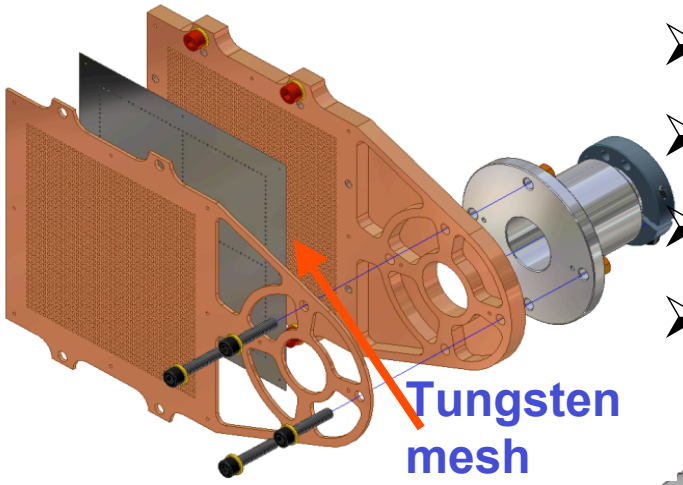
Novel Diagnostics on FETS and ISIS

- Introduction
- The pepper pot emittance / 2D profile measurement device
- Photo detachment based beam tomography
- Emittance scanner using photo detachment
- Non destructive beam profile monitors based on RGI distribution
- Emittance reconstruction from multiple beam profile measurements
- Summary

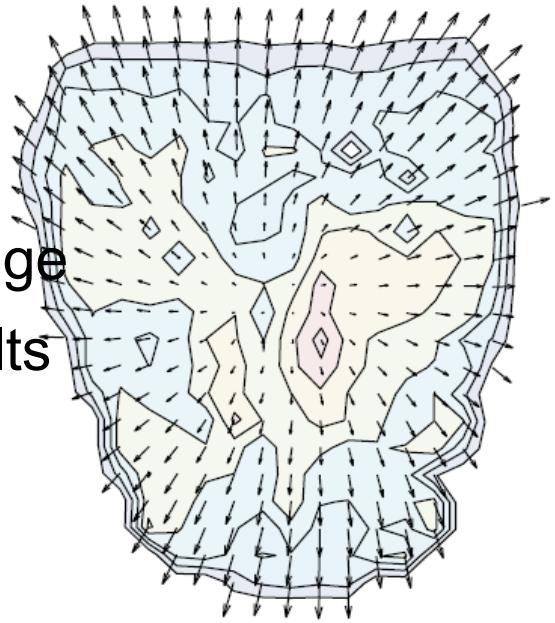
Beam diagnostic at FETS and ISIS

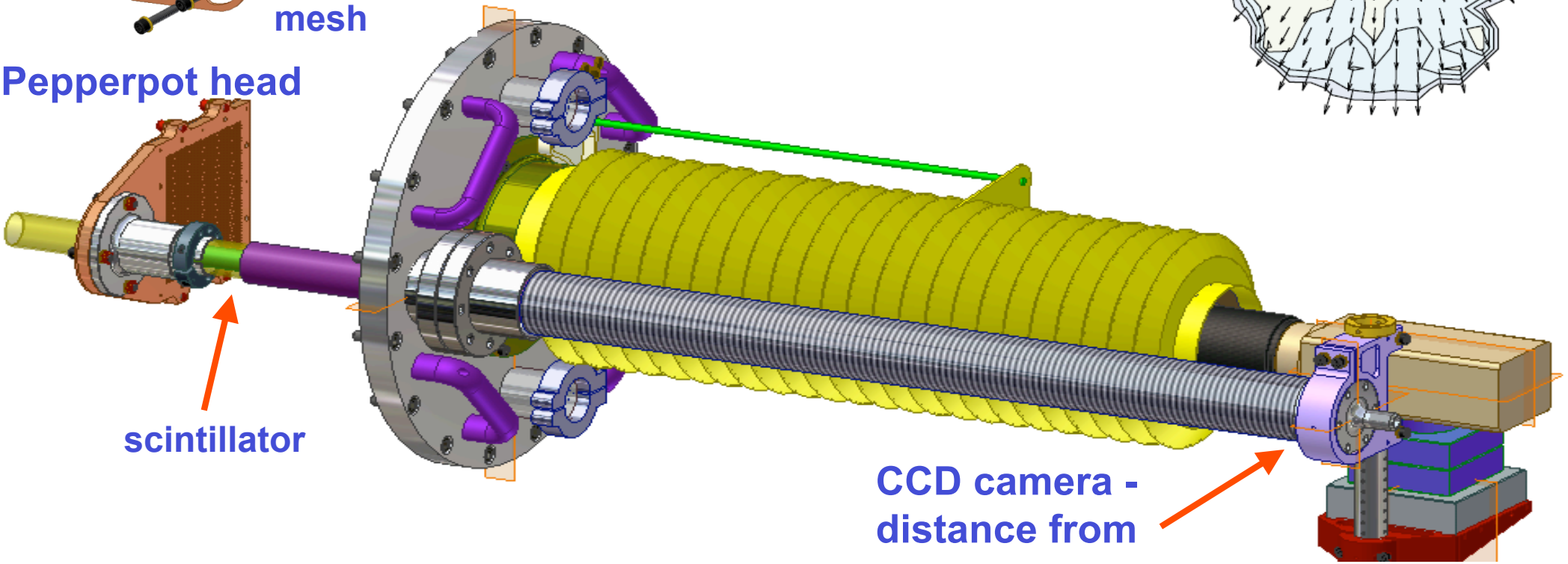
- Beam diagnostics is an essential tool for commissioning and operation of particle accelerators.
- To ensure hands on maintenance of MW class accelerators losses must be kept below 1W/m
- This requires beam diagnostic with a relative sensitivity of better than 10^{-6}
- Above the Coulomb barrier non interceptive diagnostic is required to avoid activation and/or destruction of the diagnostic device

The pepper pot emittance measurement device



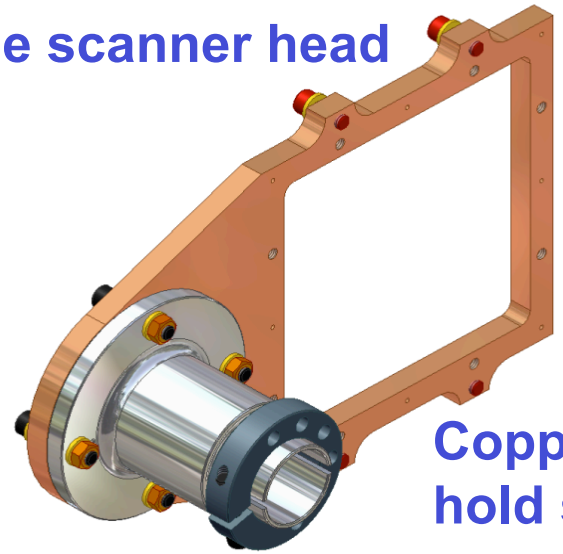
- 4 D phase space sampling
- 3 mm resolution, ±60 mm range
- 5 mrad resolution, ±100 mrad range
- good agreement with slit slit results



