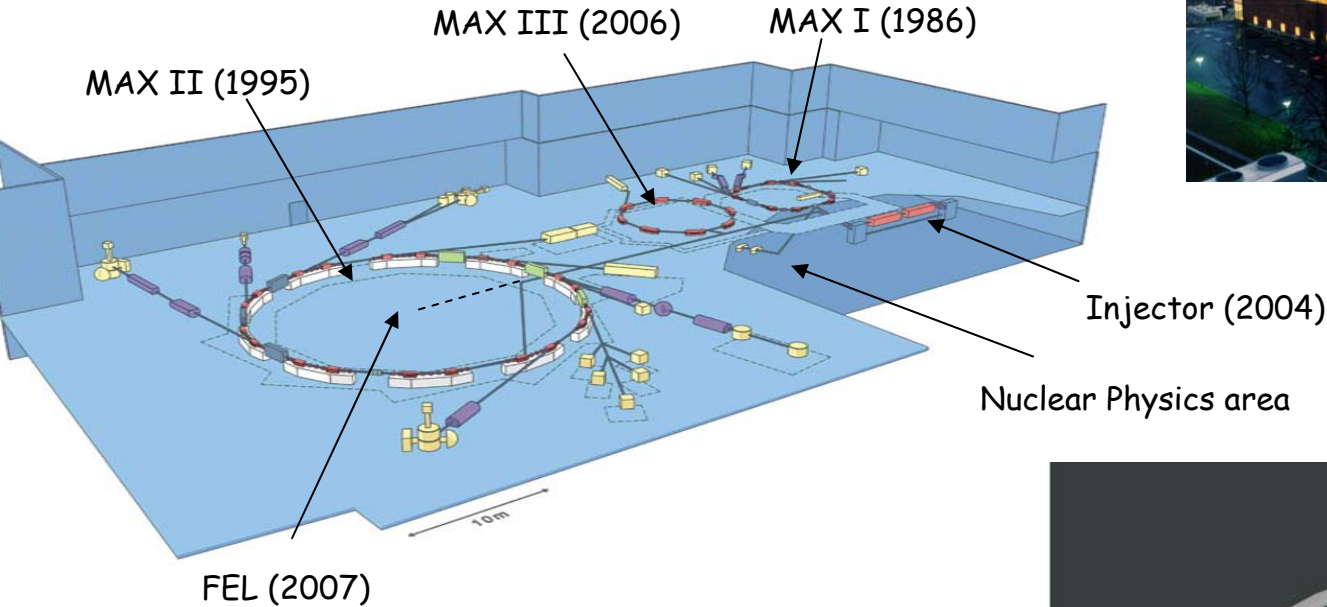
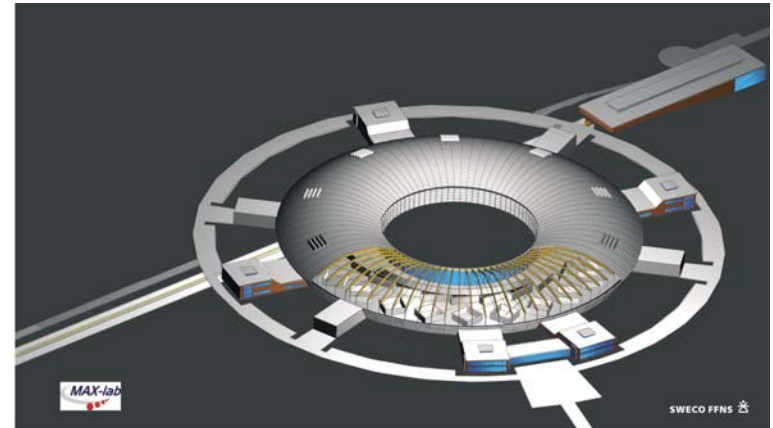


Compton scattering at



MAX IV (>2012)??

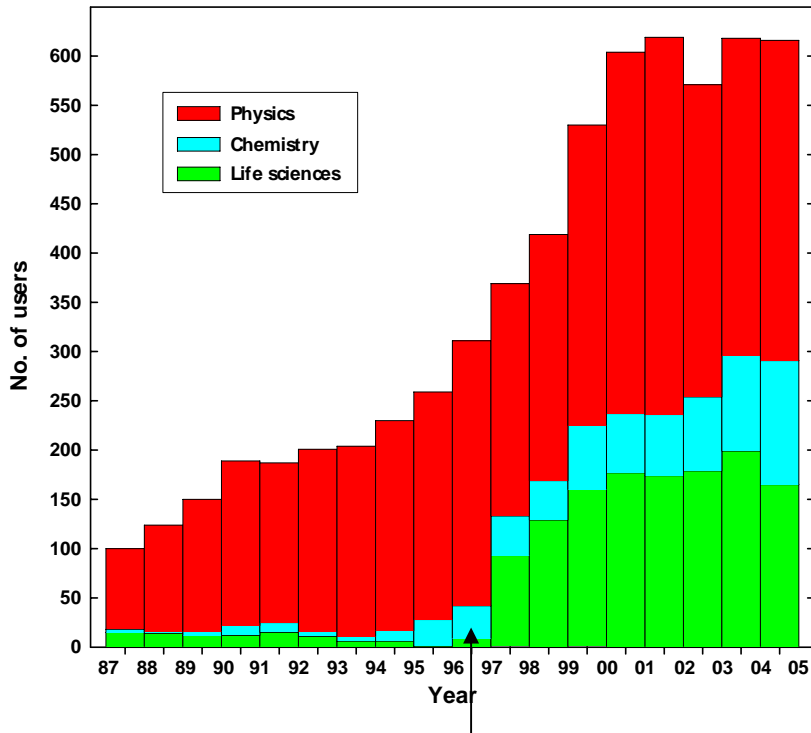


MAX-lab is a National Laboratory supported by the Swedish Research Council (5 M\$) and Lund University (2,75 M\$). Total budget 8,6 M\$.
Research areas: synchrotron light based research, accelerator physics and nuclear physics.

