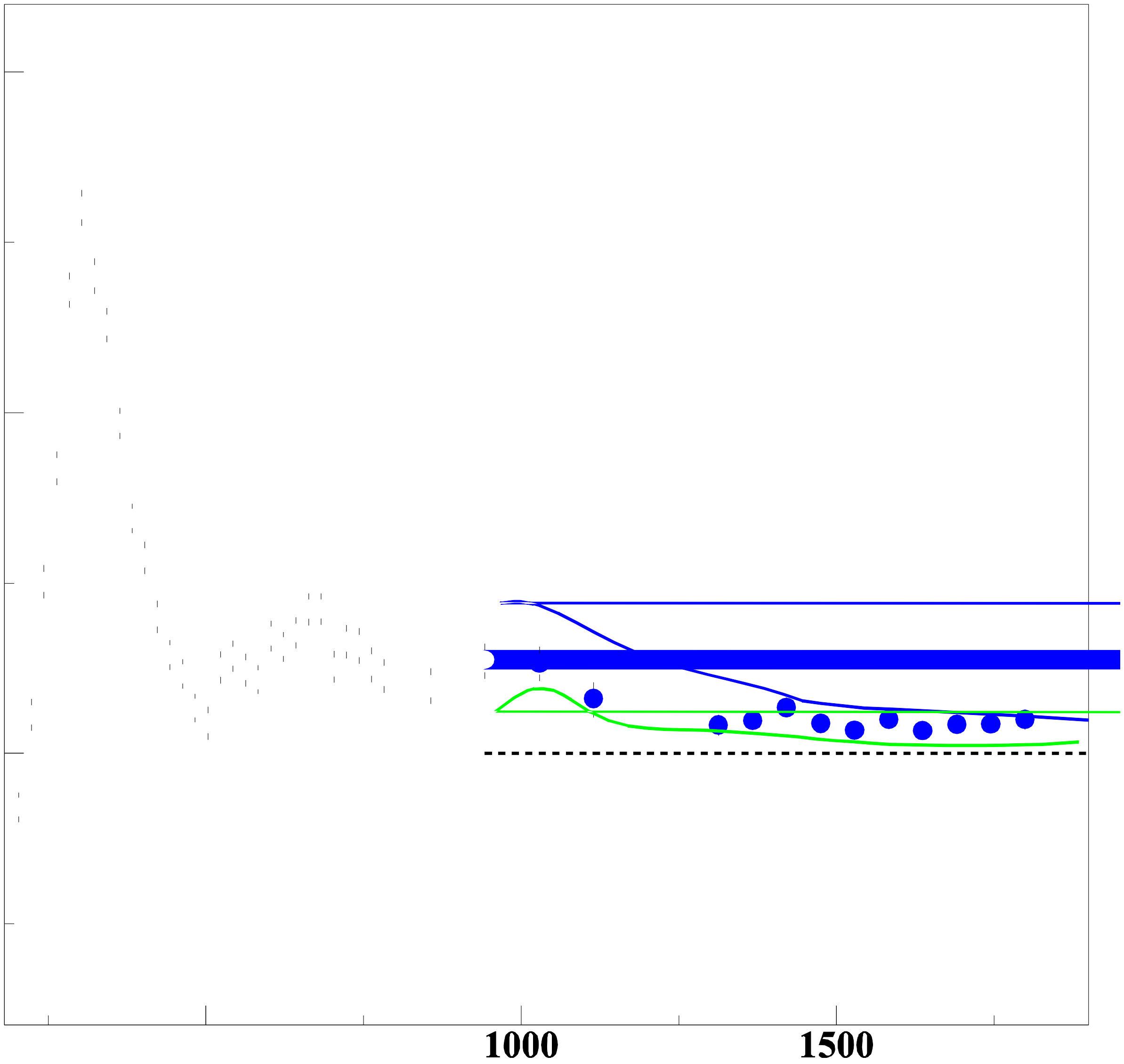


Main contribution due to F_{15}(1680) excitation

- **VERY Preliminary**
- **ONLY statistcal errors**

Data from V.Kashevarov

Status of the deuteron results



$\vec{\gamma}\,\vec{d} \rightarrow X$

AFS model from Ahrenhoevel, Fix and Schwamb

^{3}He Experimental set-up

- **Facility**

  tagged photon facility of the MAMI accelerator in Mainz

- **Beam**

  circularly polarised photons produced by bremsstrahlung of longitudinally polarised electrons