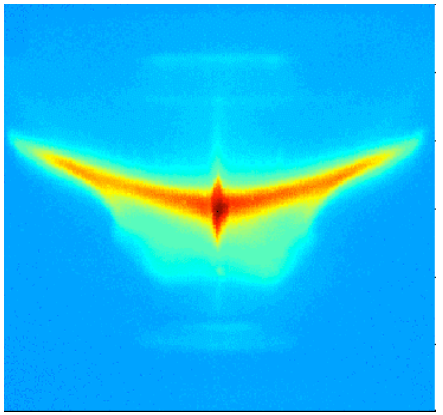


The 2D profile measurement device

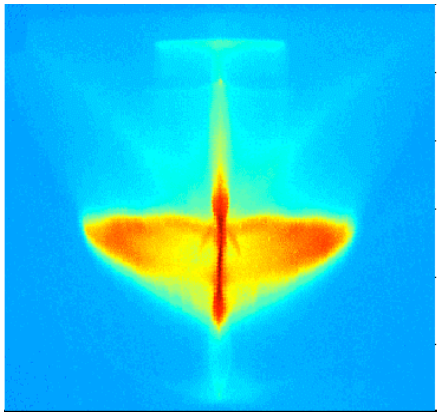
Profile scanner head



Copper frame to hold scintillator

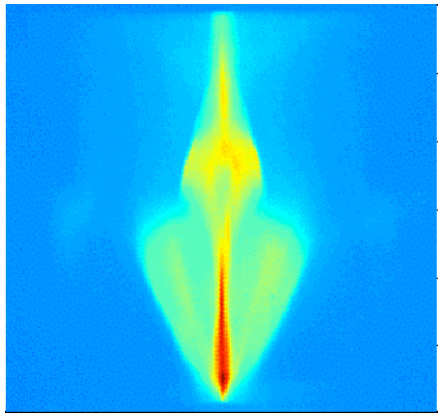


5 kV Ext

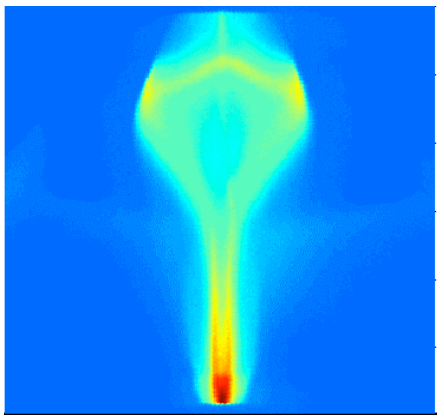


6 kV Ext

- 2 D profile measurement
- 50 μm resolution, ±60 mm range
- sampling at different position along beam propagation for emittance reconstruction possible

