

Design & optimisation of a scraper and Ionisation Monitor for Beam Profile Measurement on ELENA

BI Day

2017.06.29

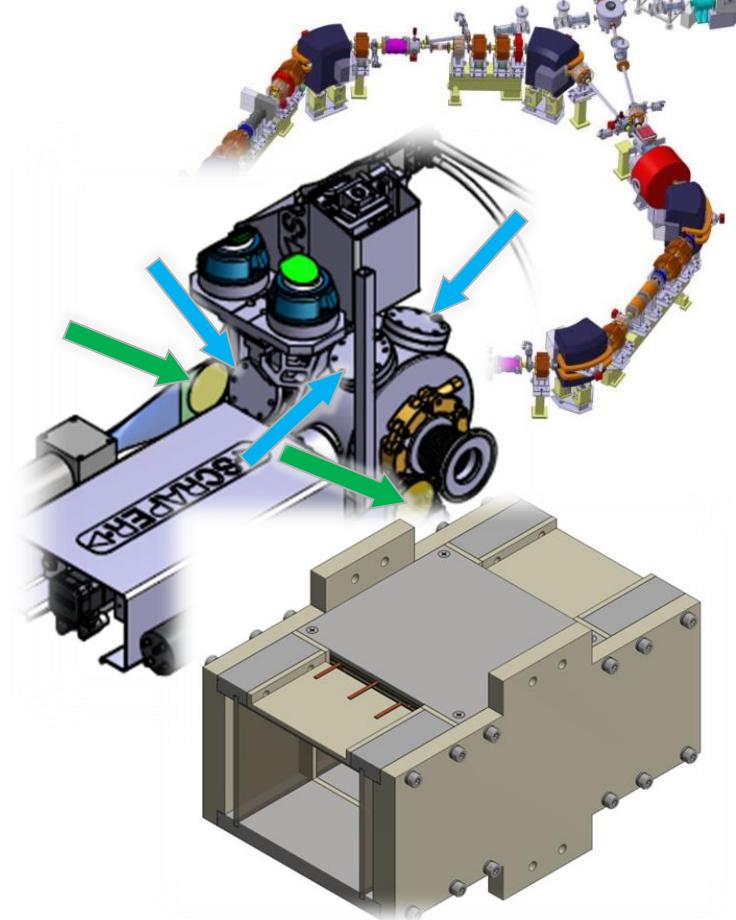
Pierre Grandemange

On behalf of experimental areas section



Overview

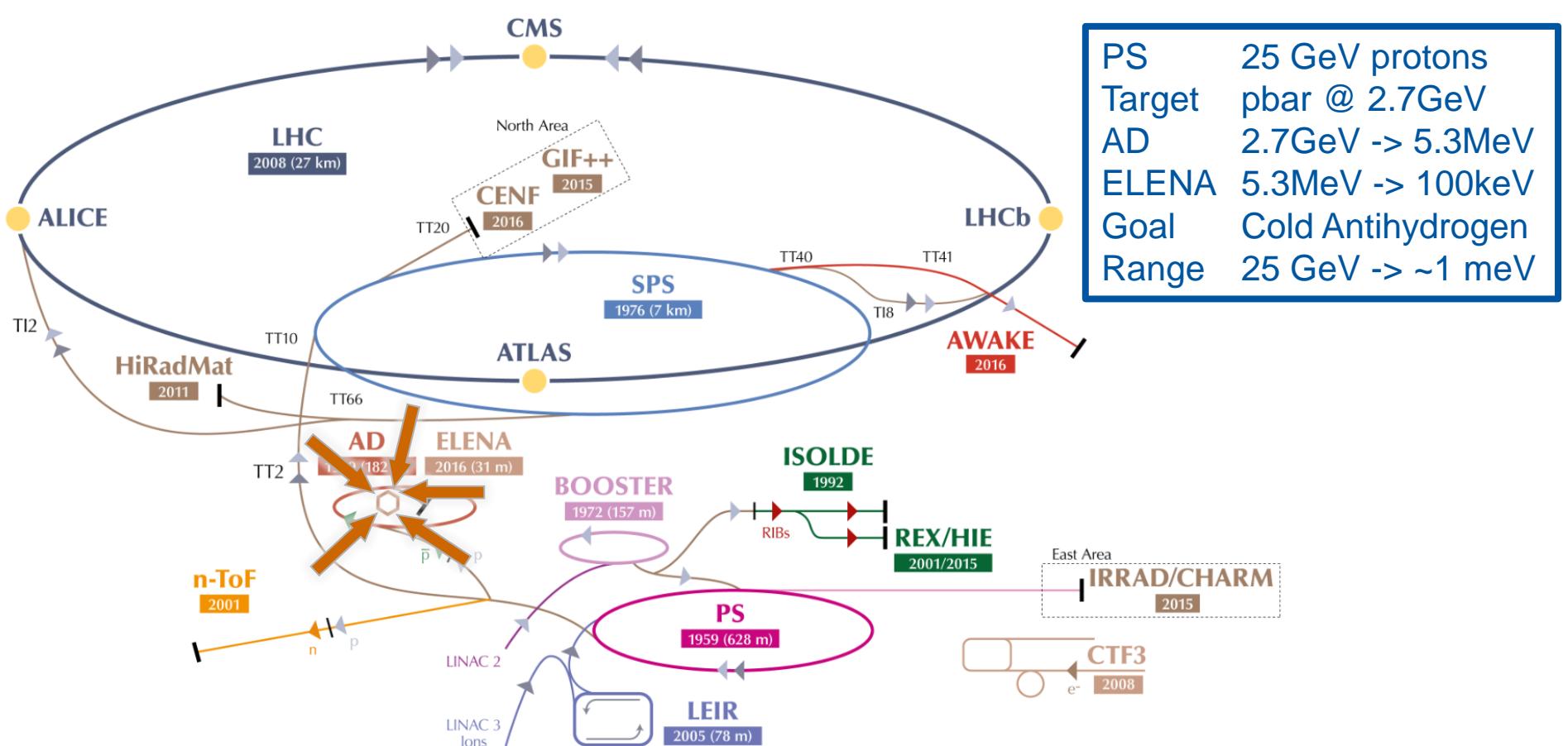
- ELENA – Extra Low Energy Antiproton ring
- Scraper : antiproton beam profile monitor
- Scraper : H⁻/proton beam profile monitor
- IPM - Ionisation Profile Monitor



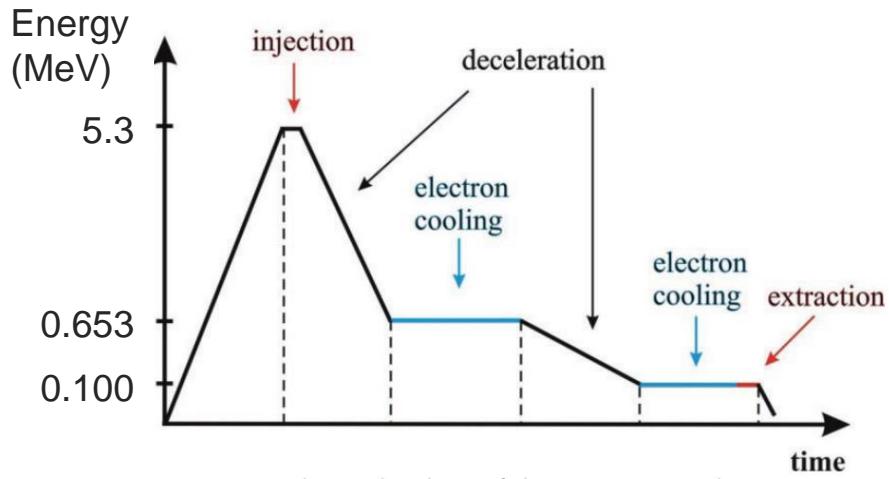
ELENA

Extra Low Energy Antiproton ring

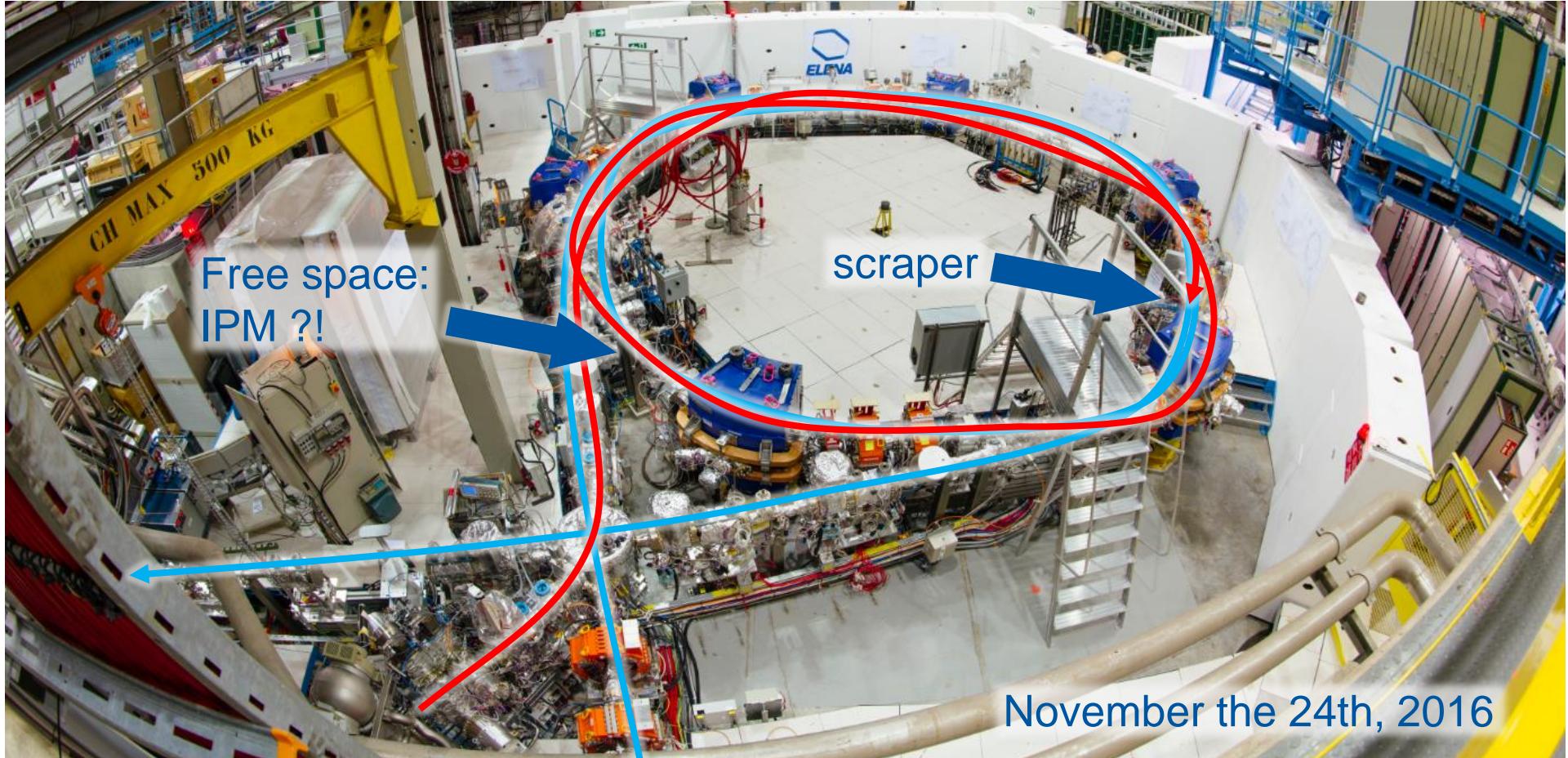




ELENA properties



ELENA length	30 m
Mean pressure	4.e-12 mbar
Antiprotons – pbar - beams	
• ~ 2.e7 pbar/beam	
• Injection energy	5.3 MeV
• Extraction energy	100 keV
• Full cycle	25-30 seconds
H-/protons beam (commissioning)	
• 100keV	



