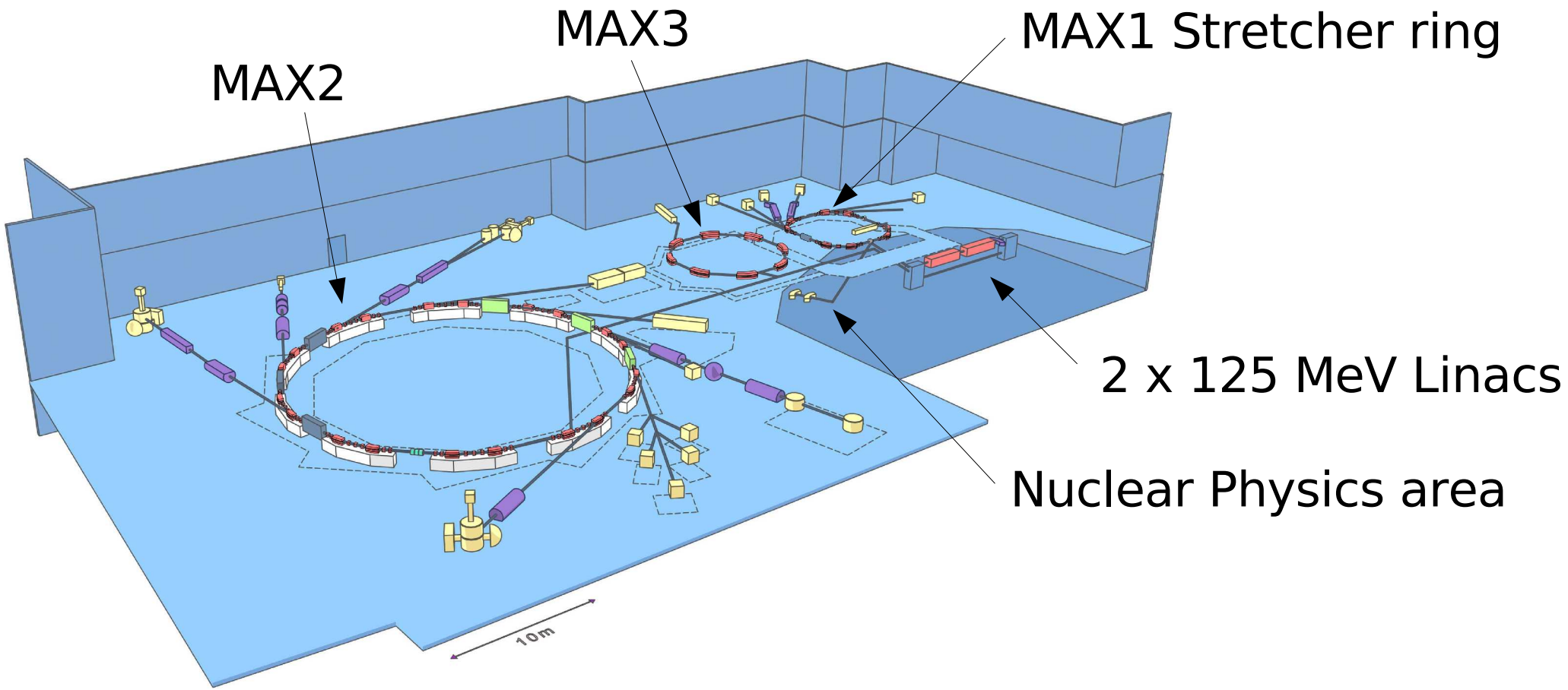
Compton Scattering at MAX-lab

Gordon Conference 2006

L. Isaksson

MAX-lab

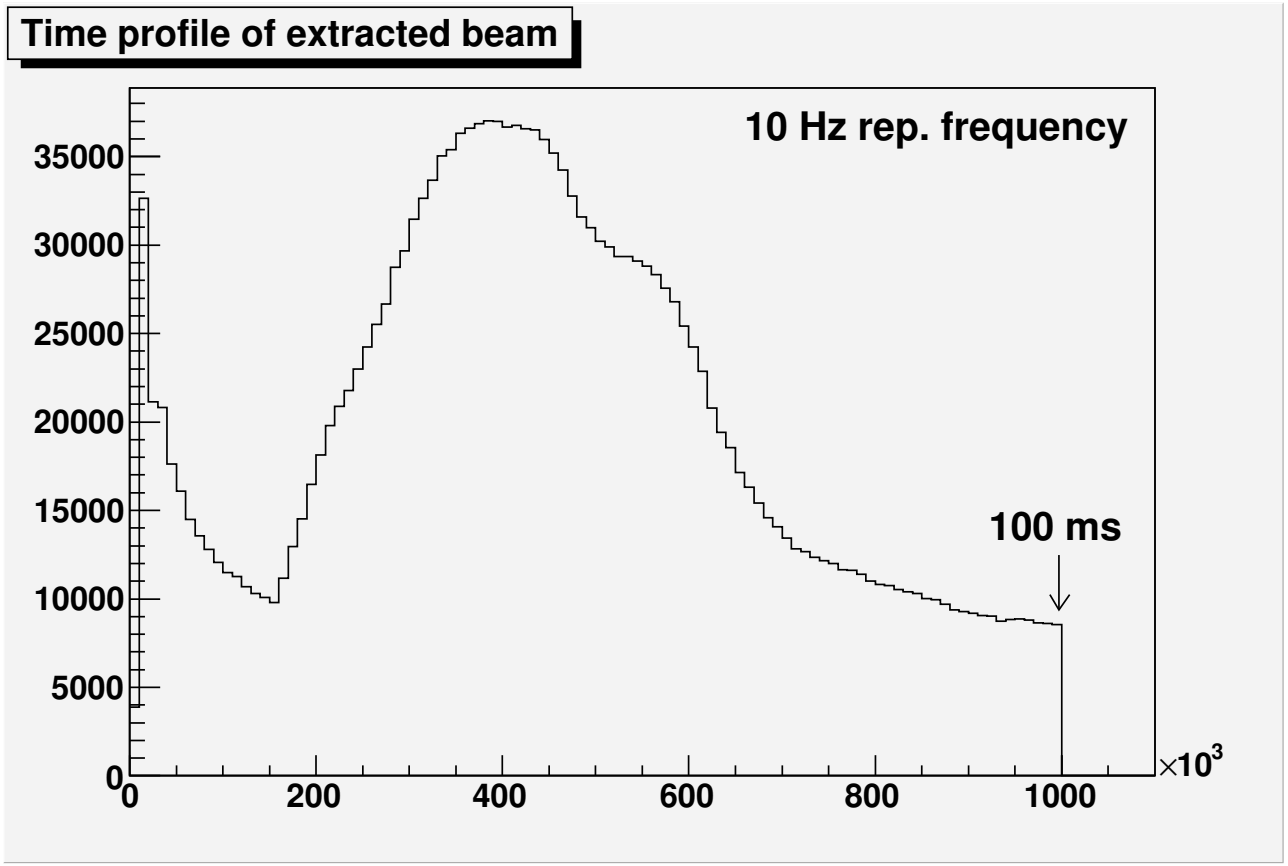


Parallel operation of the three rings

Nuclear Physics: ~30% of beam-time at MAX1

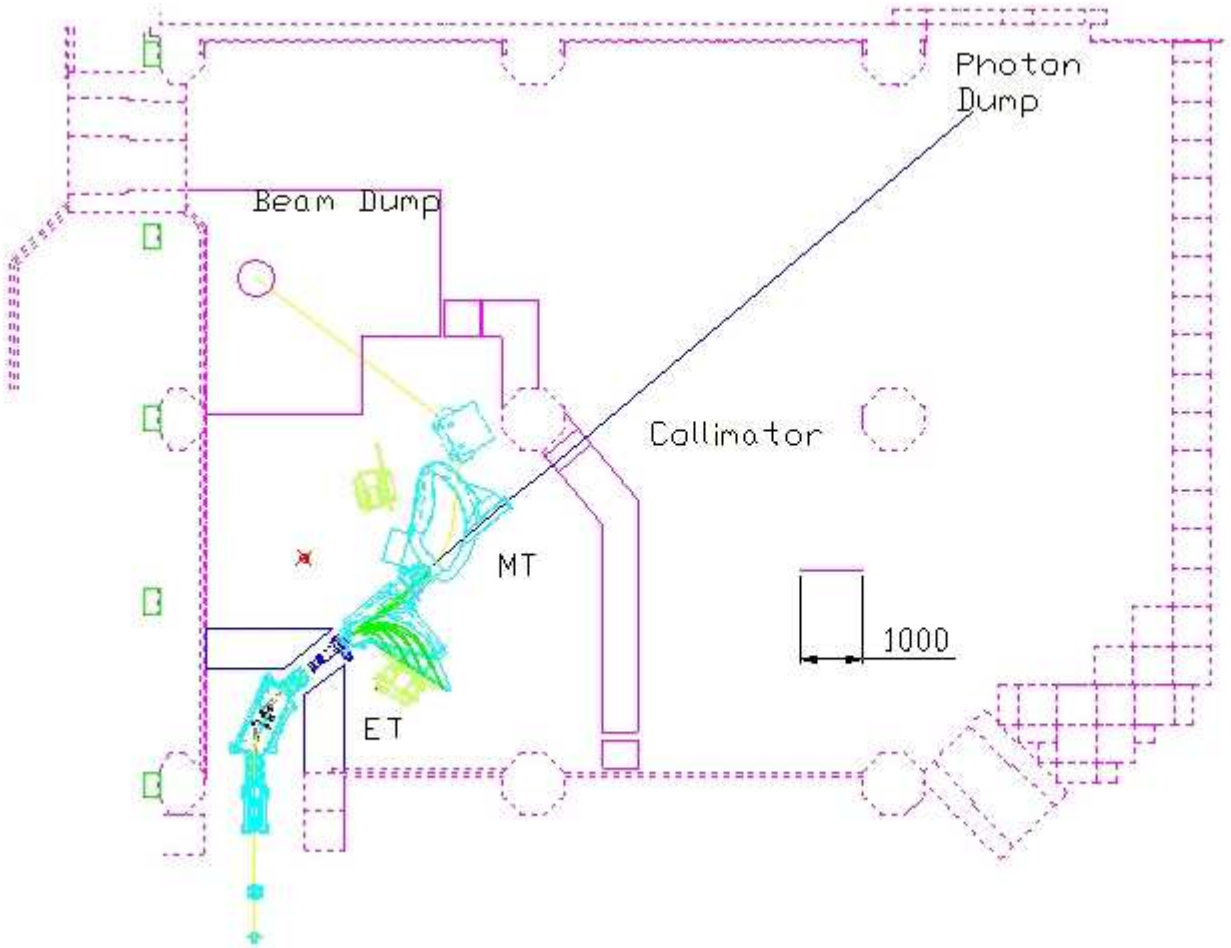
Pulse stretcher

100 ns Linac pulse → 100 ms extracted pulse



40-50% duty factor

Tagged photon beam-line



Stretched e^- beam

Main Tagger or End-point Tagger (previously at SAL)

Photon beam characteristics

Choice of:

- e^- energy (146-188 MeV)
- Tagger (MT or ET)
- Tagger setting

$\Rightarrow$ E_γ : 26-175 MeV

ΔE_γ : 0.2-1.0 MeV

Intensity (typical)

20 nA

50% tagg.eff.