  $E_{electron} = 525$ MeV

  $150 < E_\gamma < 500$ MeV

- **Target**

  Polarised ^{3}He gas

  First feasibility test

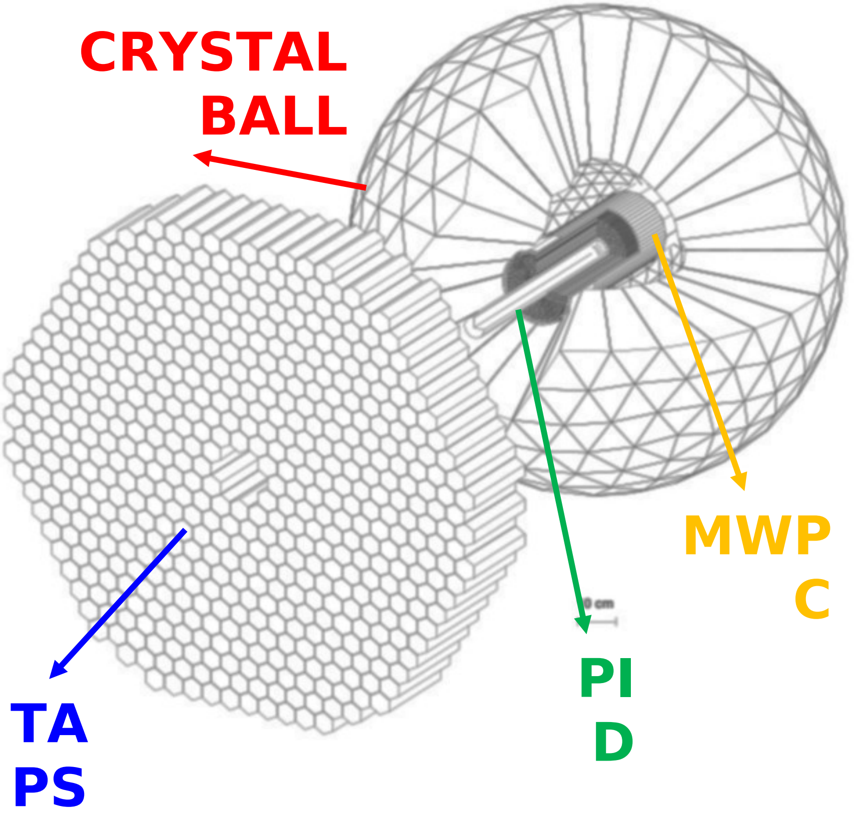
- **Detector**

  the large acceptance (93