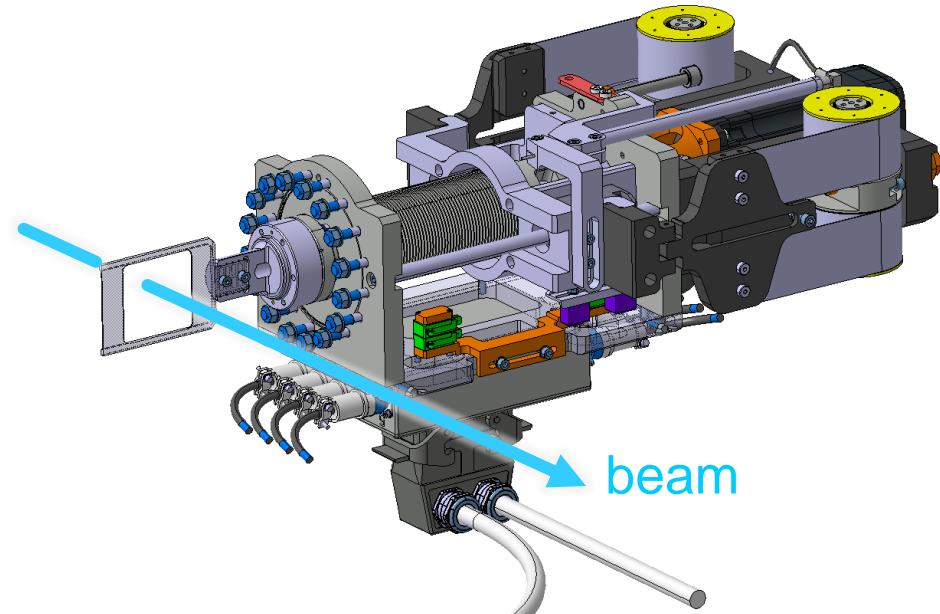
SCRAPER

antiprotons ($p\bar{n}$) beam profile monitor

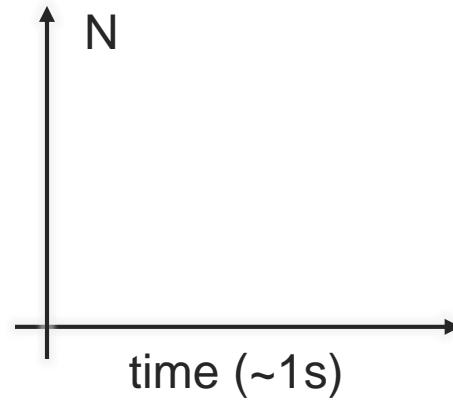
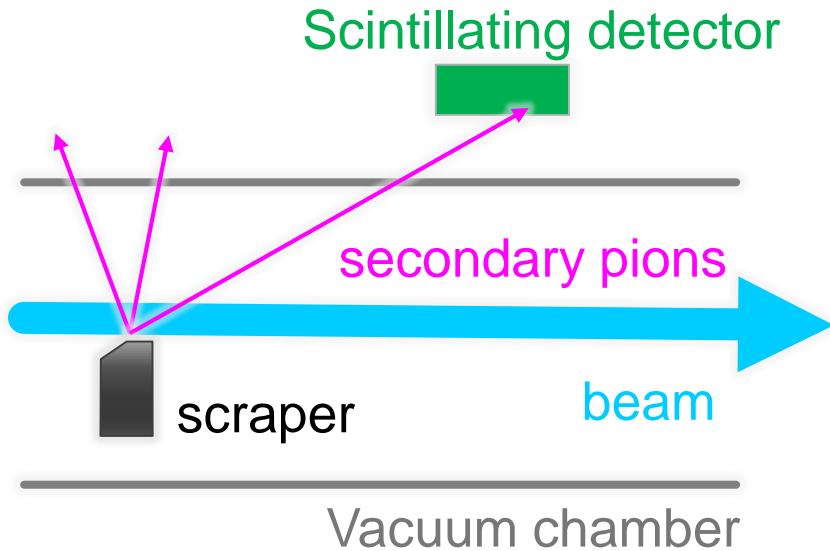
H^- ions / protons beam profile monitor