$\Rightarrow$ 0.5 MHz/MeV (tagged photons)

In operation since Sep 2005

Anticipate:

Increased e^- energy (~210 MeV)

Compton Scattering programme

- D(γ,γ)

  Test recent calculations

  Extract neutron polarizabilities α_n and β_n

- ^{4}He, ^{12}C and ^{16}O(γ,γ)

  Extract polarizabilities of bound nucleons

Participants

University of Edinburgh

University of Glasgow

University of Göttingen

University of Illinois

University of Kentucky

University of Lund

The Mount Allison University

University of Saskatchewan

The George Washington University

α_n and β_n from D(γ,γ)

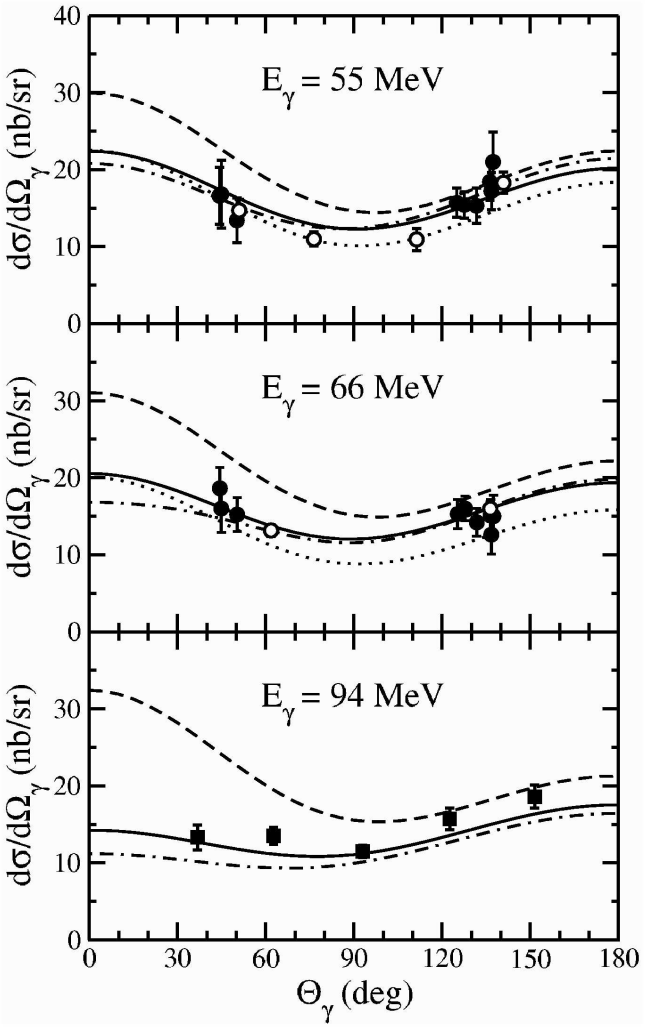
α_p and β_p well known from p(γ,γ) and Baldin sum rule

D(γ,γ) :

