AEgIS experiment: a summary of the run and a first glimpse of the data

DAMARA SAC Meeting

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Outline

* Overview of the Aegis apparatus for the May-June 2012 run

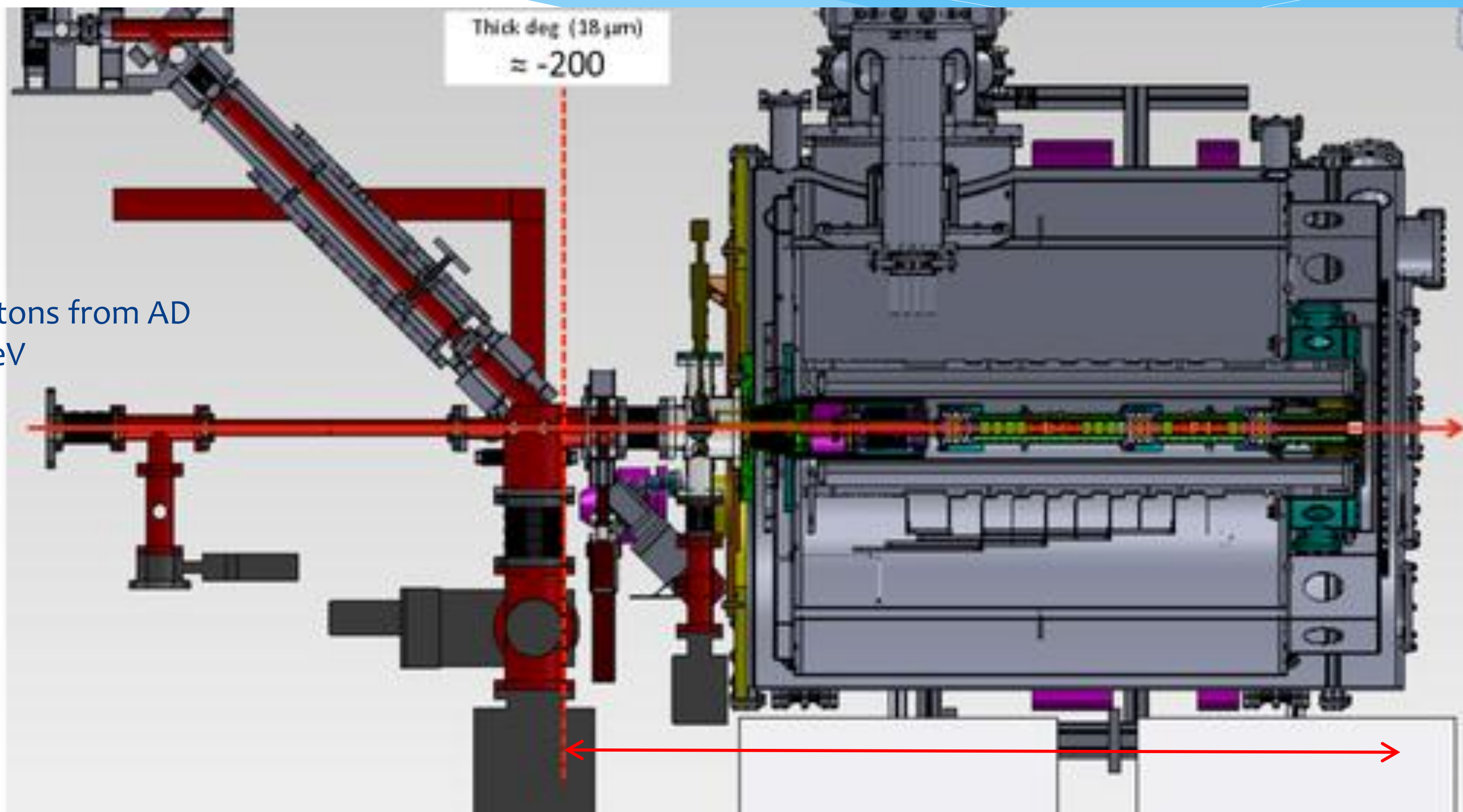
* Mimotera detector
  - properties
  - installation
  - measurements

* First glimpse at the results

* Work to be done & Conclusion

Overview of the apparatus for the first antiproton run of AEgIS

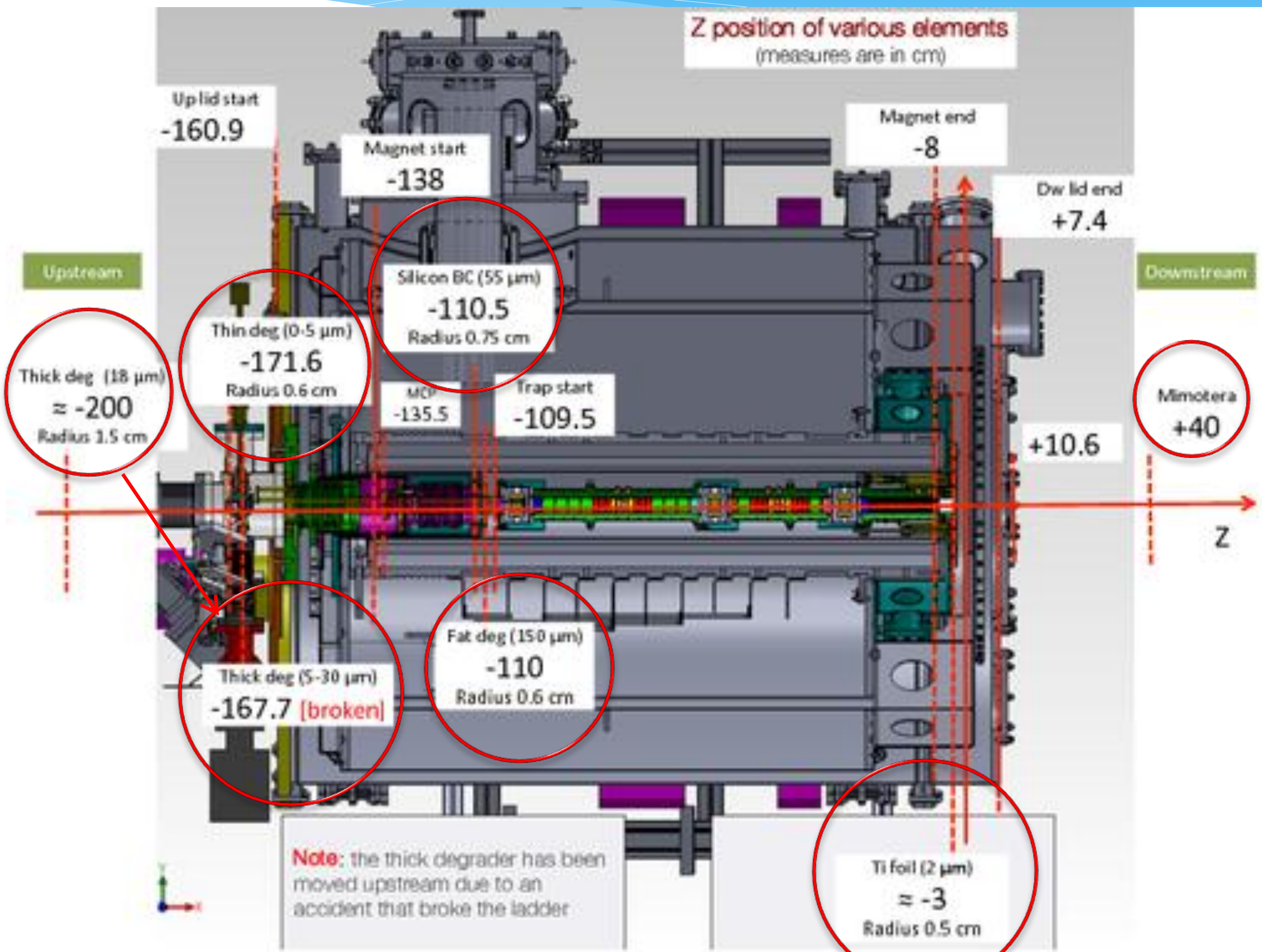
Antiprotons from AD
E = 5 MeV



2 m

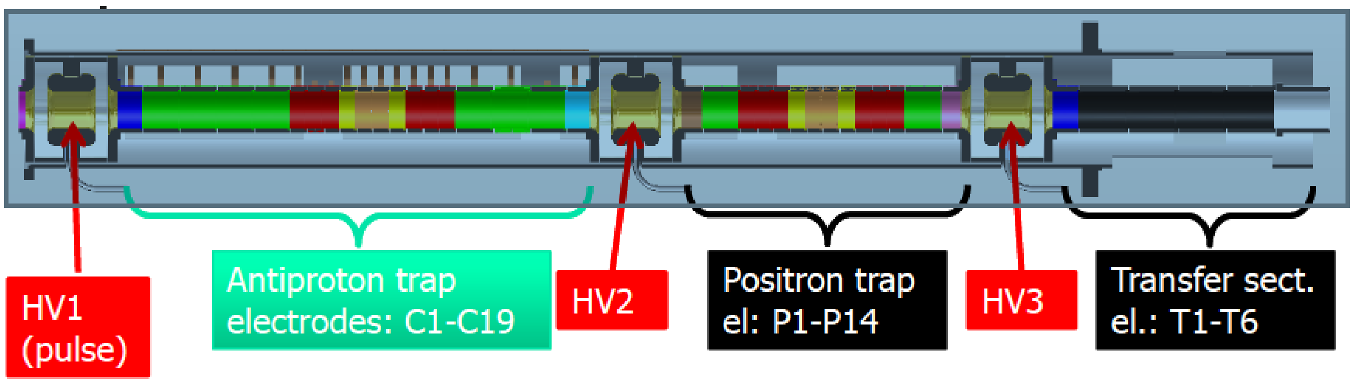
Antiprotons come in bunches of ~3×10^7;
One spill every 110 s; the spill duration is ~120 ns

z-position (in cm) of various elements in the AEgIS apparatus (spring 2012)