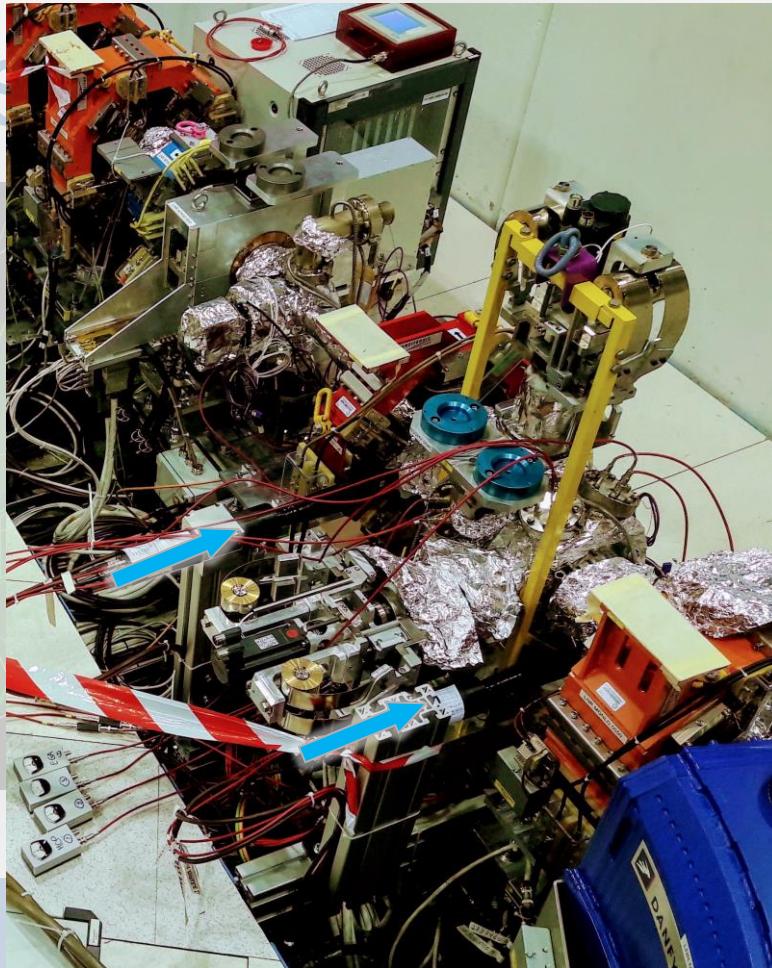
Scraper : the device



working principle - pbar



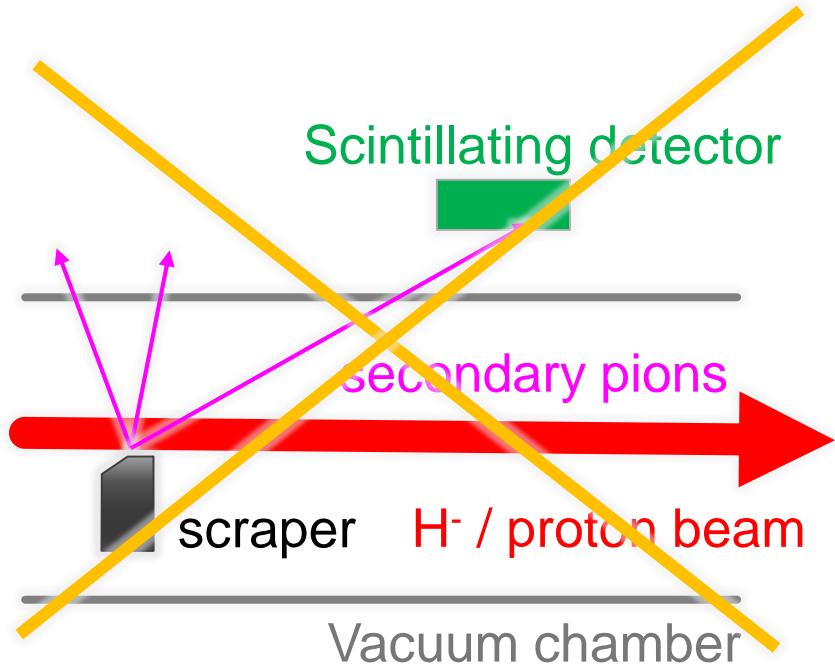
Geant4 Simulation



bar

ulators
al than in the AD: less
at low energies
ts size, orientation
on

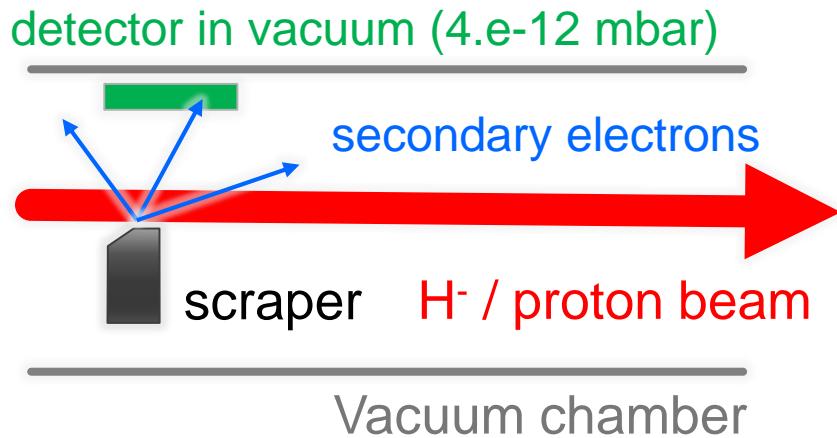
working principle - H-/proton



No annihilation

- no pions
- no signal in scintillators

working principle - H-/proton



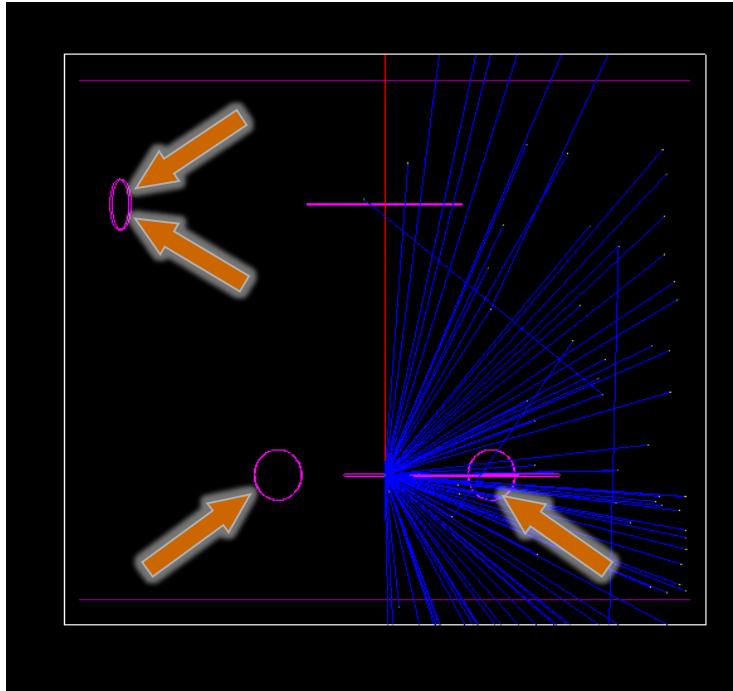
No annihilation

- no pions
- no signal in scintillators

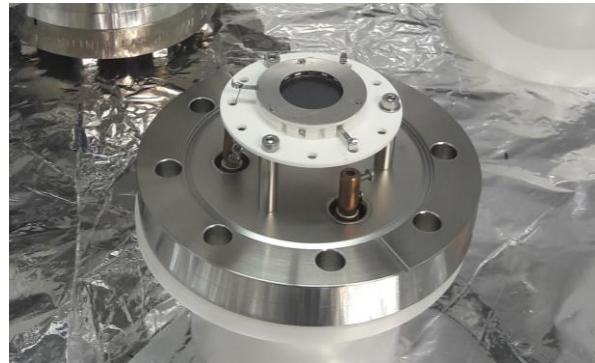
detect secondary electrons

- are there any?
- how many?
- where?

Geant4 simulation - H-/proton



- Anisotropic emission
- scraper geometry: a bevel improve secondary emission



➤ Choice of 4 MCP detectors
MCP = Micro Channel Plate

- The ELENA scraper is equipped with two acquisition systems
- The secondary electron emission detection system should work with protons/H-/antiprotons
- Commissioning is ongoing

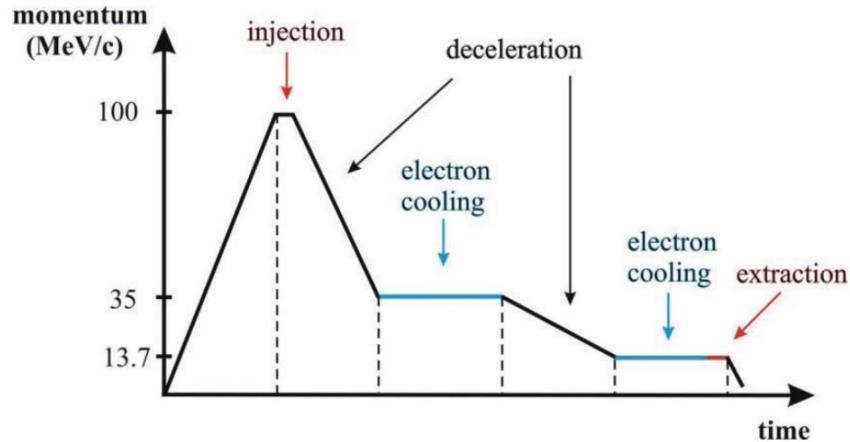


IPM

Ionisation Profile Monitor



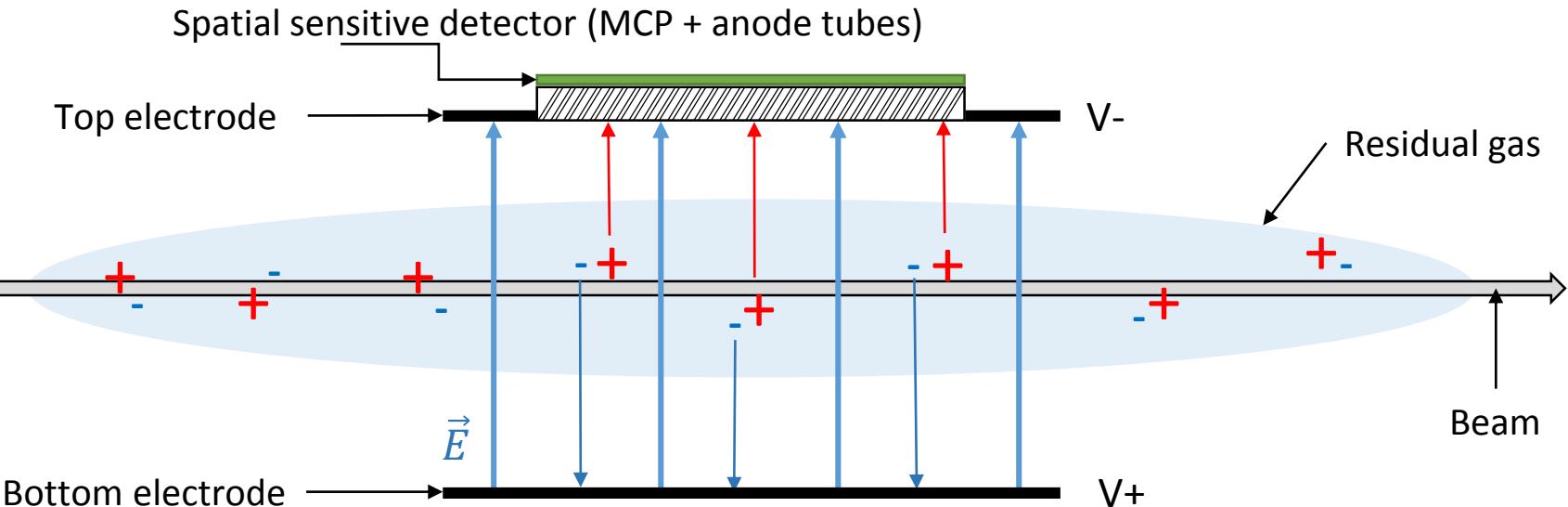
ELENA properties



The IPM - Ionisation Profile Monitor - will satisfy all your wishes!

- AD extraction : 110 seconds
- Profile measurements with the scraper at different cycle step is very long/tedious
 - Difficult to observe electron cooling efficiency in the transverse plane

IPM principle



Ionisation rate in ELENA

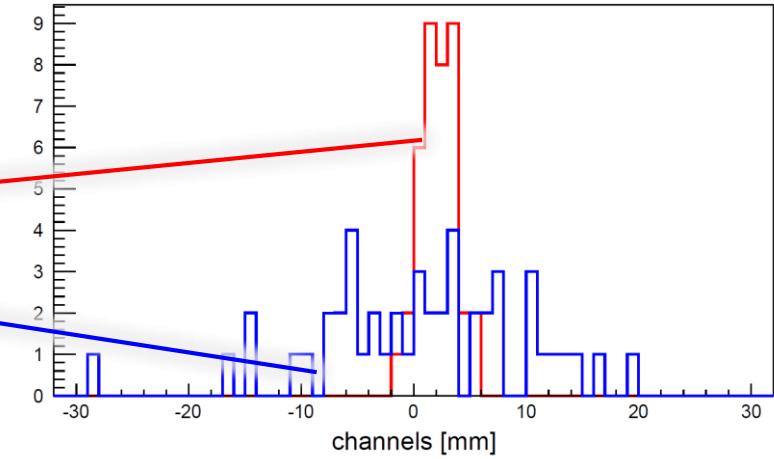
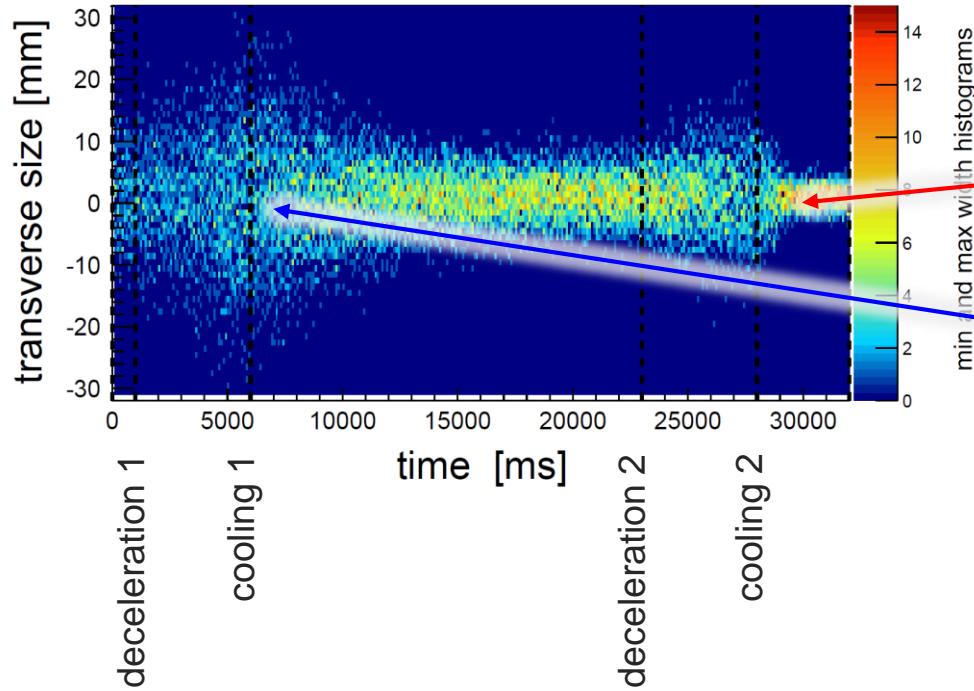
$$N_I [\text{m}^{-1}\text{s}^{-1}] = N_{\bar{p}} [\text{s}^{-1}] \times n_g [\text{m}^{-3}] \times \sigma_{\bar{p}+g}^{ion}(E) [\text{m}^2]$$