MAX-lab users 2005

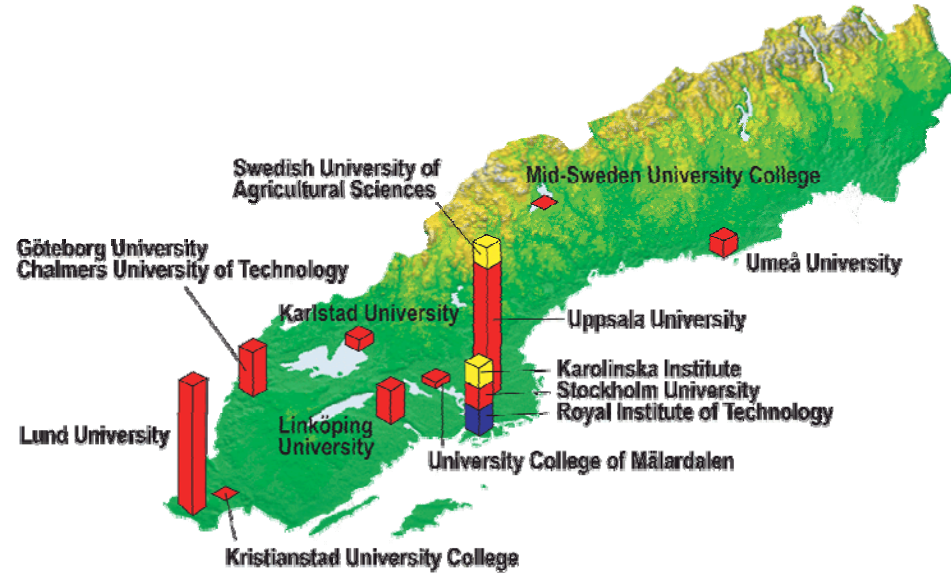
Official statistics

Users at MAX-lab

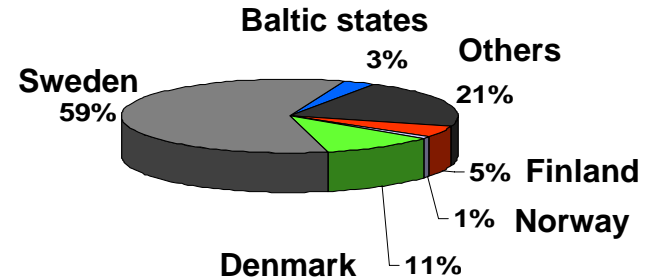


MAX II

A truly national laboratory ...



.. and international



Compton scattering before upgrade

1988 in collaboration with the Göttingen group lead by Martin Schumacher

^4He , ^{12}C , ^{16}O , ^{40}Ca and ^{208}Pb

tagged photons (centered at approximately 60 and 75 MeV).

NaI spectrometers with 10" diameter, and 10" or 14" long

angular range 45° to 150° .

- M. Ludwig 1991
- K.M. Fuhrberg 1992
- D. Häger 1995
- T. Glebe 1996
- Ch. Pösch 1996
- M-Th. Hütt 1997
- S. Proff 1998

α and β for bound nucleons are equal the free nucleon values

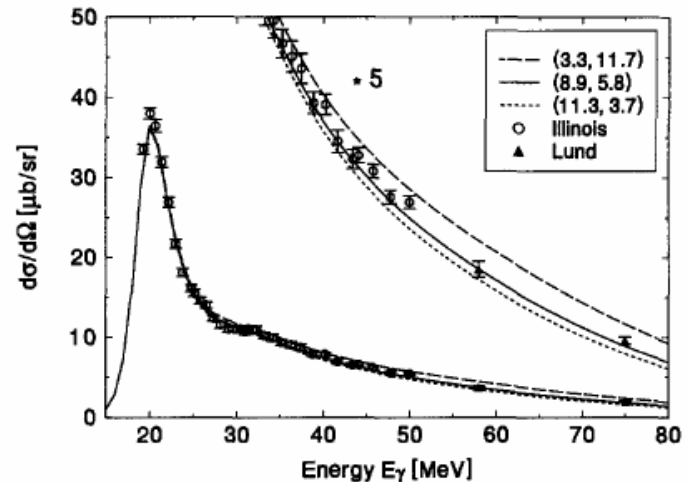
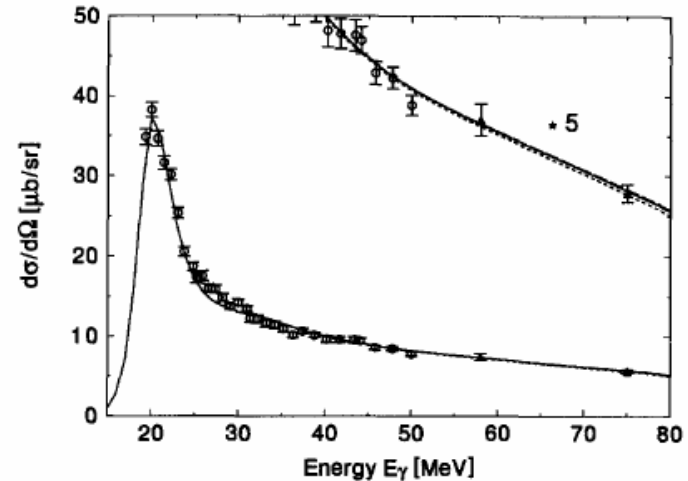
?????

