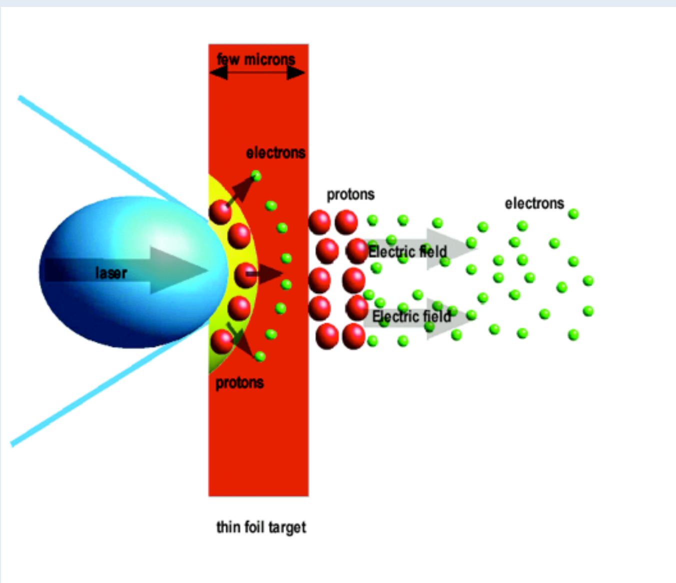
Recent results about proton acceleration

Dario Giove on behalf of the NTA_SL_LILIA group

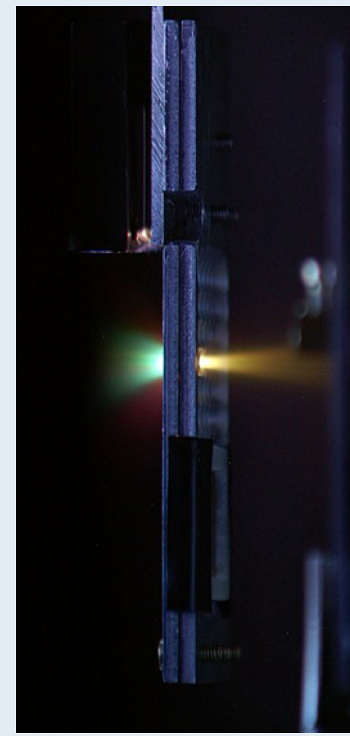
NTA-SL-LILIA (Laser Induced Light Ions Acceleration)

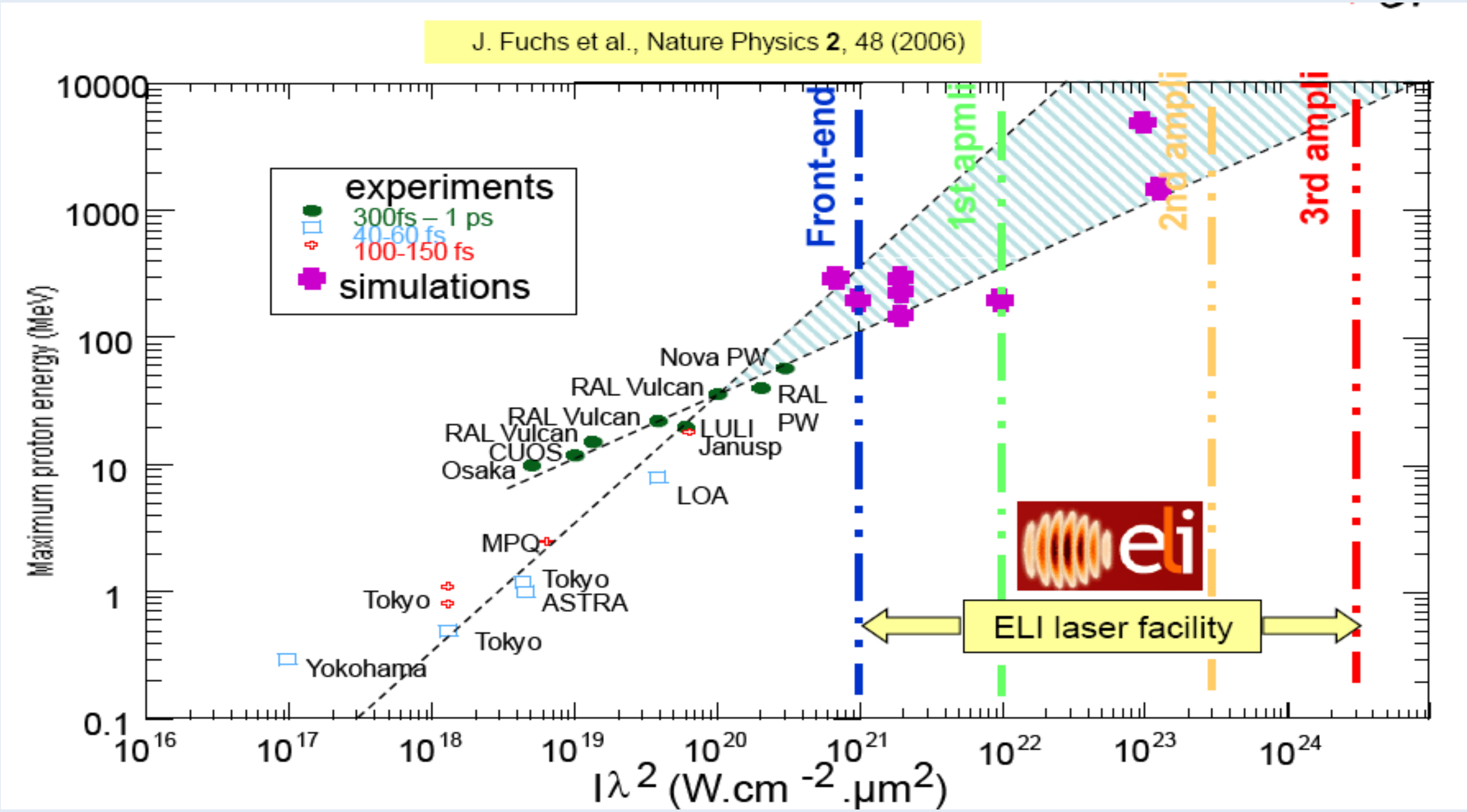
NTA-SL-LILIA LILIA is an experiment of light ions acceleration trough laser interaction with thin metal targets to be done at the SPARC-LAB facility under operation in Frascati.

The main goal is to obtain a beam suitable for injection in other accelerating structure.



Participant Groups:
Milano, Milano Bicocca, Bologna, Pisa, Lecce, LNS, LNF.





With the power density available from FLAME we could reach proton energy in excess of 100 MeV. As of now we are limited to 5x1019 W/cm2 and we can foresee a maximum proton energy of 10 MeV

Laser Parameters

Beam diameter 120mm
~flat top
M2≈1.5
Waist (I/e2)≈ 10µ
contrast≈10^{-10}
Raileigh length= 260µ
Pulse duration: 25-35 fs
Max Energy on target: 4J
Long focal length parabola
Max Intensity I=6.8 10^{19}W/cm^2 (35 fs) or 9.6 10^{19} (25fs)
Short focal length OA Parabola: waist≈2.5µ, I≈1021W/cm2

Study and Simulation of the Proton Emission

Scaling in TNSA regime from AlaDyn simulation, theory and Dresda data

Emax = k a 1.6

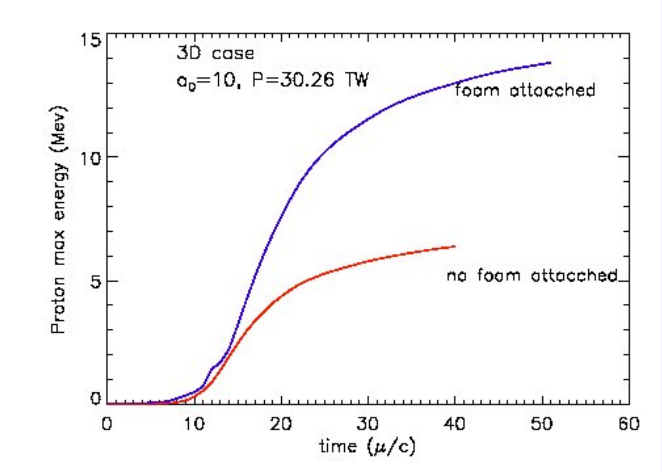
with a ~ I1/2.

For LILIA at the beginning we expect a < 8 e   Emax ~ 4 MeV.

In phase-2 we expect a> 30 e   Emax > 30 MeV.

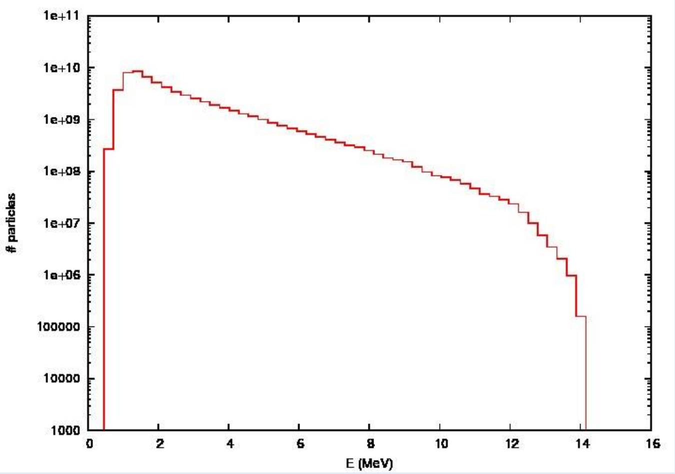
With structured targets we can double the energy

Energy evolution for a bare and structured target



Energy distribution $r(E)= N/E_0\ e^{-E/E_0}$

$E_0 \approx E_{max}/8$ average energy



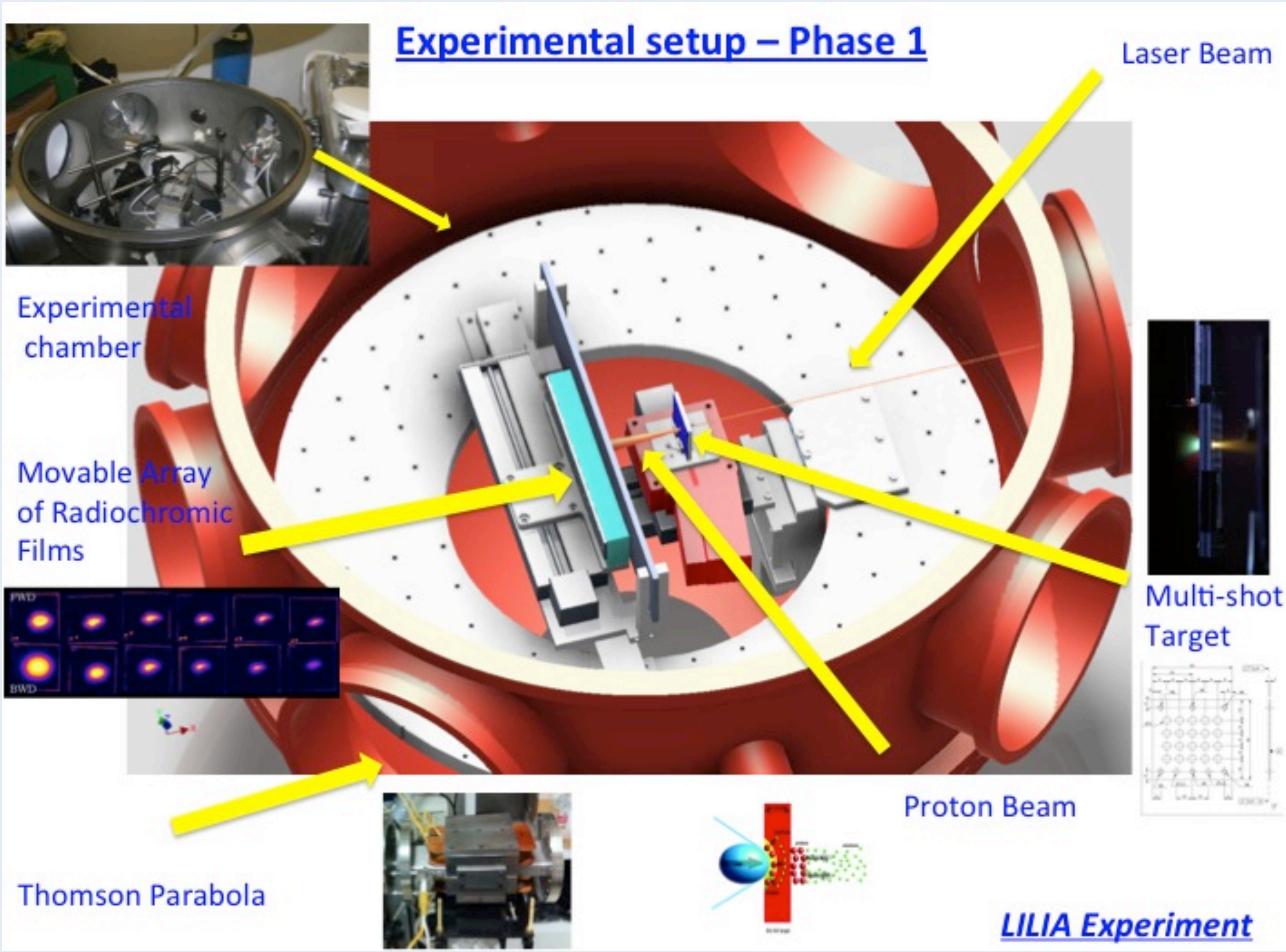
NTA_SL_LILIA (2012 and up to December 2013)