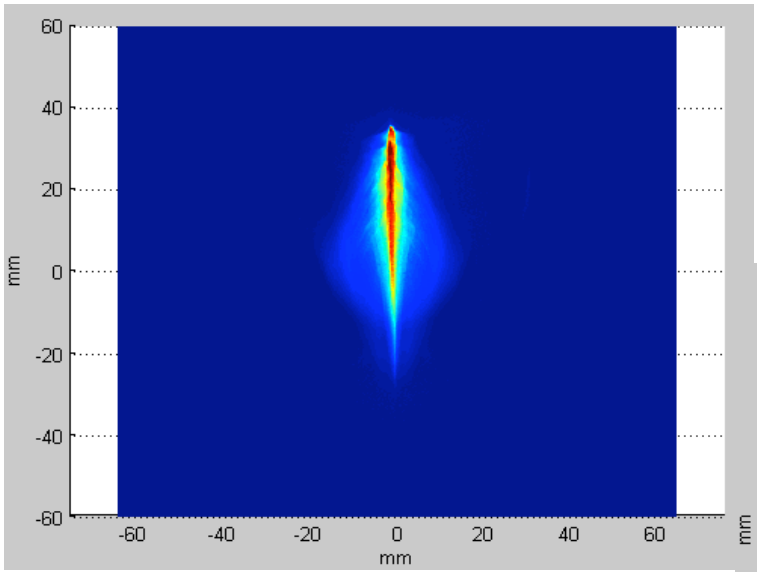


7 kV Ext

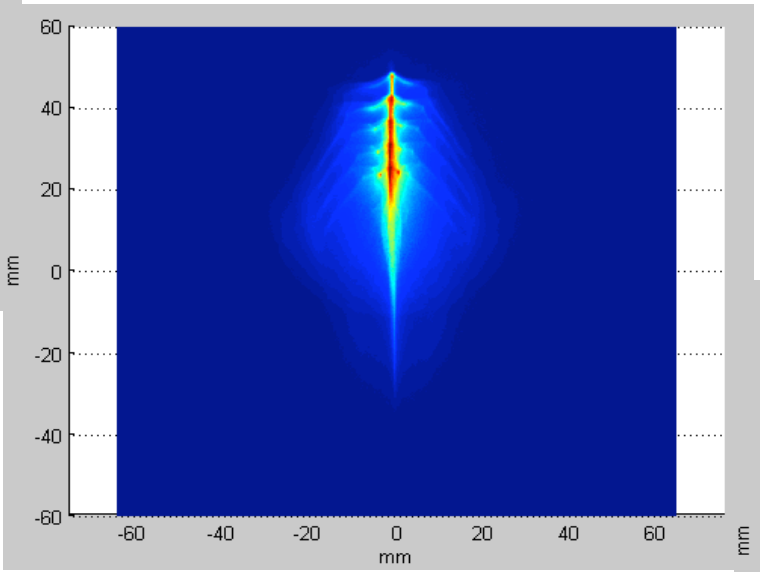


8 kV Ext

Beam profiles for different z positions

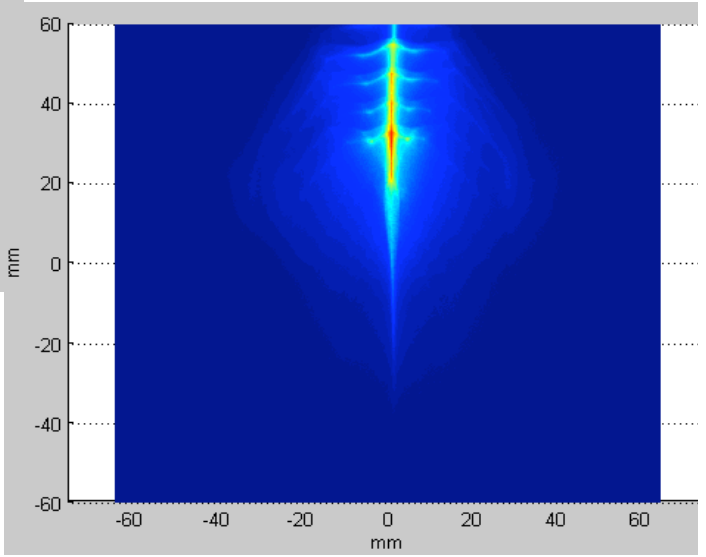


355 mm

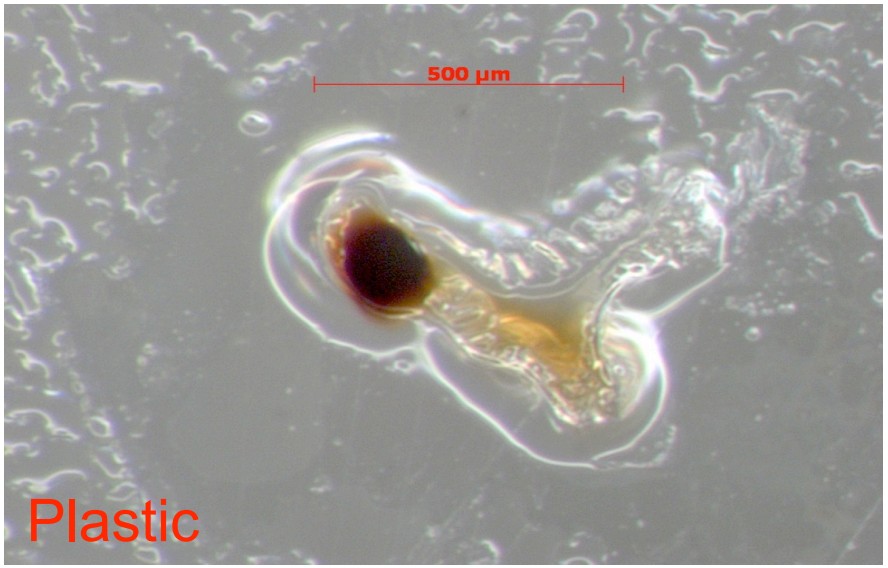


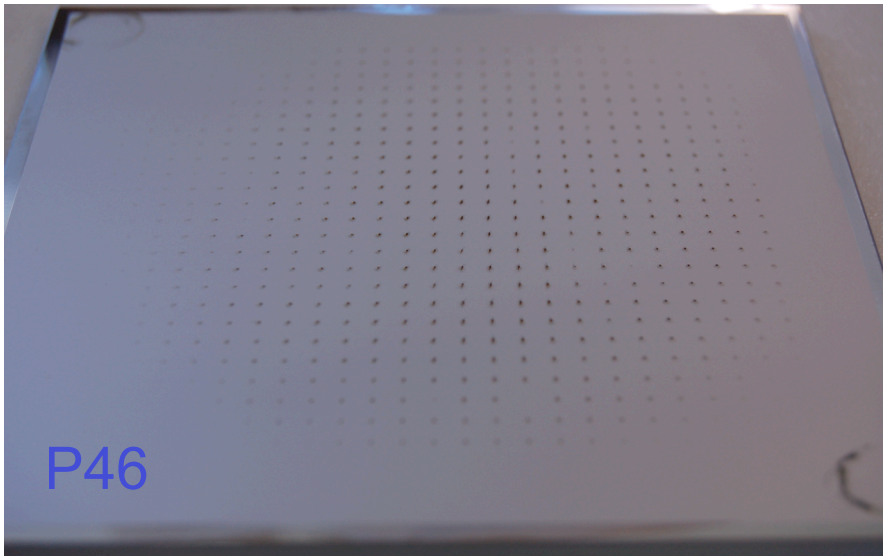
555 mm

755 mm

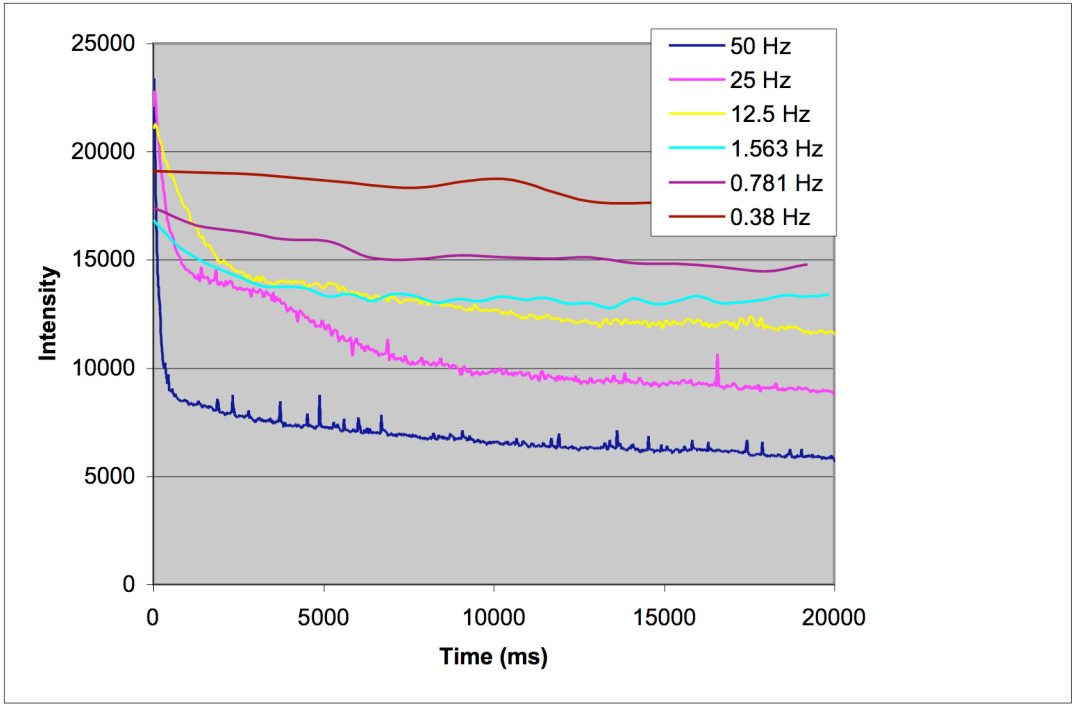


Scintillator lifetime and irradiation damage studies

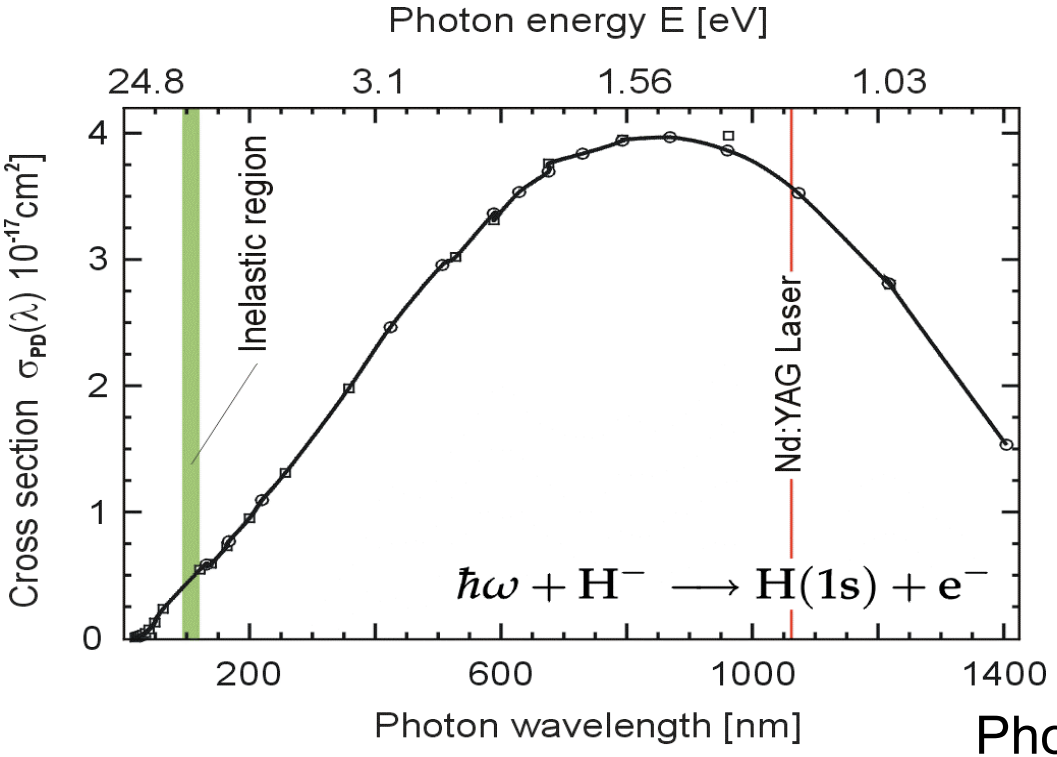




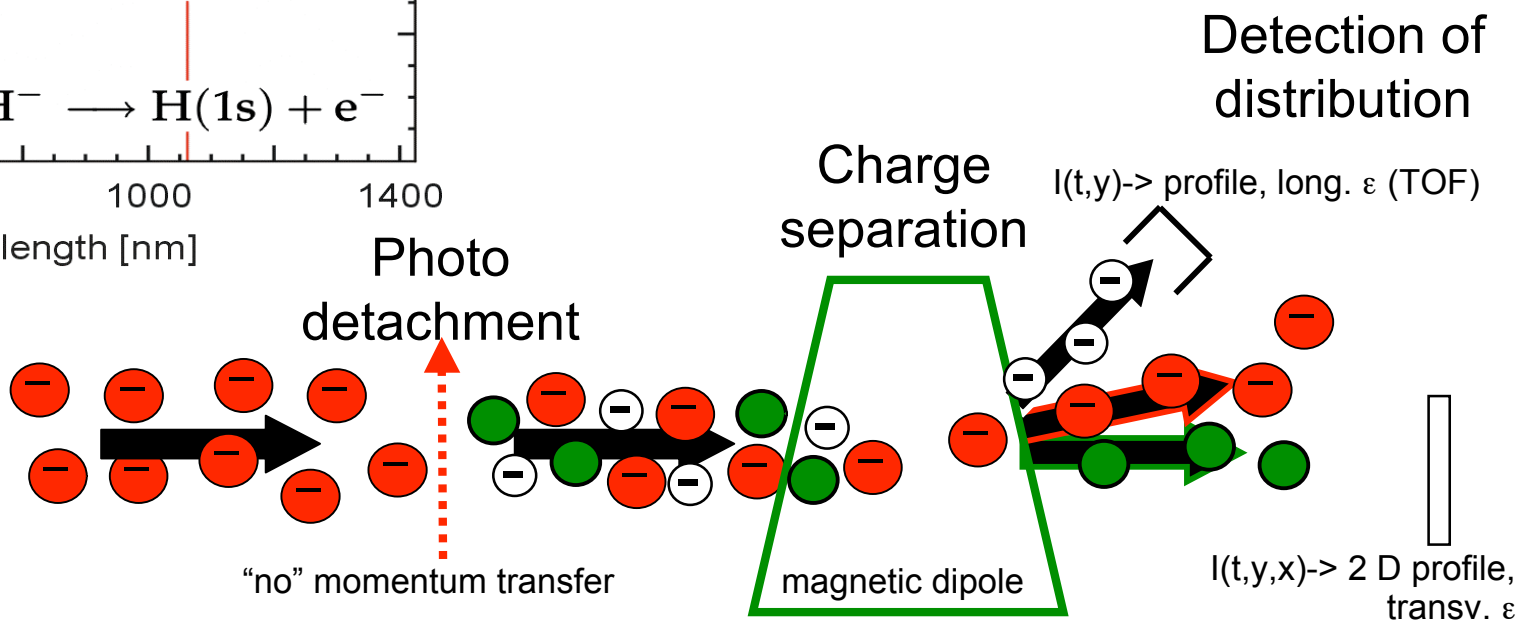