Assumptions and model dependence

Inconsistencies between data from Lund and Illinois/SAL for ^{12}C and ^{16}O .

^{40}Ca agreement with Illinois data (D.H. Wright)

S. Proff et al. / Nuclear Physics A 646 (1999) 67–82



Compton scattering before upgrade

April 1996 to September 1997

elastic photon scattering from ^2H

liquid deuterium target (constructed by T. Glebe), 16 cm long cell

two energies, 55 and 66 MeV; scattering angles $\approx 45^\circ$ and in the angular range 126° to 136°

Magnus Lundin

18 individual cross section (three run periods) statistical errors are 10-15%; systematic errors about 7%.

The fitted deuterium (dashed), calculated empty (dotted) and the fitted ice (dashed-dotted) response functions for the Uppsala detector (6% energy resolution at 60 MeV).

April 97: two weeks of beam time; $\varepsilon_+ \approx 25\%$; $N_\gamma \approx 2,5 \cdot 10^{12}$; $\Omega = 30 \text{ msr}$; $N_{\text{atoms}} = 8 \cdot 10^{23} \text{ cm}^{-1}$; $Y = 801$; $d\sigma/d\Omega = 14,7 \text{ nb/sr}$; stat. 8,4%; syst. 6.7%;

$N_\gamma = 2,5 \cdot 10^{12} \rightarrow N_e = 10^{13}$ & $150 \mu\text{m Al} \rightarrow N_e \approx 1,15 \cdot 10^6 \text{ s}^{-1} \text{ MeV}^{-1} \rightarrow \approx 0,4 \text{ MHz}$ per (non-overlapping) scintillator in the focal plane hodoscope.

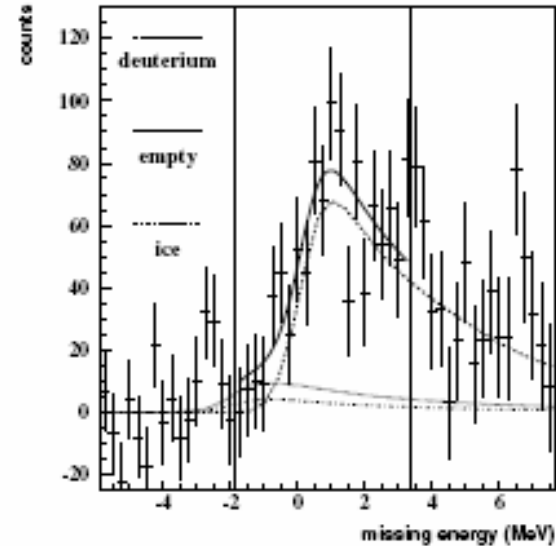


FIG. 1. E_{miss} spectrum at $\theta_y^{\text{lab}} = 126^\circ$ and $E_\gamma = 55 \text{ MeV}$. The two vertical lines indicate the ROI used to determine the yield. The solid line represents the sum of the fitted responses (see text).

Phys. Rev. Lett. 90 (2003) 192501, M. Lundin et al.