A parametric study of the correlation of the maximum TNSA accelerated proton energy, with respect to the following parameters:

Laser pulse energy (in the range 0.1-4 J)
Metallic target thickness (in the range 1-10 microns).

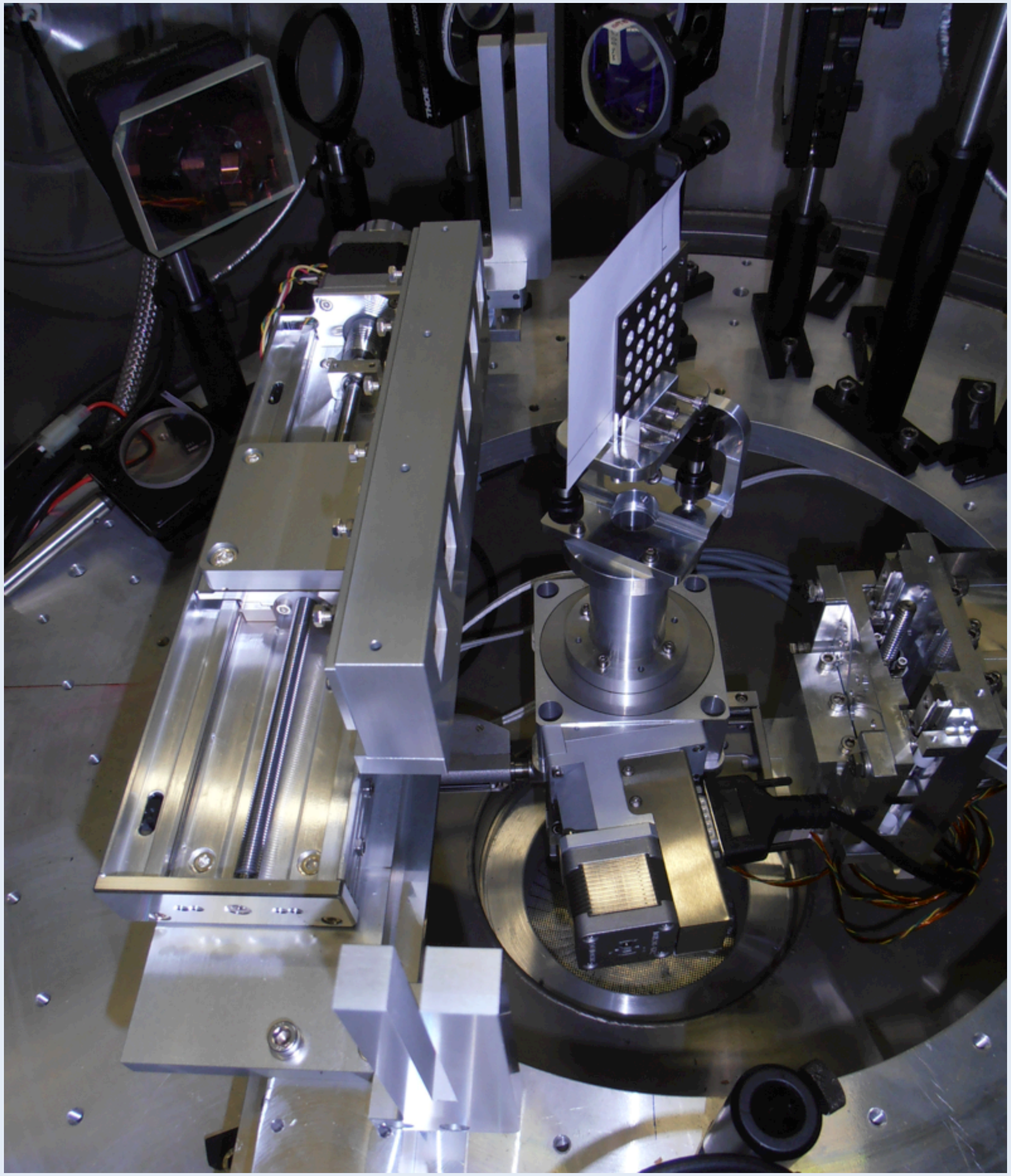
In such a frame we would deeply investigate the experimental scale rules within the possibilities offered by the FLAME facility.

Moreover, this will provide the opportunity to get experience in the development of diagnostic techniques and in target optimization.

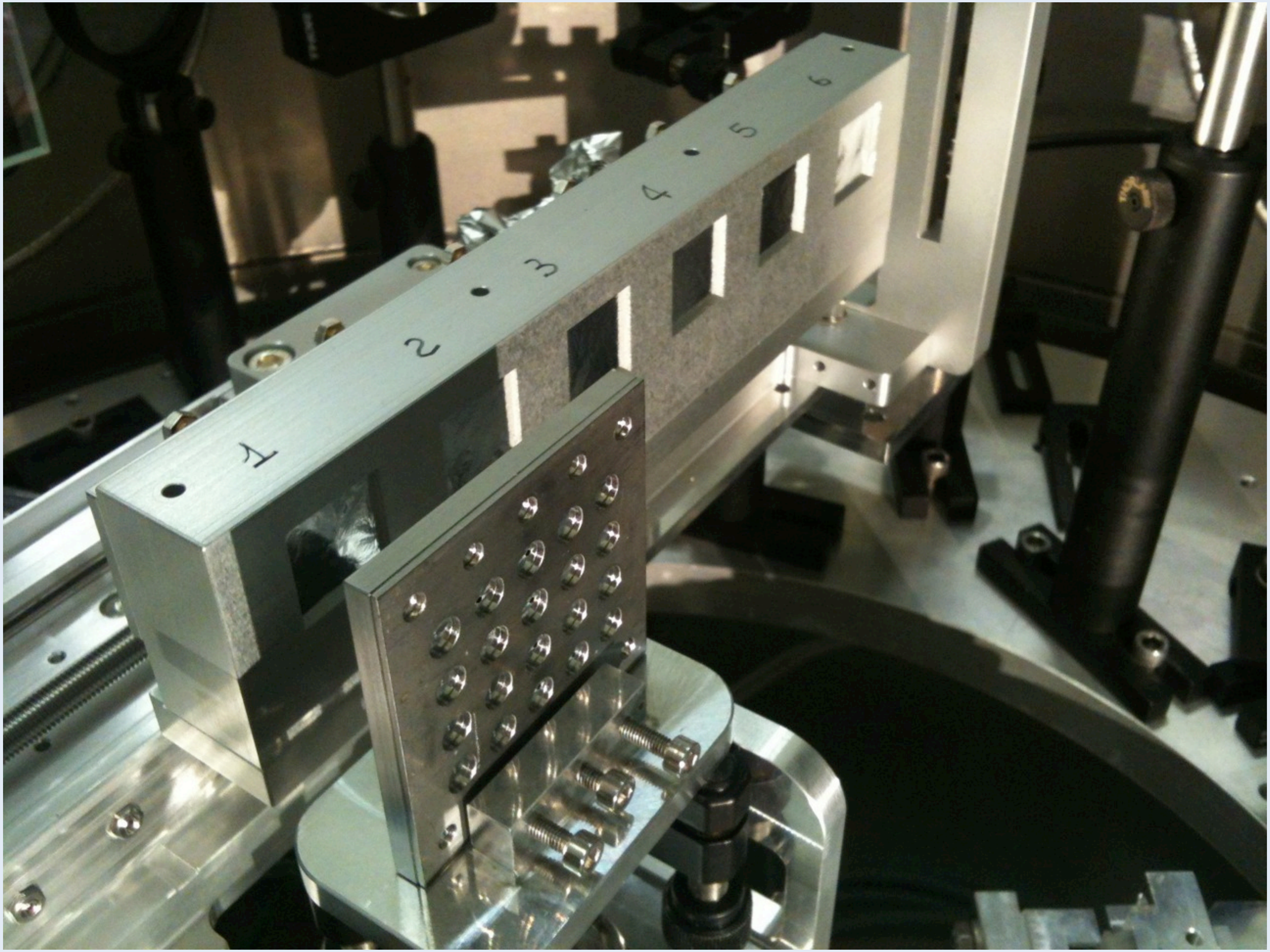

Experimental setup – Phase 1
Laser Beam
Experimental chamber
Movable Array of Radiochromic Films
Multi-shot Target
Proton Beam
Thomson Parabola
LILIA Experiment

Status @ 7 November 2012

- Mechanical setup assembled and aligned in the experimental chamber
- 4 linear stages and 1 rotation stage (for target and detectors) fully integrated in the main control system
- Start of the tests with the FLAME laser from November 13 2012
- PIN diodes detectors assembled in the interaction chamber for tests on electronic noise