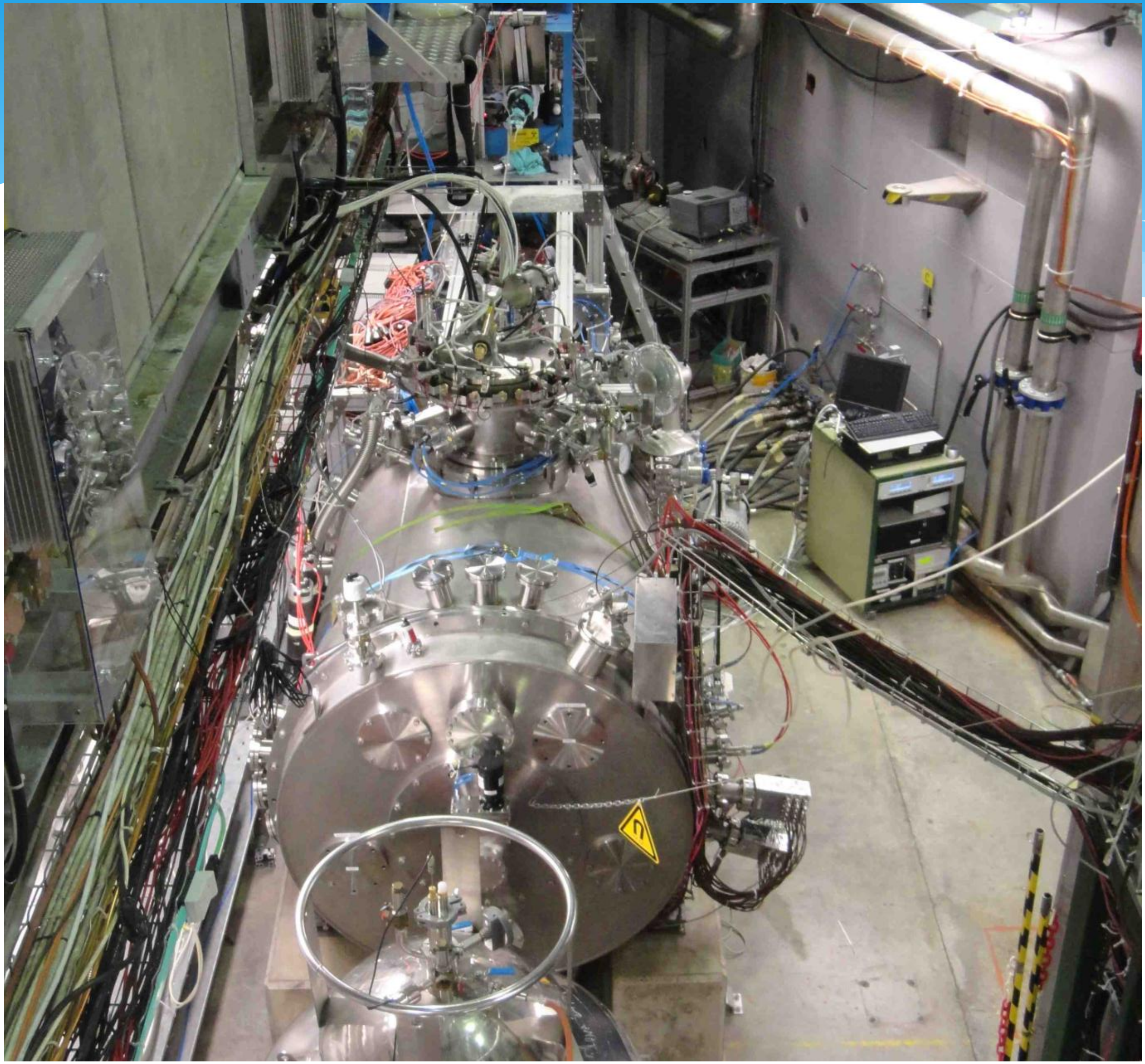
Other measurements

* May 1 – June 18
* Only the 5 T magnet in place, no positrons
* Other measurements focused mostly on optimizing the antiprotons catching procedure and its efficiency



* Catching pbar between HV1 and HV2 or between HV1 and HV3 (no positrons for this run!)
* Routinely working up to 9 KV

The Aegis apparatus placed in the AD zone



The antiprotons we detected are the ones that just fly through the apparatus without being trapped;
A rough estimation of their energy (based on the material they pass through) is ~few 100 keV;
The detector we used was triggered by the AD trigger

Mimotera detector

* Back-side illuminated Monolithic Active Pixel Sensor device
* MIMOTERA – successor of MIMOSA (TERA collaboration)
* Thanks to prof. Massimo Caccia, University of Insubria (UINS), Como, Italy, for borrowing the detector
* Why did we use it:

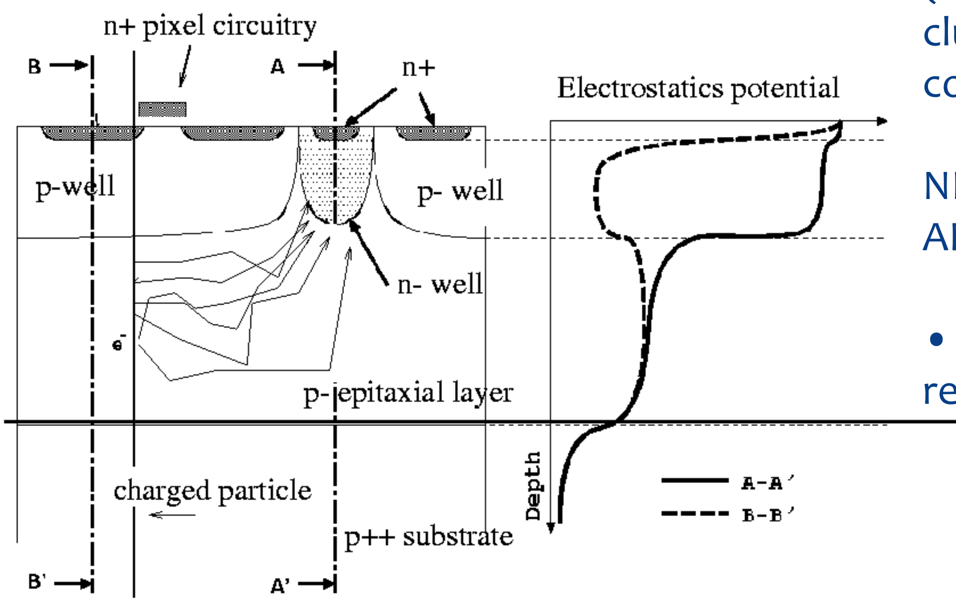
  - to study the annihilation process of slow antiprotons on Si

  - to study how the thickness of the passivation layer would influence the detection

  - no prototype detector ready for the first run

  - gain as much information as possible for developing the position sensitive detector
* Detection of “cold” antiprotons on Si has never been studied before

The baseline technology:
Monolithic Active Pixel Sensors [MAPS]



CMOS sensors for particle detection

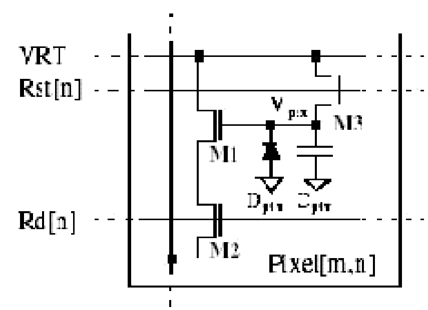
- Pioneered in LEPSI Strasbourg in the late 90's
- Main drive from digital cameras

• based on the charge carrier generated in the epitaxial layer [2-14 μm thick, depending on the technology => SMALL signal (~80 e-h pairs/ μm)]

• diffusion detector vs [standard] drift sensors (the sensitive volume is NOT depleted => charge cluster spread over ~ 50 μm [10 μm] AND collection over ~ 150 ns [10 ns])

NEVERTHELESS OFFERING SEVERAL ADVANTAGES:

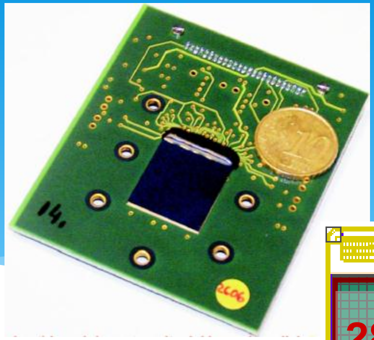
• very simple baseline architecture (3Transistors: reset, collecting diode, addressing key)