Compton scattering before upgrade

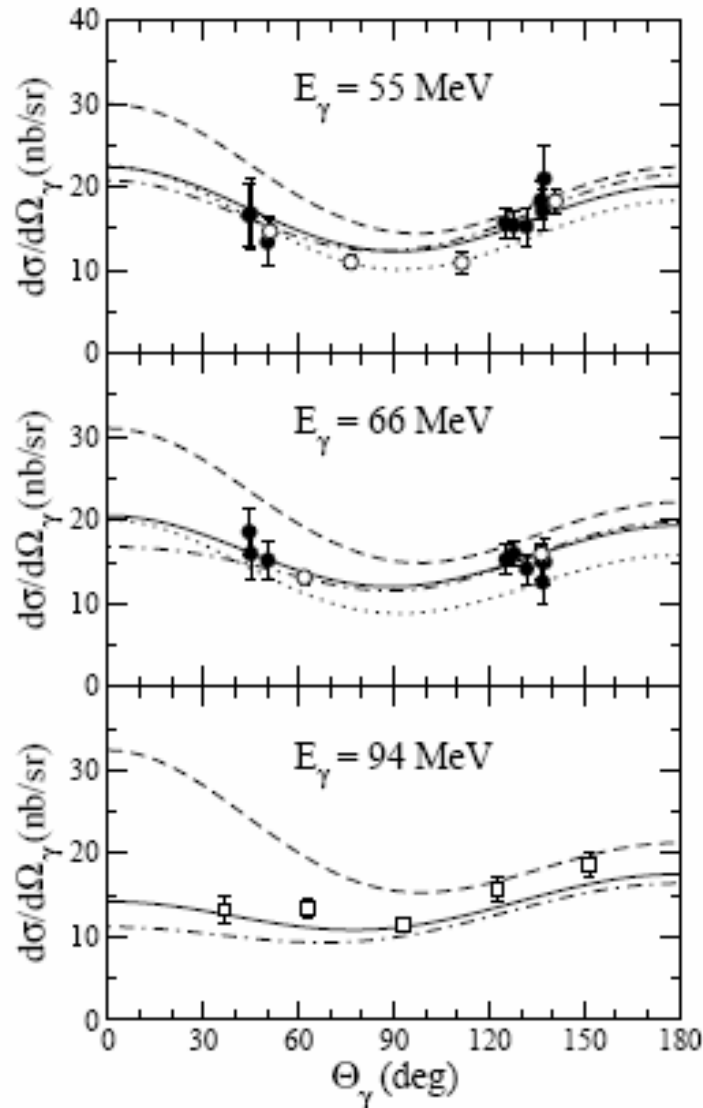


FIG. 2: CM differential cross sections for Compton scattering from the deuteron. Filled circles: present experiment; open circles: extrapolated Illinois results [15] (see text); open squares: SAL results [16]. The error bars represent the quadratic sum of the statistical and systematic uncertainties. Solid and dashed curves are the calculations of Ref. [2] (dashed: $\alpha_N = \beta_N = 0$; solid $\alpha_N = 11.9$, $\beta_N = 5.5$, see Eqs. (6), (7)). Dotted and dashed-dotted curves are the predictions of Refs. [28] and [29], respectively, extrapolated to $\alpha_N = 11.9$, $\beta_N = 5.5$.

[2] M. I. Levchuk and A. I. Lvov, Nucl. Phys. A674, 449 (2000); A684, 490 (2001).

[15] M. A. Lucas, Ph.D. thesis, University of Illinois, 1994.

[16] D. L. Hornidge *et al.*, Phys. Rev. Lett. 84, 2334 (2000).

[28] H. W. Griesshammer and G. Rupak, Phys. Lett. B 529, 57 (2002).

[29] S. R. Beane *et al.*, nucl-th/0209002.

Energy upgrade funded 1998

First PAC in May 2002 with 16 letters of intent

Second PAC in December 2004 with 14 proposals

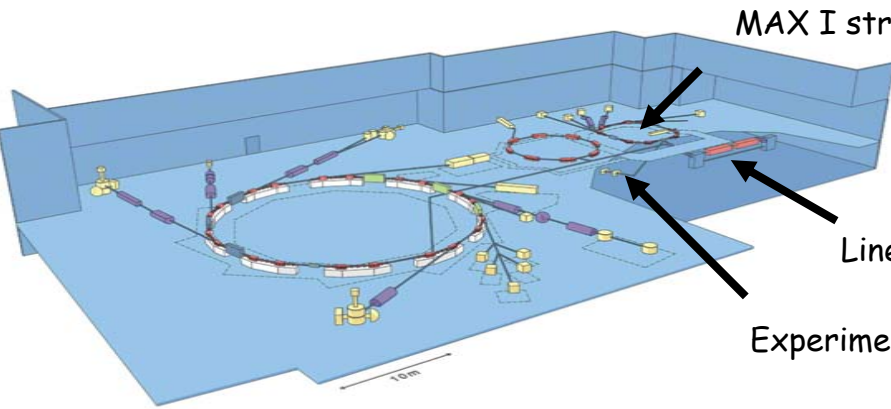
Two proposals for Compton scattering; one for ${}^2\text{H}(\gamma,\gamma)$ and one for ${}^4\text{He}(\gamma,\gamma)$

Commissioning started in 2005

First beam of electrons in May - June 2005

In April-May 2006 first Compton scattering experiment on ${}^{12}\text{C}$ with BUNI, CATS and DIANA.

Experiments at MAX-lab



MAX I stretcher ring (45%)

The linacs operate at 10 Hz with a pulse length of about 100 ns.