Beam tests from November 13 to December 22


1
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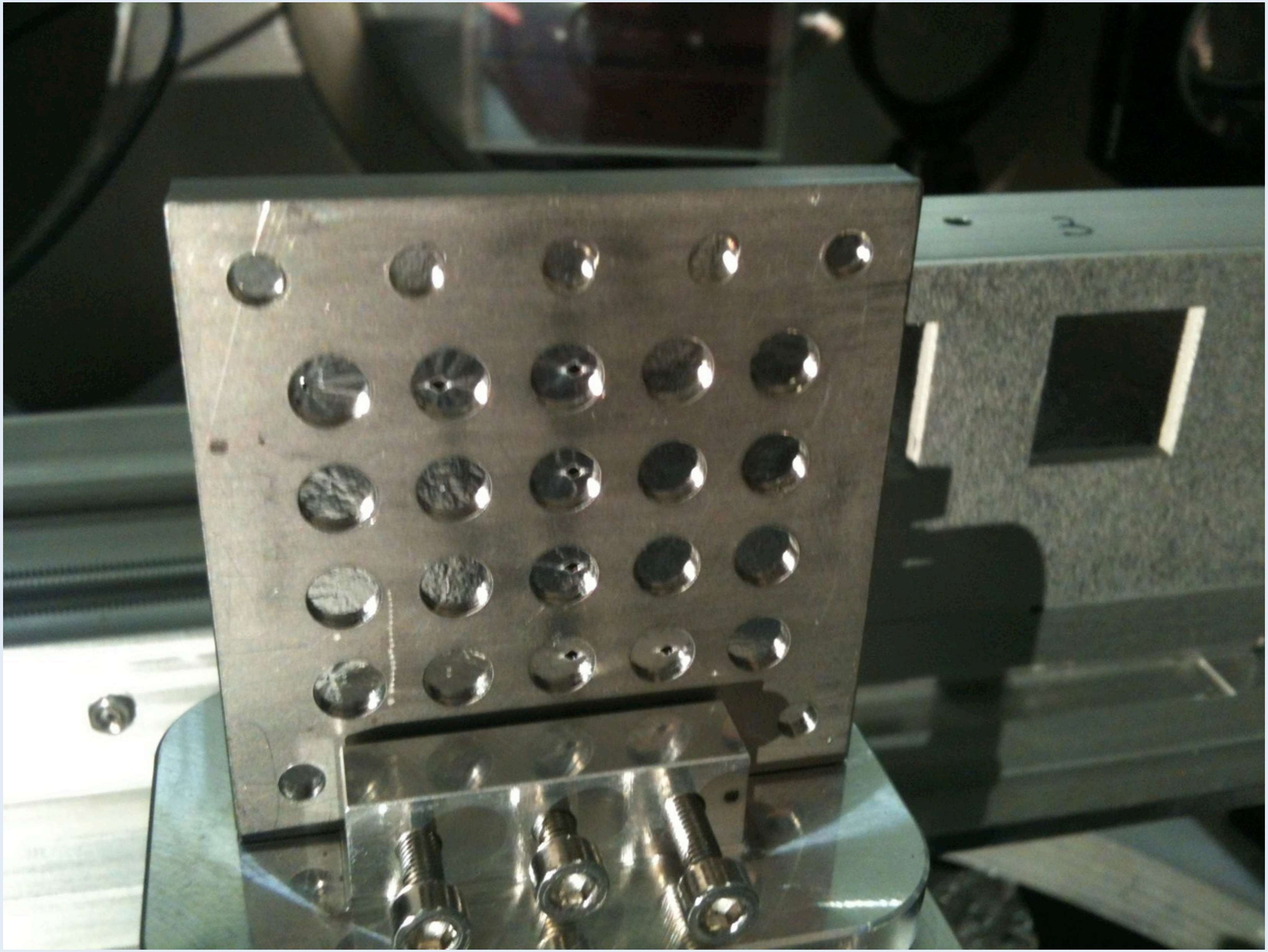
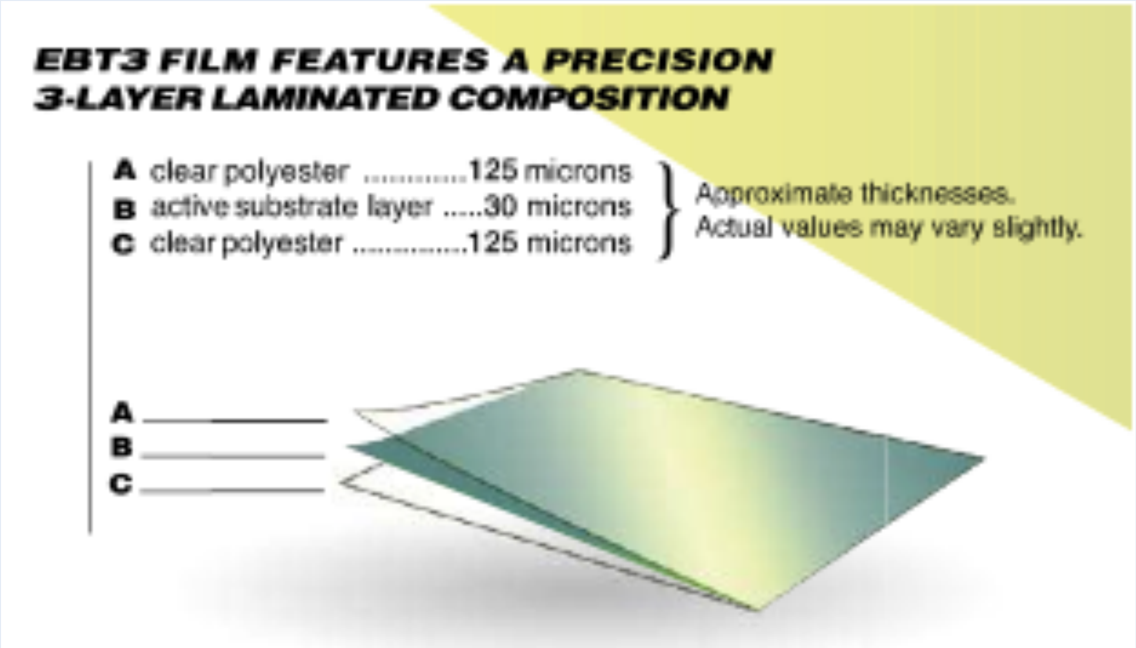
6





Range 0.01-40 Gray

GAFCHROMIC® MD-55 radiochromic dosimetry film is designed for the measurement of absorbed dose of high-energy photons. In this regard, the response of the film is energy-independent for photons above about 0.2MeV. The structure of GAFCHROMIC® MD-55 radiochromic dosimetry film is shown in Figure MD-1.

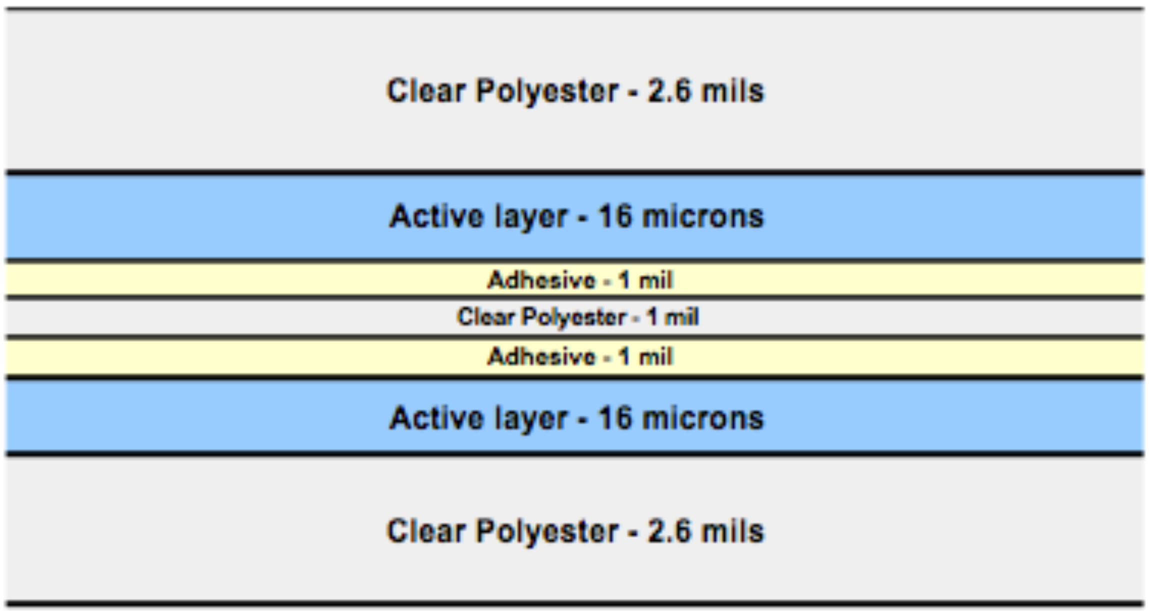


Figure MD-1: Configuration of GAFCHROMIC® MD-55 dosimetry film

Range 1-50 Gray

The structure of GAFCHROMIC® HD-V2 film is shown in Figure 1. The film is comprised of a active layer, nominally 8µm thick, containing the active component, marker dye, stabilizers and other components giving the film its energy-independent response. The thickness of the active layer may vary slightly from batch-to-batch. The active layer is coated on a clear, 97 µm polyester substrate.

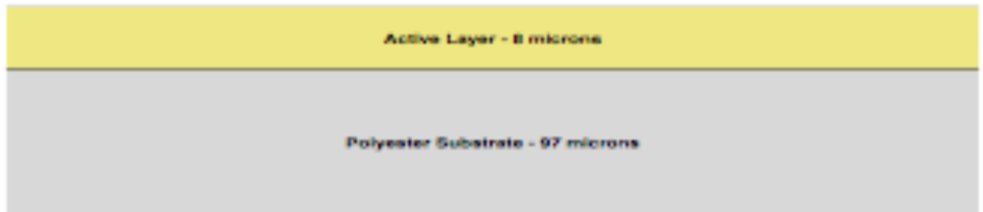
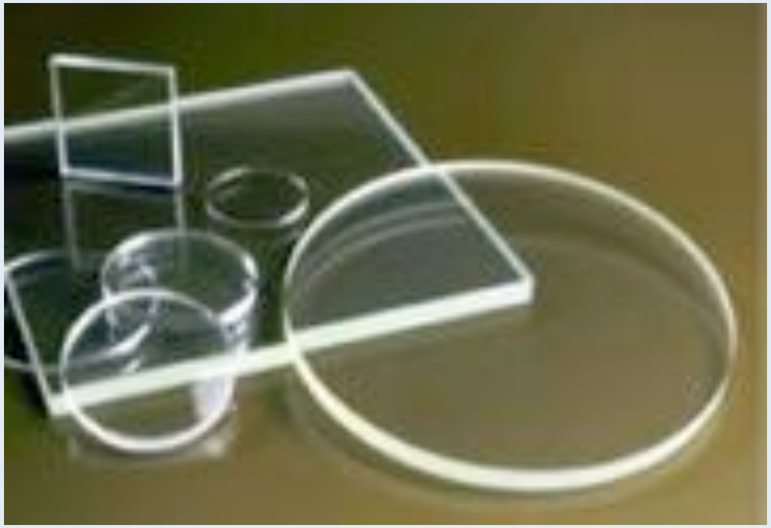


Figure 1: Configuration of GAFCHROMIC® HD-V2 Dosimetry Film

Range 10-100 Gray

CR-39 is an allyl glycol carbonate plastic that has been widely used as a passive, limited spectral reso-lution, solid state nuclear track detector (SSNTD)



Target: Al foil. Depth from 12 to 3 μm

Thin Al foil in front of the gafchromic detectors (3 μm)

Al foil in front of the CR39 detector (16 to 6 μm)