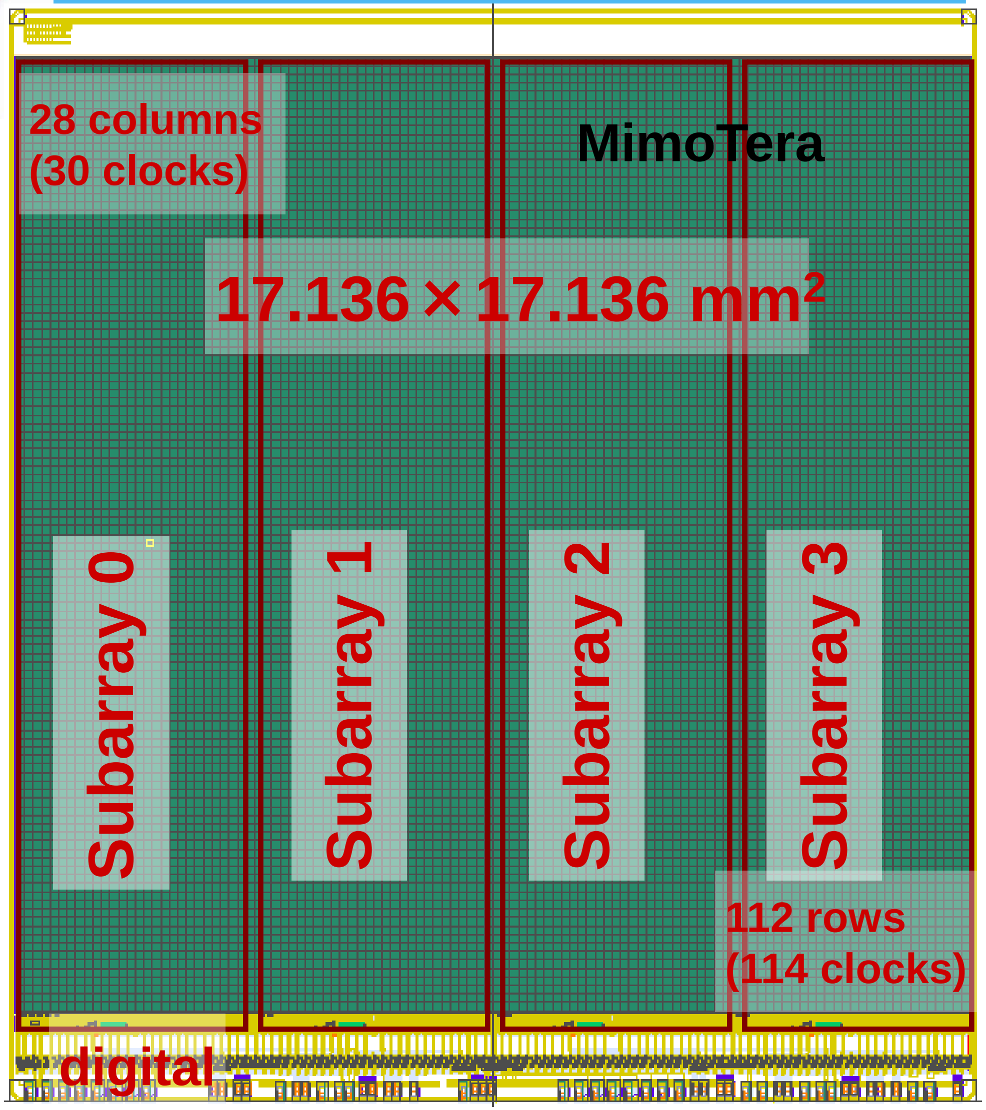
• standard, well established industrial fabrication process, granting a cost-effective access to state-of-the-art technologies

• ever evolving technologies, pushed by consumer electronics

Essentials on the MIMOTERA

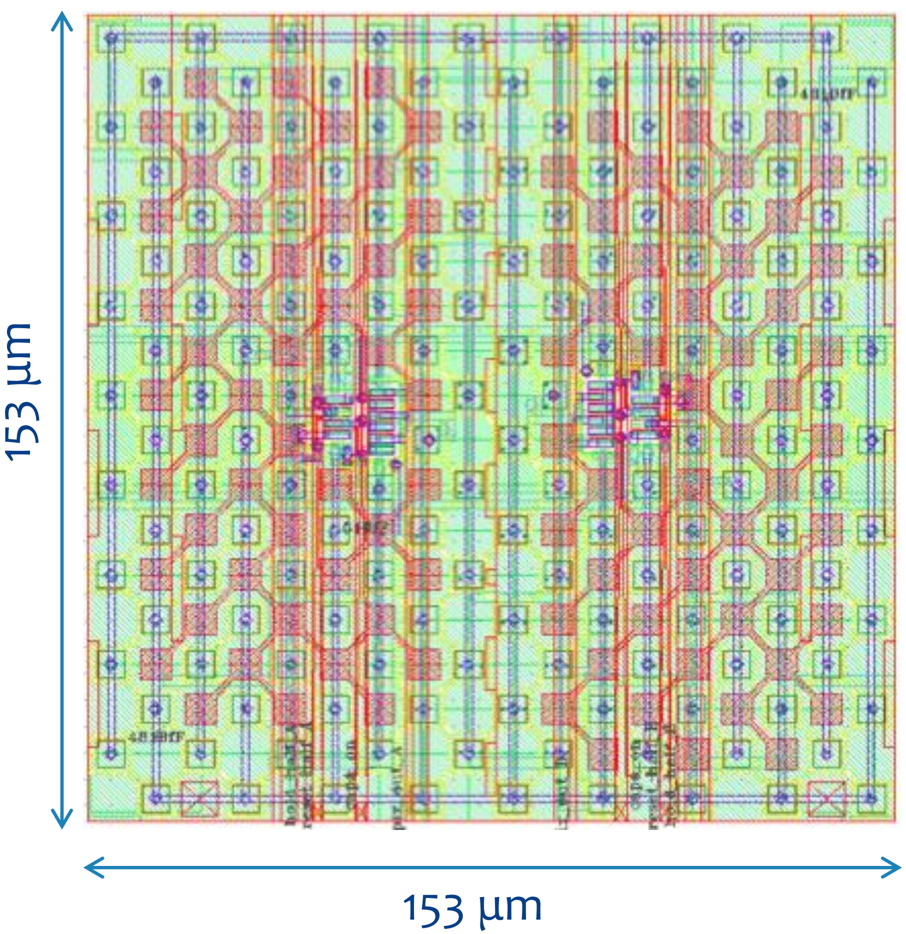


- CMOS 15 µm epi
- Chip size: 17350×19607µm²
- 112x112 square pixels
- Array 112×112 square pixels, each pixel is 153x153 µm²
- Four sub-arrays of 28×112 pixels read out in parallel $t_{read/integr}$<100µs **(i.e. 10 000 frames/second)**
- **Backthinned** to the epi-layer (~ 15 µm), back illuminated through an ~80 nm entrance window
- in order to guarantee the planarity during the process, it was "bonded" on a silicon substrate, acting as a pure mechanical support. So, all in all, the silicon thickness is ~ 600 micron and the active volume is 15 micron thick

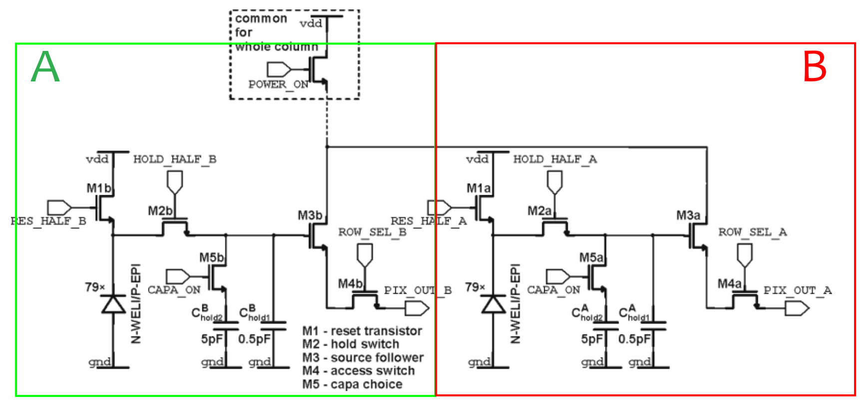


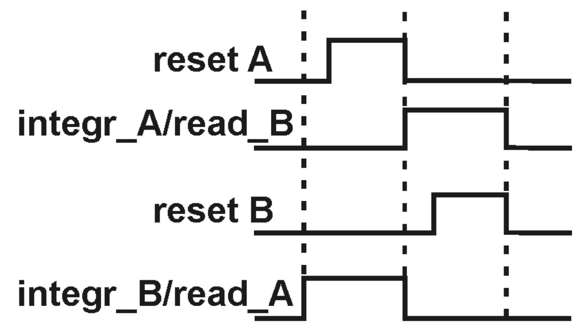
Mimotera

One pixel of the Mimotera



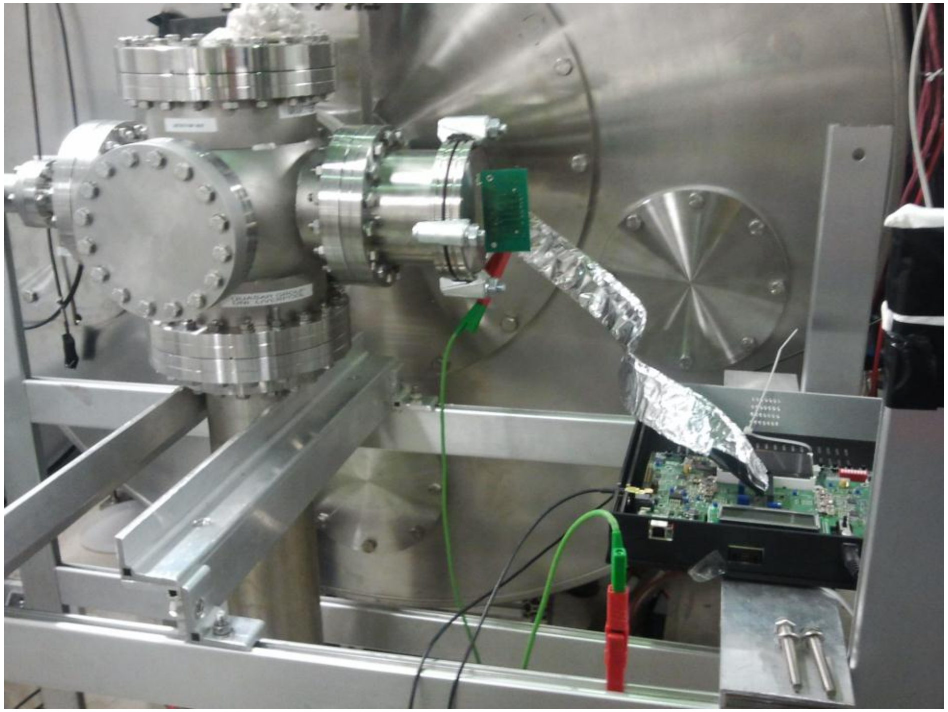
- two 9×9 interdigited arrays (**A** and **B**) of n-well/p-epi collecting diodes (5×5 µm²) + two independent electronics – avoiding dead area