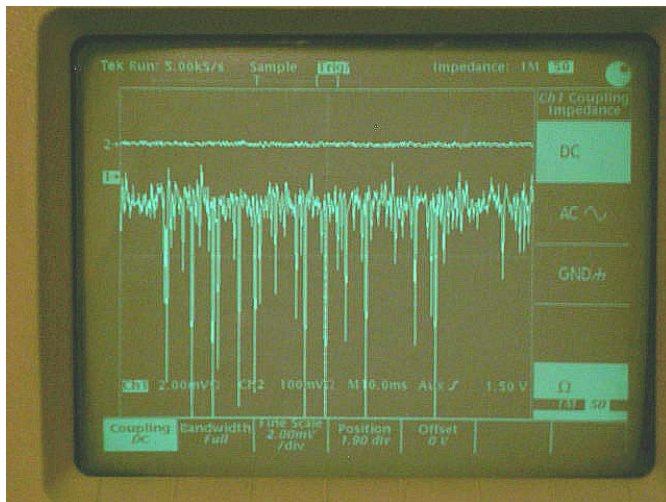
Linear accelerators

20 mA in the ring \rightarrow 20 nA extracted

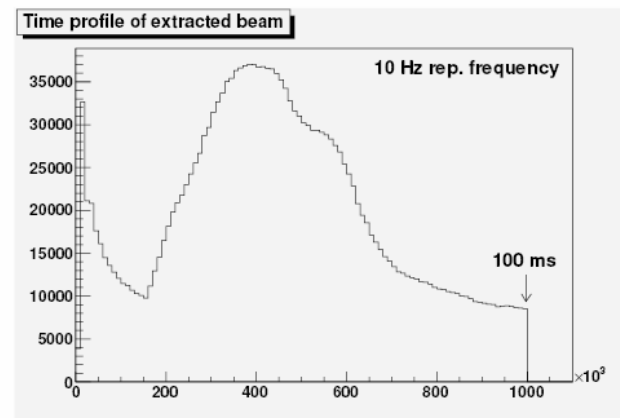
Experimental area



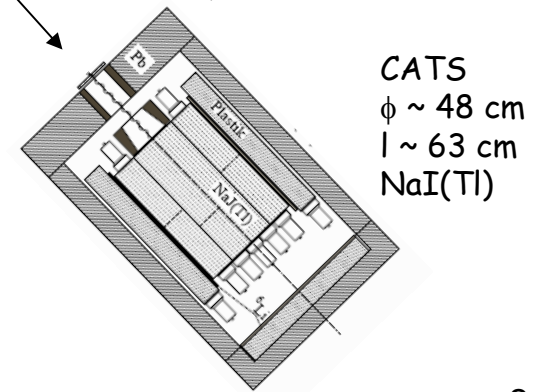
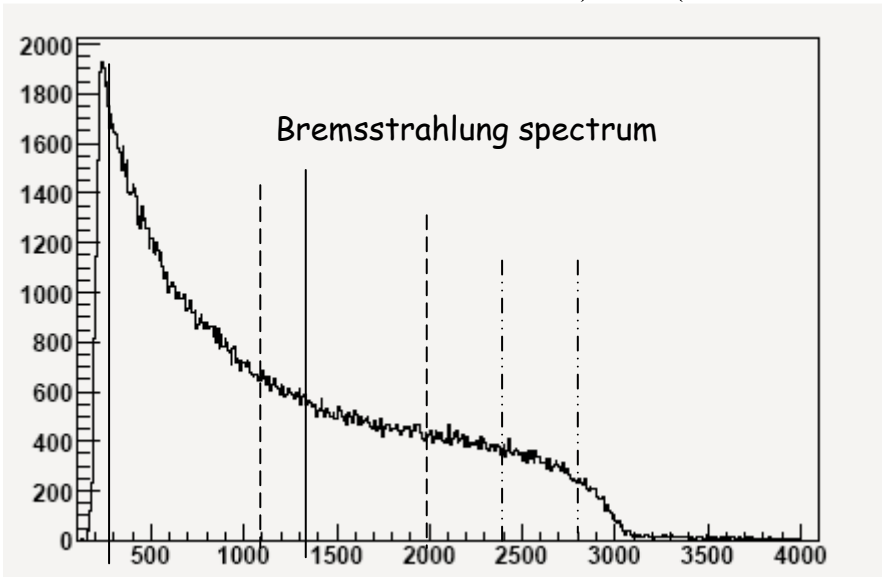
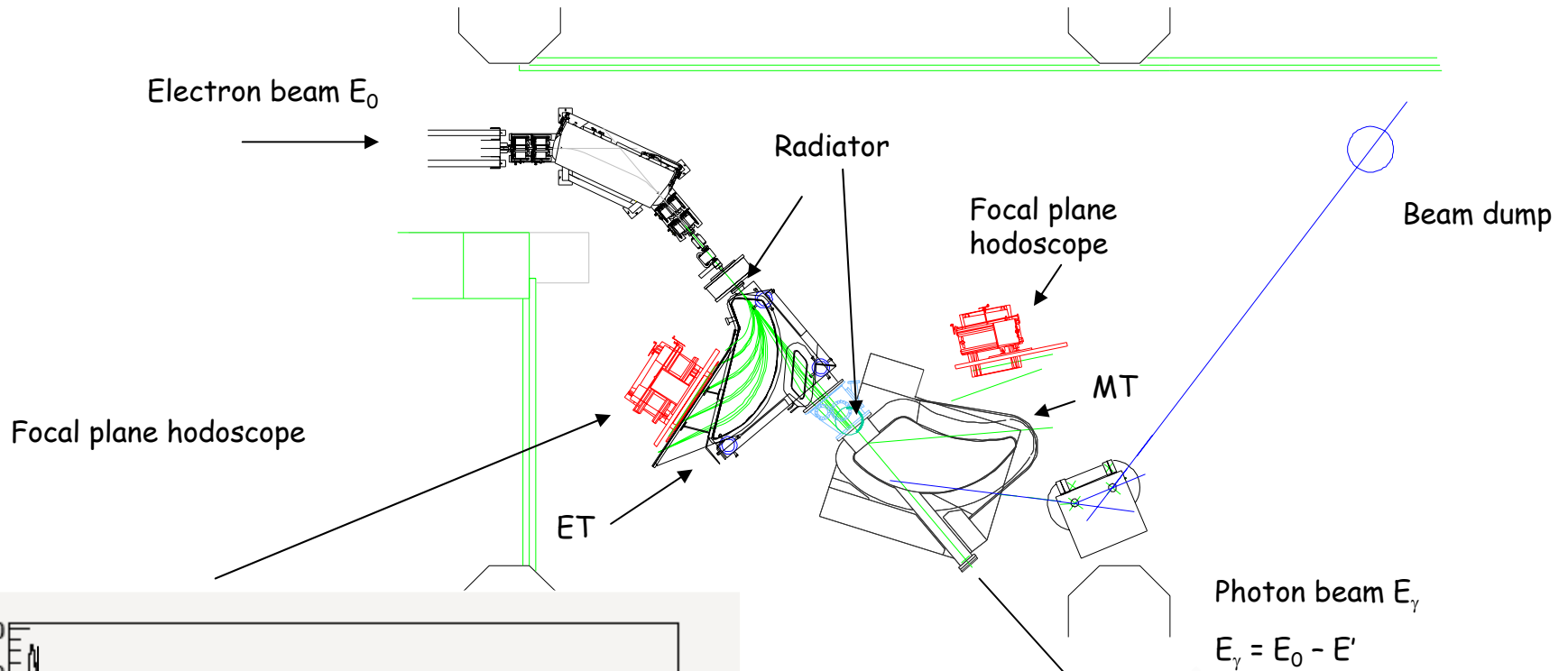
Signals from a scintillator in the focal plane hodoscope. The time scale is 100 ms.



