Beam Diagnostics at the RAL Front-End Test Stand
First Results and New Ideas

- Introduction
- The pepper pot emittance / 2D profile measurement device
- Photo detachment based beam tomography
- Emittance scanner using photo detachment
- New ideas
- Summary

The Front End Test stand project at RAL - Overview :

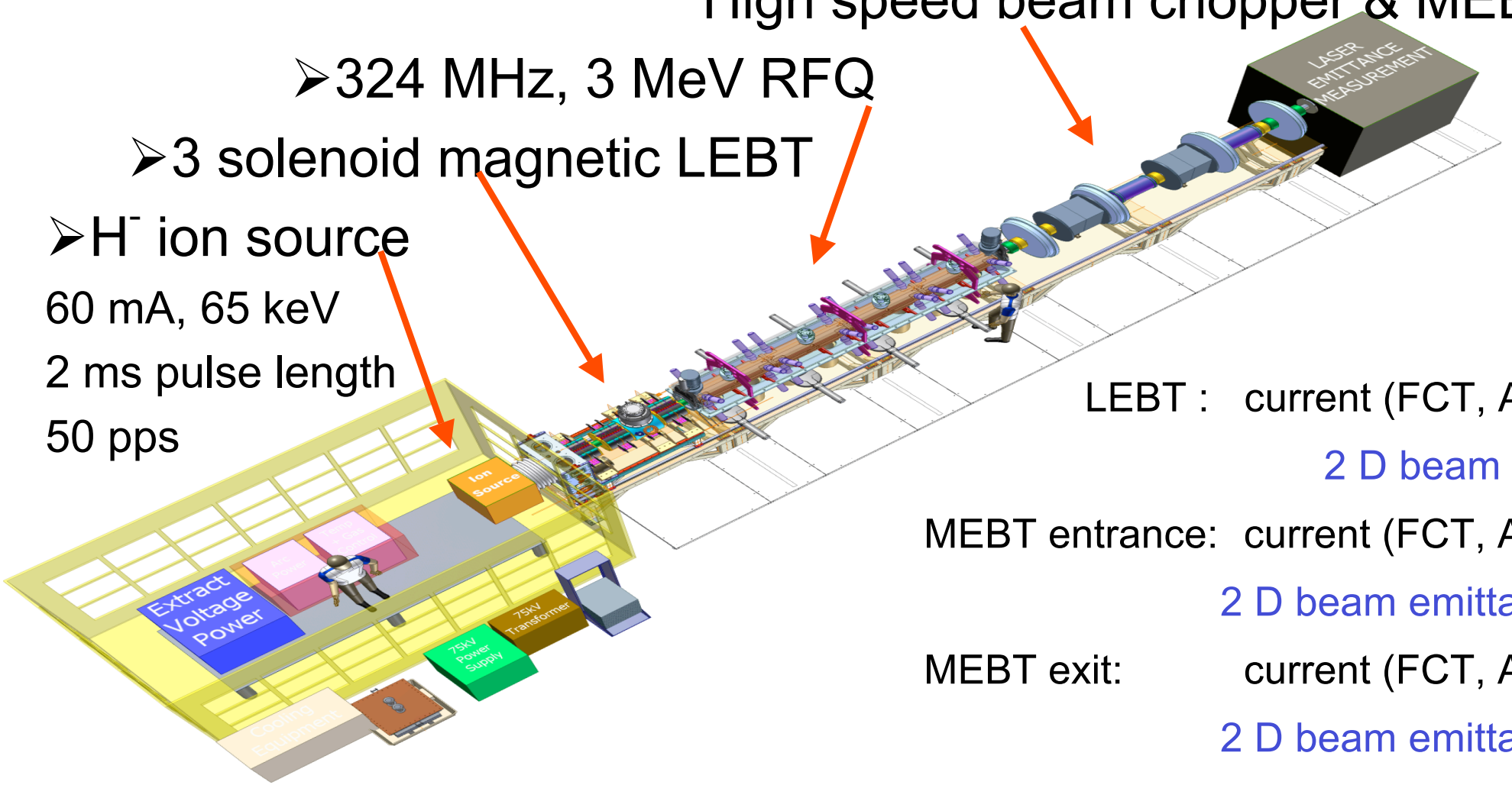
High speed beam chopper & MEBT

- 324 MHz, 3 MeV RFQ
- 3 solenoid magnetic LEBT
- H^- ion source

60 mA, 65 keV

2 ms pulse length

50 pps



LEBT : current (FCT, ACCT)