Various different scintillator materials tested (Plastic, P46, Ruby, YAG, Quartz,…) and all show radiation damage (decrease in light yield over time). Quartz seems to be most stabile and is most often used for the experiments.



Beam diagnostics using laser detachment

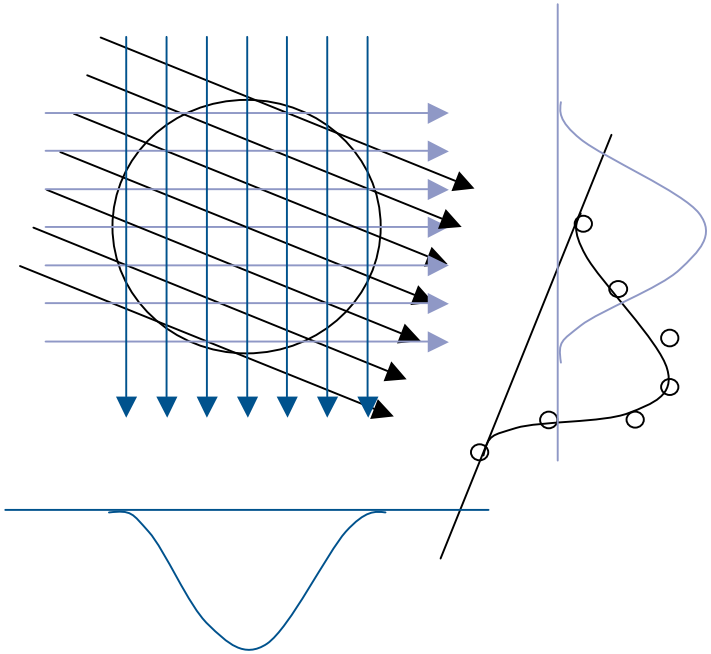


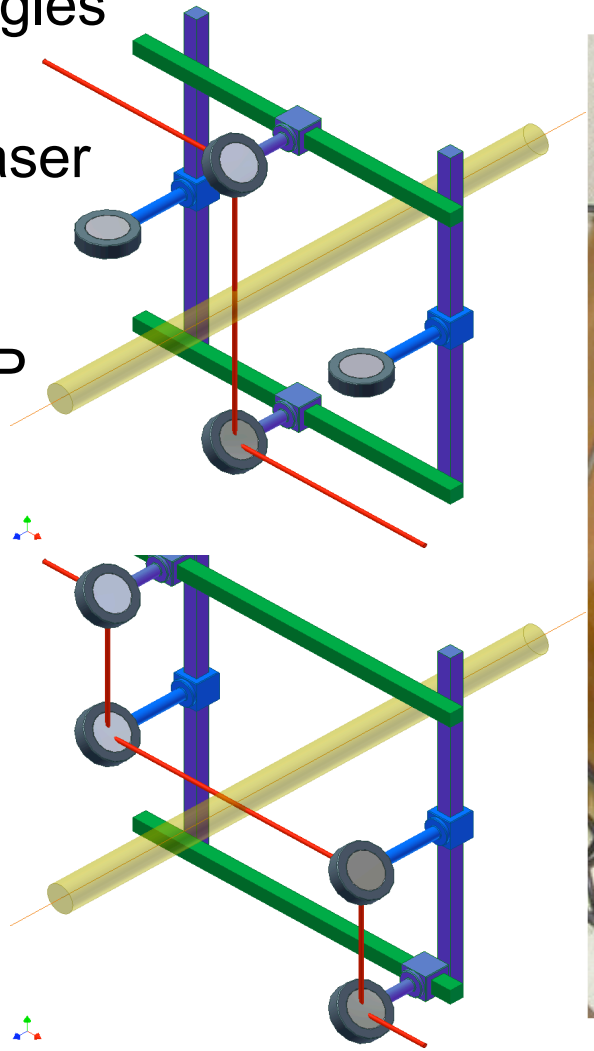
- Interaction between laser and H- beam produces neutrals and free electrons.
- magnetic dipole field separates the detached electrons and neutrals from the ion beam