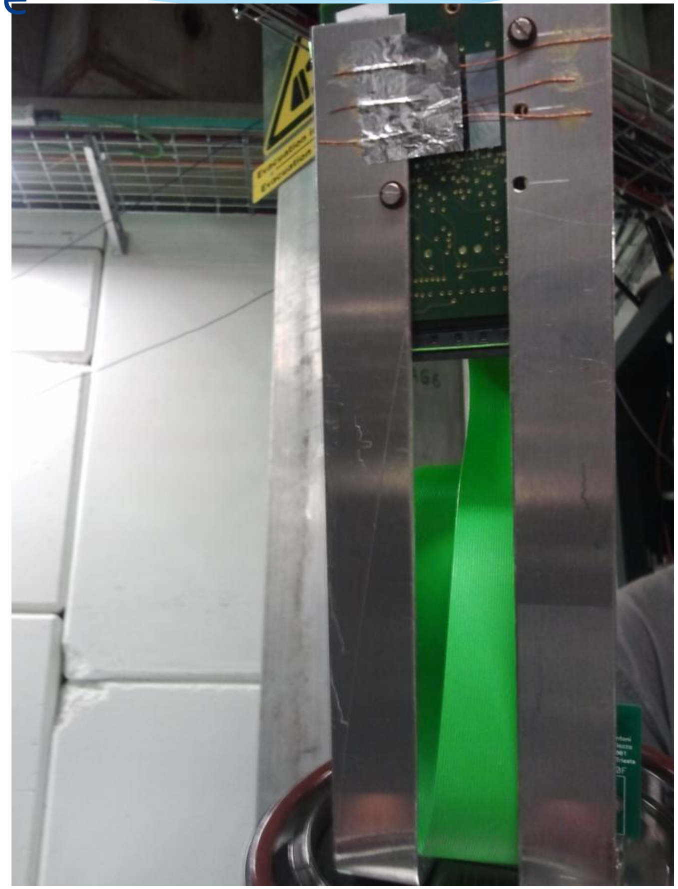




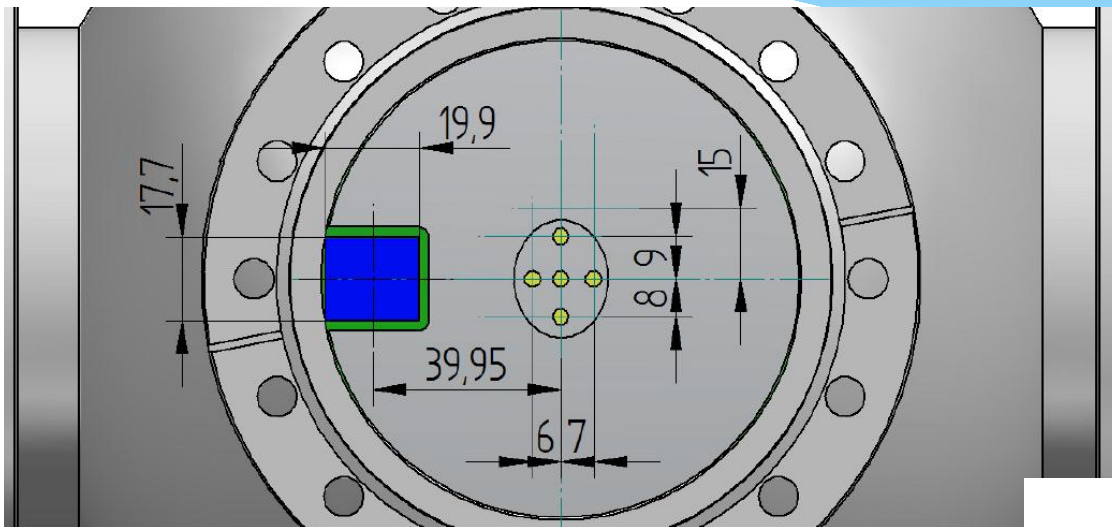
Installation

- Measurements were carried out at room temperature
- Vacuum ~ 10^{-6} mbar before opening the gate valve
- Vacuum ~ 10^{-7} after stabilizing



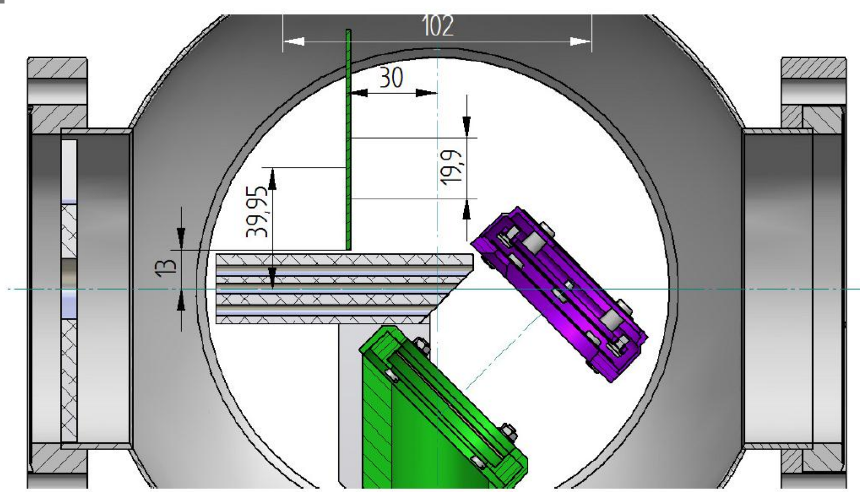


Position in the six cross chamber



Front view

Top view



Measurements

* The Mimotera run took place from 28 May until 15 June (not every day, we shared the beam time with an emulsion detector)
* The detector was placed in a six cross chamber, separated from the main apparatus with a gate valve
* A frame is a 2D matrix (112x112) with the corresponding amplitudes for each pixel
* The measured amplitude is proportional to the deposited energy from the particle
* 51 frames were made for each trigger (20 frames before, 30 frames after the trigger + the triggered one)
* The frames are taken at 400 khz, that is, 2.5 μs between two frames
* Roughly 1500 triggers x 51 frames = 76500 frames taken
* One trigger (and successively one spill of antiprotons) every 110 s
* ~3×10^7 antiprotons per spill, still missing numbers from other people in the collaboration about the mean number of trapped antiprotons (in order to determine the number of antiprotons available for the Mimotera)

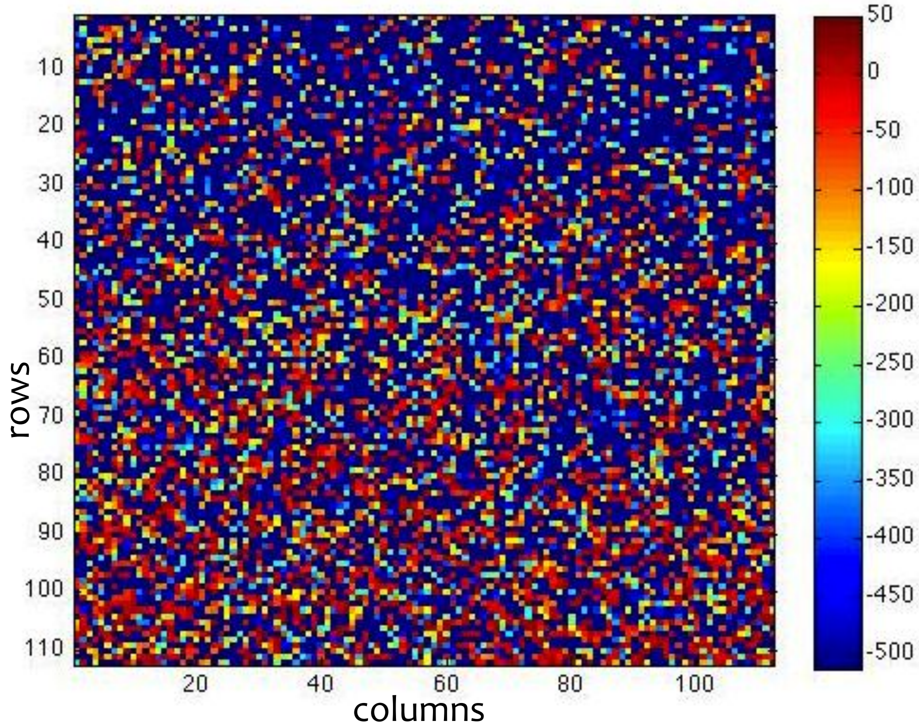
Measurements

* Data with different settings (in terms of thickness of the thin degrader, focused/defocused beam, different gain of the Mimotera)
* Defocussing of the beam was done by changing the current on two of the quadrupole magnets placed in the Aegis beam line QN40 – 10,5 mA , nominal value - 42,54 mA
* First run – no antiprotons, gate valve closed, only secondaries observed – these measurements provide information on the amplitude (energy deposited) obtained from secondaries
* Second run – antiprotons on Mimotera – information on the deposited energy by antiprotons
* Third run – Mimotera partially covered with foil with different thickness (3 μm, 6 μm and 9 μm) – this was done in order to see whether the antiprotons might be fully stopped in these layers and what would be the energy deposited from those who make it through