800 KeV protons have a range in Al equal to 10,42μm
1.1 MeV protons have a range in Al equal to 16,00 μm

4 MeV protons have a range in poliethilene
(density ’ 0,93 $g/cm^{3)}$ equal to 210,64 μm.

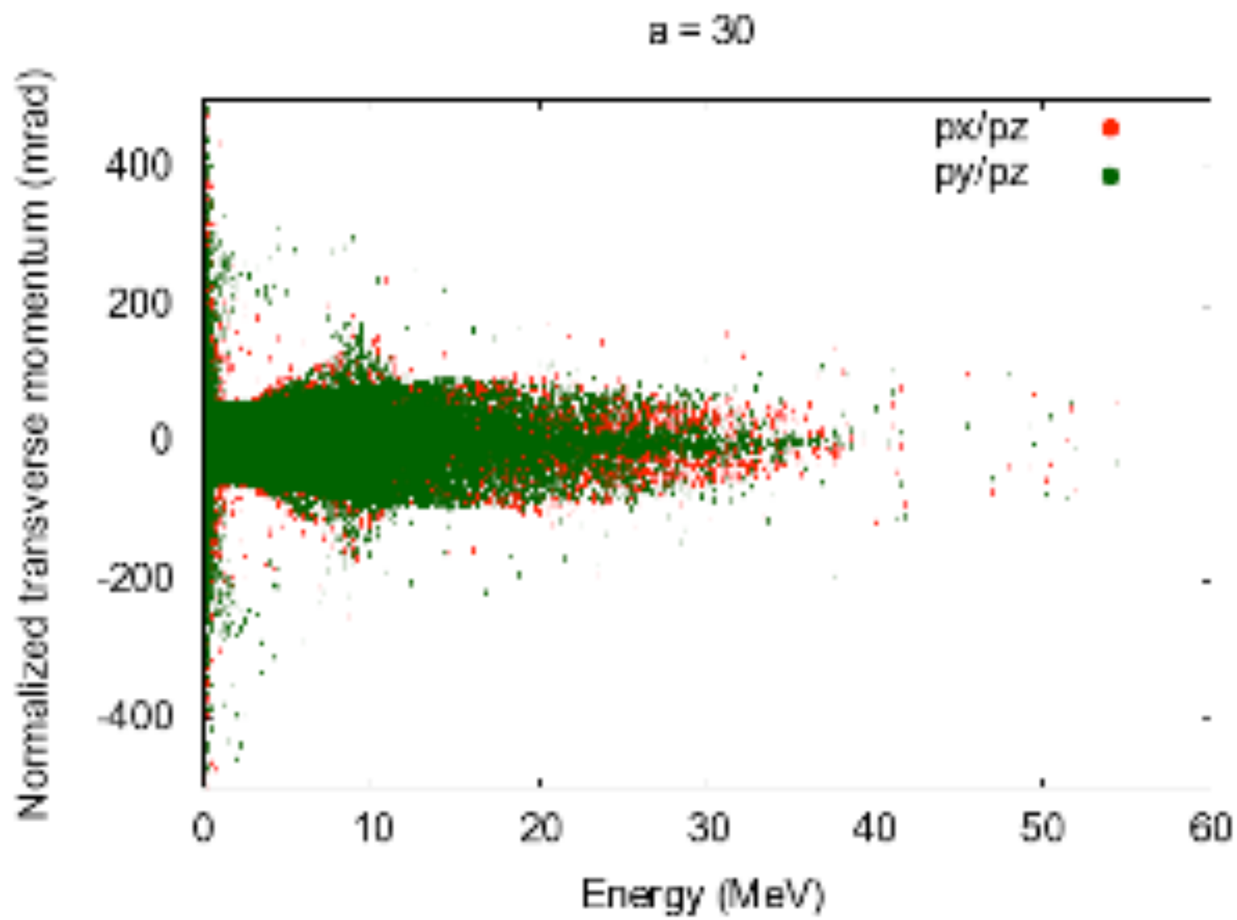
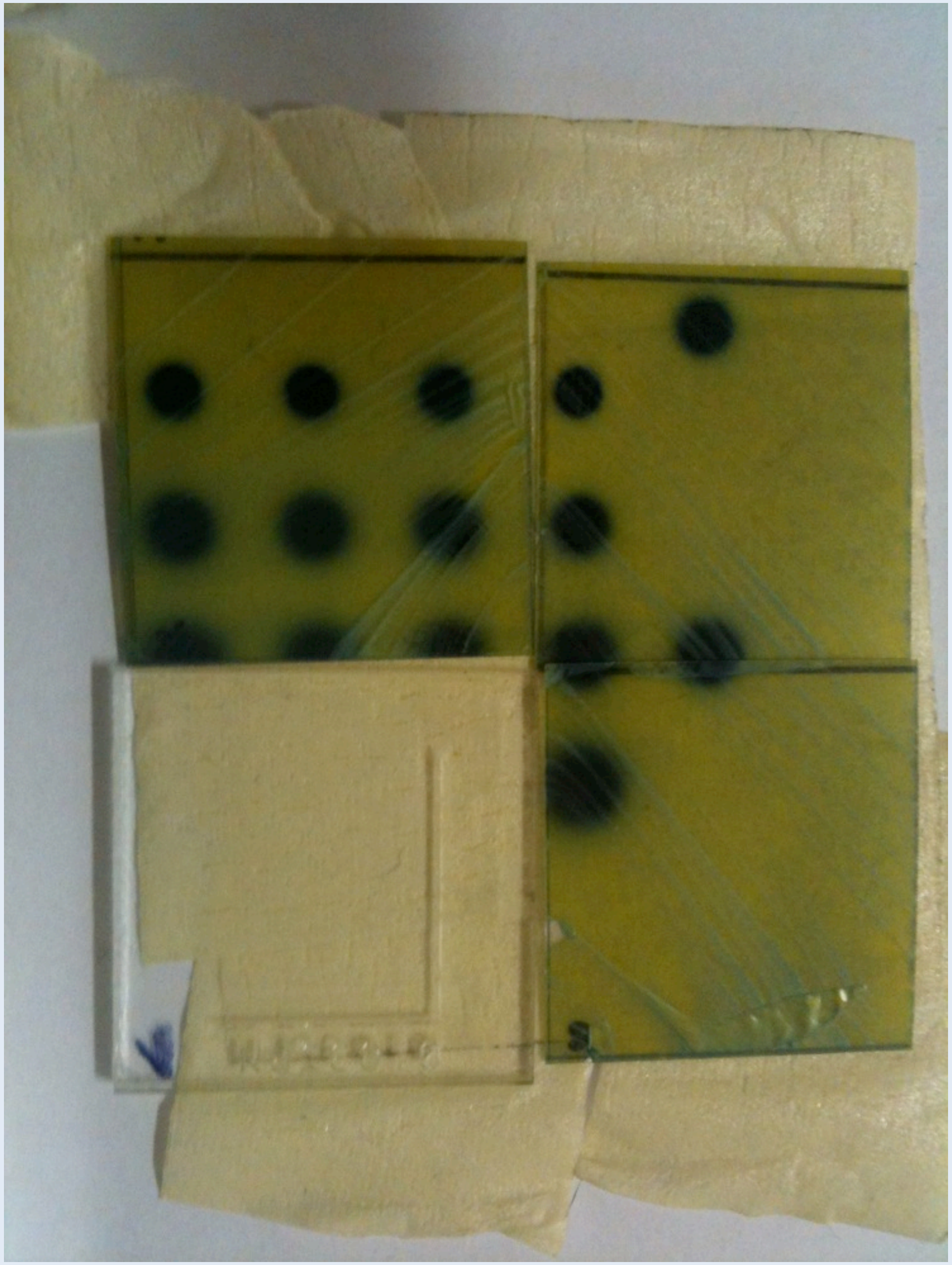
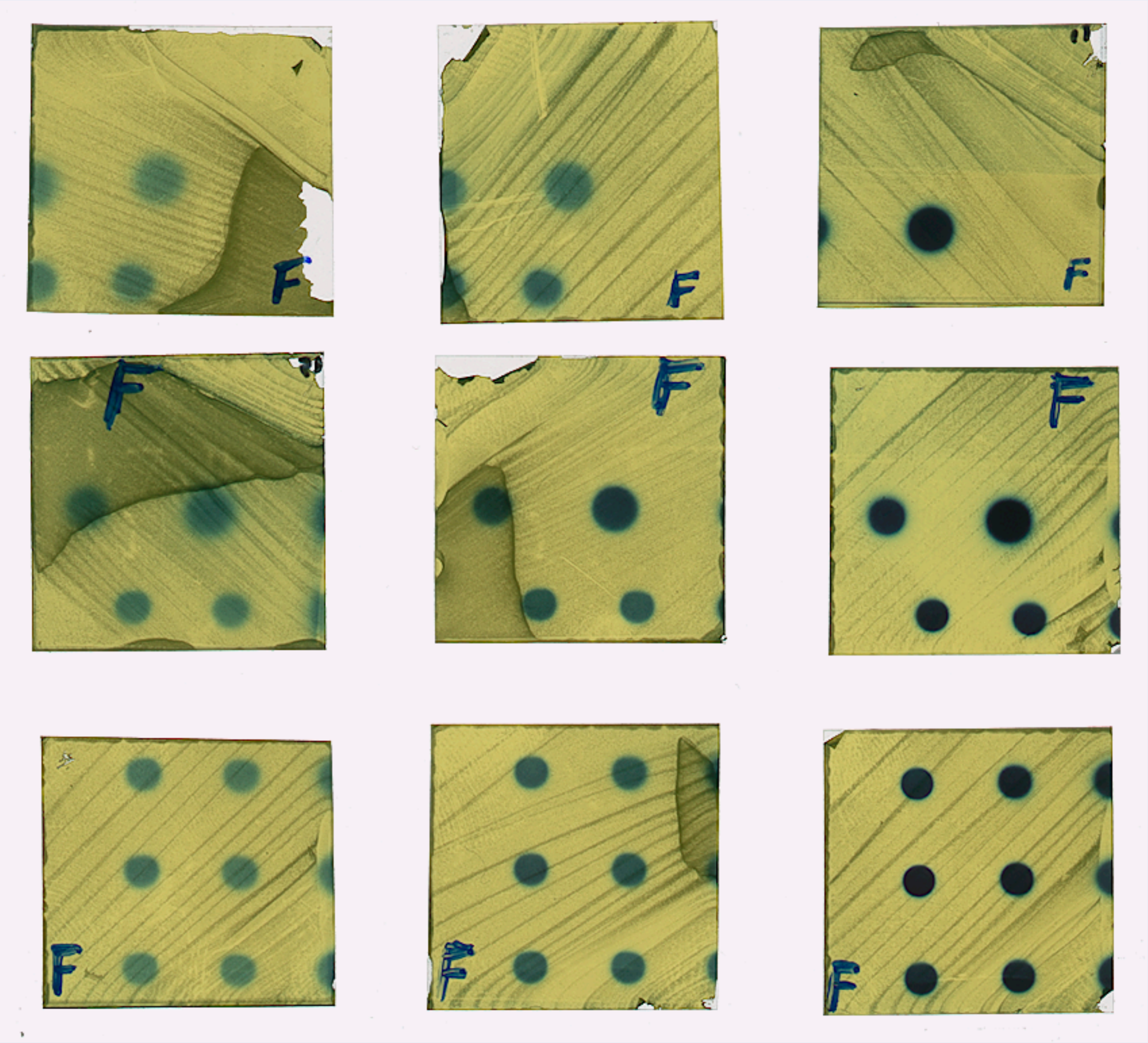