synchrotron light from a bending magnet in MAX I (20 ms/division)



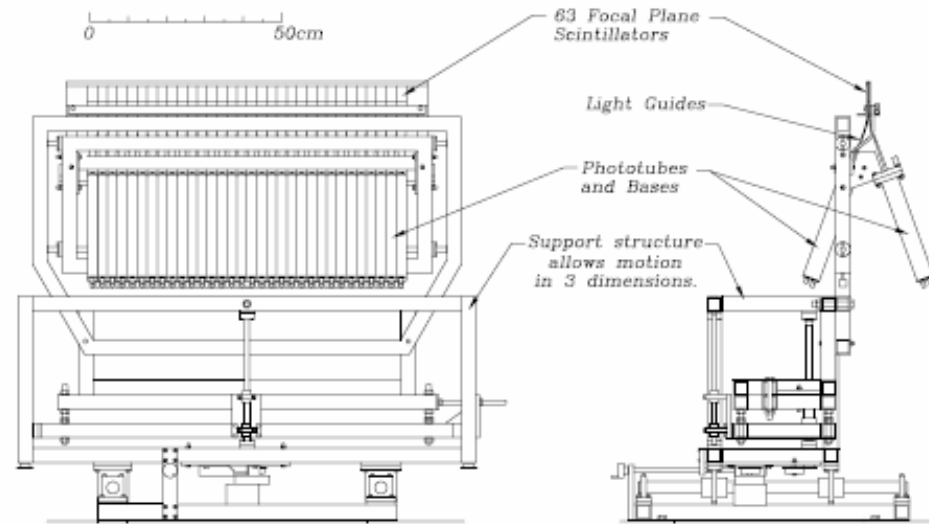
Tagging systems (shielding not shown) from SAL