$N_{\bar{p}}$	antiproton flux	2.e-7 \bar{p} /turn @ 100keV	$N_{\bar{p}} = 2.9\text{e}12 \bar{p}/\text{s}$
n_g	gas density	H_2 @ 3.8e-12 mbar	$n_g = 9.2\text{e}10 / \text{m}^3$
$\sigma_{\bar{p}+g}^{ion}$	gas ionisation cross section with antiprotons	@ 100keV	$\sigma_{\bar{p}+\text{H}_2}^{ion} = 1.7\text{e}-20 \text{ m}^2$
N_I	linear ionisation rate	@ 100keV	$N_I \sim 4600 \text{ ionisations/m/s}$

➤ 4.6 ions /1cm/100ms



Ionisation in ELENA

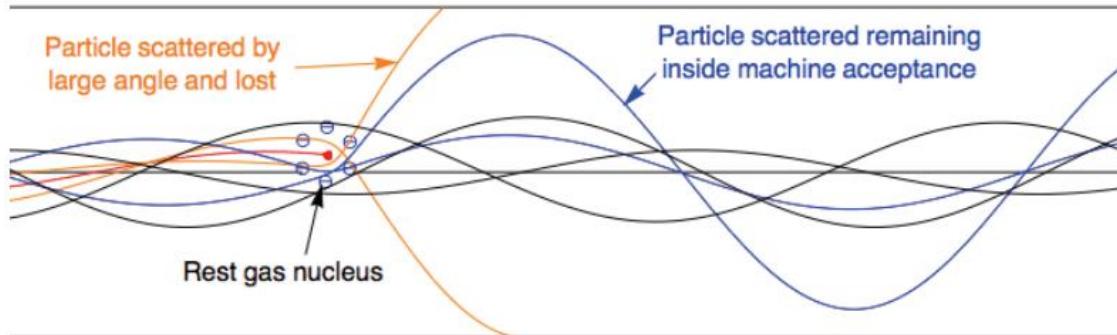


➤ Cheat a little by injecting gas?!

Gas injection impact

$$N_I [\text{m}^{-1}\text{s}^{-1}] = N_{\bar{p}} [\text{s}^{-1}] \times n_g [\text{m}^{-3}] \times \sigma_{\bar{p}+g}^{ion}(E) [\text{m}^2]$$

➤ ionisation



$$N_L [\text{m}^{-1}\text{s}^{-1}] = N_{\bar{p}} [\text{s}^{-1}] \times n_g [\text{m}^{-3}] \times \sigma_{\bar{p}+g}^L(E) [\text{m}^2]$$

from IPAC2014, TUPRI028,
C.Carli

$$N_{BU} [\text{m}^{-1}\text{s}^{-1}] = N_{\bar{p}} [\text{s}^{-1}] \times n_g [\text{m}^{-3}] \times \sigma_{\bar{p}+g}^{BU}(E) [\text{m}^2]$$

- large angle scattering loss
- emittance blow up

Pressure constraint

large angle scattering loss criterion:

*"loss due to gas injection is less than 1.e-4
the normal loss over a full cycle"*

$$\triangleright N_L = N_{pbar} \times \eta_L t_c \frac{l_{gas}}{l} \leq N_{pbar} \times 10^{-4}$$

emittance blow up criterion:

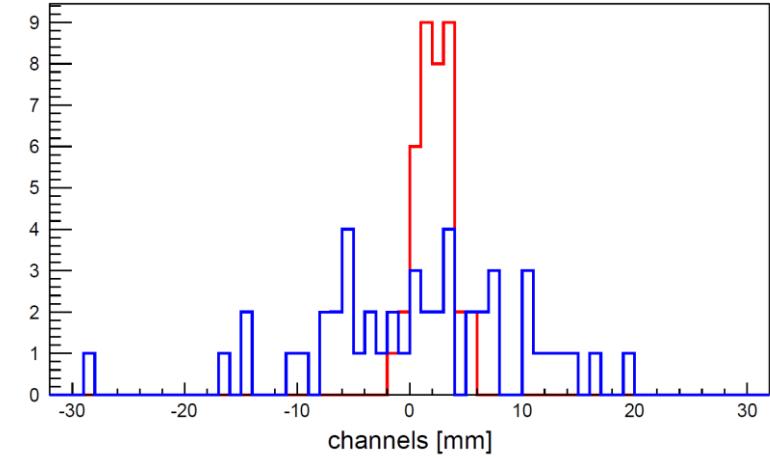
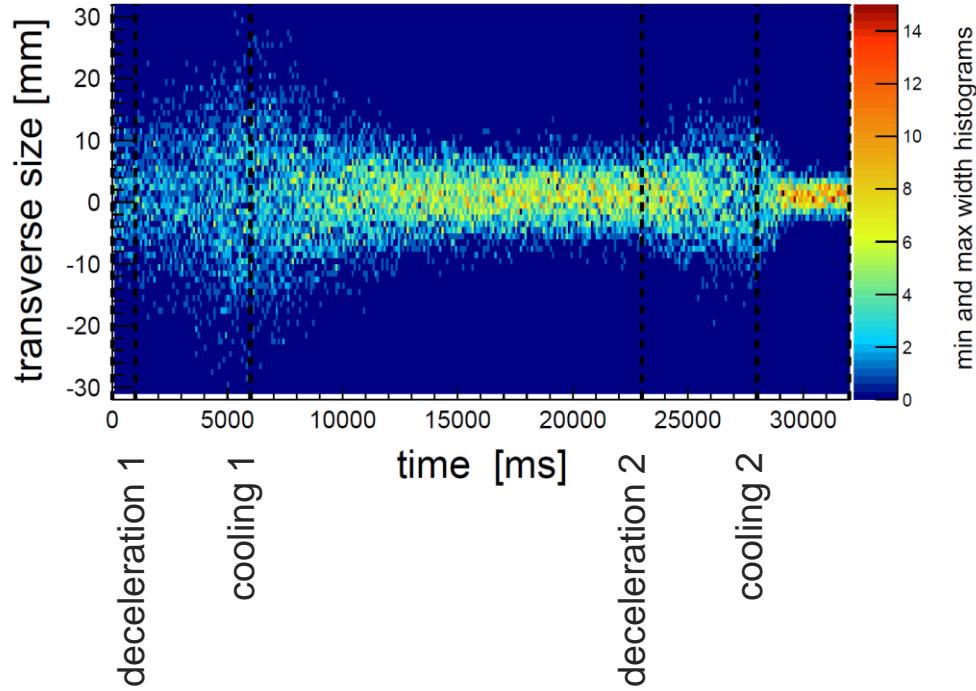
*"emittance blow up growth due to gas
injection should not exceed 5% of
emittance decrease during electron
cooling"*

$$\triangleright \eta_{BU} \leq 30 \times 5\% \frac{1}{A} \frac{\Delta \varepsilon_C}{\Delta t} \sim 2 \times 10^{-3} \text{ s}^{-1}$$

criterion	$\eta_L < 2 \times 10^{-3}$	$\eta_{BU} < 2 \times 10^{-3}$
gas	pressure [mbar]	pressure [mbar]
H ₂	4.3×10^{-10}	2.9×10^{-10}
CO	8.6×10^{-12}	1.1×10^{-11}
CO ₂	5.2×10^{-12}	6.5×10^{-12}
CH ₄	2.1×10^{-11}	2.3×10^{-11}
N ₂	8.8×10^{-12}	1.1×10^{-11}
Ne	8.6×10^{-12}	1.2×10^{-11}
Ar	2.6×10^{-12}	5.2×10^{-12}
Kr	6.6×10^{-13}	2.3×10^{-12}
Xe	2.9×10^{-13}	1.6×10^{-12}

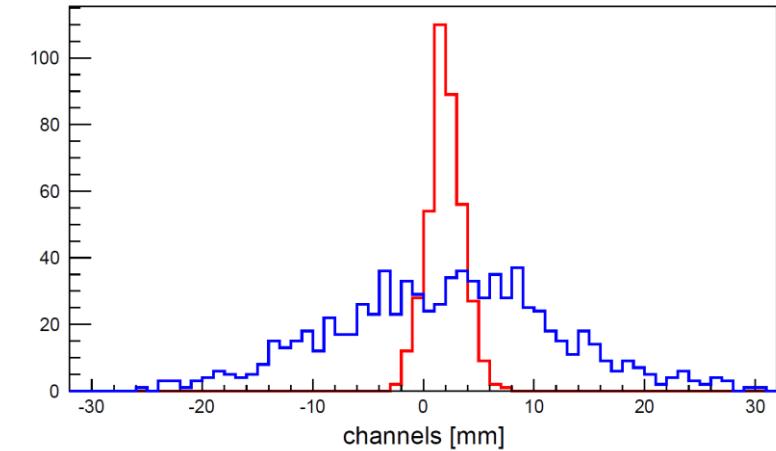
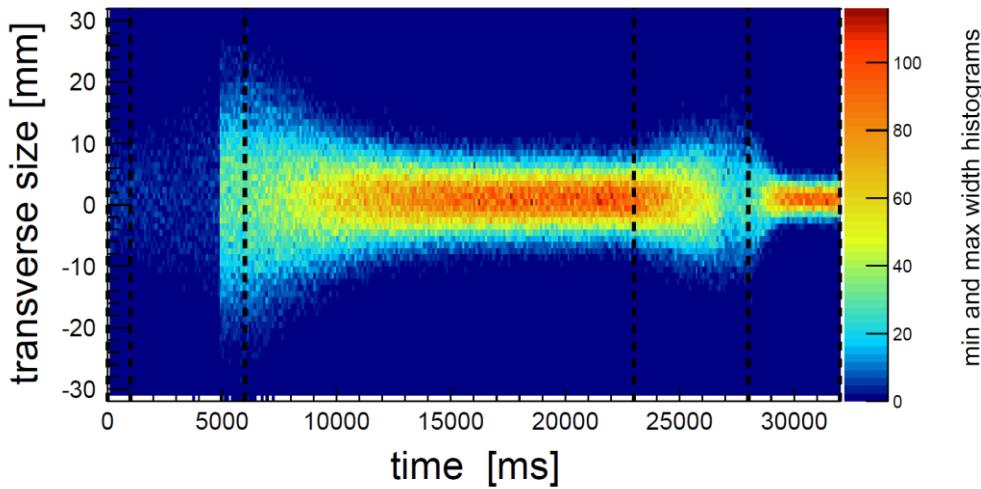


Ionisation in ELENA



➤ Cheat a little by injecting gas?!