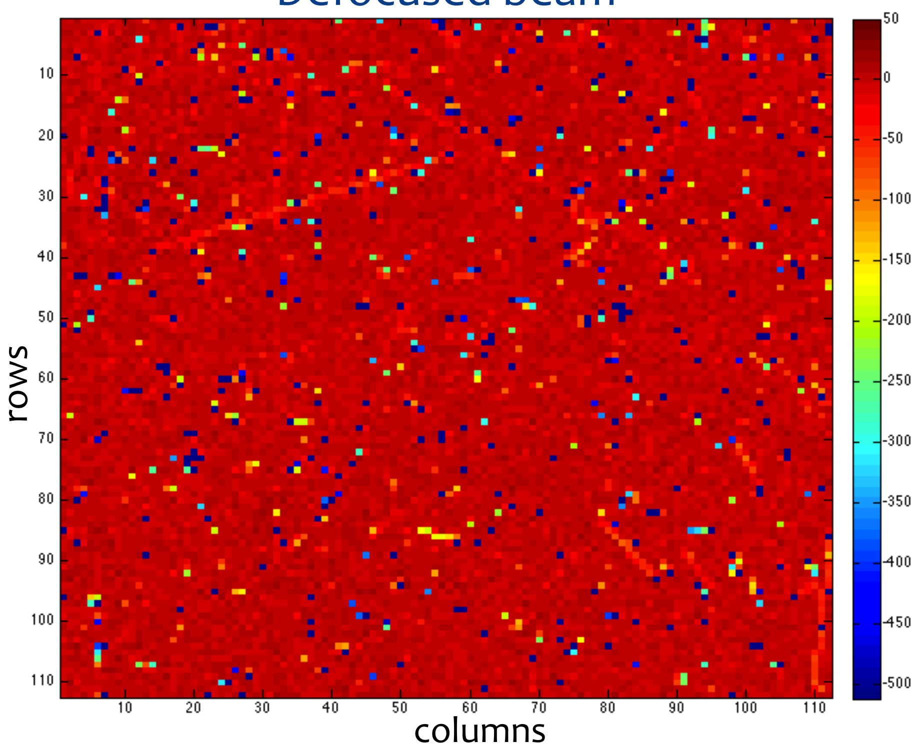
Results

* Two frames taken under different conditions (focusing of the beam)
* Color coding of the amplitude; Amplitude is negative! (red means no hit, deep blue is an antiproton hit)

Focused beam

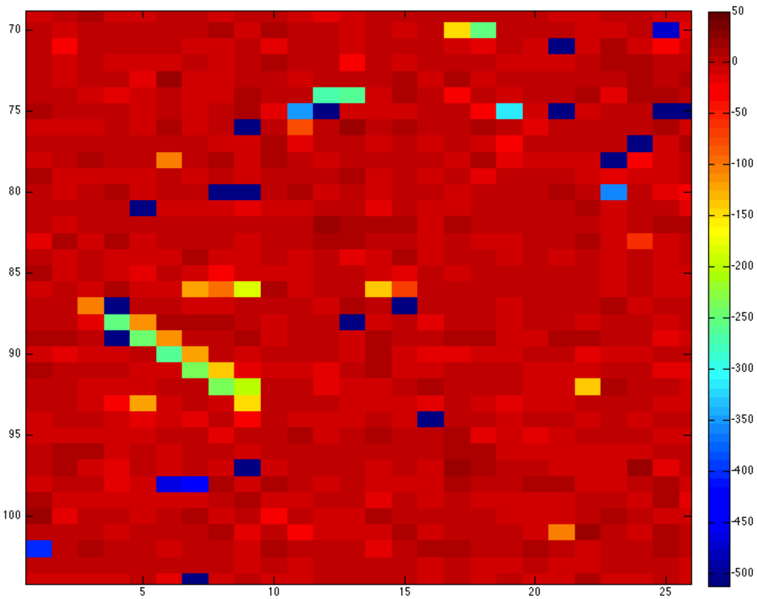


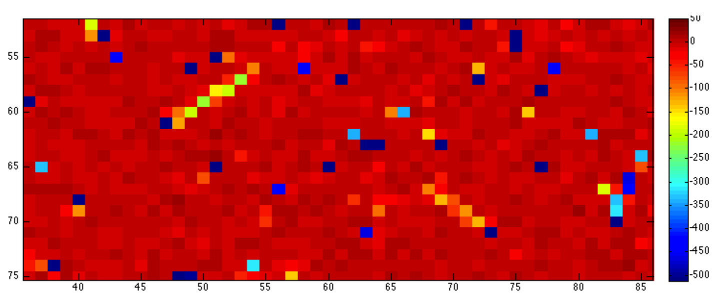
Defocused beam



Tracks from secondaries

* What happens to an anti-hydrogen (antiproton, we neglect the positron) when it reaches the surface of a silicon detector?





The antiproton undergoes an annihilation with a nucleon/nucleus of the Si-nucleus, with the extraction of few pions

$$\bar{p}Si \rightarrow \pi' s X$$

Although no direct measurement have been done with Si, data on ^{12}C, ^{14}N and ^{94}Mo give a percentage of events with more than 2 charged pions of 80-85 %. For what concerns the X, there are no measurements available.

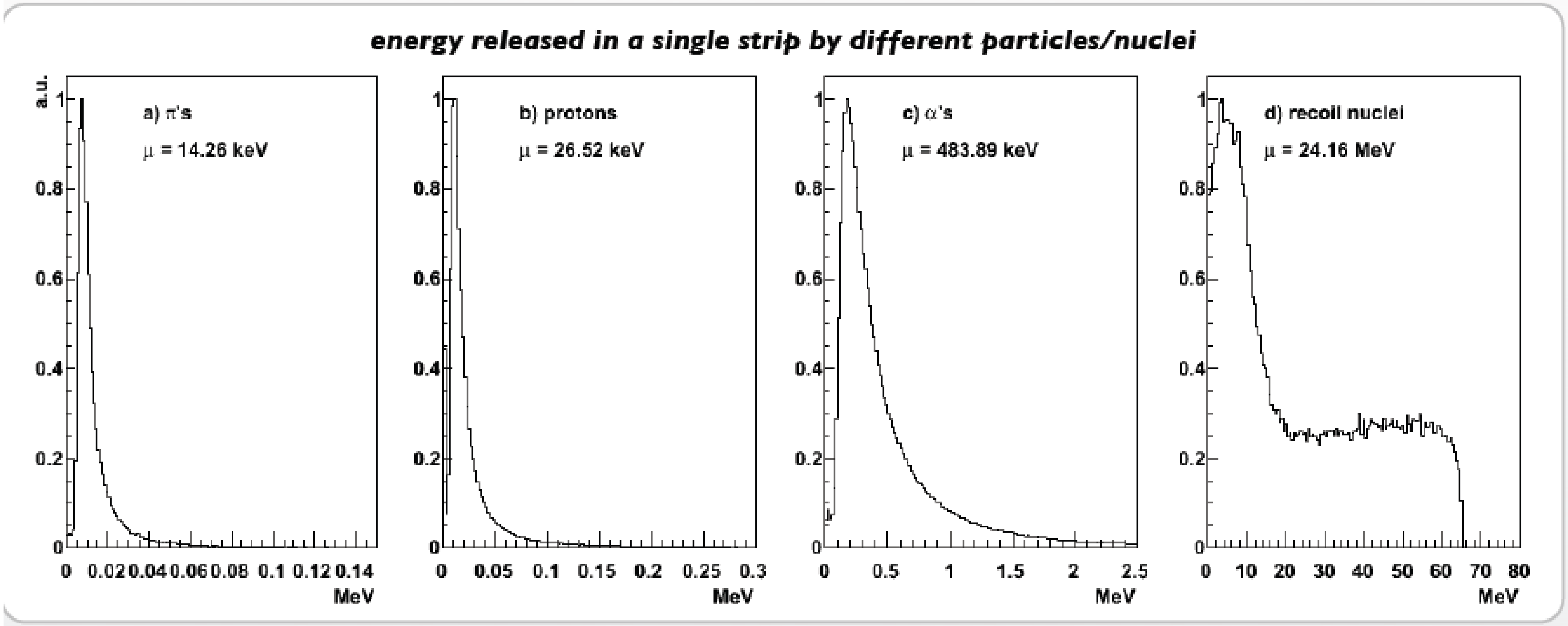
In average, for ^{28}Si, there should be one charged particle, besides pions, emitted from the annihilation (most of the time a proton)

Reference: G. Bendiscioli and D.Kharzeev, *"Antinucleon-Nucleon and Antinucleon-Nucleus Interaction. A review of Experimental Data"*, La rivista del Nuovo Cimento 17 (N.6) (1994) 1-142

* For the proposal of Aegis, few cases were considered and simulations were made

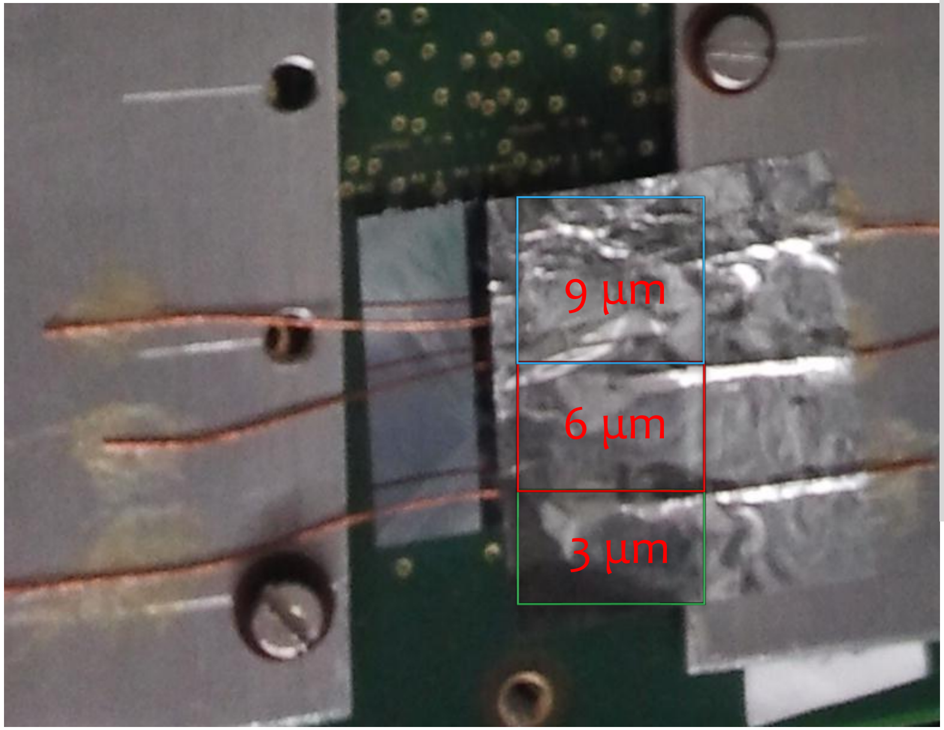
$\overline{p}^{28}Si \rightarrow \pi^+\pi^{-27}Al$ **RECOIL** (very high and localized energy deposit)	$\overline{p}^{28}Si \rightarrow \pi^+\pi^-p\ ^{26}Mg$ **"QUASI" RECOIL** (very high and localized energy deposit)	$\overline{p}^{28}Si \rightarrow \pi^+\pi^{-12}C\alpha\alpha t$ **DISINTEGRATION** (many fragments take away the energy from the impact point)