  Crystal Ball (CB) photon

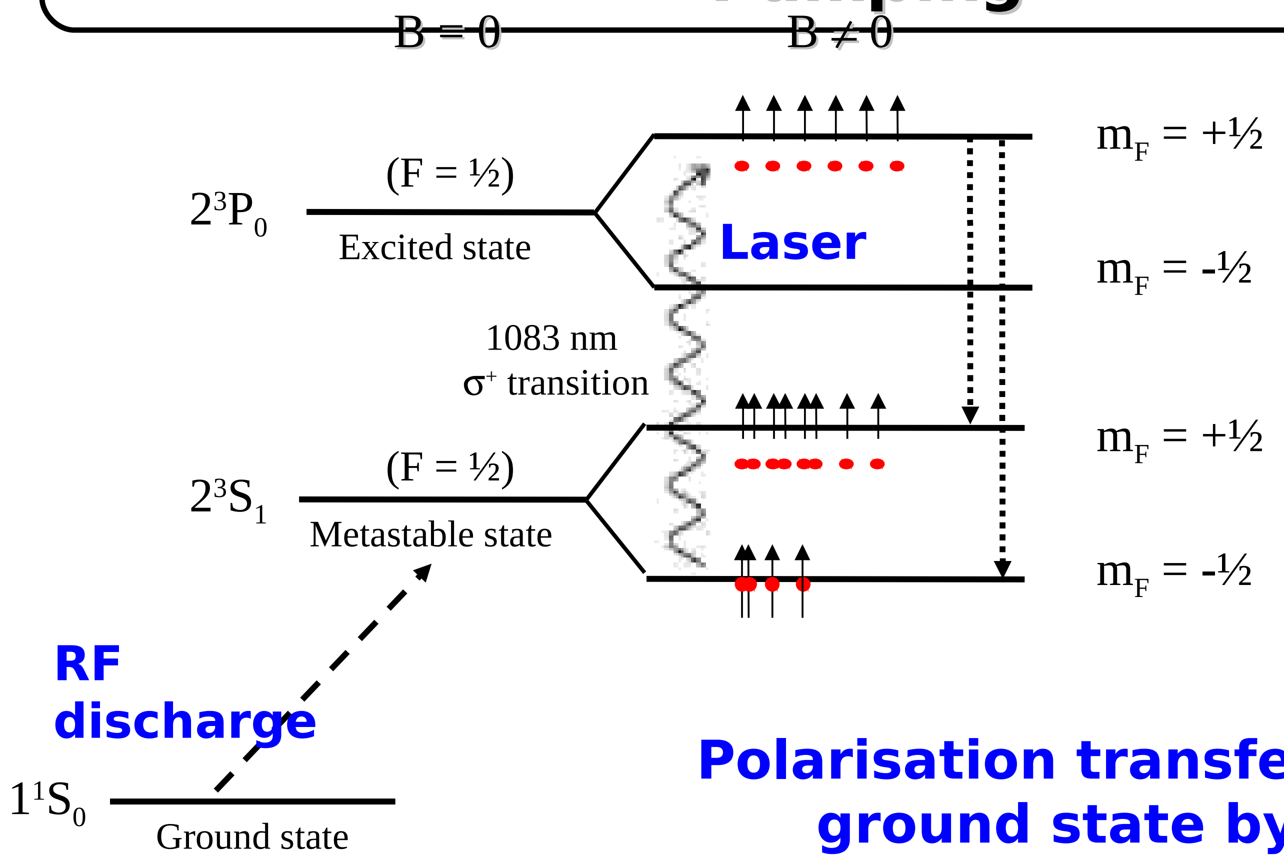
  spectrometer in combin

  with the TAPS detector



³He polarisation

MEOP: Metastability Exchange Optical Pumping



Simplified !