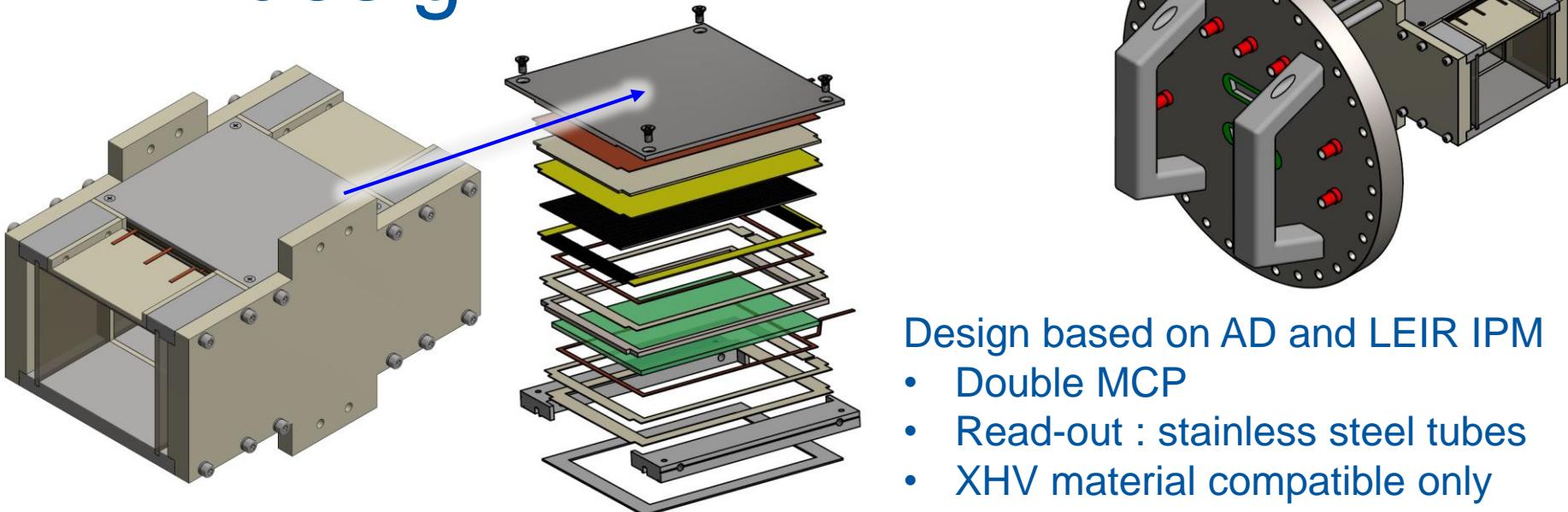
Ionisation in ELENA



CO₂ @ 1.0e-11 mbar

➤ 9% average pressure rise

IPM design



External dimensions: 206 x 140 x 128 mm

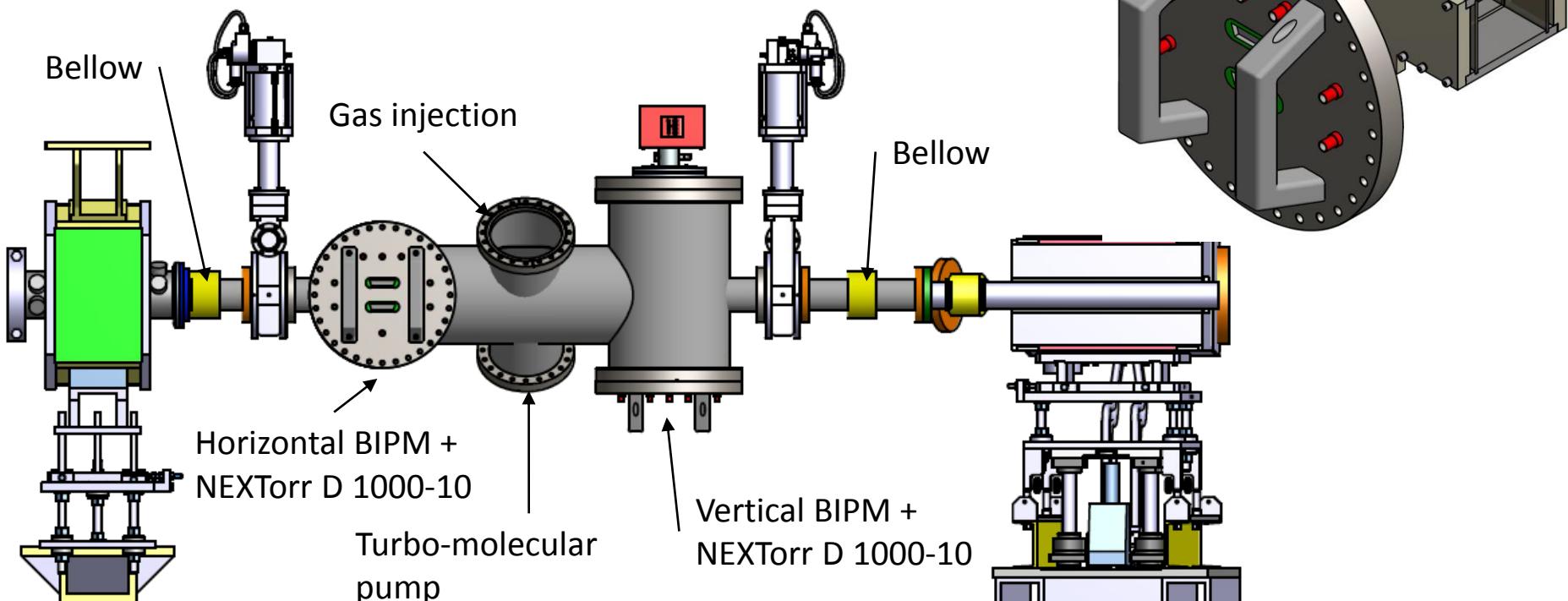
Beam aperture: 82 x 70 mm

Design based on AD and LEIR IPM

- Double MCP
- Read-out : stainless steel tubes
- XHV material compatible only

Two orbit correction electrodes
Long detection length : 80mm

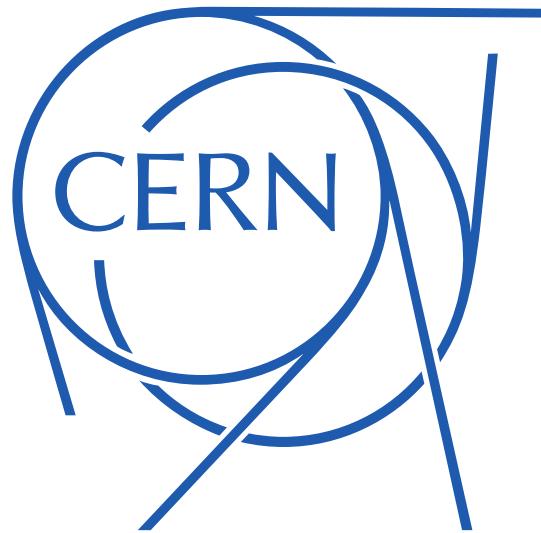
integration in ELENA

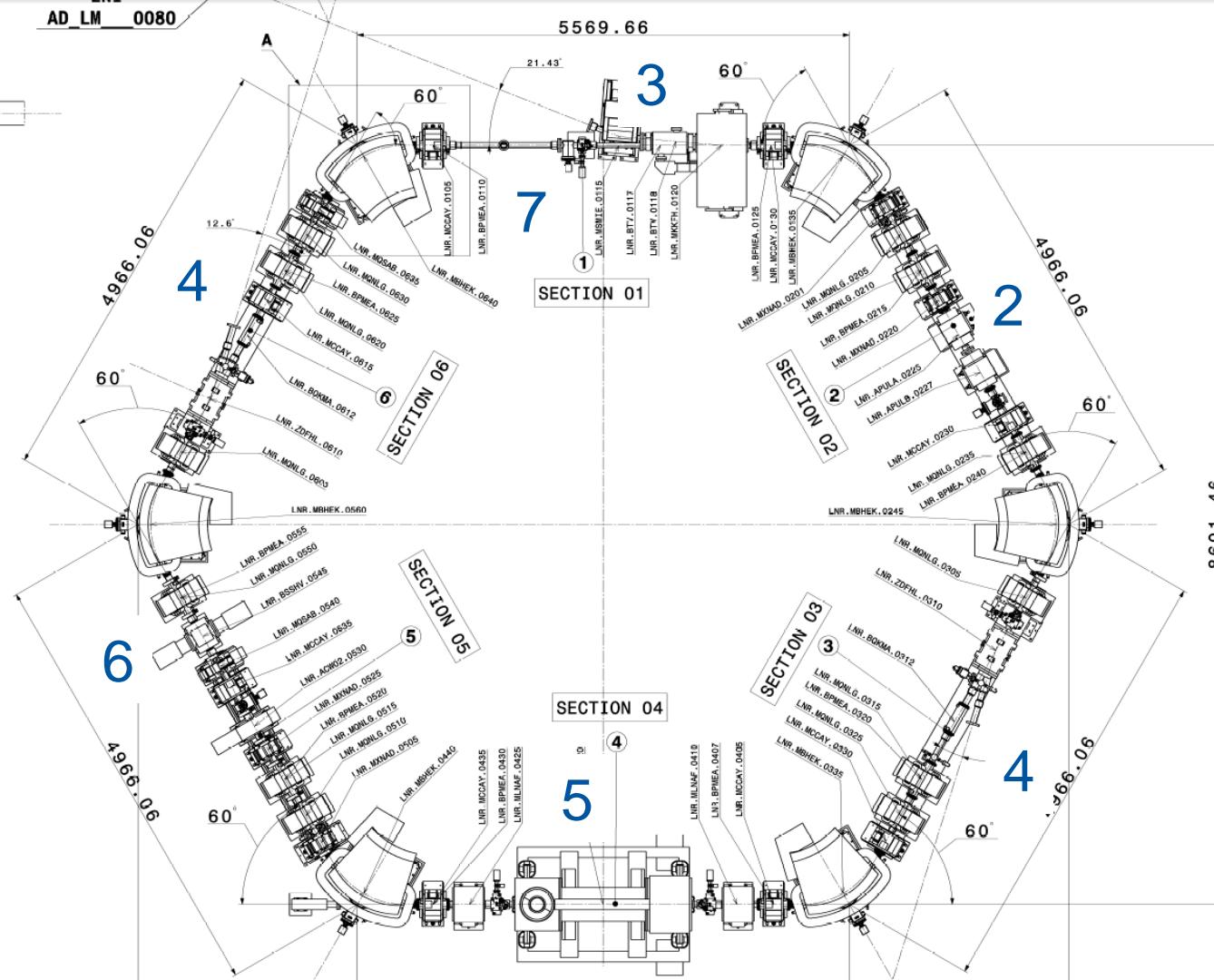


Conclusion

- The scraper's detection systems are installed and ready.
- ELENA Commissioning with H- (and pbar) has started, profile measurement soon!
- We propose to install an IPM in ELENA, especially to monitor electron cooling efficiency: preliminary study is promising.
- A engineer change request is available on EDMS:
<https://edms.cern.ch/document/1754985/0.1>