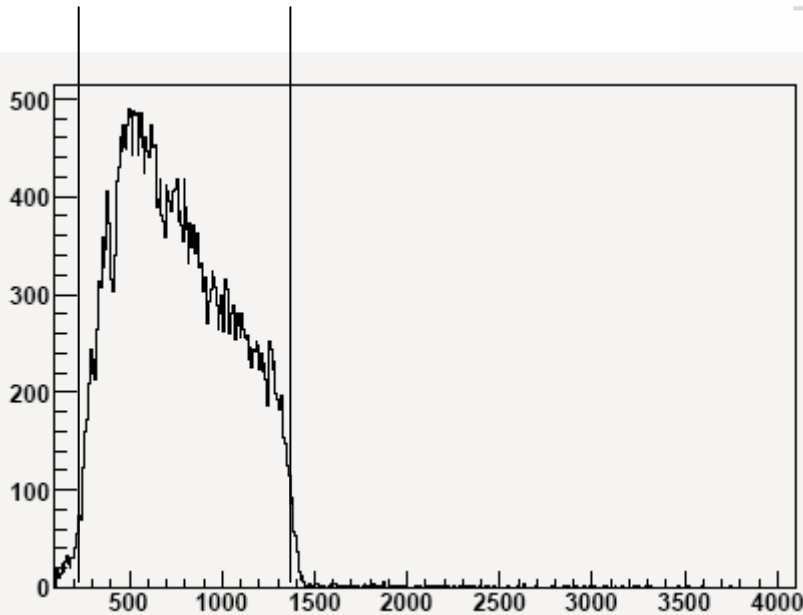
Energy resolution

$$\Delta E_\gamma = \text{range} / 62$$

$$\Delta E_\gamma \approx 1 \text{ MeV}$$



31 MeV 95 MeV



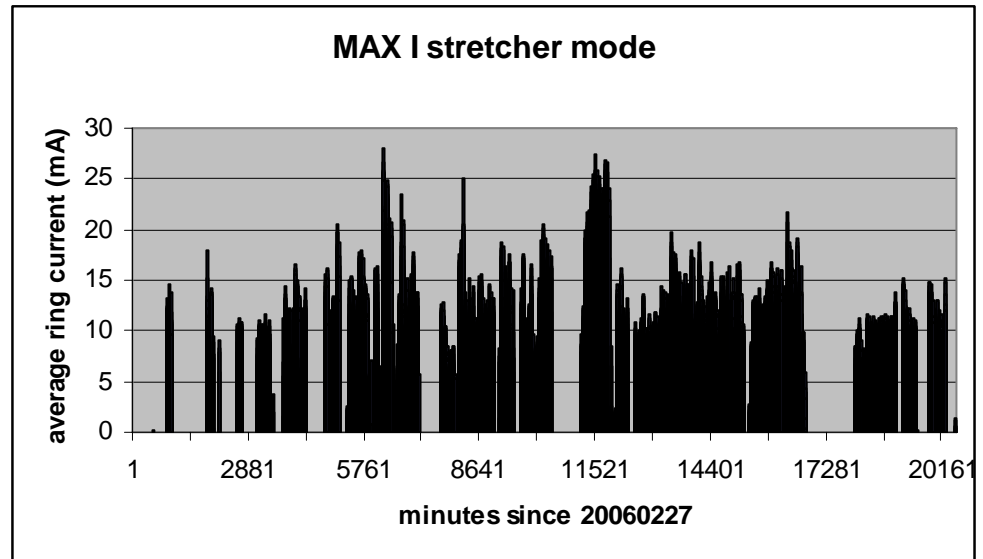
Focal plane hodoscope

A choice of tagging spectrometer (MT or ET), magnetic field (ET), tagger setting (MT) and hodoscope, make a variation in the tagged range and energy resolution possible.

Programme

Knockout reactions e.g. $^{12}\text{C}(\gamma, p)^{11}\text{B}$
Light nuclei e.g. $^4\text{He}(\gamma, n)^3\text{He}$, $^3\text{He}(\gamma, d)p$
Compton scattering e.g. $^2\text{H}(\gamma, \gamma)$,
 $^4\text{He}(\gamma, \gamma)$
Pion production e.g. $p(\gamma, \pi^+)n$, $^2\text{H}(\gamma, \pi^0)$
Pionic atoms

Beam in February/March 2006



Status report

In May/June 2005 combined construction of shielding, beam tests, detector tests, tagger commissioning, tagging efficiency measurements.

In September 2005, 2 weeks were used for the initial commissioning of the MT, the Lund hodoscope and the (γ, p) set up (Si-strip detectors + HpGe detector).

In October 2005 the commissioning experiment $^{12}\text{C}(\gamma, p)$ was measured in the energy range 31 to 95 MeV with the SAL focal plane hodoscope. Detailed data are analysed by Vialimi Takau, University of Melbourne.

In December 2005 CATS was commissioned and the ET was used for the first time to look for π^+ .

In February/March 2006 two new NaI spectrometers were commissioned, BUNI and the Kentucky NaI (1 week), photon beam intensity increased a factor of 5 (1 week), 2 weeks for $^{12}\text{C}(\gamma, \pi^+)$, $^2\text{H}(\gamma, \pi^+)$ and in parallel $^{12}\text{C}(\gamma, \pi^0)$ with CATS and BUNI. Analyses in progress.

In April/May 2006 the lead shielding of BUNI and DIANA were completed. Data from $^{12}\text{C}(\gamma, \gamma)$ at $E_e = 188,5$ MeV. Severe background from π^0 decay photons. New E_e settings: 179,2; 171,7; 163,0; 154,7 and 146,3 MeV. Data from $^{12}\text{C}(\gamma, \gamma)$ at $E_e = 146,3$ MeV; $57,5 < E_\gamma < 92$ MeV, $\Delta_\gamma \approx 550$ keV. Analyses in progress.

Compton@maxlab

University of Edinburgh
Duke University
University of Glasgow
University of Göttingen
University of Illinois
University of Kentucky
Lund University
The Mount Allison University
University of Saskatchewan
The George Washington University

Proposals

2004-03 Compton Scattering from ^4He and ^{12}C

2004-06 Elastic Compton Scattering from Deuterium at 40 - 110 MeV

The goal is to significantly increase the world $^2\text{H}(\gamma,\gamma)$ data set:

40 - 120 MeV

30° - 150°

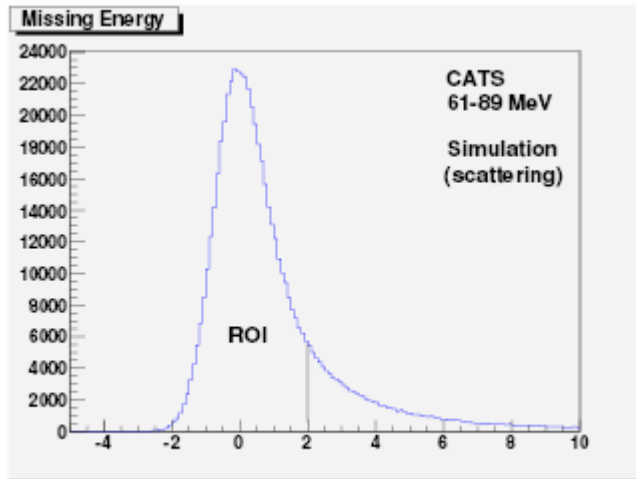
statistical errors < 5%

Three of the largest NaI detectors worldwide:

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

CATS





CATS in beam

$$\Omega_{\text{eff}} = 18,7 \text{ msr}$$

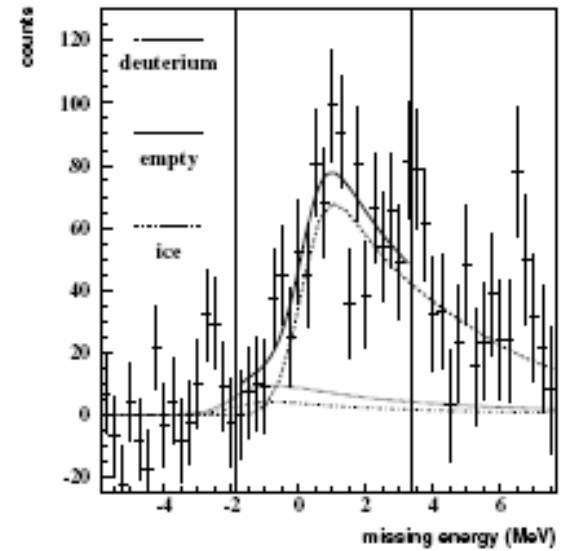
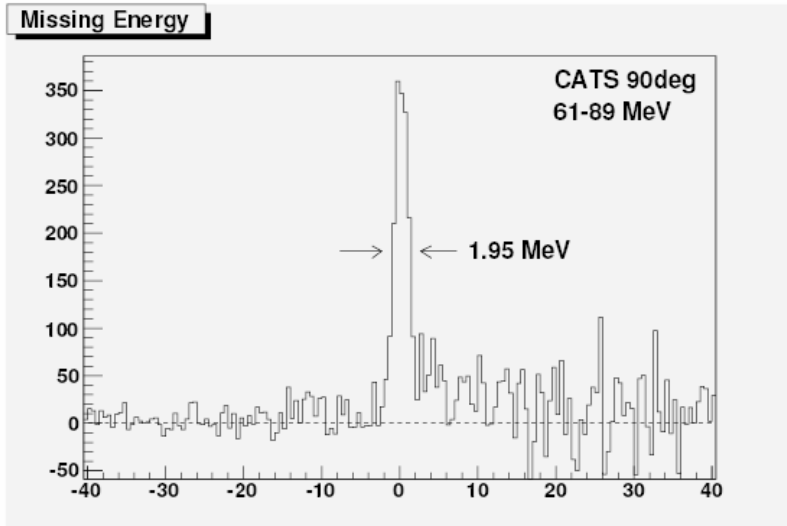


FIG. 1. E_{miss} spectrum at $\theta_y^{\text{lab}} = 126^\circ$ and $E_y = 55 \text{ MeV}$. The two vertical lines indicate the ROI used to determine the yield. The solid line represents the sum of the fitted responses (see text).

Uppsala in scattering position

$$\Omega_{\text{eff}} = 30 \text{ msr}$$

Cross-section

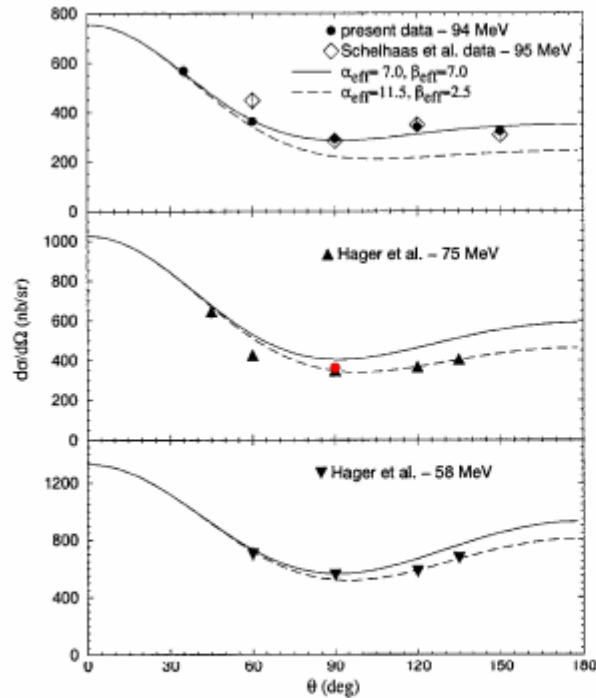
Number of events in ROI:	Y	1703
Number of electrons in FP:	N_e	1.898×10^{12}
Tagging Efficiency:	ϵ_{tag}	0.388
Number of target nuclei:	N_{target}	$4.45 \times 10^{23} \text{ cm}^{-2}$
Effective solid angle:	Ω_{eff}	18.7 msr
Target absorption:	f_{abs}	0.818
Stolen coincidences:	f_{stolen}	0.925

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

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

Expect ~4%

PRELIMINARY



- Warkentin *et al.*, SAL
94 MeV 292 ± 5 nb/sr
- ▲ Hager *et al.*, Lund
75 MeV 348 ± 11 nb/sr
- This measurement
75 MeV 367 ± 19 nb/sr

2004-06 Elastic Compton Scattering from Deuterium at 40 - 110 MeV

Three of the largest NaI detectors worldwide:

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

Two different liquid ^2H targets (HIGS, Lund)

$30^\circ, 60^\circ, 90^\circ, 120^\circ, 150^\circ$

40 - 65 MeV, 60 - 95 MeV, 90 - 110 MeV

with $E_e = 146,3 \text{ MeV}$ MT(460) \rightarrow 57,5 - 92 MeV
ET \rightarrow 100 - 116 MeV

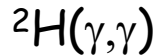
Conclusions

The upgraded tagged photon beam at MAX-lab is operational and experiments have started

First data from Compton scattering on ^{12}C are under analysis

Commissioning work remains (shielding, ET, ...)

Once data from CATS, BUNI and DIANA "agree", the next step is



Supported by the Swedish Research Council, The Crafoord Foundation, The Royal Physiographical Society, and the European Community under the "Structuring the European Research Area" Specific Programme Research Infrastructures Action (Hadron Physics, contract number RII3-cT-204-506078).