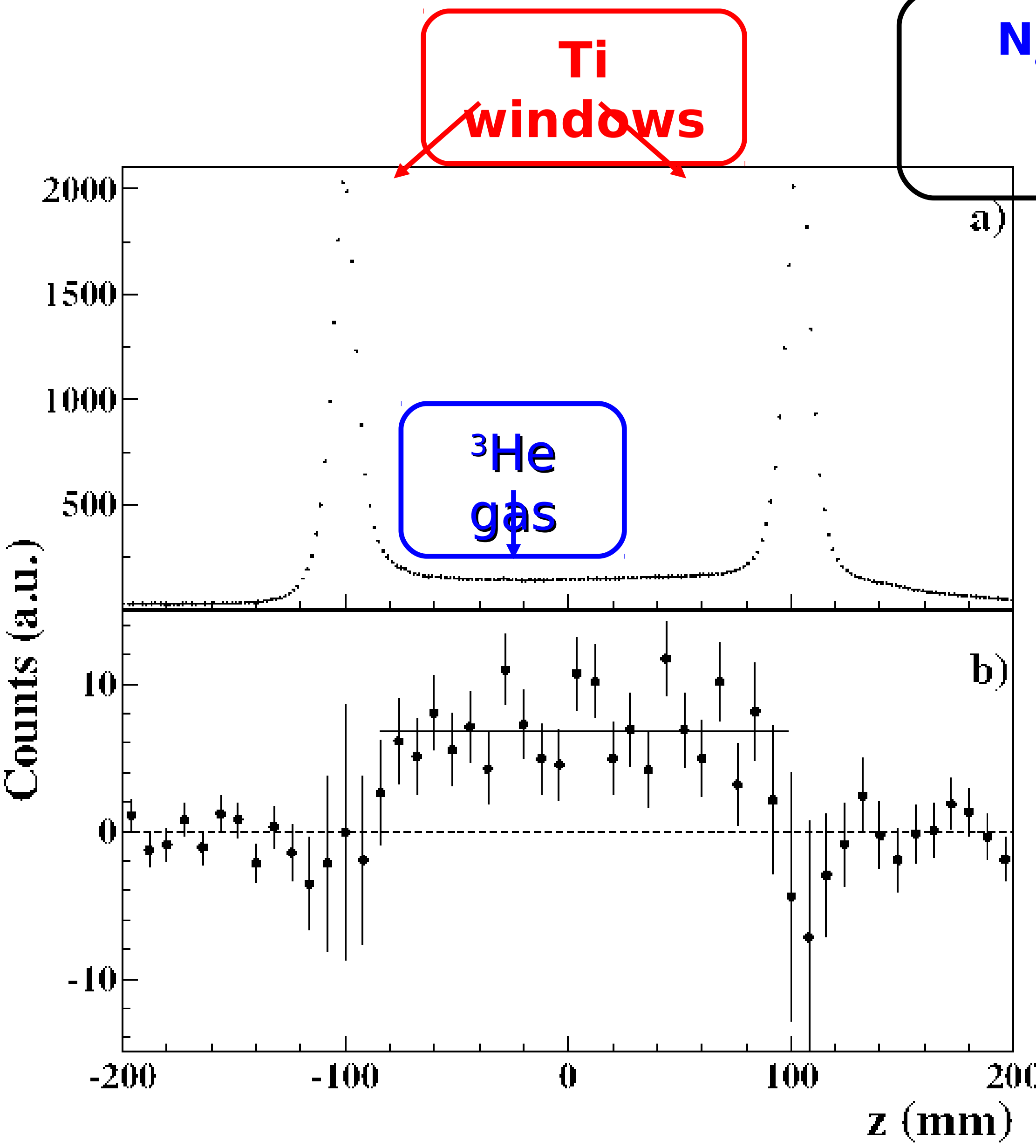
Polarisation transfer to the ³He ground state by atomic collisions

$$ {}^3\vec{H}e\left(2^3S_1\right) + {}^3He\left(1^1S_0\right) \rightarrow {}^3He\left(2^3S_1\right) + {}^3\vec{H}e\left(1^1S_0\right) $$

J.Krimmer et al., NIMA 648,
35 (2011)

Charged Particle Z-Vertex from MWPCs

$N_{atoms} \sim 10^{21}/cm^2 \rightarrow \sim 10^2$ times less than in a solid/liquid target