* These simulations (using the Geant 3.1) consist of antiprotons annihilating at rest on a 20x20 cm^2, 300 μm thick Si strip detector, composed of 8000, 25 μm wide and 20 cm long horizontal strips

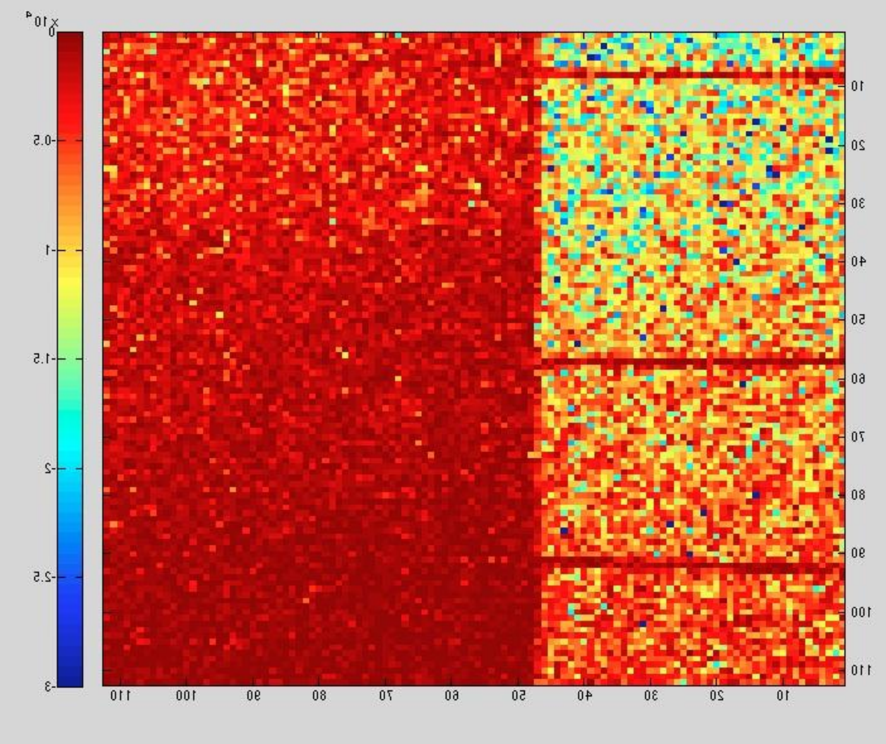


Inserting a foil

* The foil was inserted to slow down the antiprotons even more and see if some of them still make it through



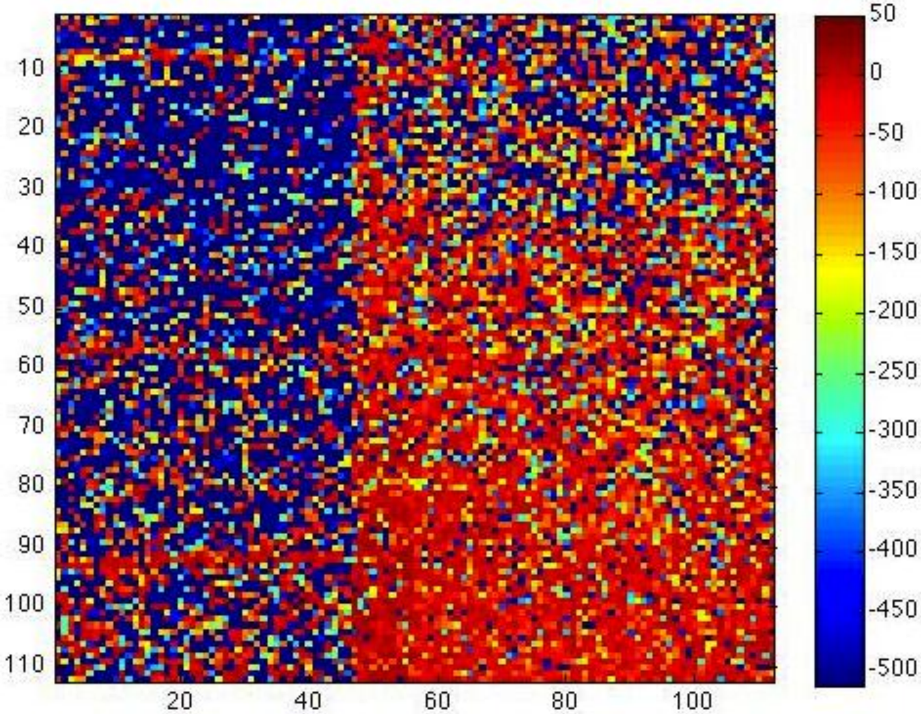
The Mimotera with foil on top



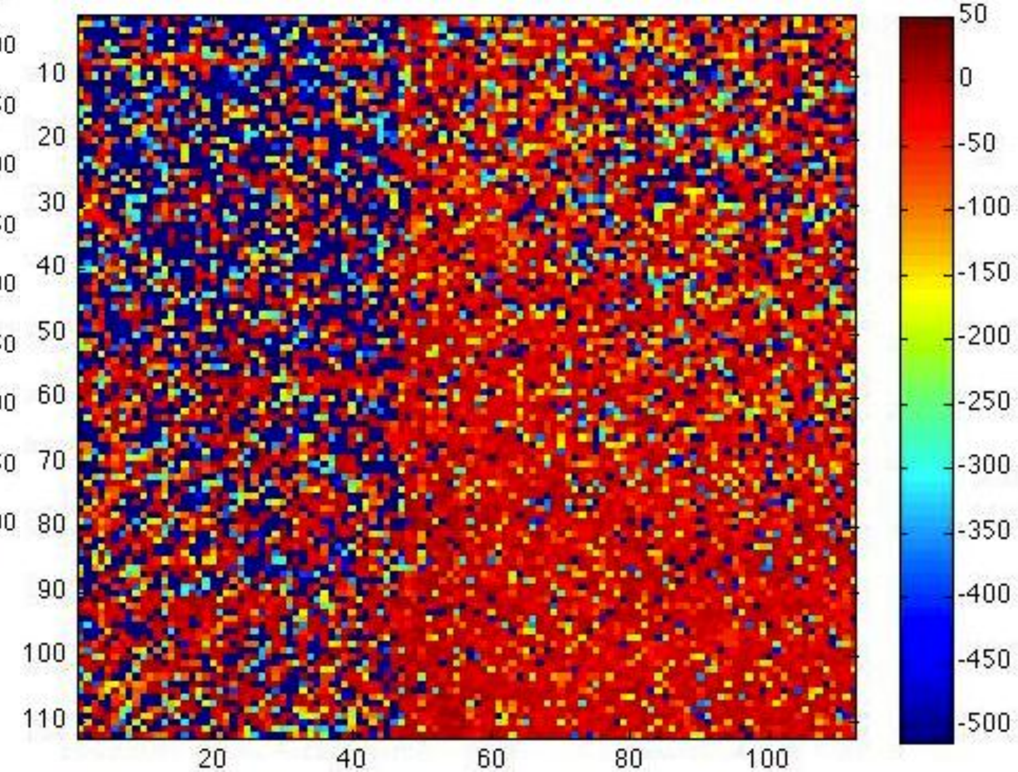
30 triggered frames piled up; color code differ only in this picture – red color means high amplitude (antiproton hits)

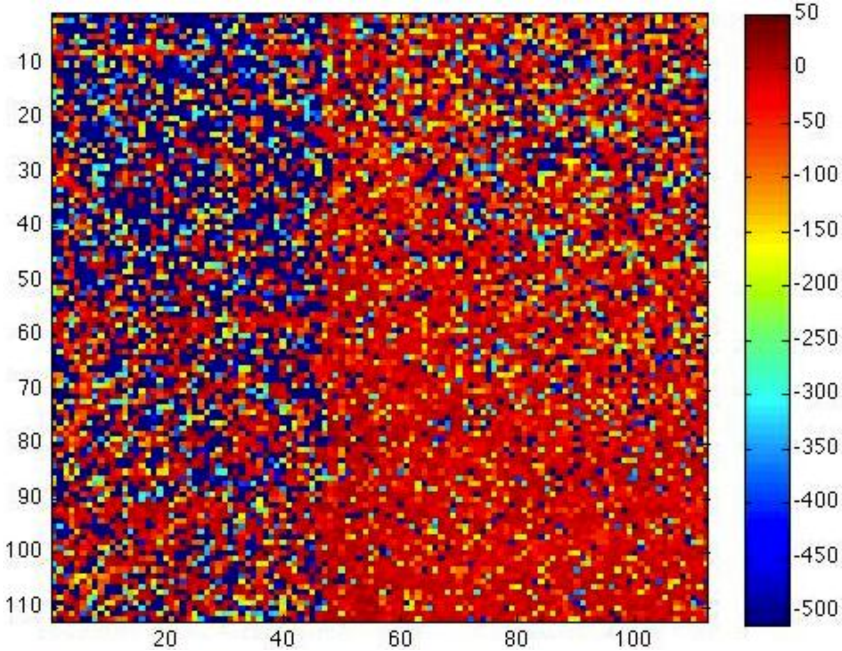
Different degrador thickness (0.8, 2, 3, 4 and 5 microns)