FIG. 2: Plot of the angular spread as a function of energy

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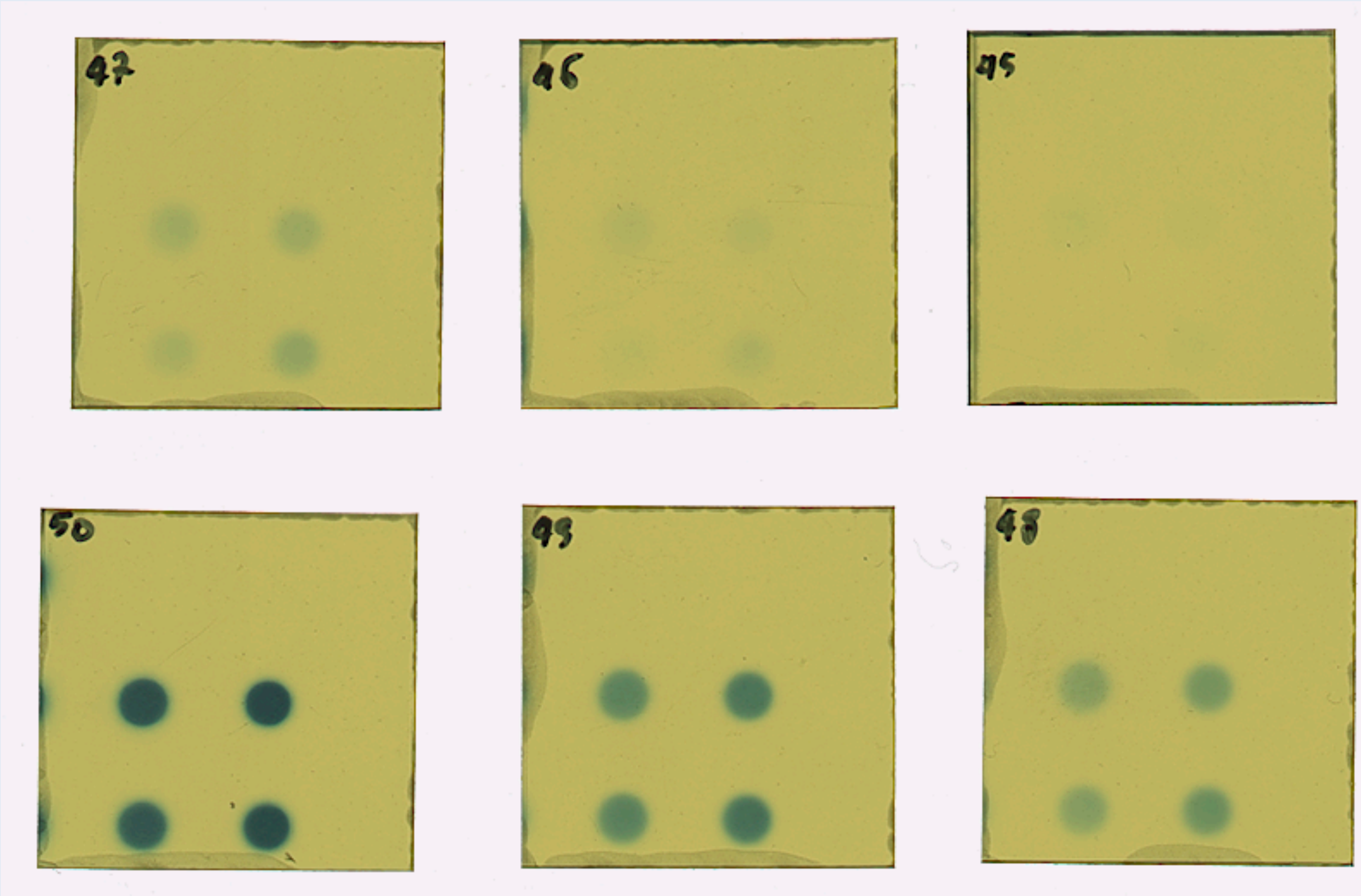
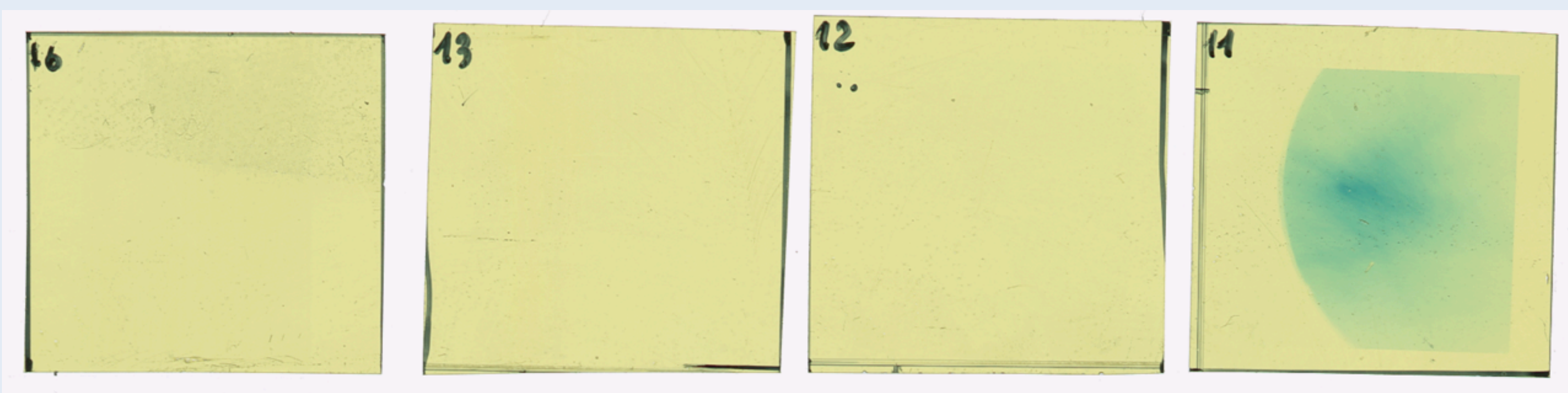
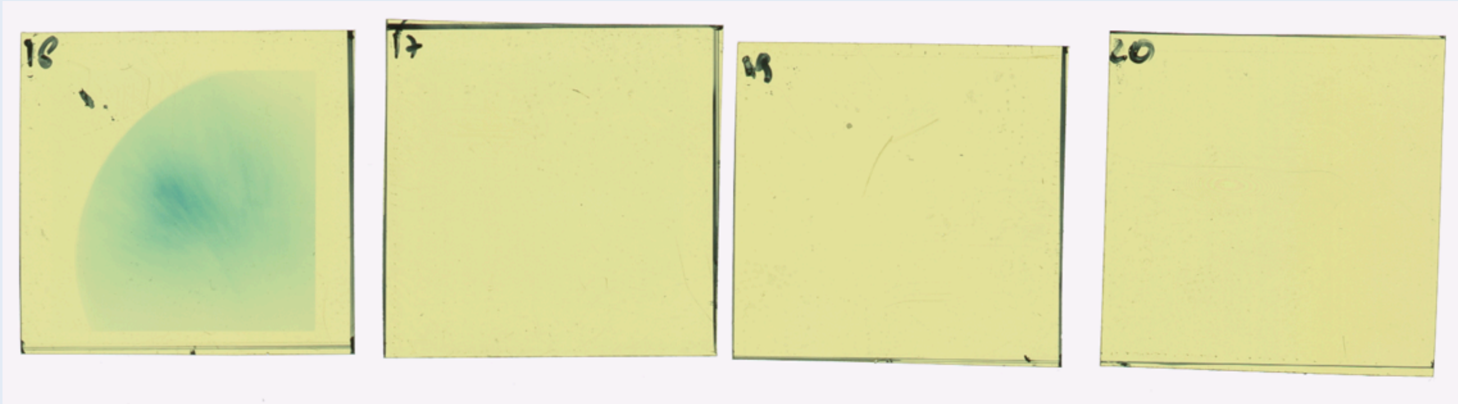
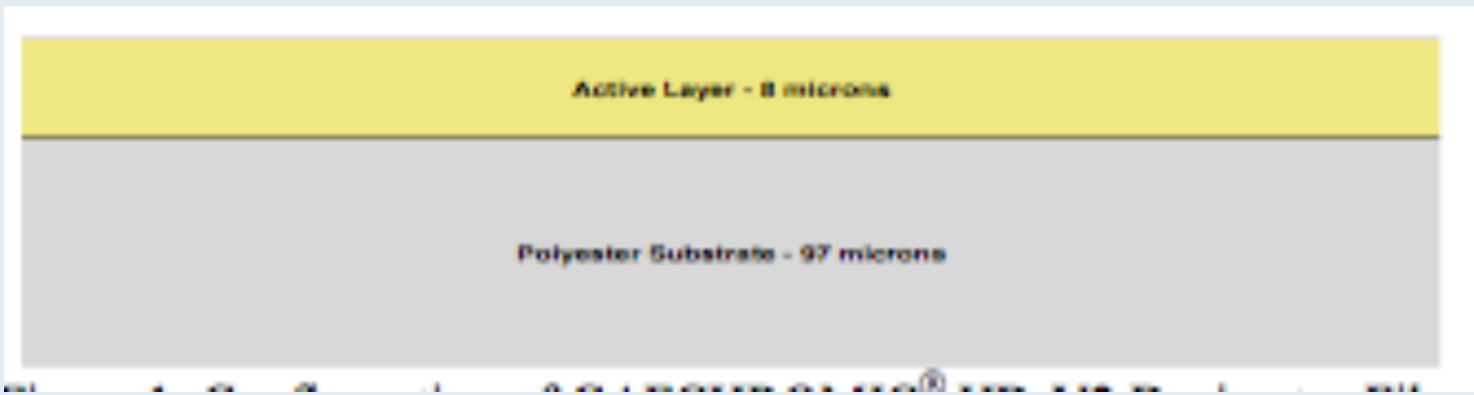