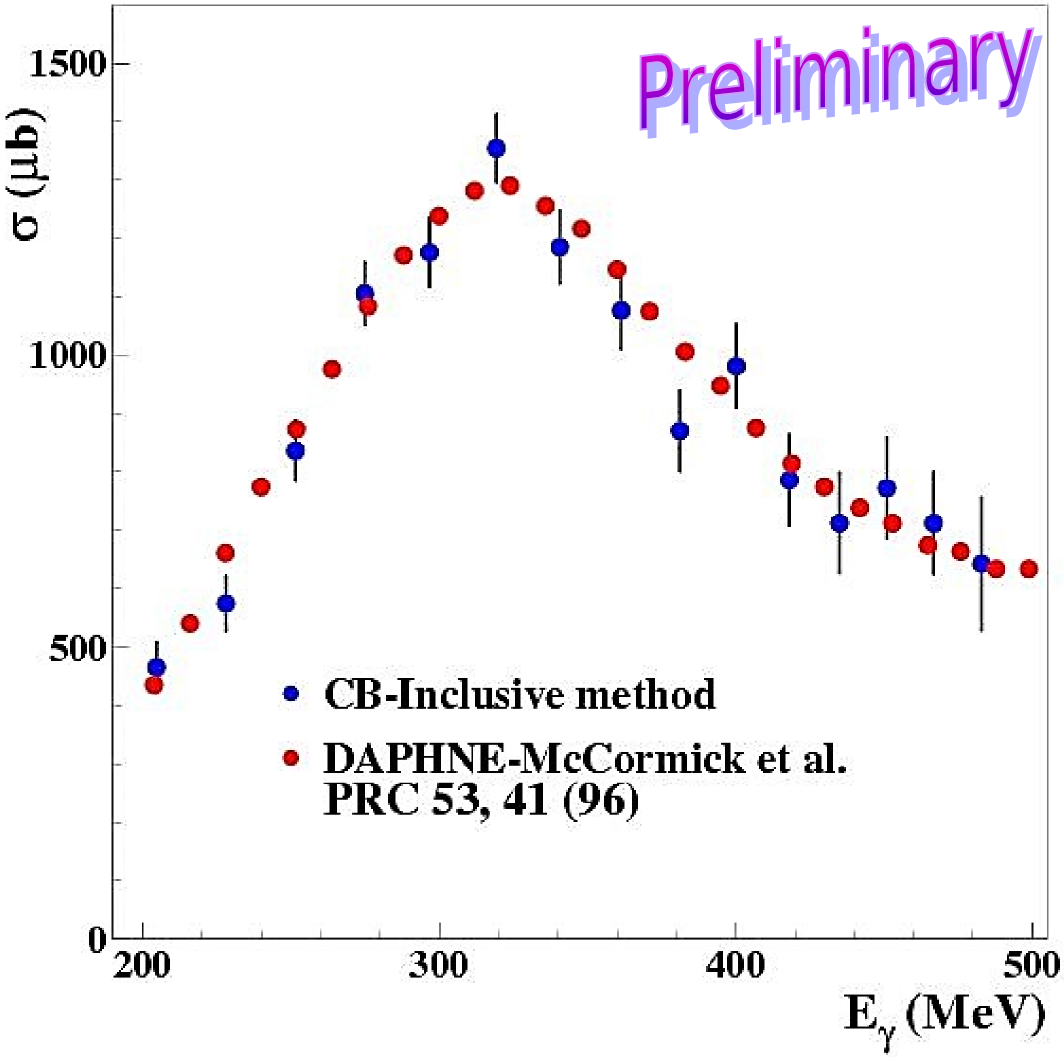
All charged particle events

(P-A) difference

$\gamma\, ^3He \rightarrow X$

Unpolarised data

"Inclusive" analysis method



(NO partial channel separation)