$\frac{d\sigma}{d\Omega}$ (backward direction) sensitive to α_N and β_N

$\Rightarrow$ α_n and β_n can be extracted

Previous D(γ,γ) measurements



Lucas *et al.*, Illinois

49 and 69 MeV

Lundin *et al.*, Lund

55 and 66 MeV

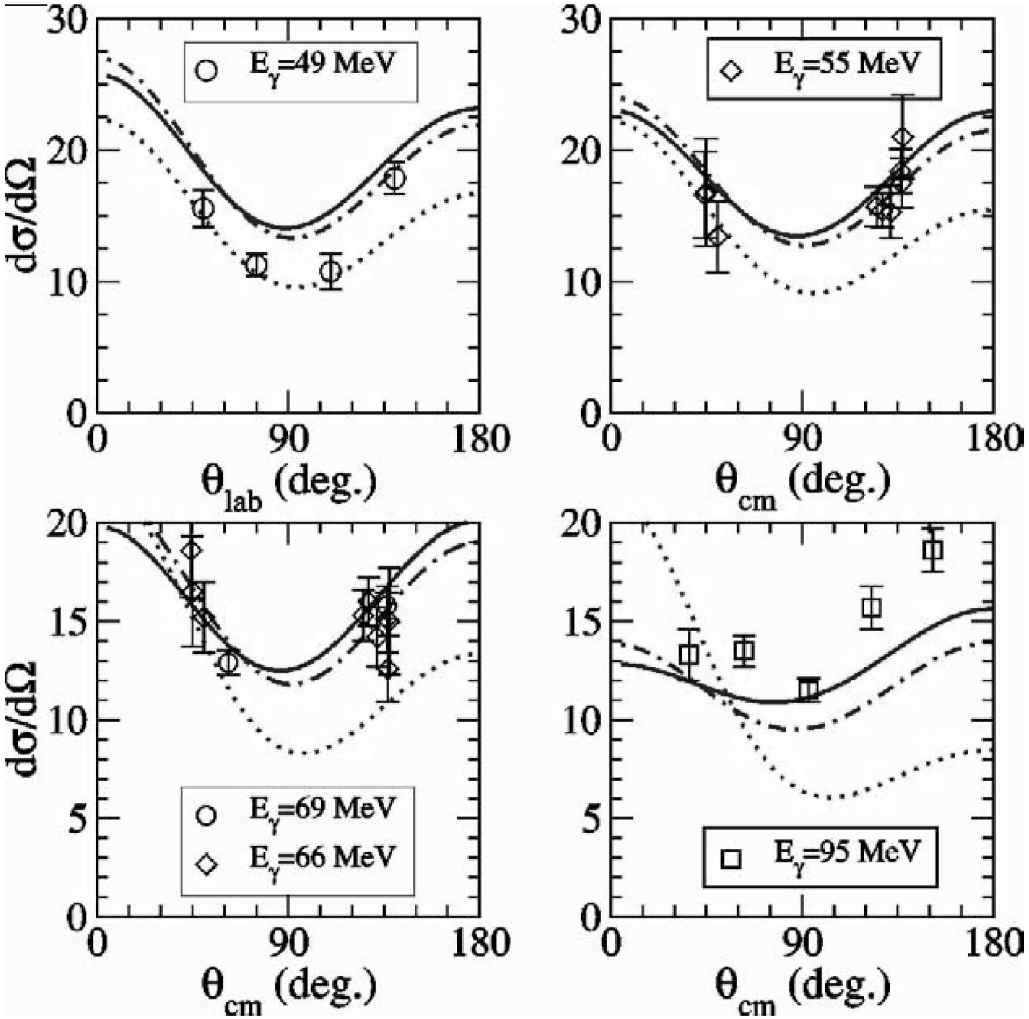
Hornidge *et al.*, SAL

94 MeV

Present calculations (Levchuk *et al.*, Karakowski *et al.*, ...) can not reconcile the three measurements

Recent χPT calculations

Beane *et al.*, Nucl.Phys.A747(2005)311



$O(Q^4)$

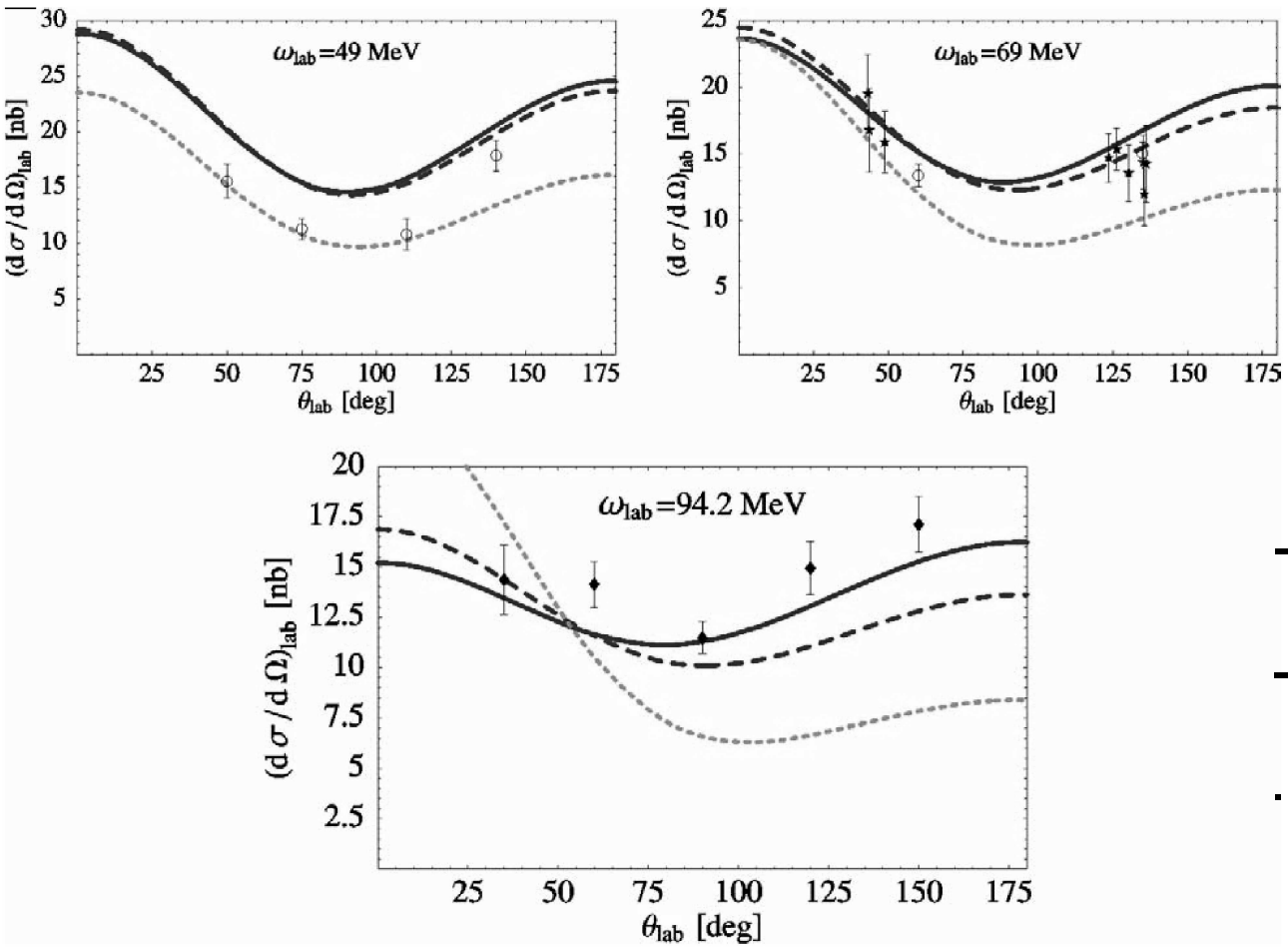
$O(Q^4)$

$O(Q^3)$

$O(Q^2)$

Recent χPT calculations

Hildebrandt *et al.*, Nucl.Phys.A748(2005)573



Δ-resonance explicitly included

$O(\epsilon^3)$ SSE

$O(Q^3)$ HBχPT

$O(Q^2)$

Goal of present D(γ,γ) measurement

Significantly increase the world D(γ,γ) data set:

- 40-110 MeV
- 30˚-150˚
- Statistical errors <5%

Set-up

Three of the largest NaI-detectors worldwide:

CATS	(Mainz)
BUNI	(Boston)
DIANA	(Kentucky)

CATS

Fairly standard electronics set-up

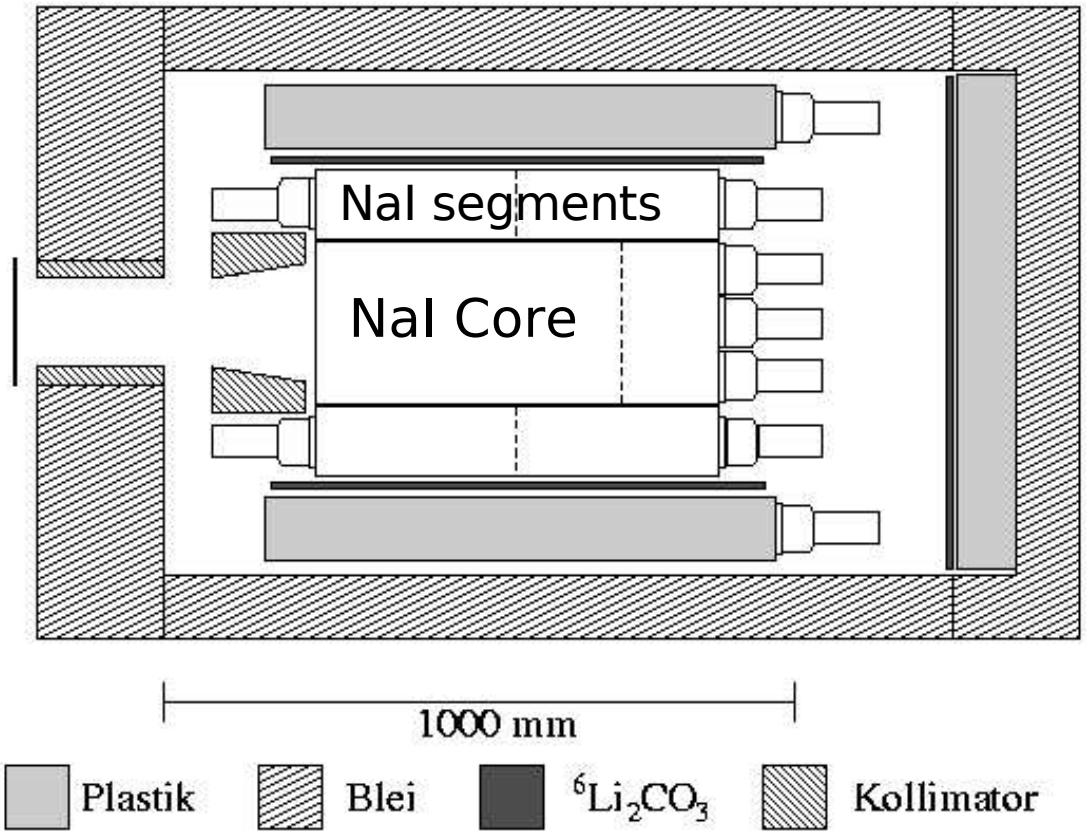
Trigger: single NaI-detector (scattered photon)

Incoming photon energy determined by tagger coincidences

NaI-detectors

The three detectors share a similar design:

CATS



(figure from O.Jahn, Diplomarbeit, Mainz)

NaI Core: ϕ27cm $\times$ 64cm

Six NaI segments

NaI total: ϕ48cm x 64cm

First test-run: $^{12}C(\gamma,\gamma)$

- 20 times higher cross-section
- Less severe resolution requirements
- Simpler target

May 2006

5.22 cm graphite

E_γ : 61-89 MeV

Θ : 45˚, 60˚, 90˚, 135˚, 150˚

Analysis

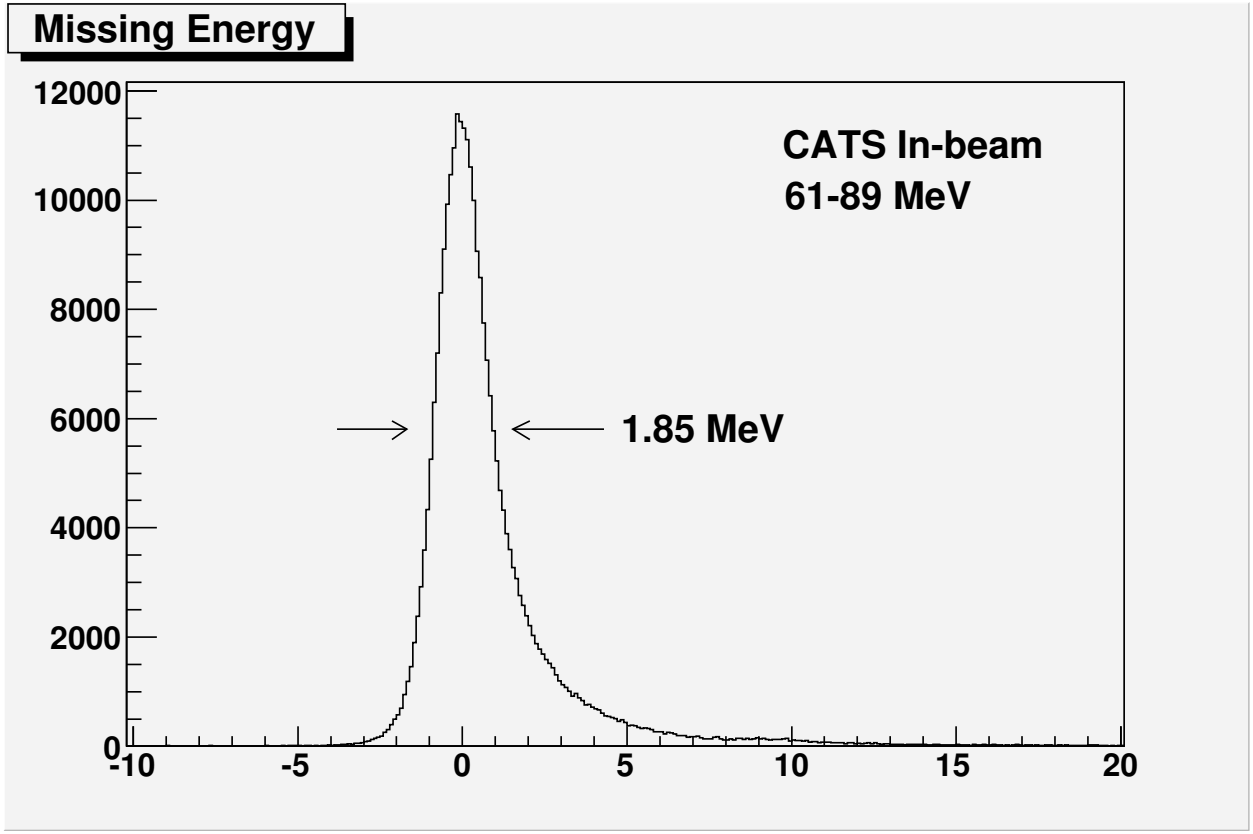
First stage: Independent analyses of the three detectors