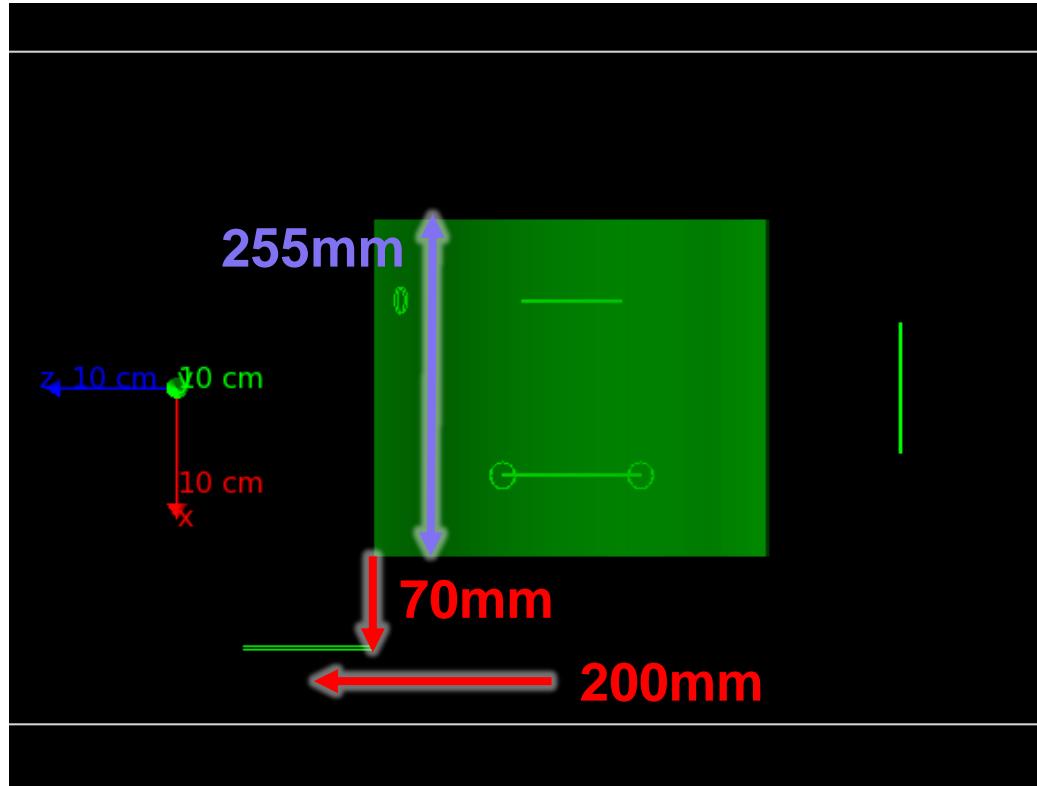


List of equipment for BI in ELENA

1. BPM (20)
 2. Pick up Shottky longitudinal
 3. BTVs
 4. Tune “BBQ”
 5. Electron Cooler
 6. Scraper
 7. Empty space ?!

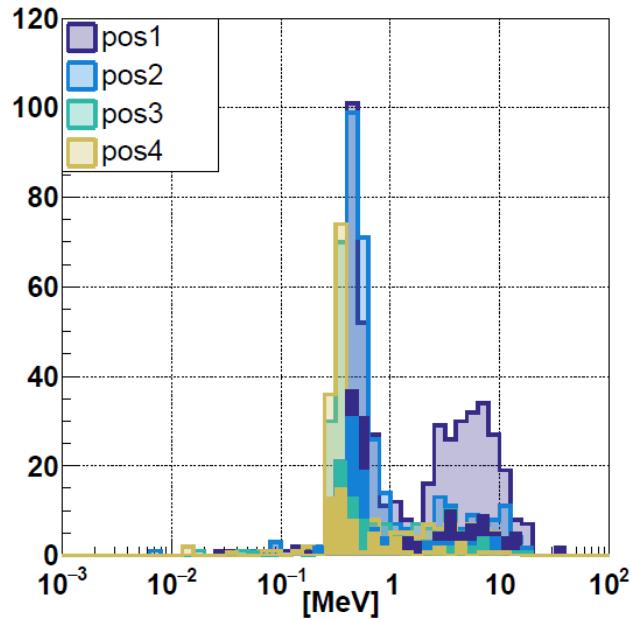
Geant4

- pbar -> pions
 - plastic scintillator
 - Polyvinyltoluene (EJ-2125)
 - 50mm (radius)*2mm
 - 10000 photons/MeV (e-)
 - rise/decay time : 0.9/2.4 ns

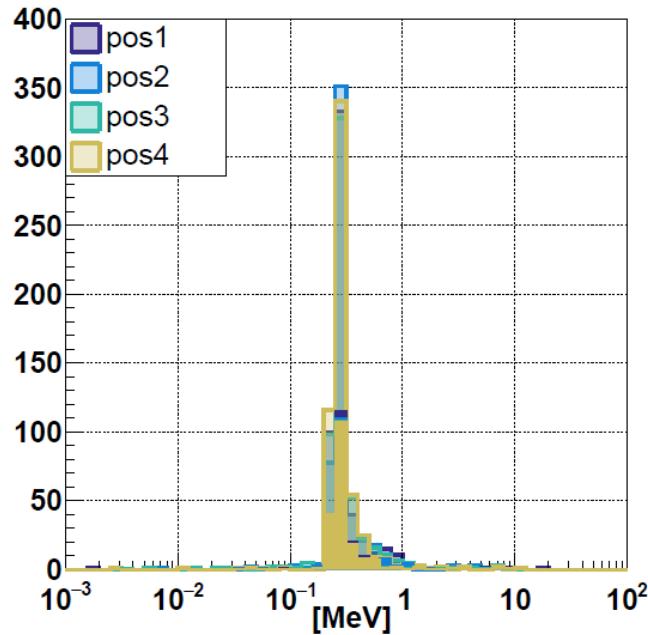


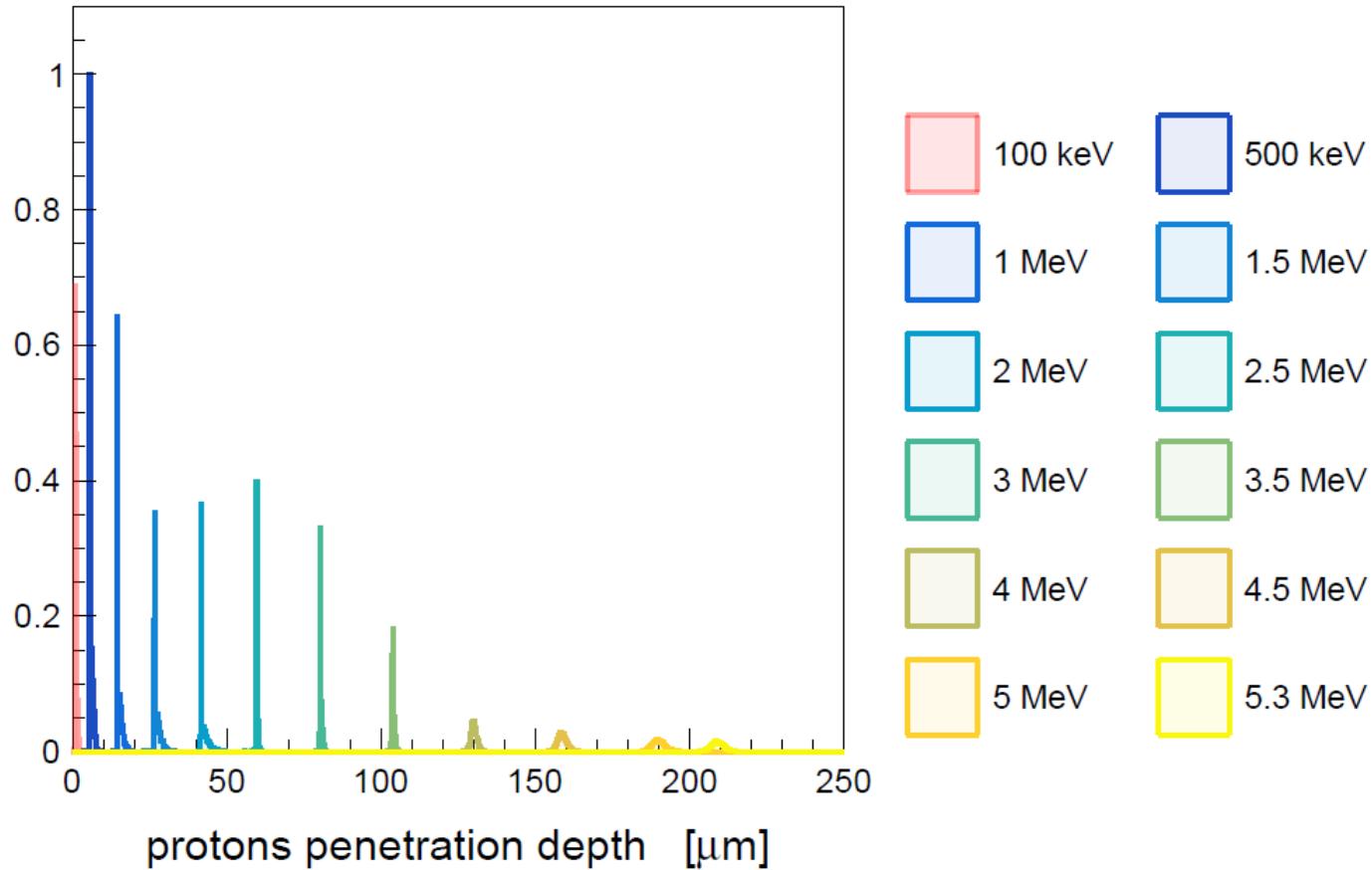
pbar results – energy deposition

energy deposition in scintillator01 (log scale)