47
46
45
50
49
48

Detectors @ 45 mm from the target

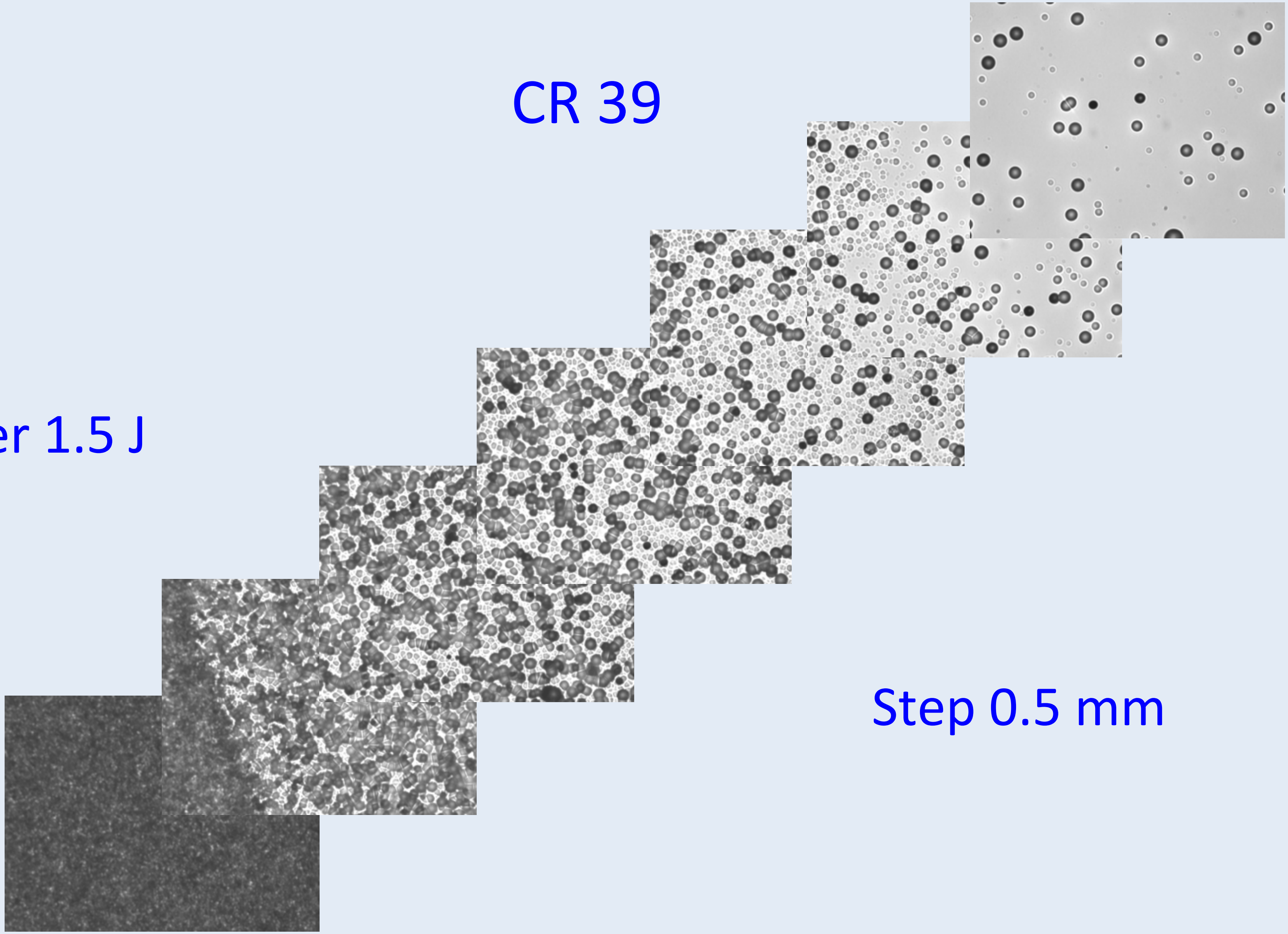




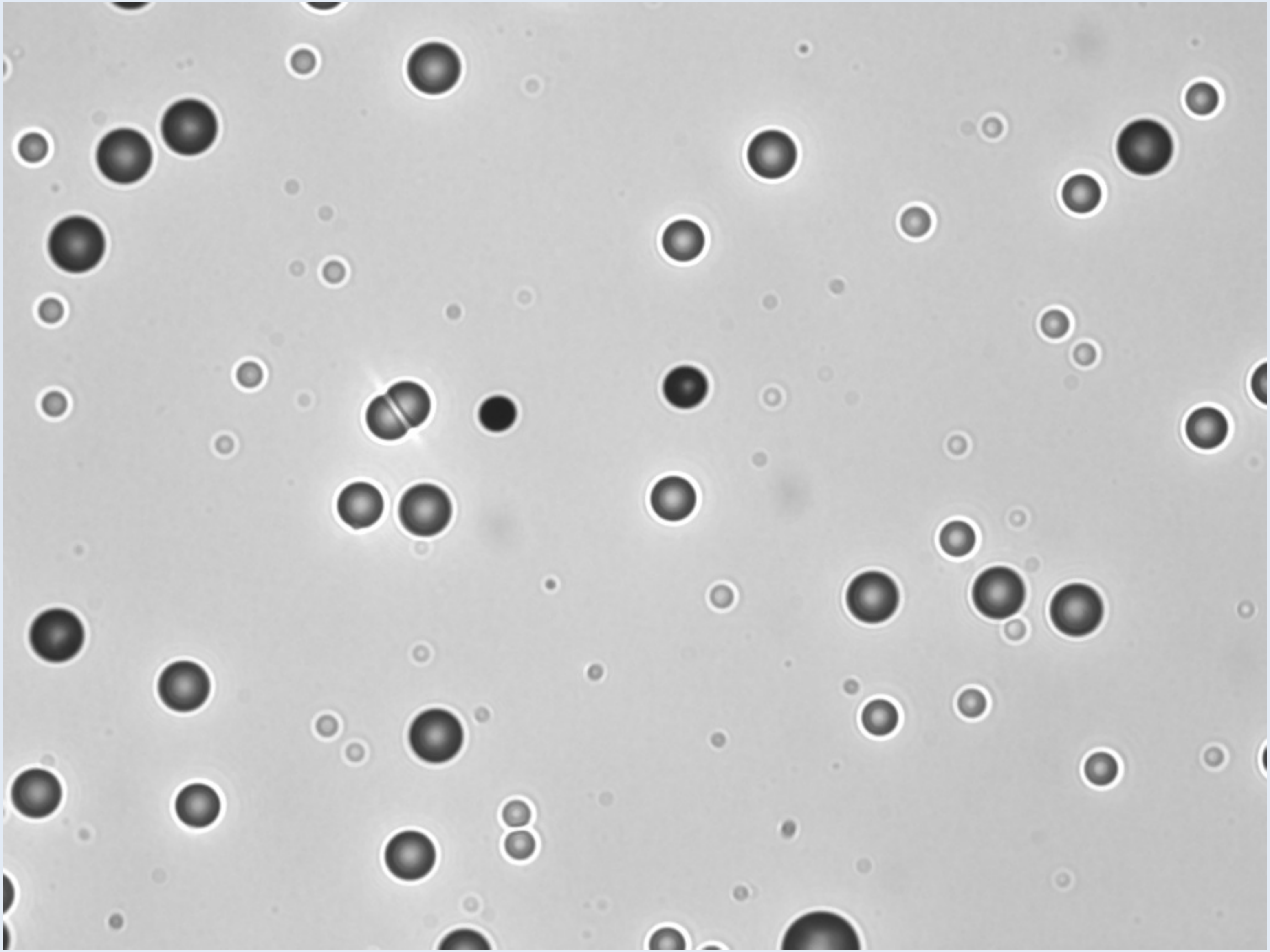

Active Layer - 8 microns
Polyester Substrate - 97 microns

CR 39

laser 1.5 J



Step 0.5 mm



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Determination of *LET* in PADC detectors through the measurement of track parameters

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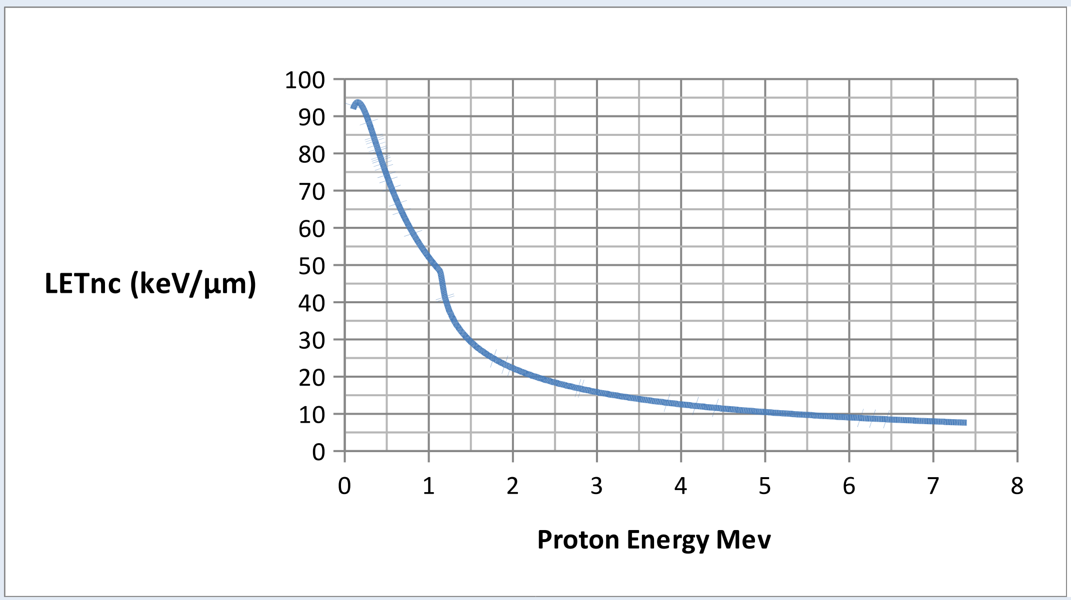
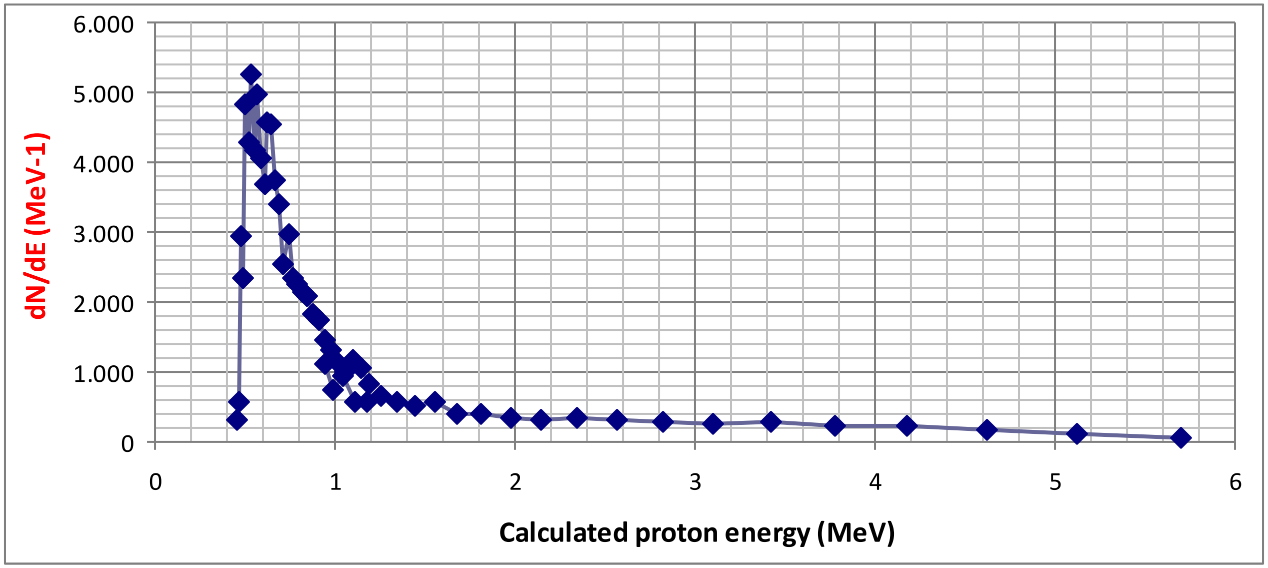
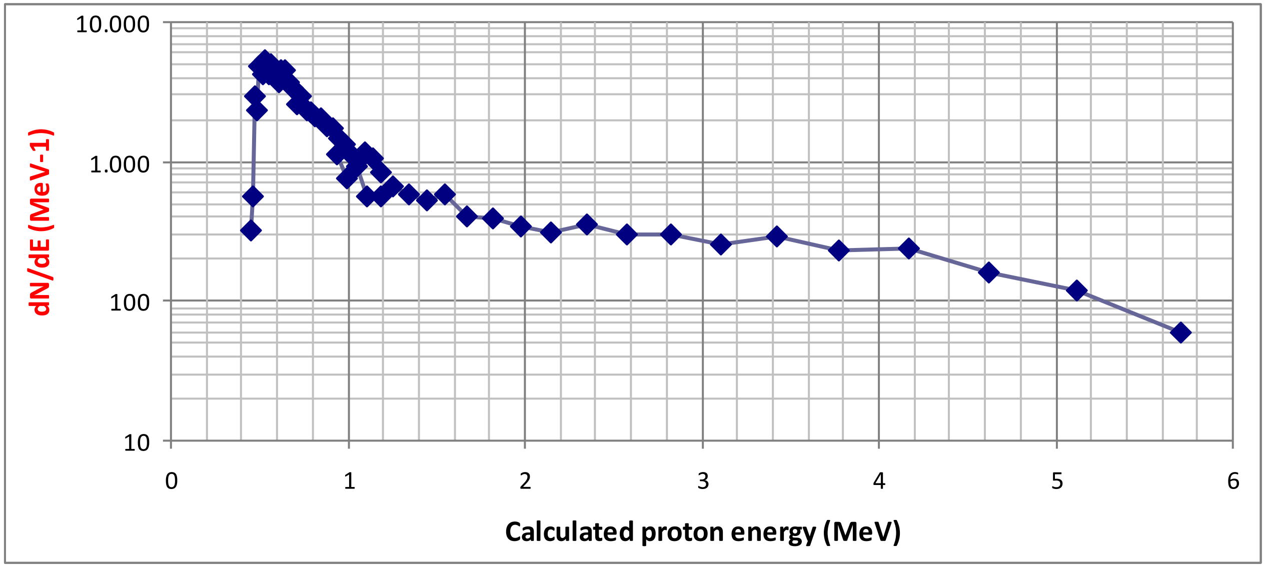
[c] Paul Scherrer Institut (PSI), Radiation Metrology Section, CH-5232 Villigen PSI, Switzerland