Only hadron counting and empty target subtraction

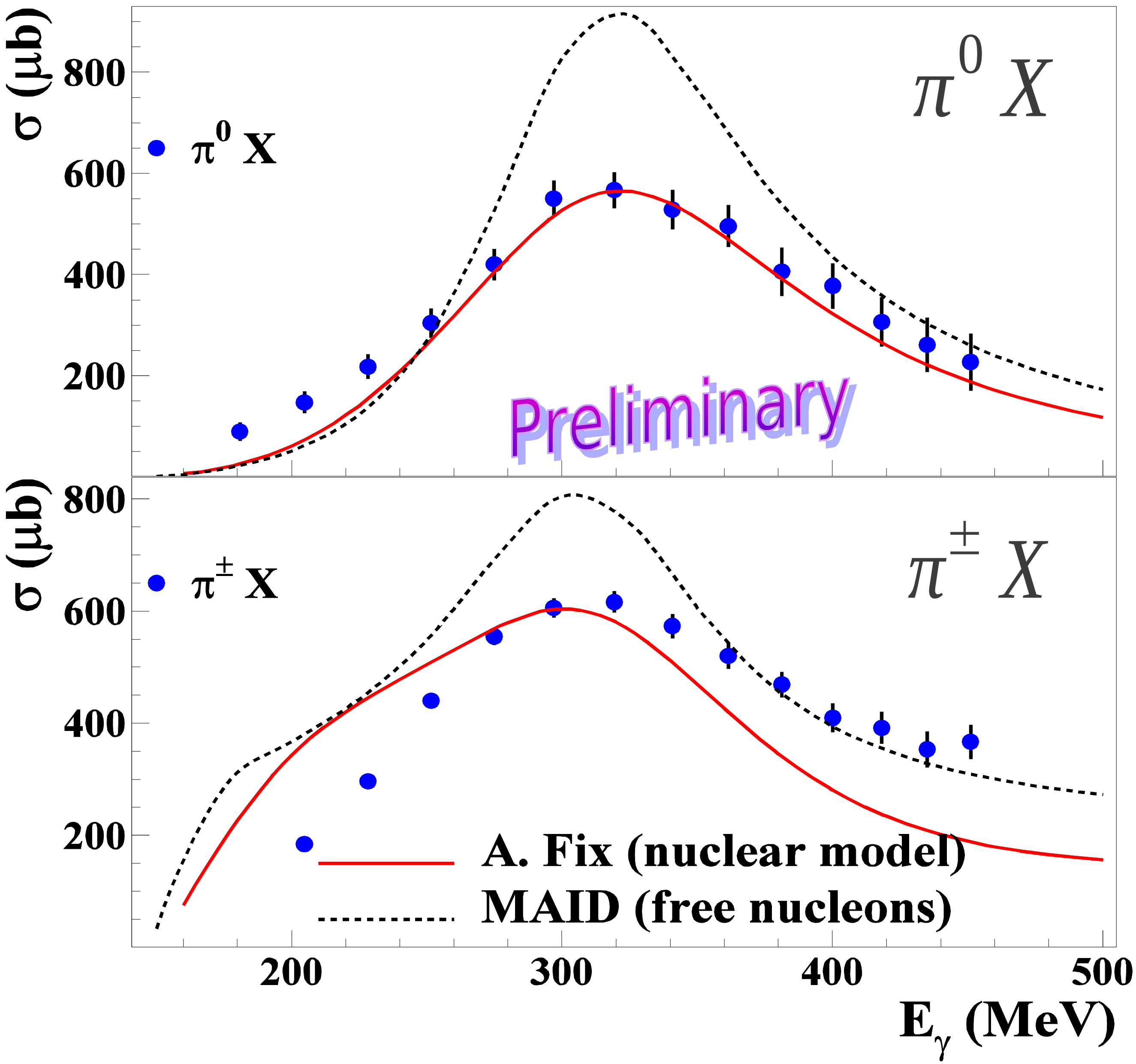
- Extrapolation from quasi-free pion production and MAID cross sections
- Extrapolation from Schwamb model for ppn