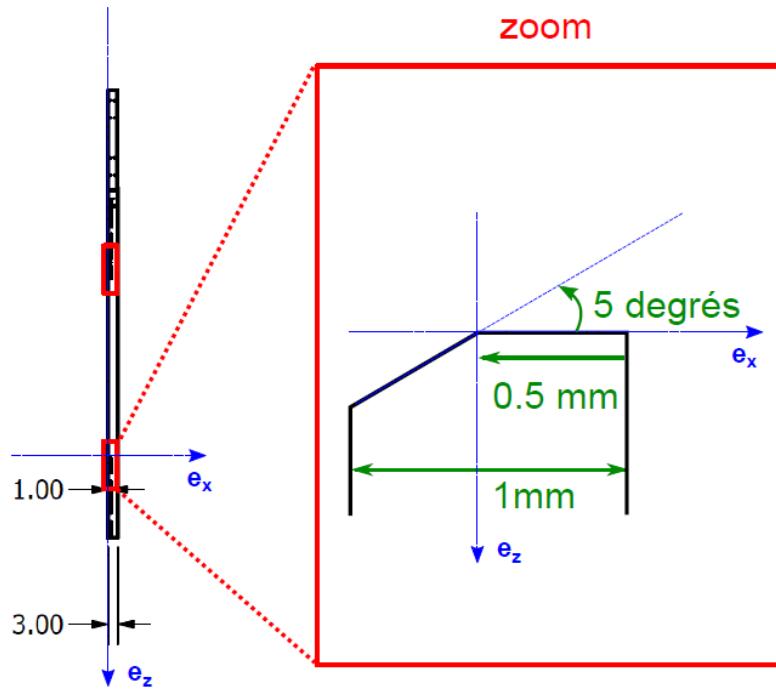
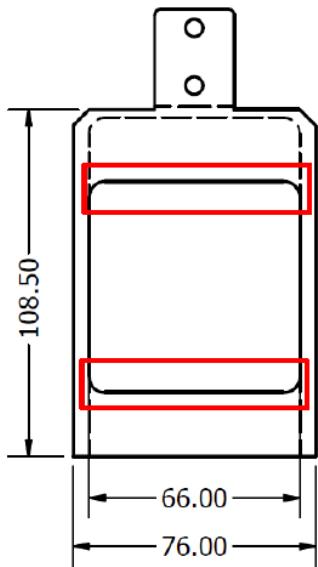


energy deposition in scintillator02 (log scale)

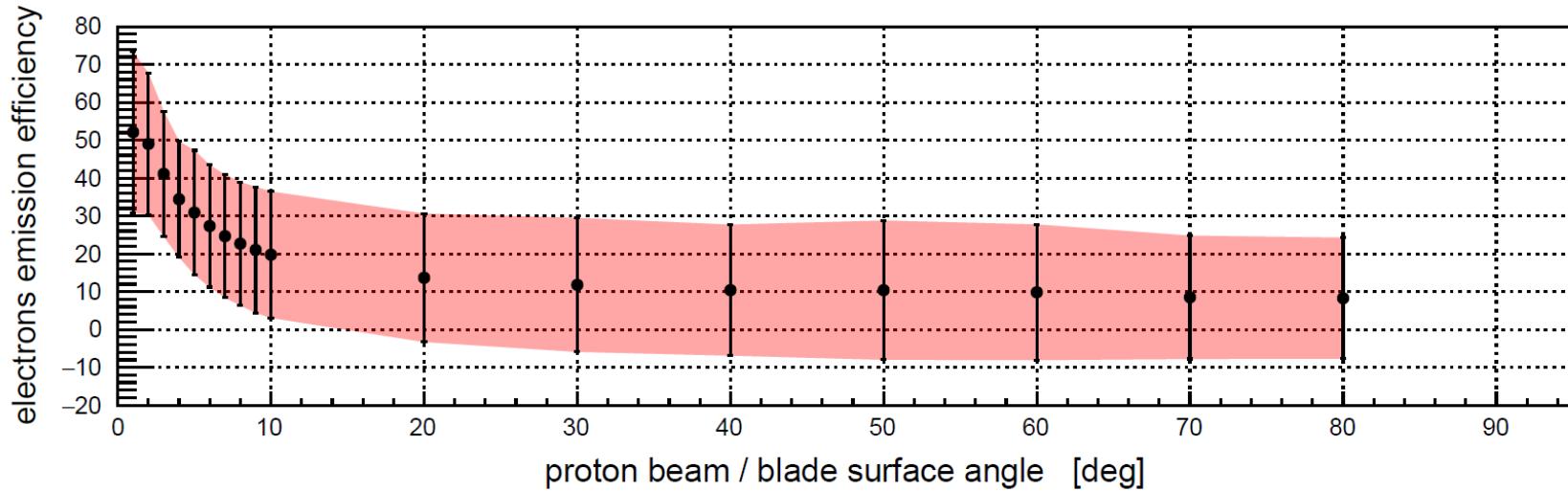




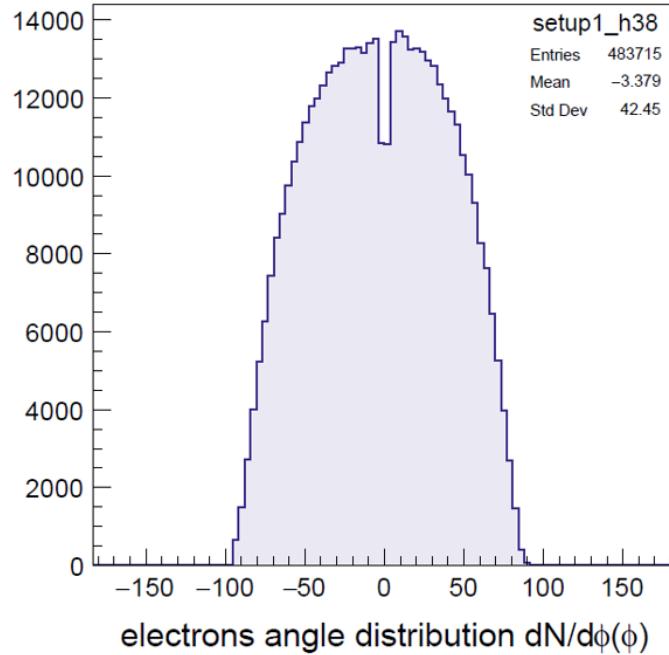
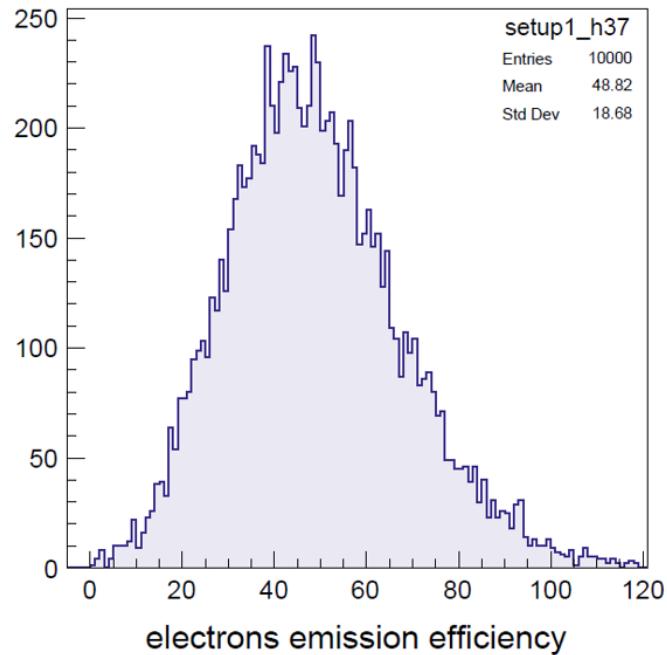
Scraper bevel



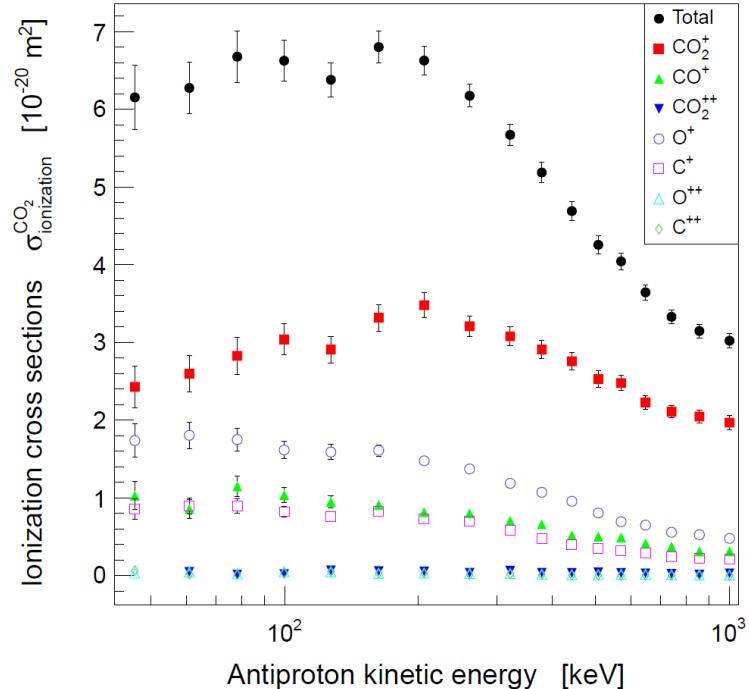
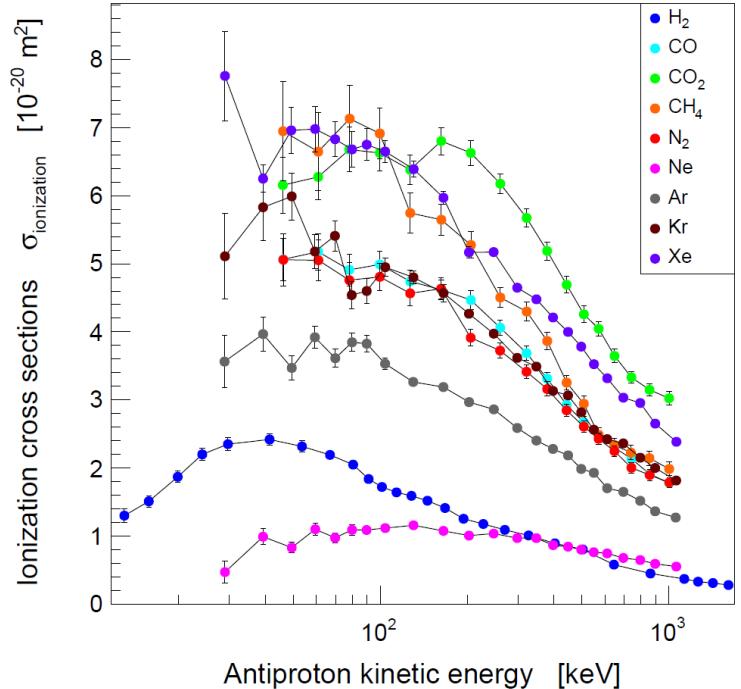
Scraper bevel