H^- beam tomography using laser detachment

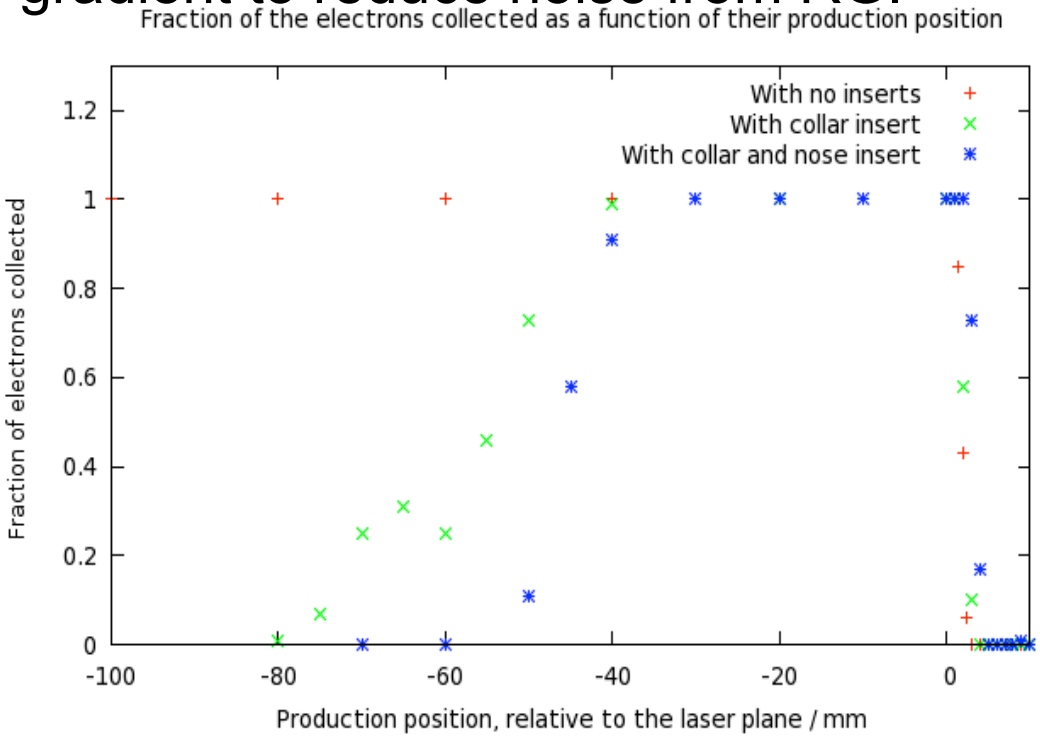
- Beam profiles for different angles have to be taken.
- requires the ability to move laser beam around the ion beam.
- 2 D density profile can be reconstructed using ART or FBP