2 D beam profile

MEBT entrance: current (FCT, ACCT)

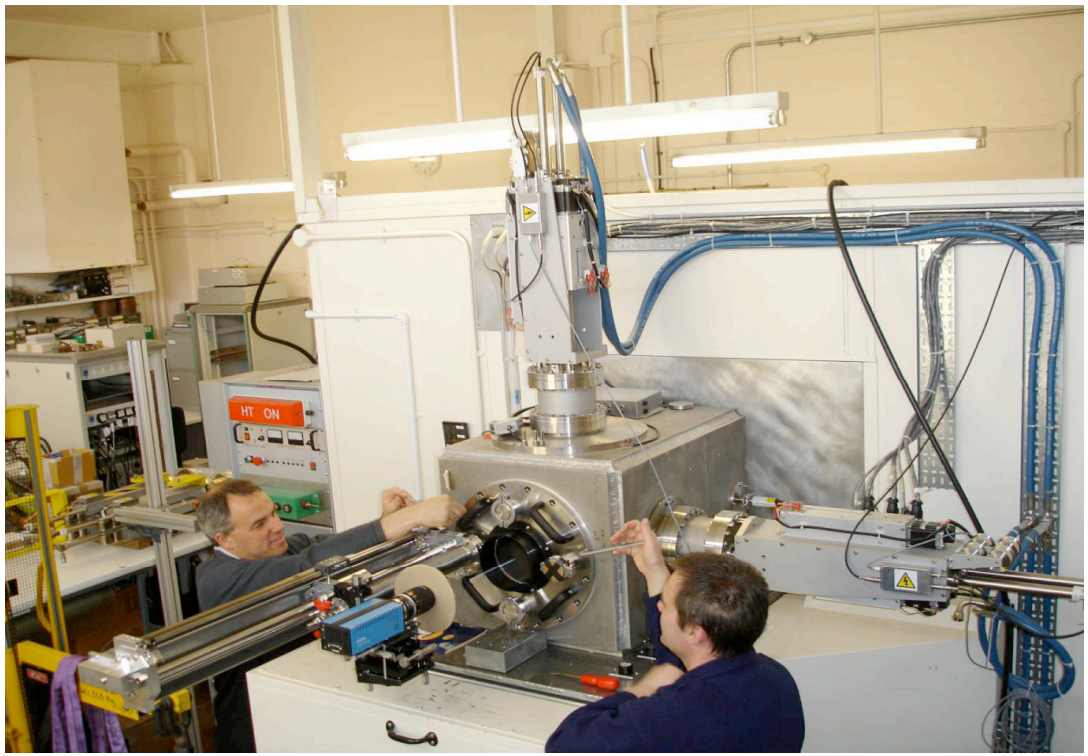
2 D beam emittance

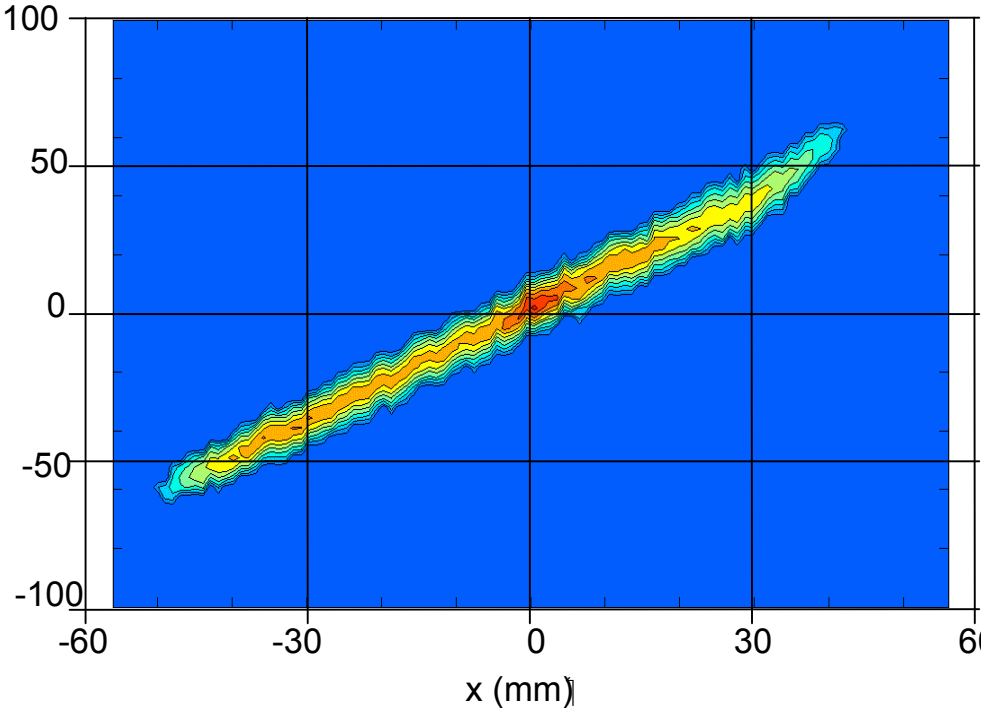
MEBT exit: current (FCT, ACCT)

2 D beam emittance

Beam diagnostic at the ISDR