dN/dE (MeV-1)
6.000
5.000
4.000
3.000
2.000
1.000
0
0
1
2
3
4
5
6
Calculated proton energy (MeV)


dN/dE (MeV-1)
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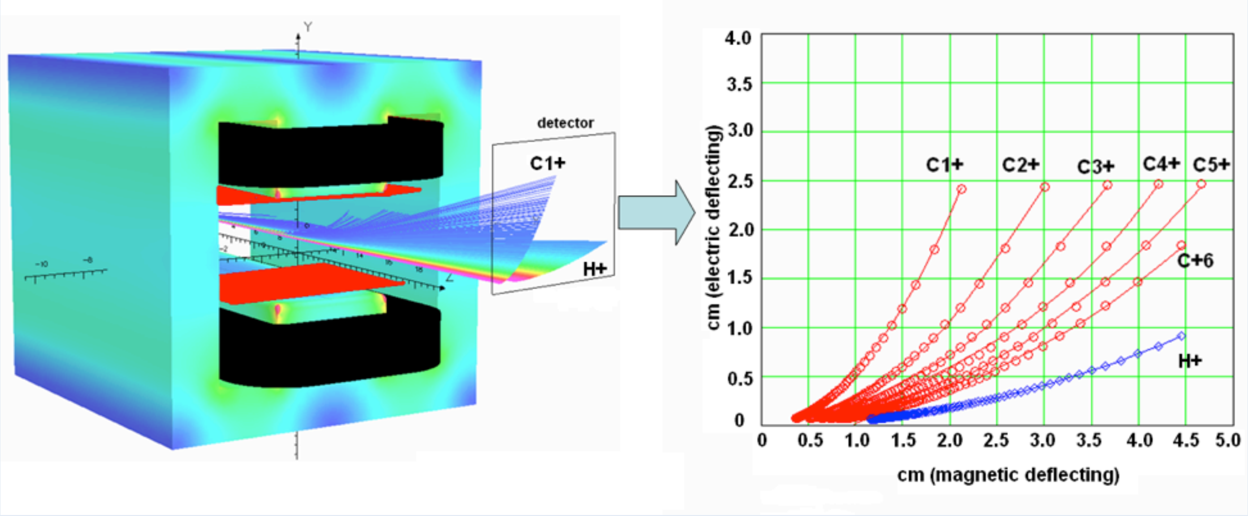
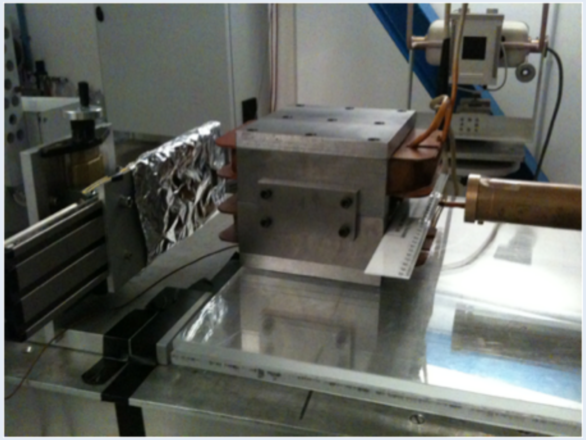
1.000
100
10
0
1
2
3
4
5
6
Calculated proton energy (MeV)

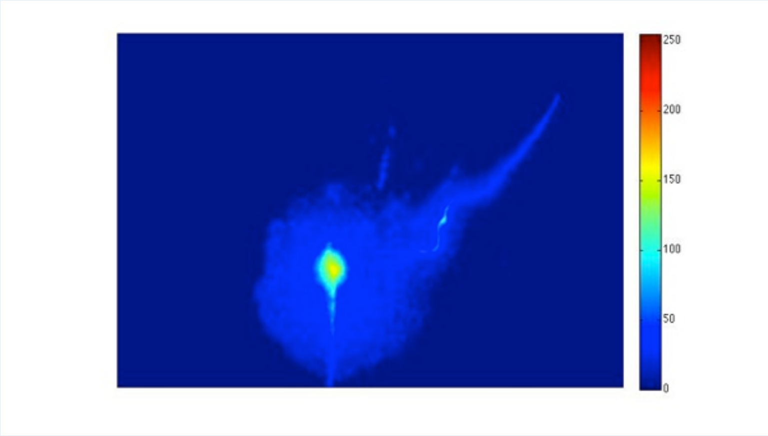
May 2013 run



Thomson Parabola during tests with a proton beam at LNS cyclotron



THOMSON SPECTROMETER: Analysis of proton and carbon beams (Q=+1 to + 6) from 0.1 MeV to 10 MeV



Laser Shot Induced Noise

- Background em noise along signal cables (length up to 50 m):
  +-50 mV, 5 MHz, 2 μs, 16 kHz

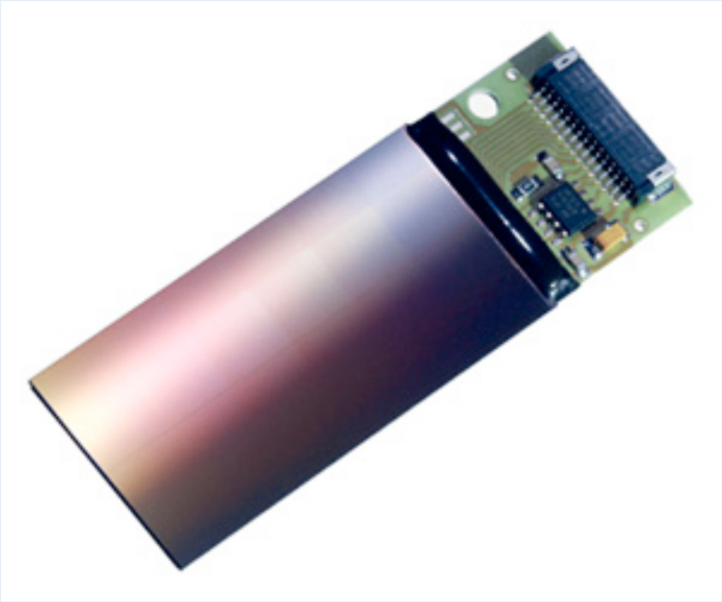
- Em noise induced by the laser shot on the target:
  +-1 V, 250 MHz, 200 ns

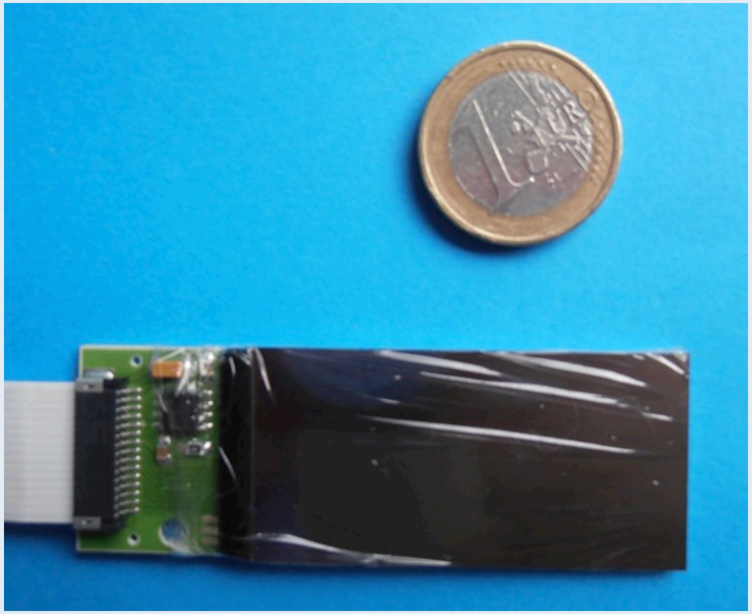
Very Preliminary

In progress

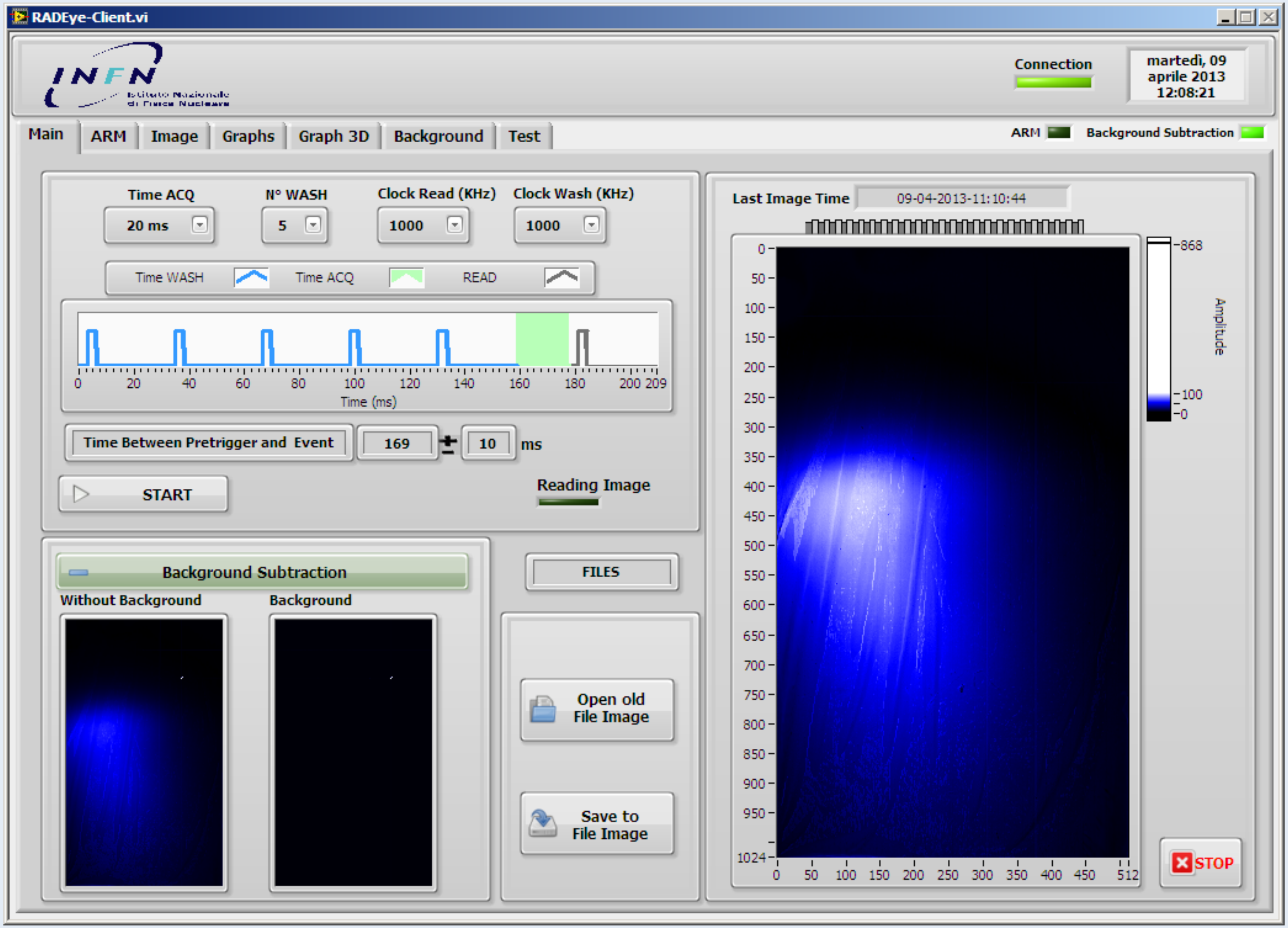
Large area detector: CMOS photodiodes array