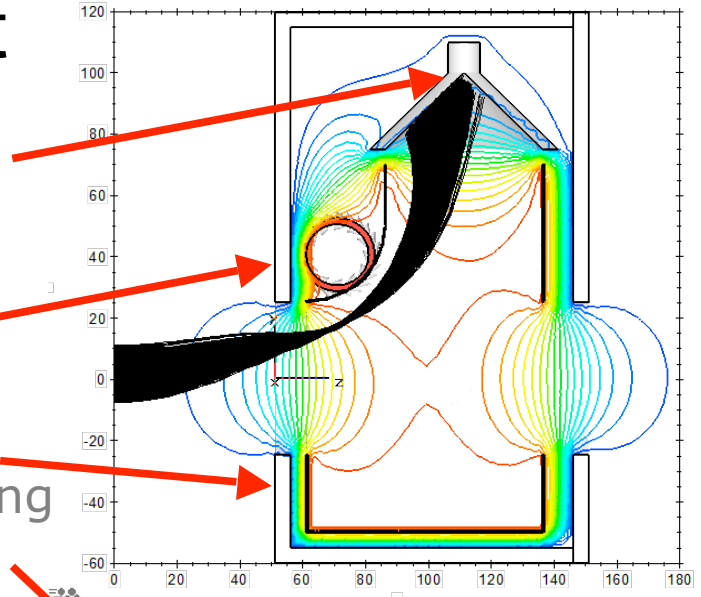


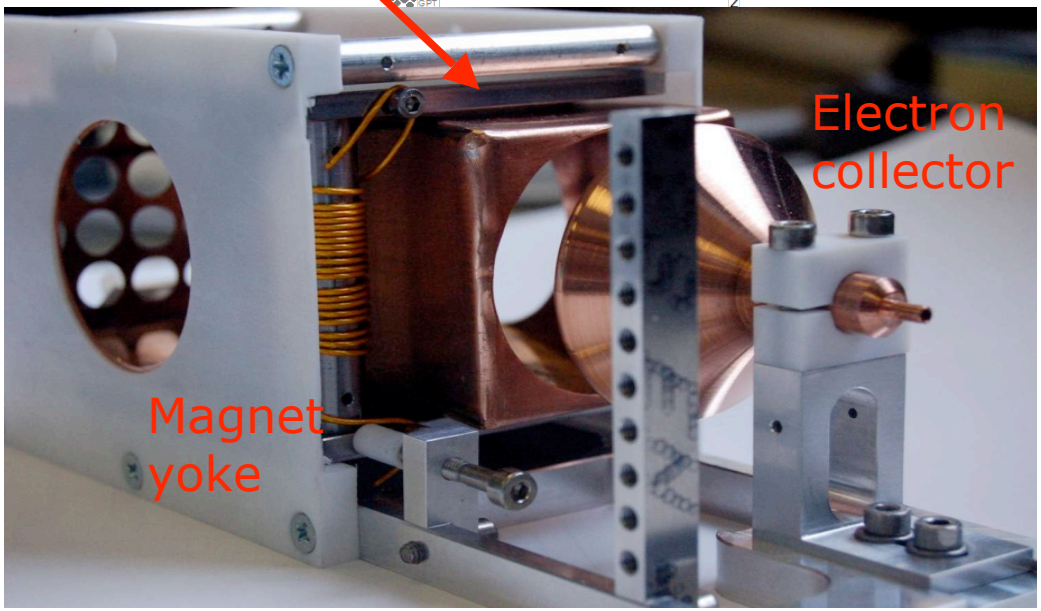


Particle detector layout

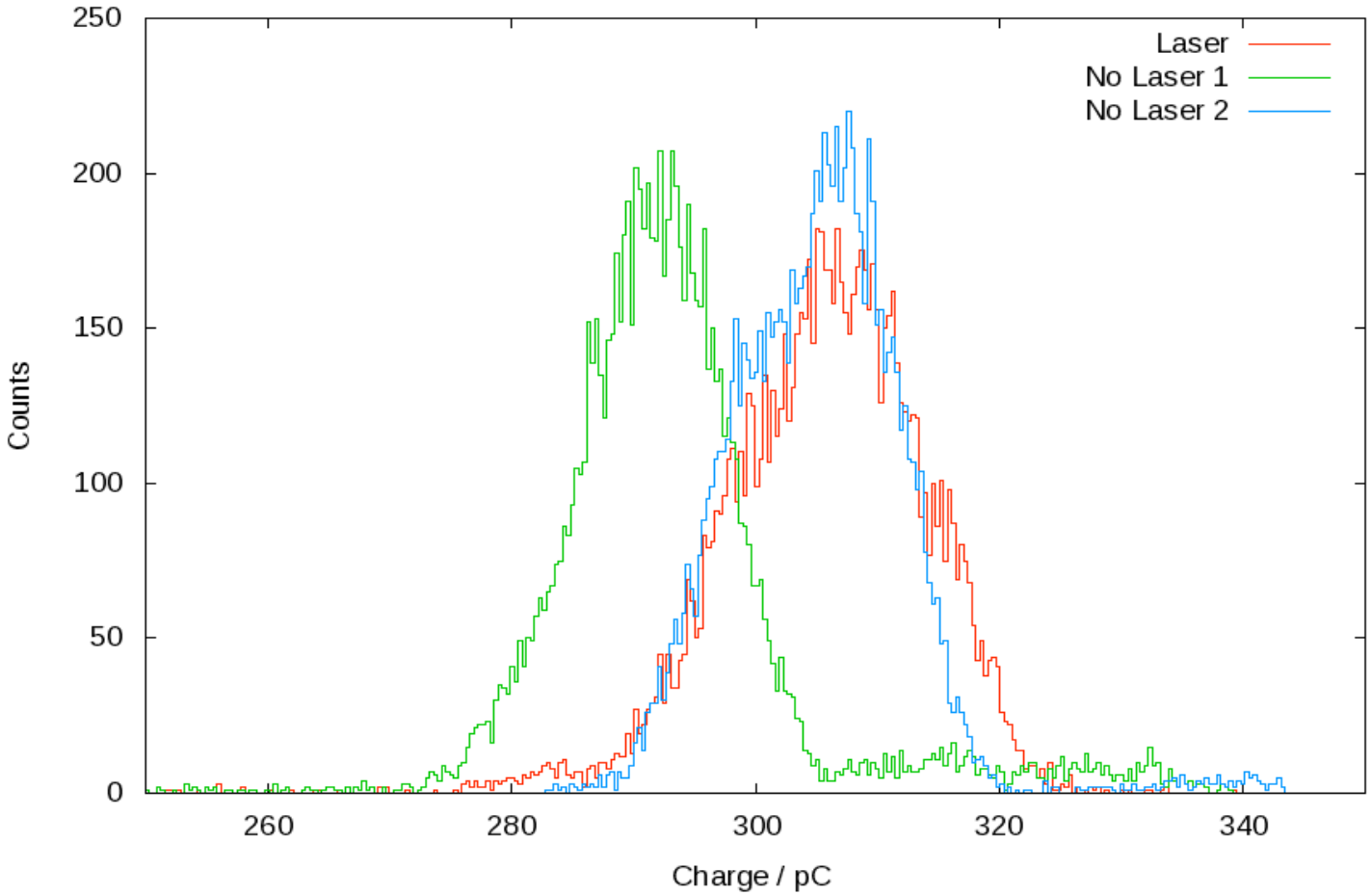
- Post acceleration of particles into the detector to increase magnetic rigidity.
- Dipole field to separate the electrons from the ion beam
- Laser neutralisation in electric field gradient to reduce noise from RGI







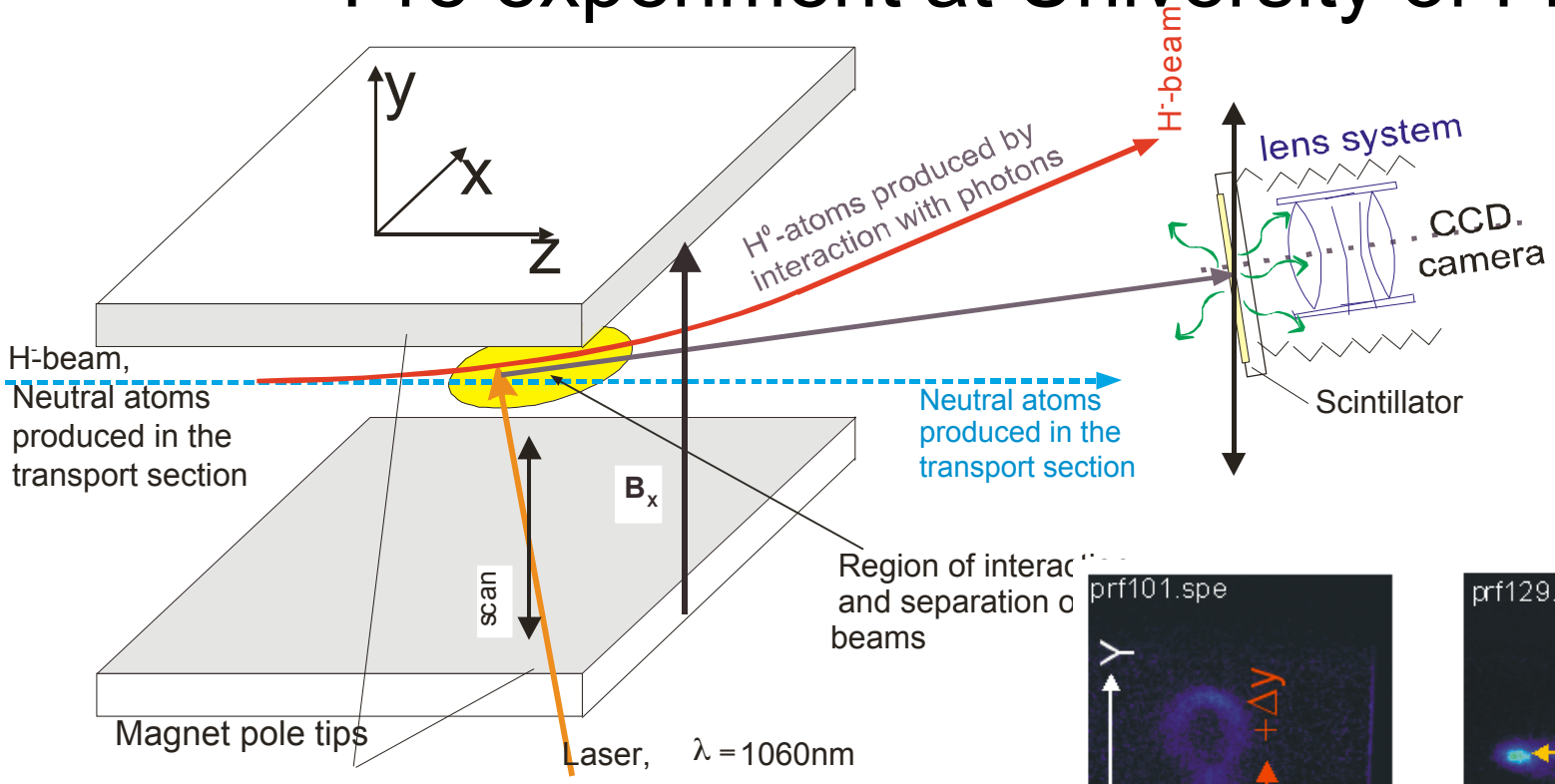
Preliminary result : Background and Laser

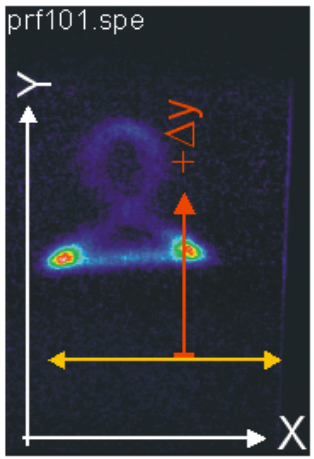


Hint of LD electrons detected but higher laser power required due to large background in proximity of ion source : 10 kW high repetition rate pulsed Laser system purchased

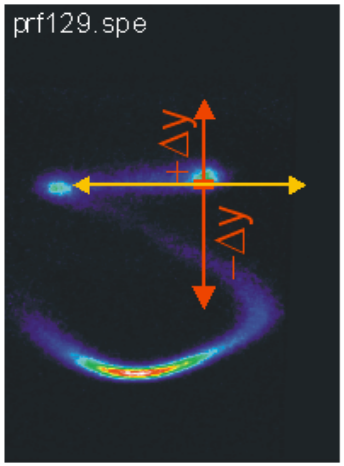
J. Pozimski, Proton accelerator for Science and Innovation Workshop, January 12-14, 2012 Fermilab

Emittance scanner based on photo detachment: Pre experiment at University of Frankfurt.