Overlap in E_γ and Θ $\Rightarrow$ Consistency check

This presentation: Mostly preliminary CATS results

In-beam measurement

Missing energy = Incoming photon energy (Tagger) -
Detected energy (Core + Segments)

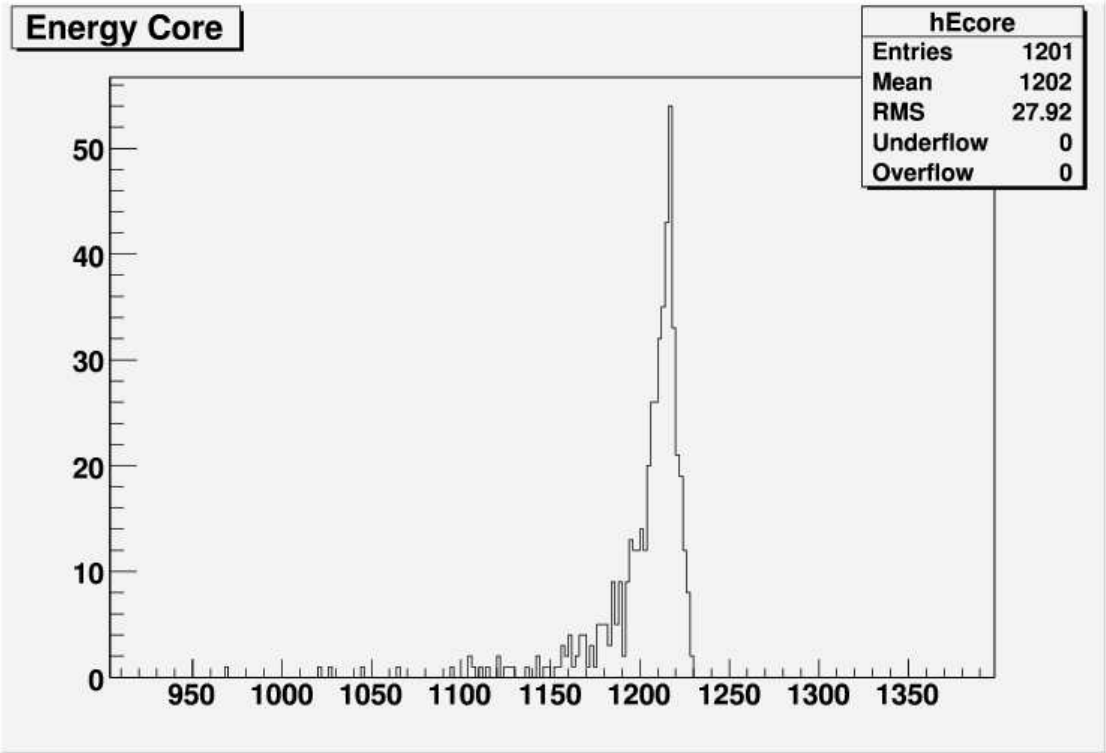


Energy resolution: 1.85 MeV FWHM (E_γ : 61-89 MeV)

DIANA In-beam measurement

On-line spectrum

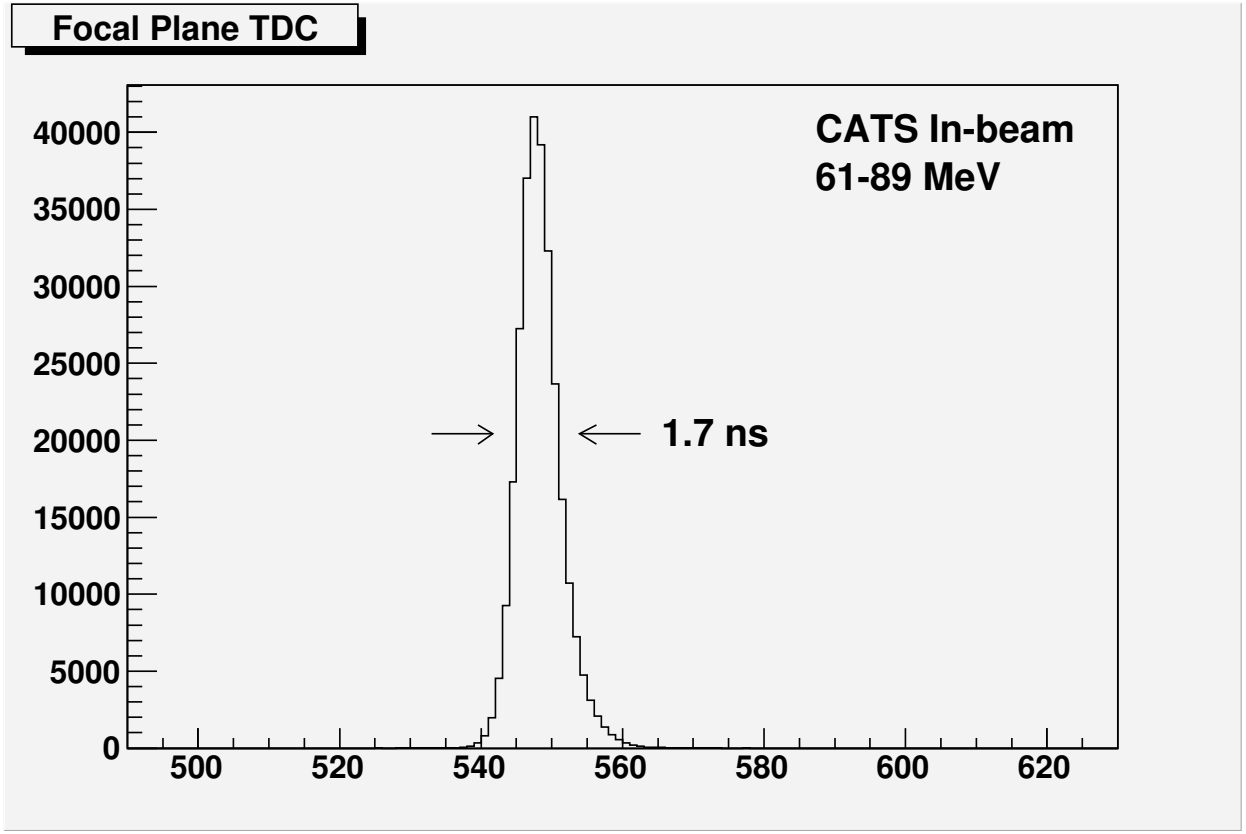
Single tagger channel



Energy resolution: 1.3 MeV FWHM (E_γ : 121 MeV)