Data from CB detector ONLY

Overall Extrapolation is about 5% of the measured yields

Good agreement with previous data

$\gamma\,{}^3He \rightarrow \pi X$



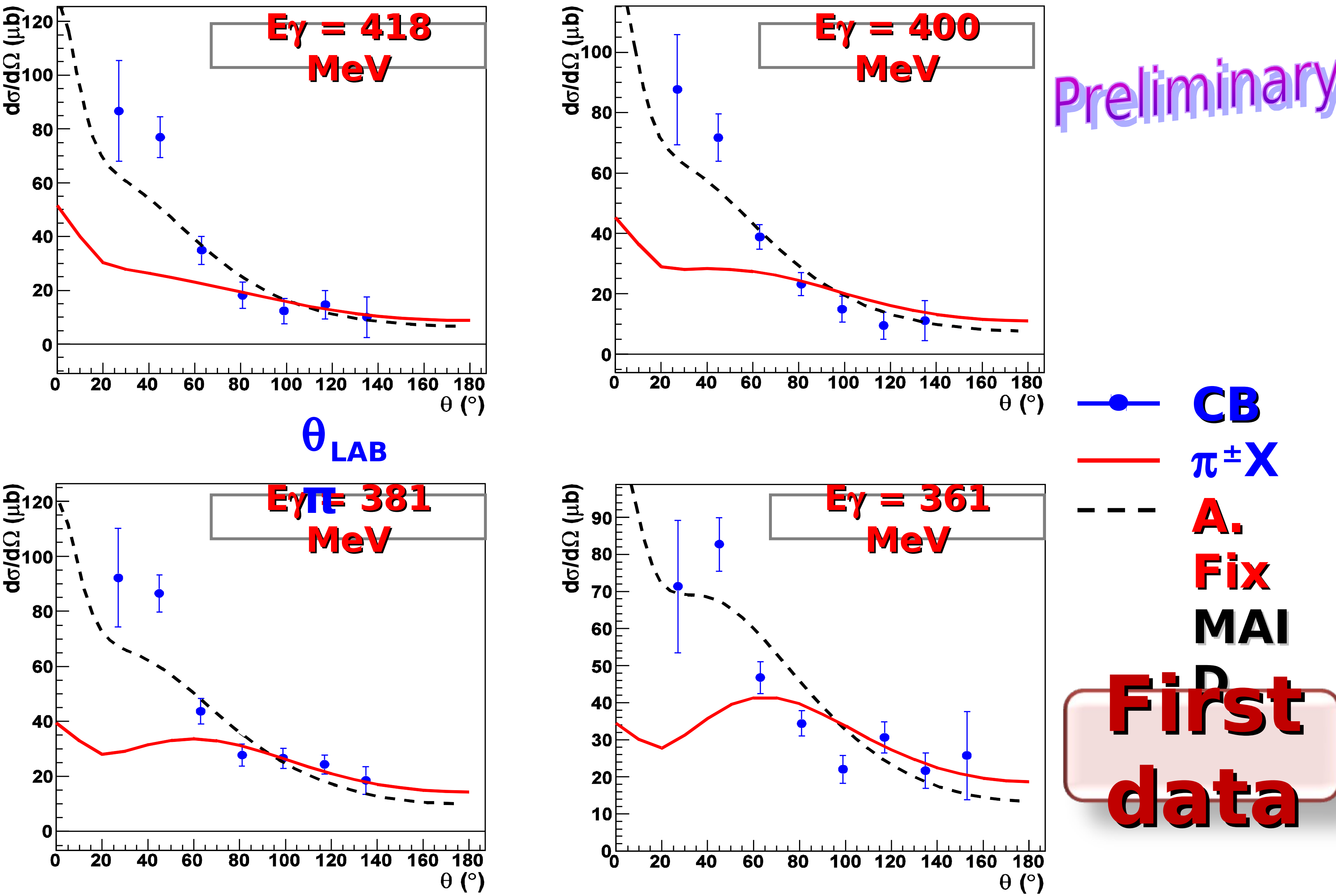
A. Fix model:

- Input: Free γN→πN amplitudes from MAID
- Free Amplitudes embedded inside ³He wave function
- FSI taken into account in an approximate way
- **As expected , FSI play a bigger role in the π^0 case**