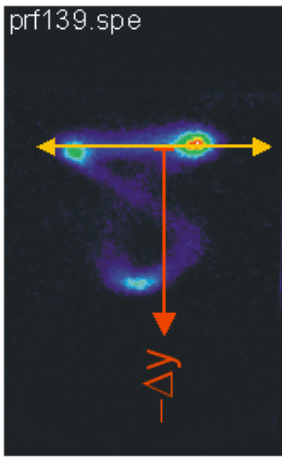




y=-7,8mm



y=+4,7mm



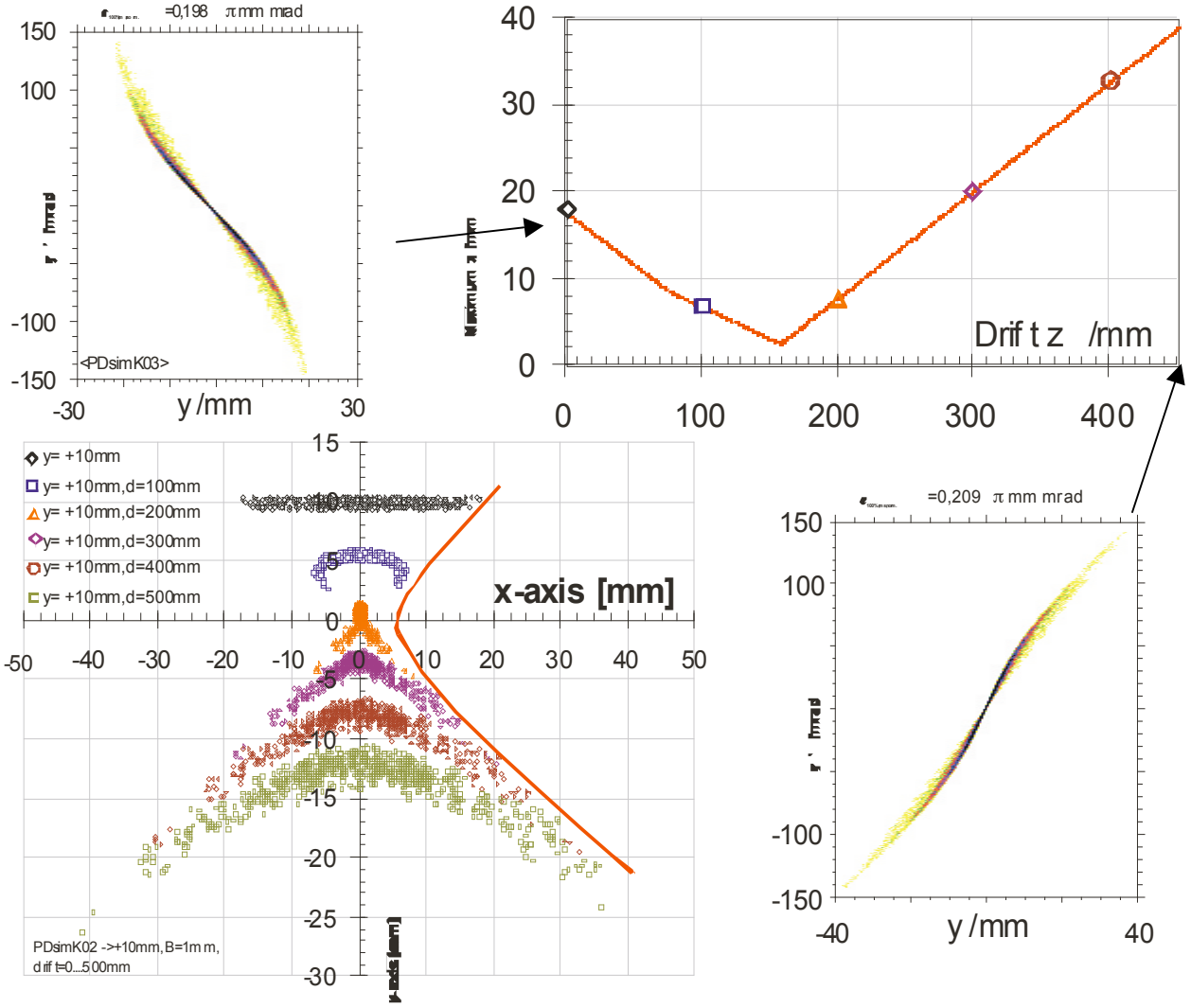
y=+8,4mm

Emittance measurements in both transversal planes requires scanning of the laser in both planes.
=> mechanically difficult setup between poles of dipole

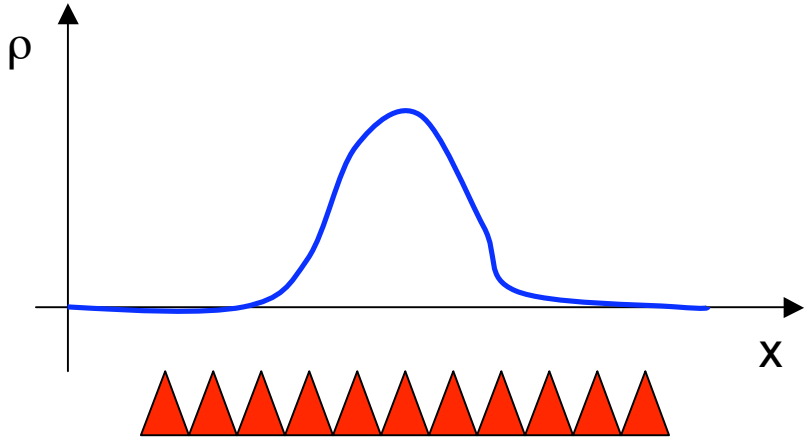
Determination of correlated transversal emittance measurements – movable detector

Utilizing the variation of the 2-D density distribution of the neutrals as a function of the drift length z offers the opportunity of determining both x' & y'

- would make dipole much more conventional
- Pepper pot mechanism could be reused or rebuild
- Simpler than 2D profile reconstruction.

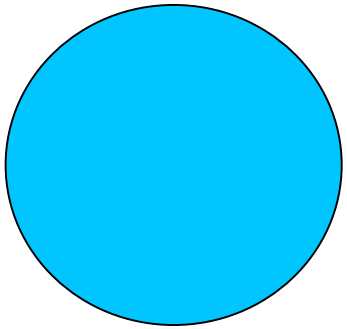


Distribution of extracted residual gas ions for non destructive beam profile measurements at ISIS