Scraper - see

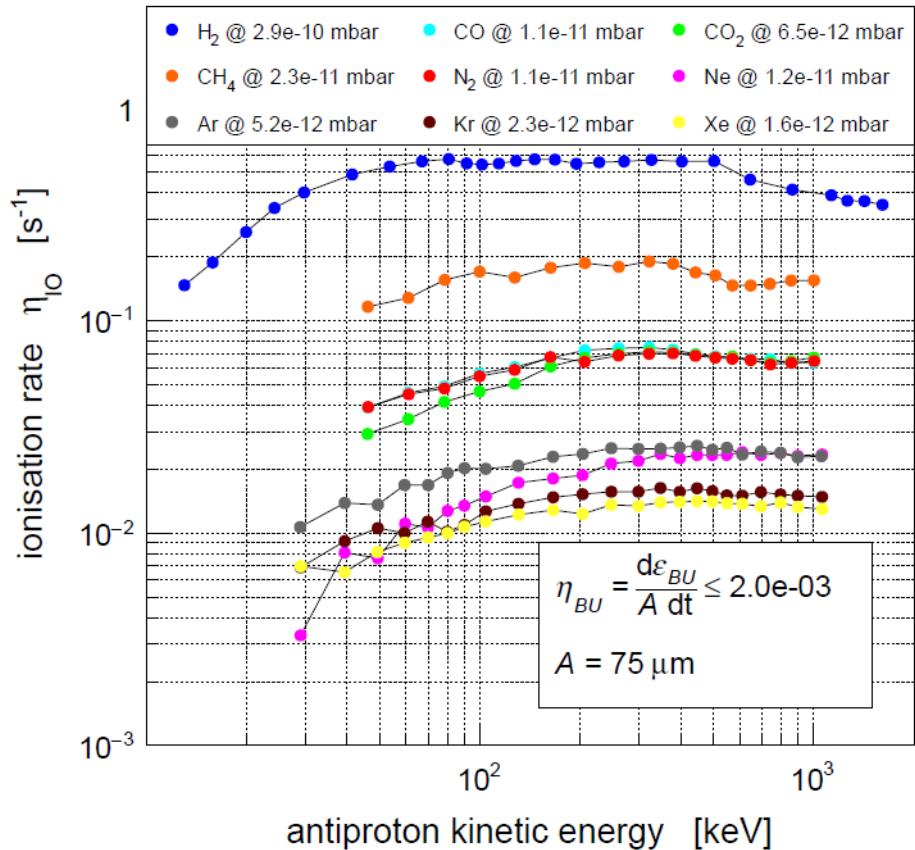


IPM - molecules cross sections

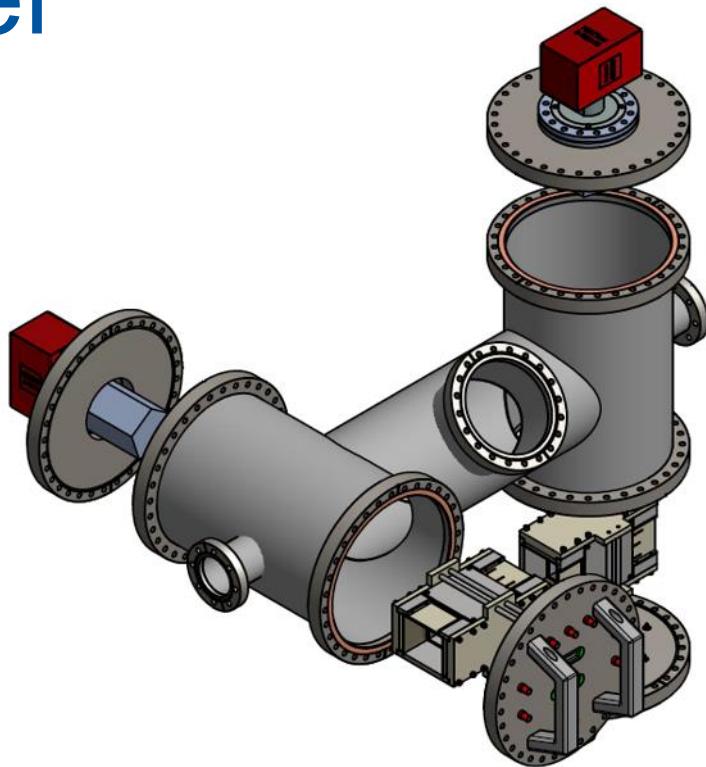
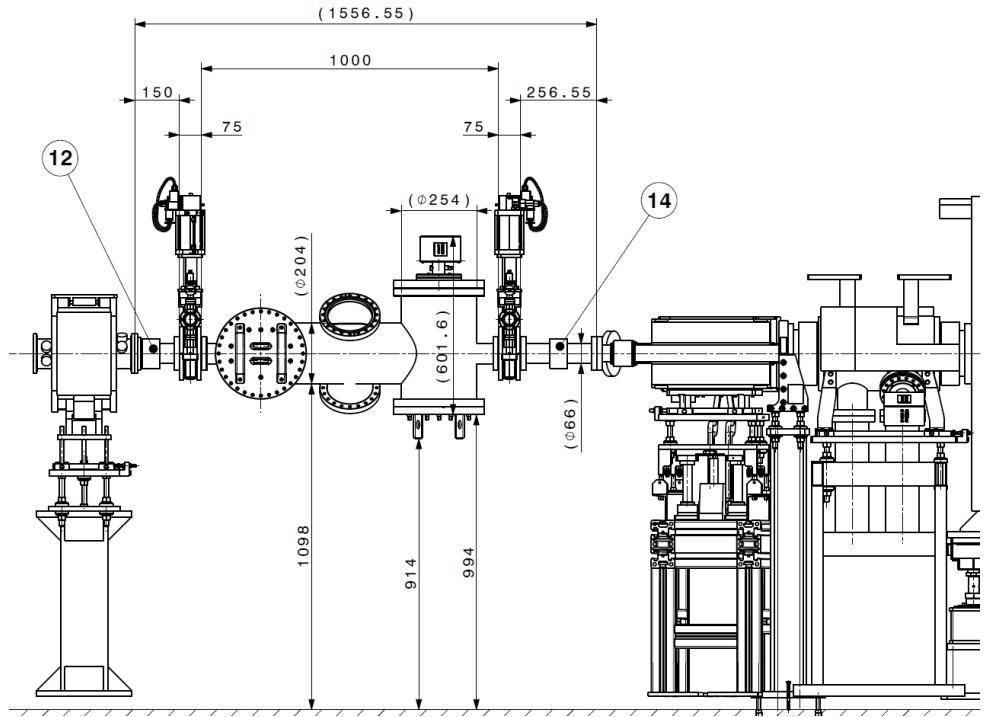


IPM - gas

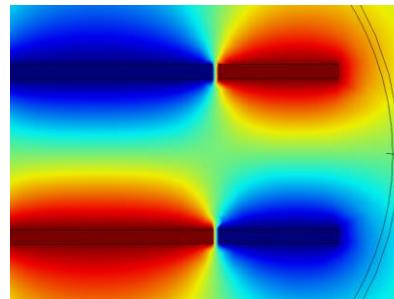
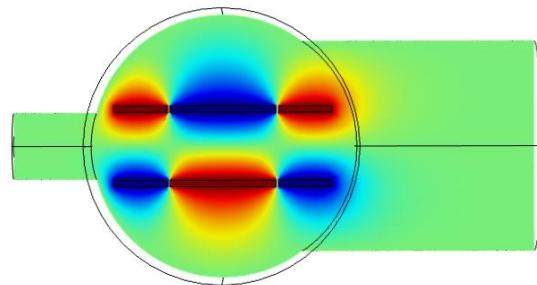
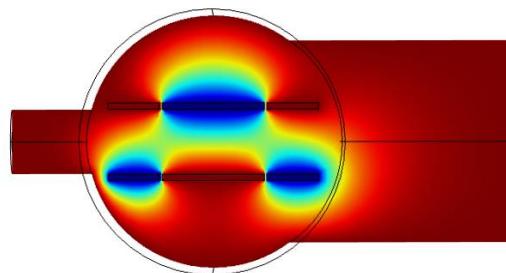
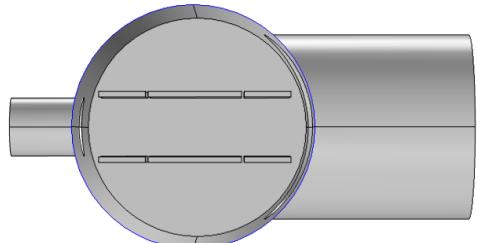
criterion	$\eta_L < 2 \times 10^{-3}$	$\eta_{BU} < 2 \times 10^{-3}$
gas	pressure [mbar]	pressure [mbar]
H ₂	4.3×10^{-10}	2.9×10^{-10}
CO	8.6×10^{-12}	1.1×10^{-11}
CO ₂	5.2×10^{-12}	6.5×10^{-12}
CH ₄	2.1×10^{-11}	2.3×10^{-11}
N ₂	8.8×10^{-12}	1.1×10^{-11}
Ne	8.6×10^{-12}	1.2×10^{-11}
Ar	2.6×10^{-12}	5.2×10^{-12}
Kr	6.6×10^{-13}	2.3×10^{-12}
Xe	2.9×10^{-13}	1.6×10^{-12}



IPM - vacuum chamber



IPM – comsol simulation



IPM – comsol simulation