0,8 μm

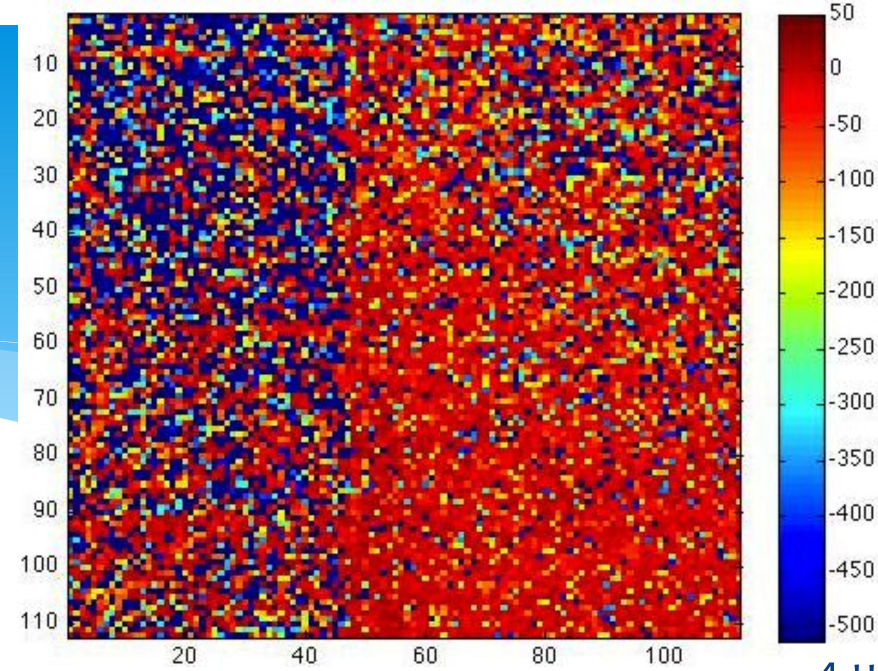


2 μm



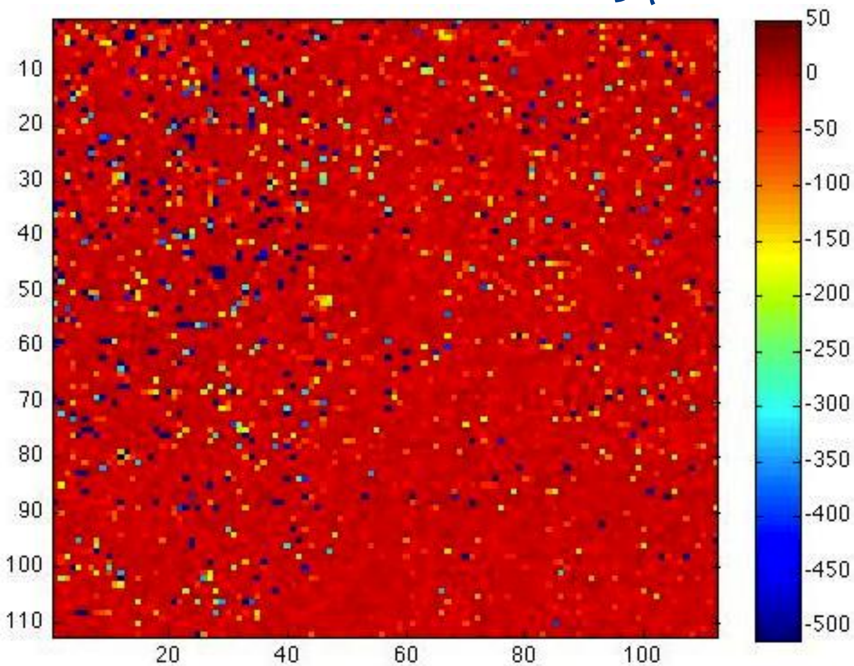


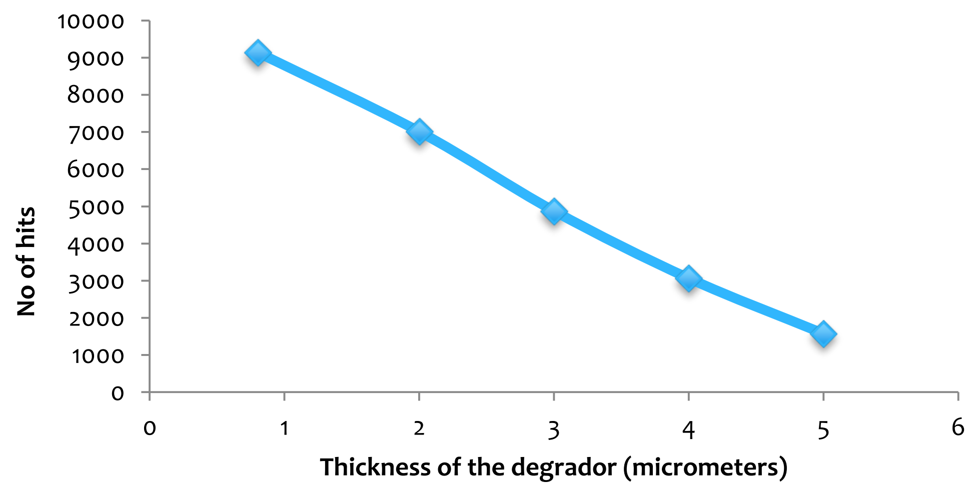
3 µm



4 µm

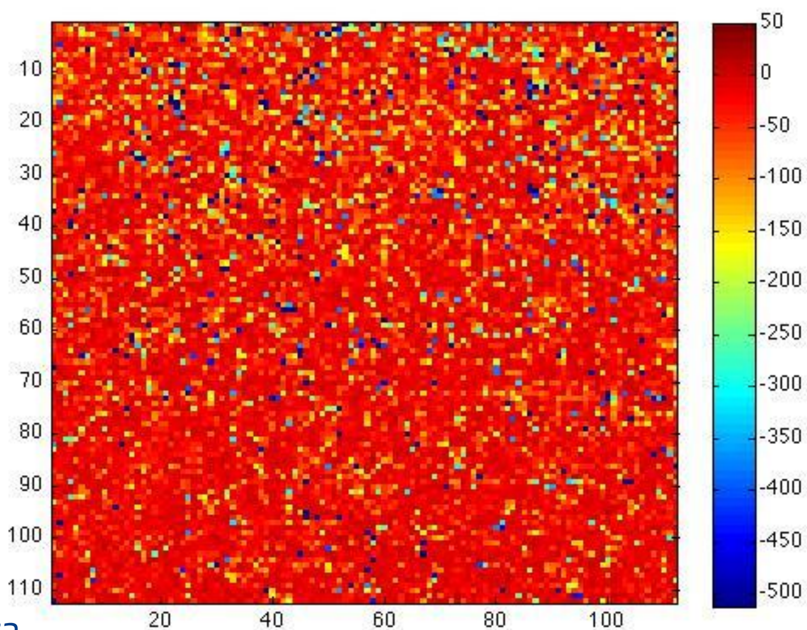
5 µm



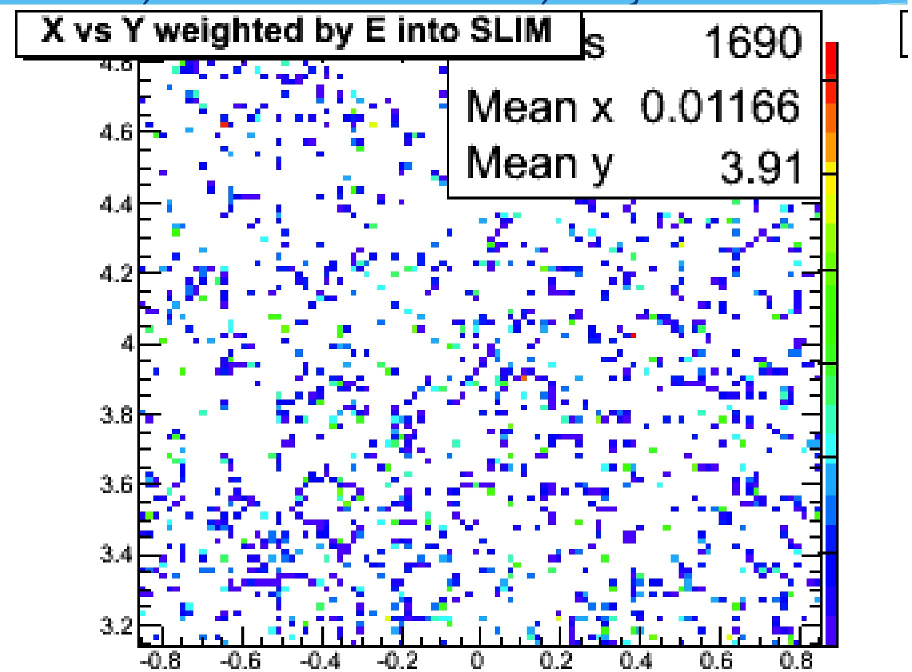


Number of total hits for different degrader thickness

Data taken without Al foil, 5 microns degrader in and defocused beam
Simulations are done with Geant4 package, CHIPS model, with the same position of the Mimotera along the z axis and xy plane, also all the degraders placed in the apparatus are considered
Simulations by Germano Bonomi &Cristina Riccardi, INFN Pavia-Brescia, Italy