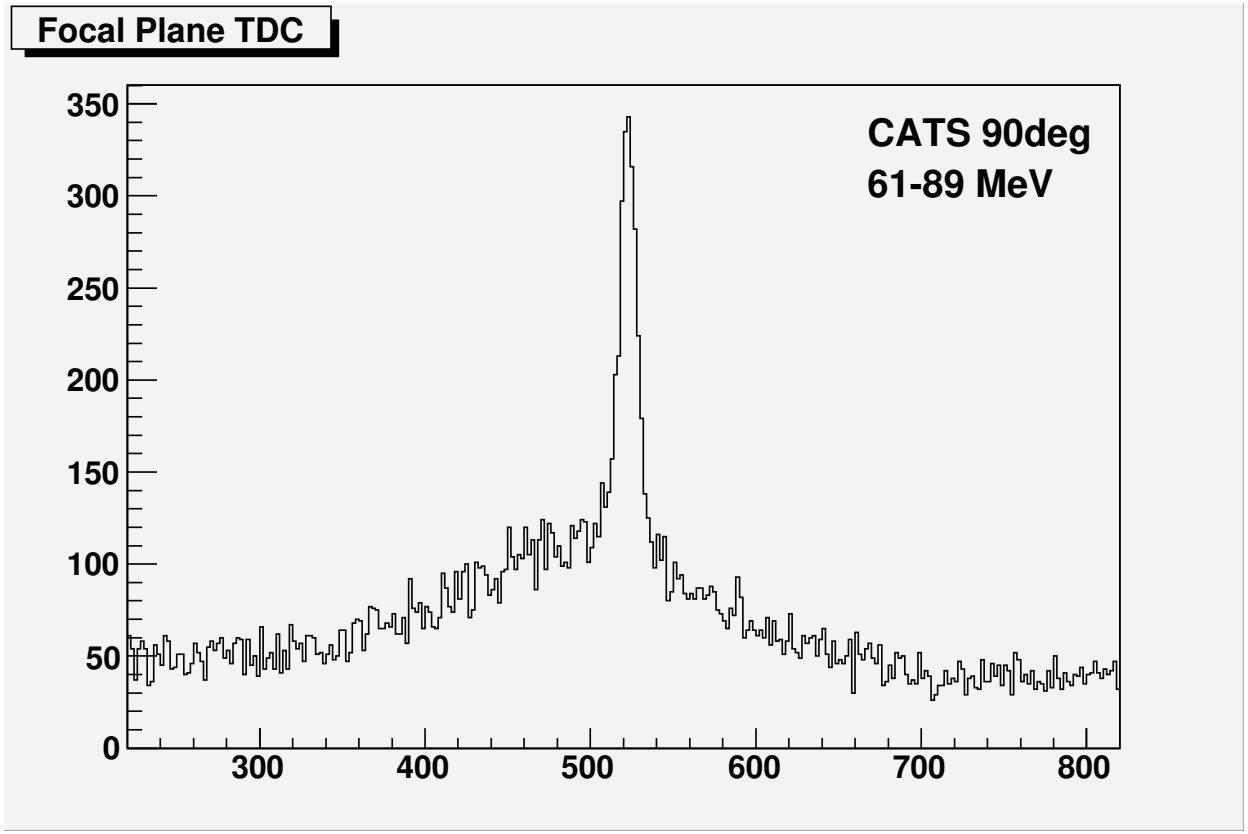
In-beam time-resolution

Coincidences with Tagger Focal Plane detectors:



Time resolution: 1.7 ns FWHM

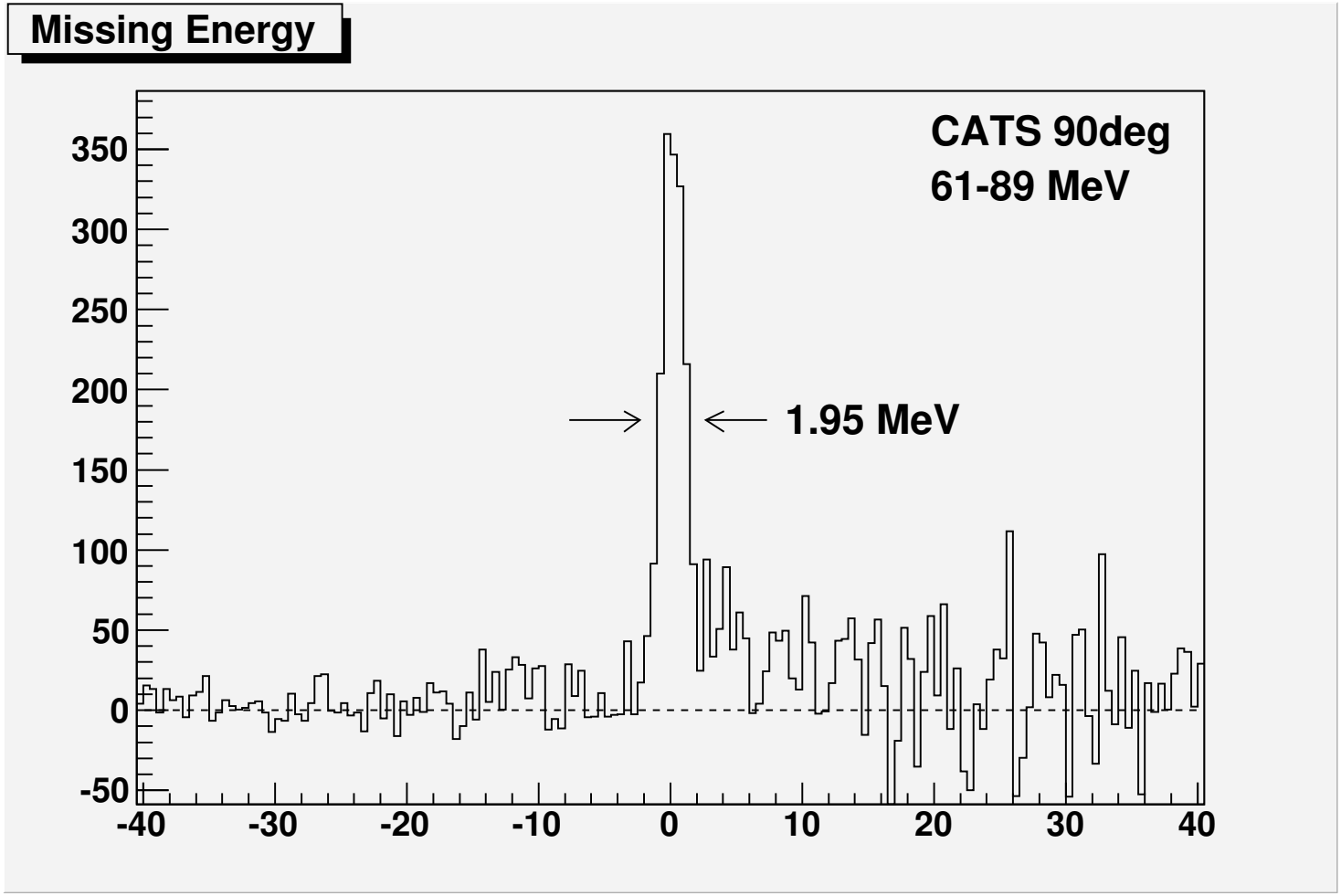
Tagger coincidences



Time-structure in extracted beam ⇒

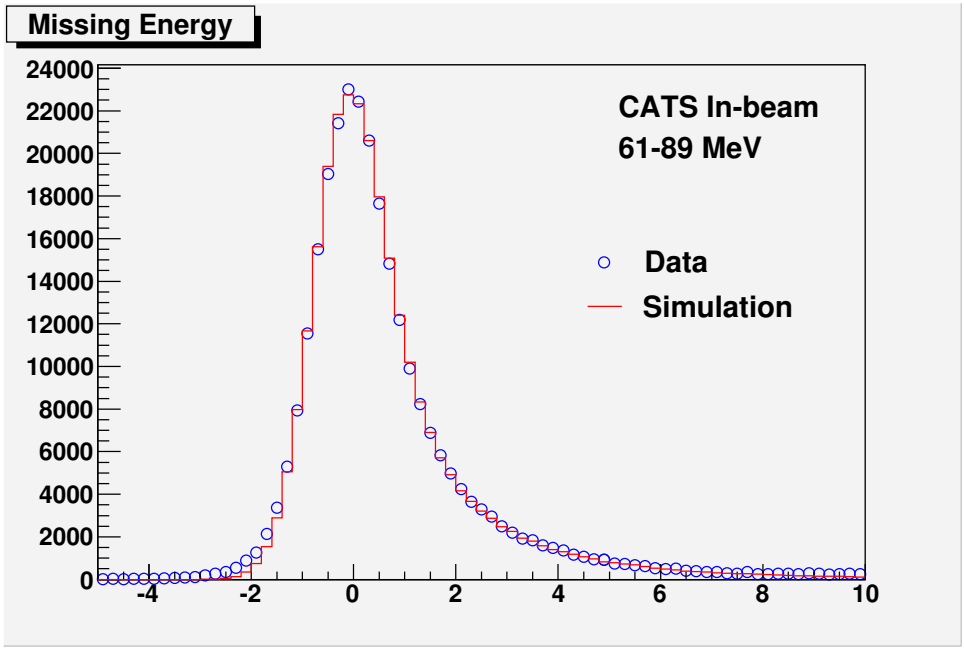
Structure in randoms-background

$^{12}C(\gamma,\gamma)$ Missing Energy



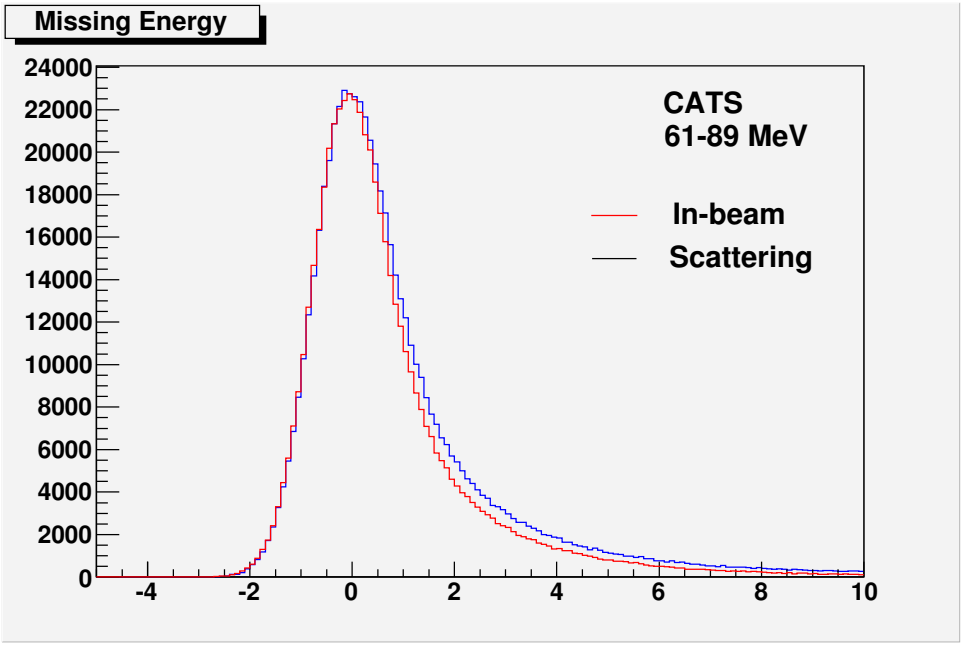
~6 shifts

Simulation of Response-function



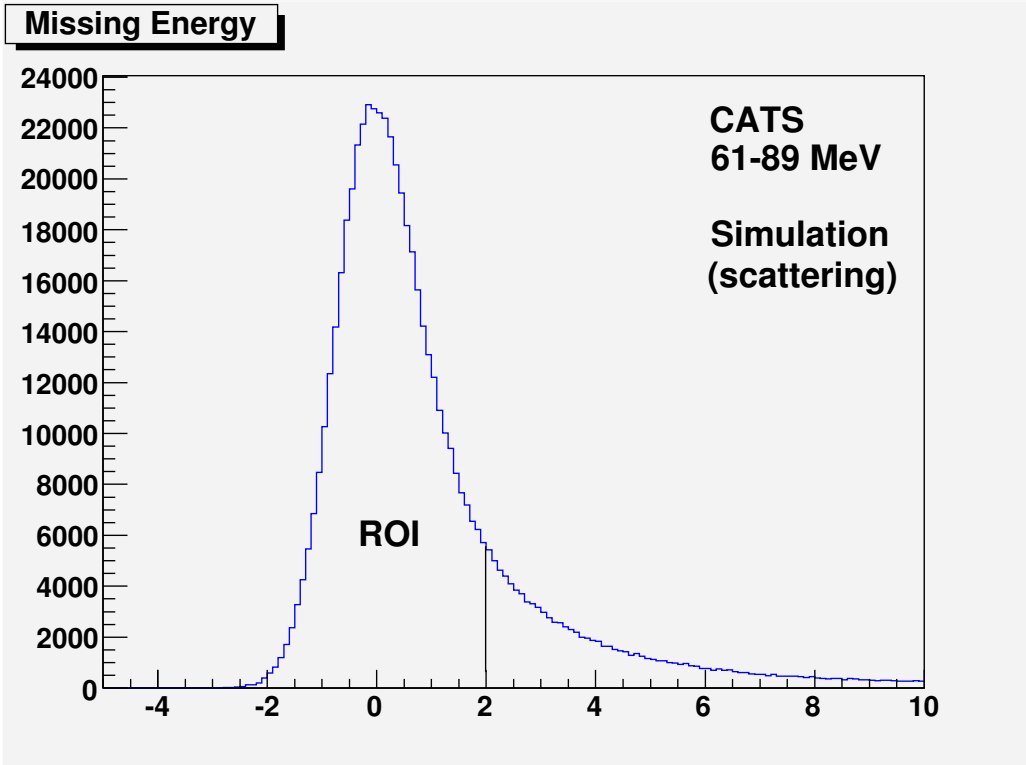
In-beam Geant4 simulation folded with Gaussian (width fitted to the data)

Use same Gaussian width for scattering configuration (extended beam)



Effective Solid Angle

Define (conservative) ROI: -3 to 2 MeV



ϵ_{ROI} : 83.9%

Ω_{eff} : 18.7 msr

Other corrections

- Target-absorption

  Both primary and scattered photons are lost due to absorption in the target

  Geant4 simulation:

  Correction factor f_{abs} : 81.8%

- Stolen coincidences

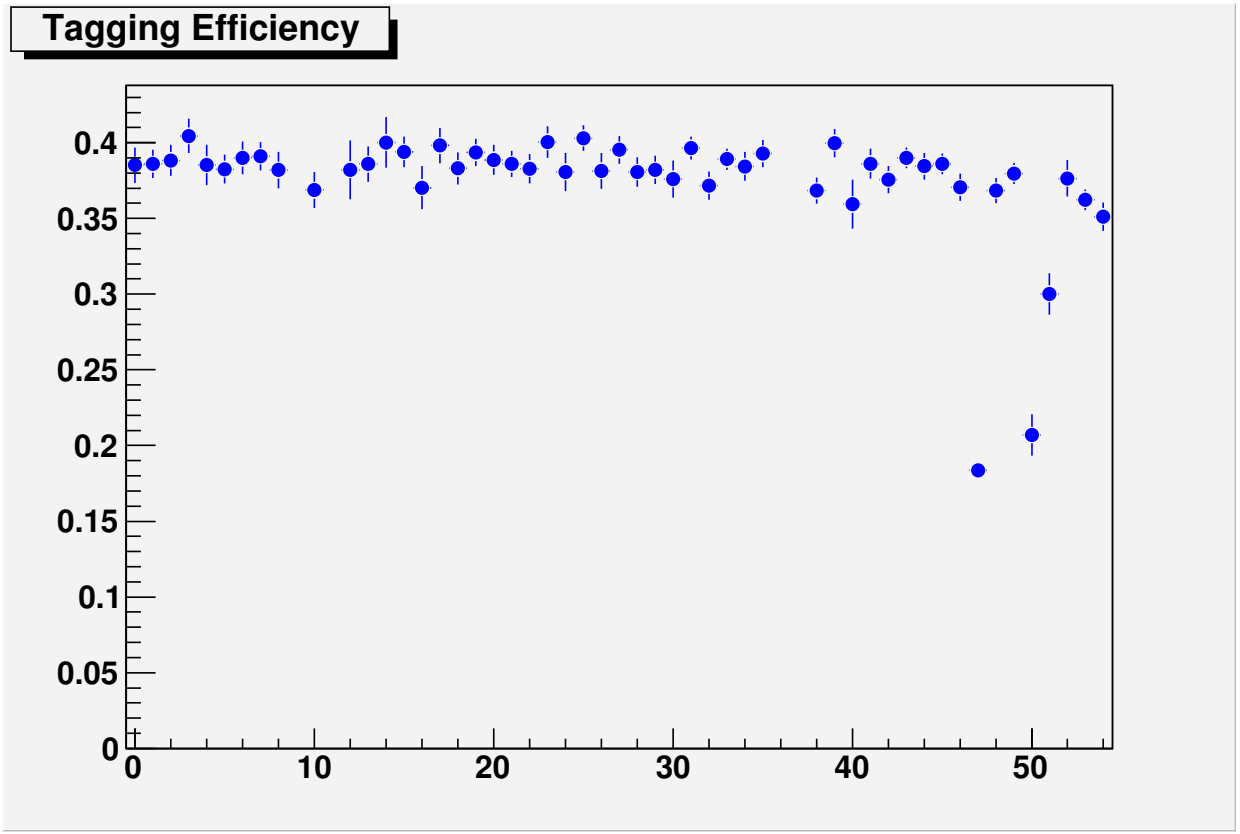
  Some true coincidences are lost due to random events stopping the TDC prematurely

  From TDC spectrum:

  Correction factor f_{stolen} : 92.5%

Tagging Efficiency

Measured at regular intervals (Pb-glass detector in beam)



Mean ϵ_{tag} : 39%

Cross-section

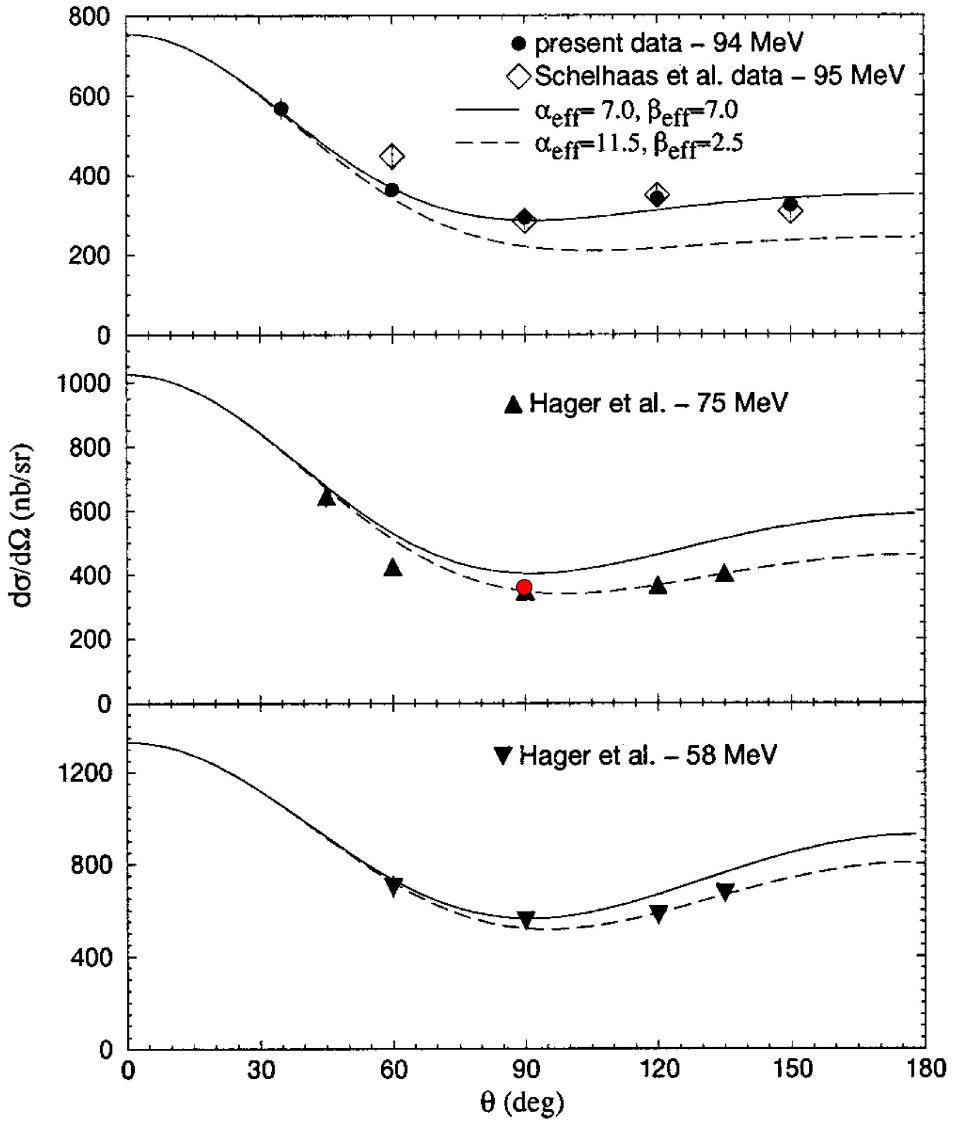
Number of events in ROI:	Y	1703
Number of electrons in FP:	N_e	1.898×10^{12}
Tagging Efficiency:	ϵ_{tag}	0.388
Number of target nuclei:	N_{target}	4.45×10^{23} cm^{-2}
Effective solid angle:	Ω_{eff}	18.7 msr
Target absorption:	f_{abs}	0.818
Stolen coincidences:	f_{stolen}	0.925

$$\frac{d\sigma}{d\Omega} = \frac{Y}{N_e \epsilon_{tag} N_{target} \Omega_{eff} f_{abs} f_{stolen}} = 367 \pm 19 \text{ nb/sr}$$

Systematic uncertainty (at present stage of analysis) <10%

Expect ~4%

Previous measurements



- Warkentin *et al.*, SAL

  94 MeV 292±5 nb/sr

- Häger *et al.*, Lund

  75 MeV 348±11 nb/sr

- This measurement

  75 MeV 367±19 nb/sr

Summary

- Upgraded tagged photon beam at MAX-lab is operational and experiments have started
- First Compton scattering data have been taken
- The three very large NaI-detectors show the expected good energy-resolution
- ^{12}C(γ,γ) cross-section agrees well with previous measurements

Next step: D(γ,γ)