- Detector size 25 x 50 mm
- Pixel size 48 micron
- 512 by 1024 matrix of silicon photodiodes
- Dinamic range 85 dB
- Max. frame rate 4.5 fps





In progress


RADEye-Client.vi
Connection
martedì, 09 aprile 2013 12:08:21
Main
ARM
Image
Graphs
Graph 3D
Background
Test
ARM
Background Subtraction
Time ACQ
20 ms
N° WASH
5
Clock Read (KHz)
1000
Clock Wash (KHz)
1000
Time WASH
Time ACQ
READ
Time (ms)
Time Between Pretrigger and Event
169
10
ms
START
Reading Image
Background Subtraction
Without Background
Background
FILES
Open old File Image
Save to File Image
Last Image Time
09-04-2013-11:10:44
Amplitude
STOP

In progress

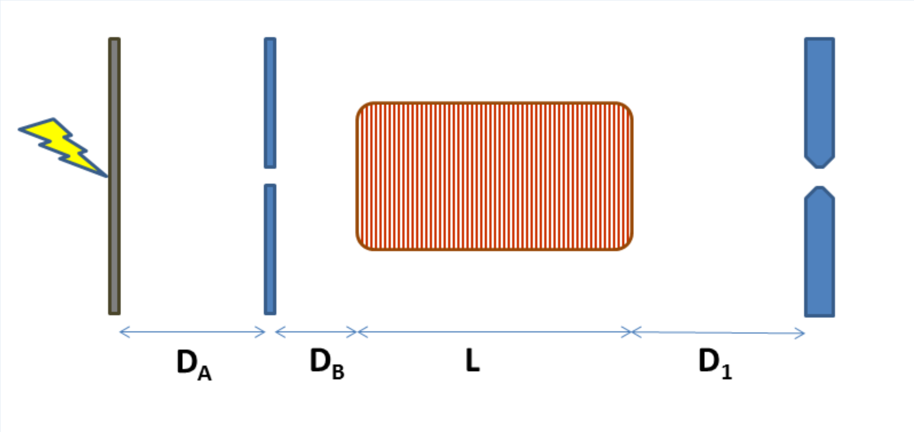


FIG. 4: Schematic draw of the transport line. $D_A = D_B = 10$ mm, $D_1 = 510$ mm, L = 300 mm, first iris radius = 0.5 mm, second iris radius = 0.6 mm, second iris minimum thickness = 5 mm.

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 031301 (2013)

Transport and energy selection of laser generated protons for postacceleration with a compact linac

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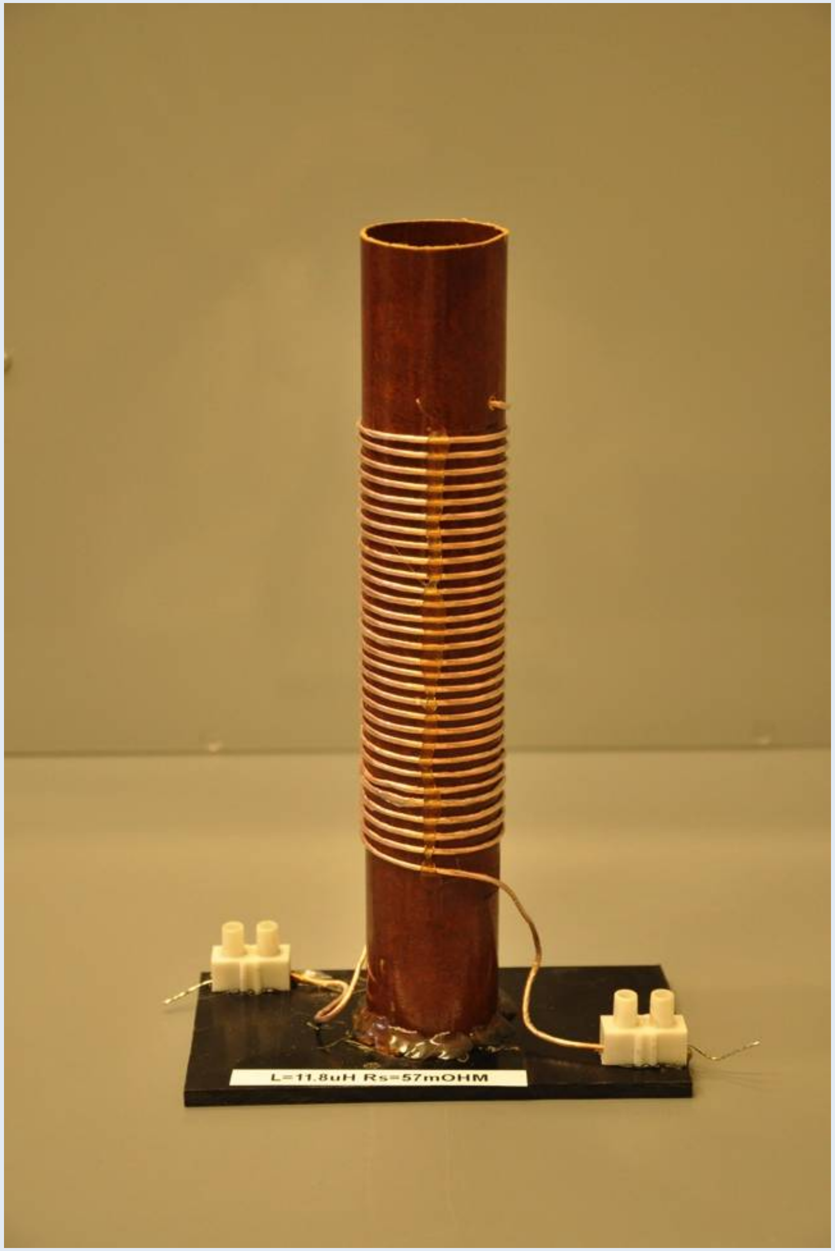
(Received 23 May 2012; published 1 March 2013)

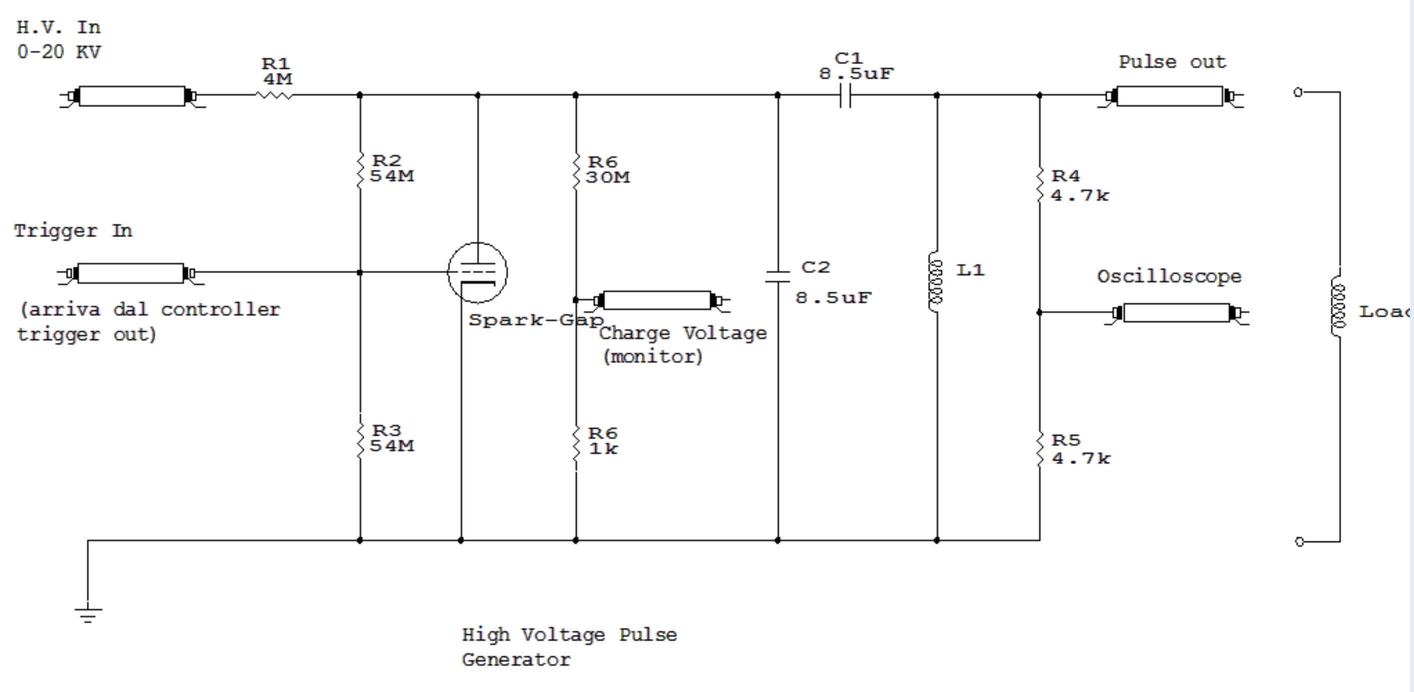
In progress

Prototype of a solenoid designed for pulsed operations and maximum field of 3 Tesla. The internal diameter is of 50 mm.

The excitation pulse will last nearly 10 microseconds and the related current is of the order of 20 kA.



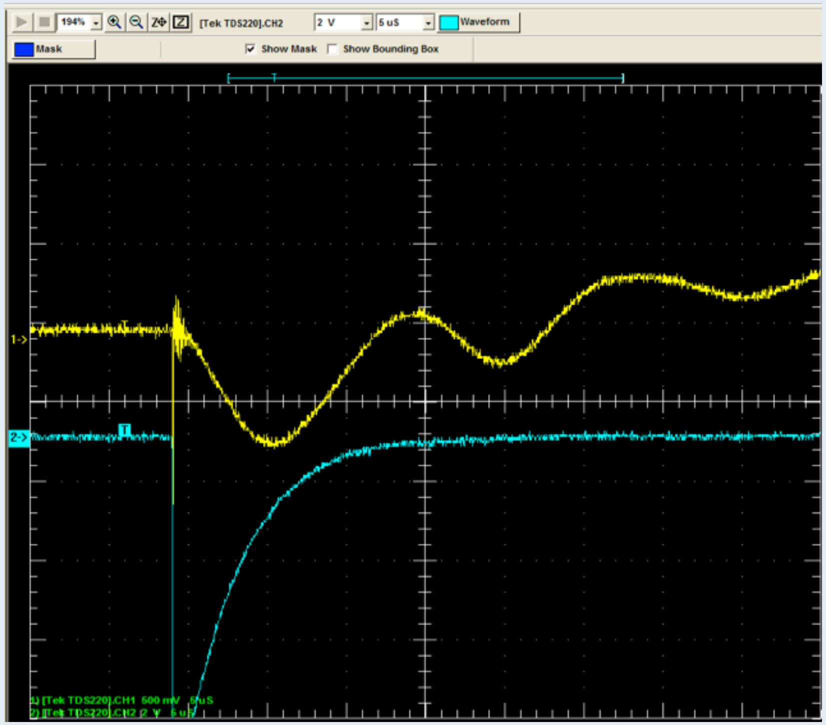
In progress



Basic scheme of the foreseen pulsed high voltage power supply.
The two capacitors named C1 and C2 will charge to a maximum voltage of 20 KV due to the connection to an external standard high voltage, few mA high voltage power supply. The spark gap in the scheme will discharge suddenly the stored energy toward an external solenoid (named load in the picture).

In progress


HEINZINGER
PNC 10000-6 pos
H.V.
0V
0÷25 KV 0÷5 mA
mA
kV


[Tek TDS220].CH2
2 V
5 uS
Waveform
Mask
Show Mask
Show Bounding Box
1->
2->
1) [Tek TDS220].CH1 500 mV 5 uS
2) [Tek TDS220].CH2 2 V 5 uS