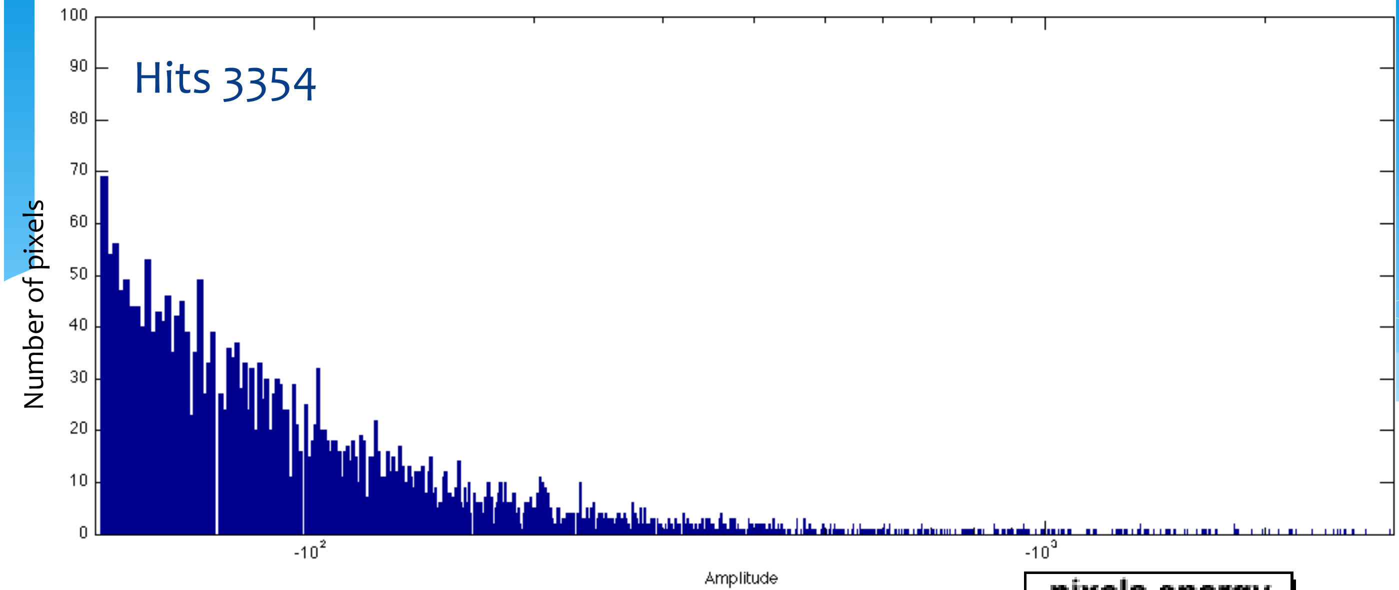
Data



Simulations Geant 4, CHIPS

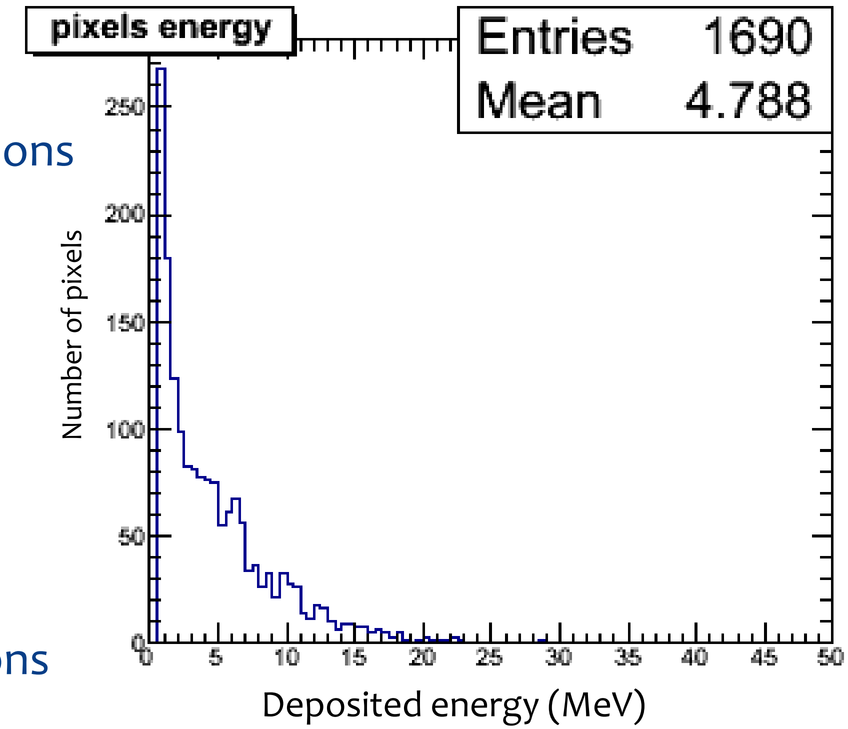
* The CHIPS (Chiral invariant phase space event generator) model of the GEANT4 simulation toolkit is used for nuclear fragmentation following nuclear capture of negative hadrons. The CHIPS simulation for pion capture and for anti-proton annihilation at rest fits data, but it is not clear if the process can be applied to the weak process of muon capture.

Ref. Eur. Phys. J. A 33, 7-10 (2007)

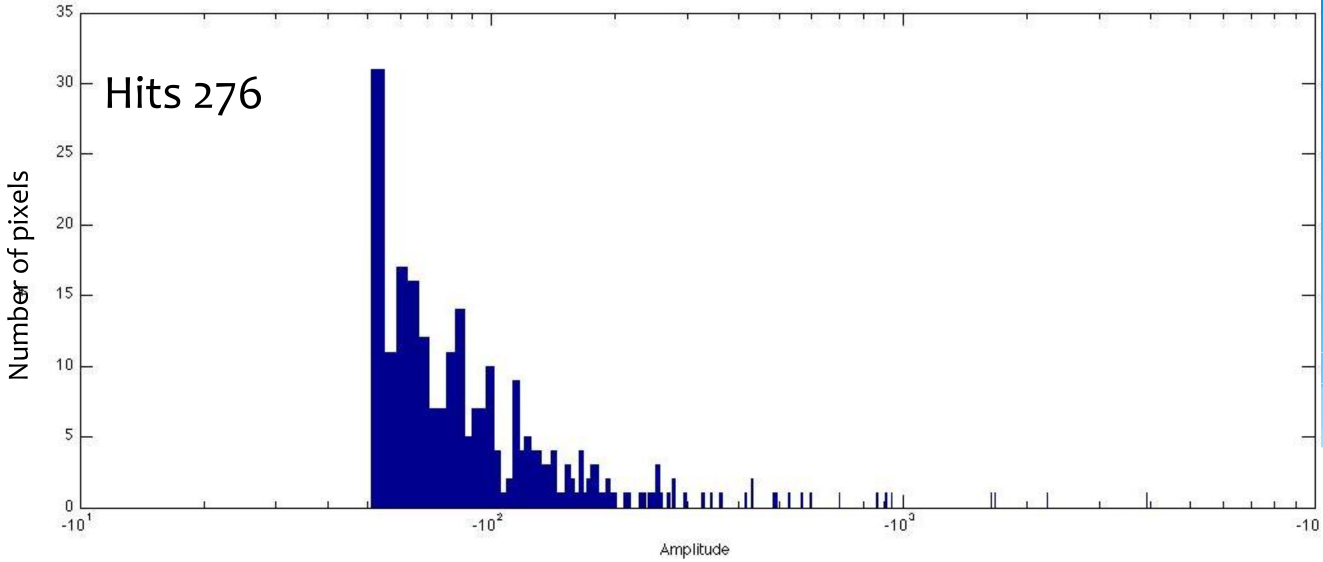


Data

Comparison between data and Geant4 simulations on the energy (amplitude) of the fired pixels
Total number of generated antiprotons in the simulation is 100000



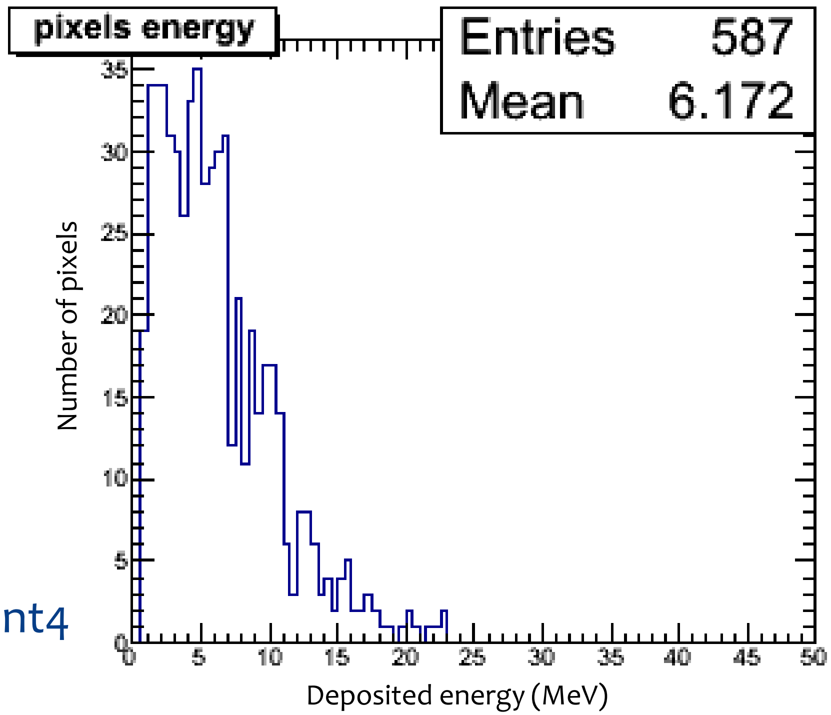
Simulations



Data

Comparison between the energy(amplitude) of single pixel clusters

Simulations with Geant4



Analysis to follow & Conclusion

* # Cluster search
* # Pixels per cluster
* # Total charge per cluster
* # Some geometrical shaping
* Two main goals of the analysis:

  - to compare the Geant4 simulation and verify if they could be reliable into future R&D for the position sensitive detector

  - make an energy calibration (with alpha particles) of the detector in order to obtain an information on the deposited energy

* In the end, we have to keep in mind that the energy of the detected antiprotons is still not low enough compared to the one in the final experiment…