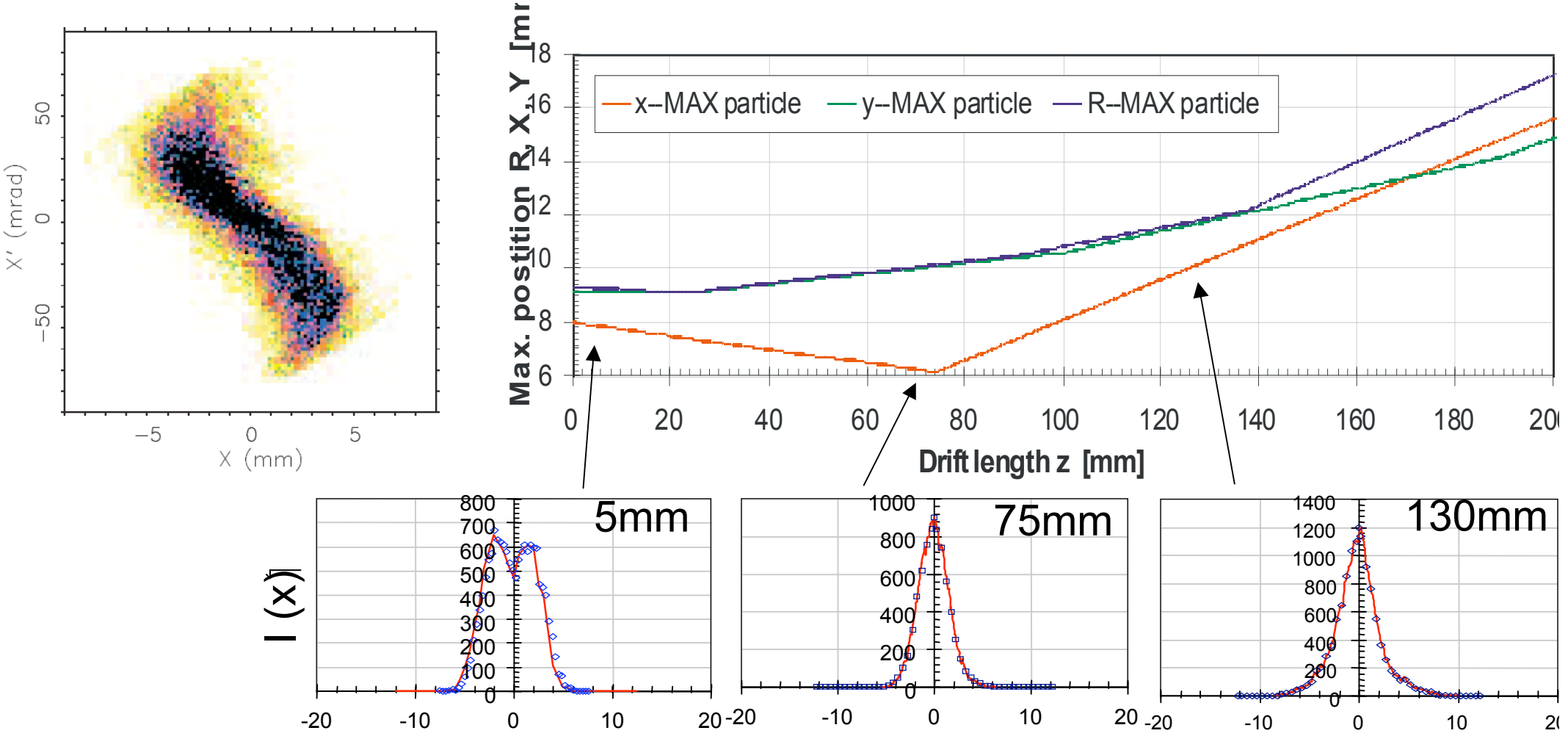
Channeltrons
(rotatable by 90 degree
for normalisation)

Electric field for extraction
of secondary particles
(RGI and electrons)

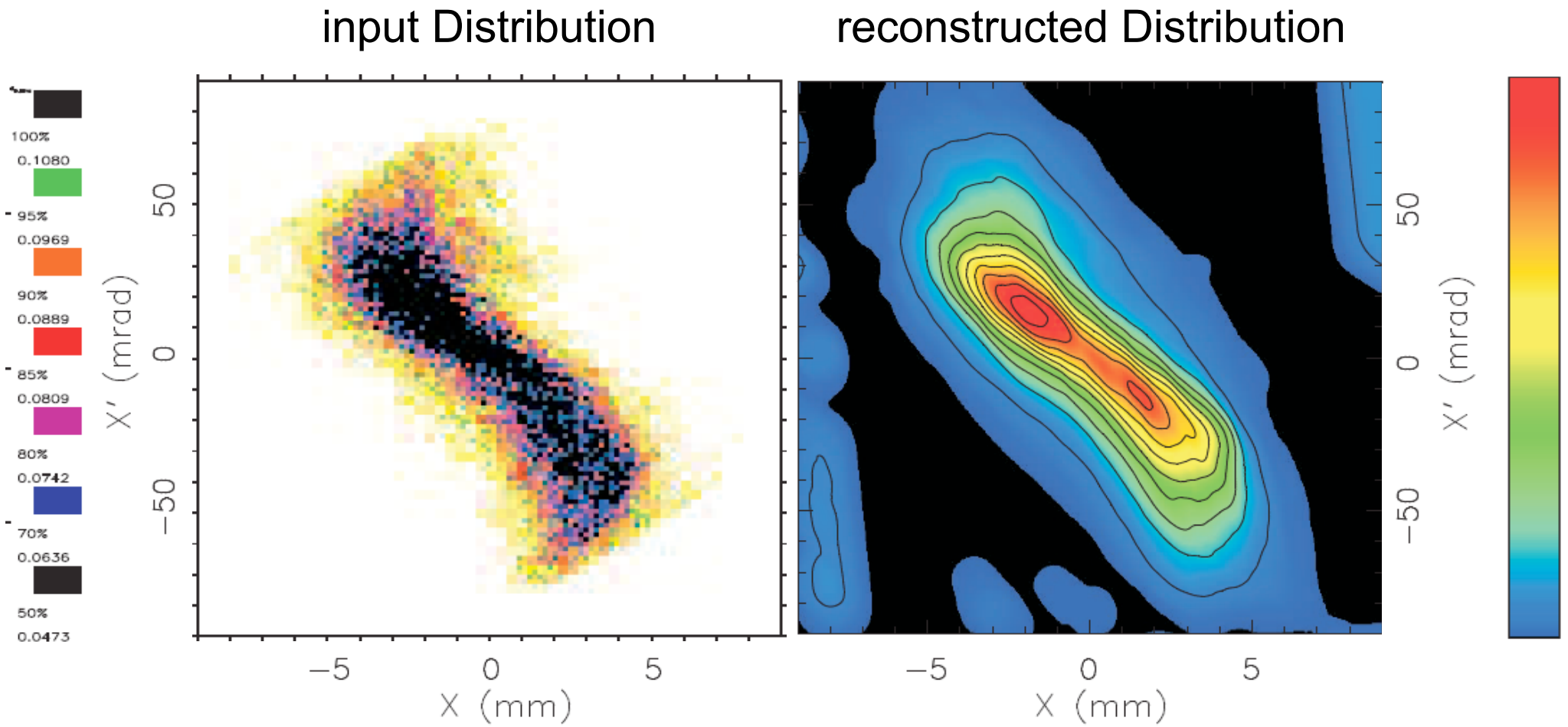


Beam

Conversion of multiple I(x,z) profiles into the correlated phase space distribution I(x,x') using a Maximum entropy algorithm



Conversion of 5 I(x, z) profiles into the correlated phase space distribution I(x,x') using a Maximum entropy algorithm



Summary

- Pepper pot device successfully tested, comparison show good agreement with slit-slit scanner. Results of pepper pot data lead to significant improvement of particle dynamics in the LEBT
- Laser detachment beam profile diagnostics tested at low Laser power (0.5 & 10 W). First results of beam measurements not conclusive due to high background (RG pressure). 10 kW pulsed laser system now available.
- Development of LD emittance device underway. Setup for mechanical 2D scanning difficult (dipole), but new improved data analyses might facilitate mechanical set up substantially.
- Fast non destructive beam profile measurements utilizing the distribution of extracted RGI have been tested at ISIS.
- Reconstruction of emittance from multiple profile measurements using a Maximum Entropy algorithm shows very promising results.