First data

$\gamma\,^{3}He \rightarrow \pi^{\pm} X$

Differential unpolarised cross section



$$\vec{\gamma}\,^3\vec{H}e \to \pi^{\pm} X$$

Differential polarised cross section

Eγ = 418 MeV

Eγ = 400 MeV

Preliminary

CB

π^0X

A. Fix

MAID

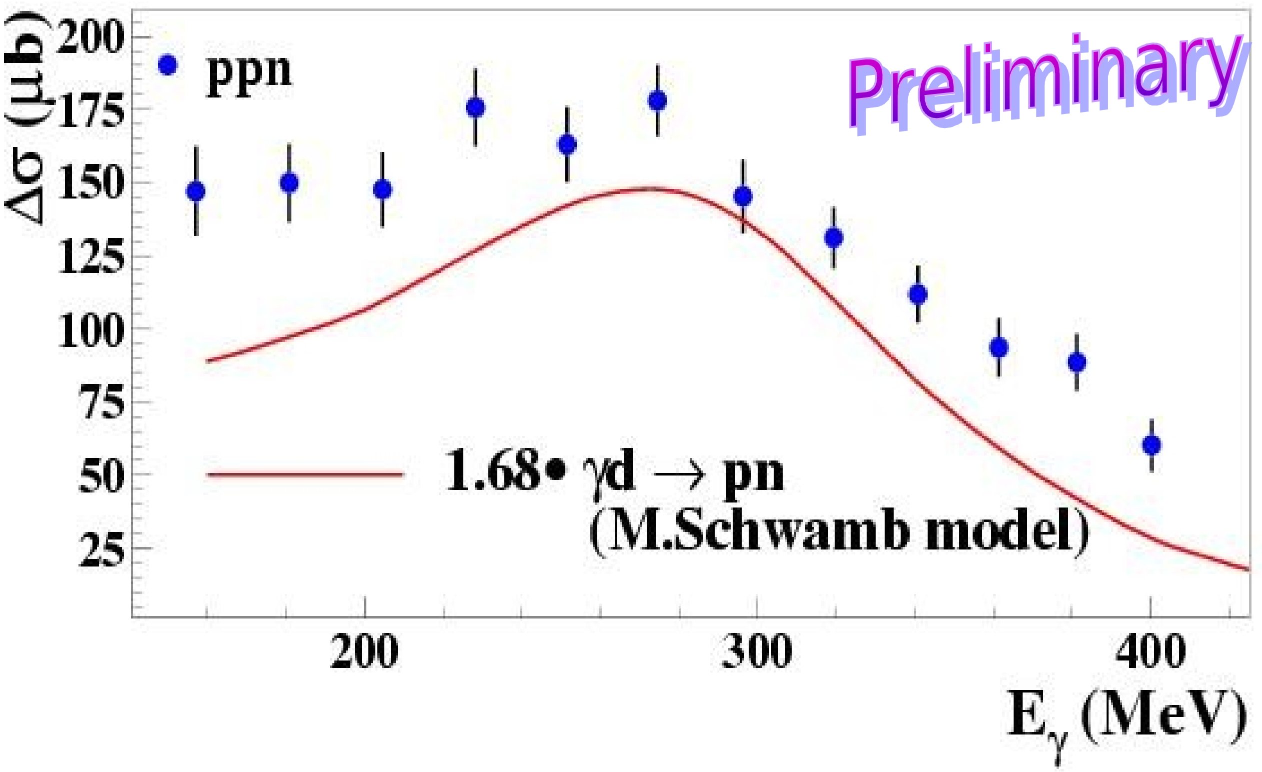
θ_{LAB} π

Eγ = 381 MeV

Eγ = 361 MeV

First data

$\vec{\gamma}\,^3\vec{H}e \rightarrow ppn$



$\Delta\sigma \approx \sigma_{unpol}$

No model estimation available for this channel
"Quasi-deuteron" approximation ($\gamma\,^3He \rightarrow pnp_s$)

First data