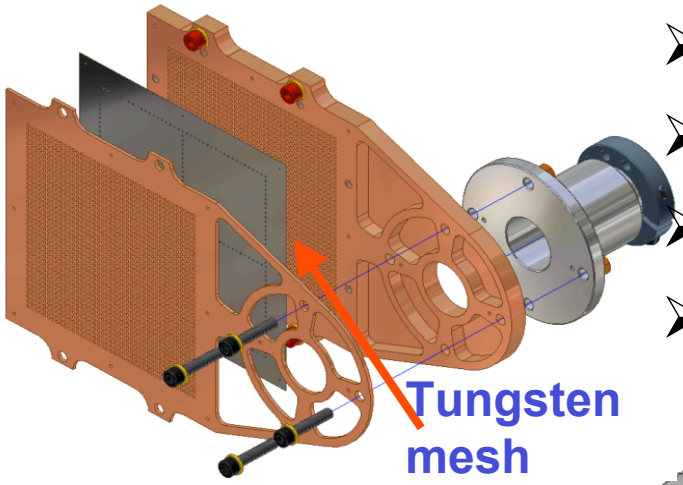
- 2 x 2 D phase space sampling with slit-slit scanner (uncorrelated)
- 0.25 mm resolution, ± 40 mm range
- 2 mrad resolution, ±100 mrad range



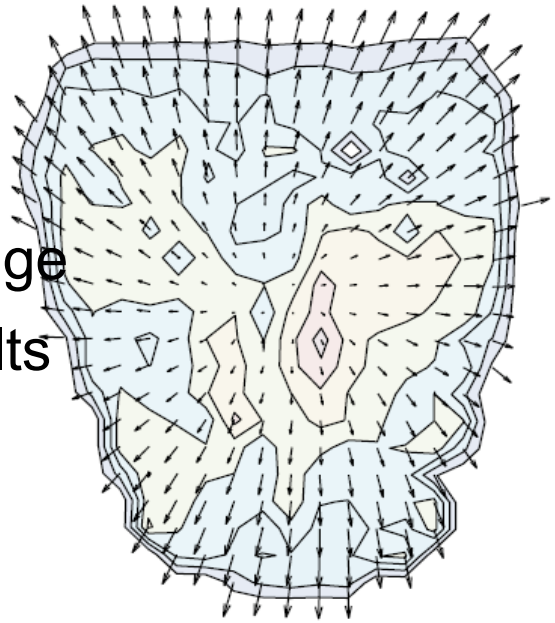


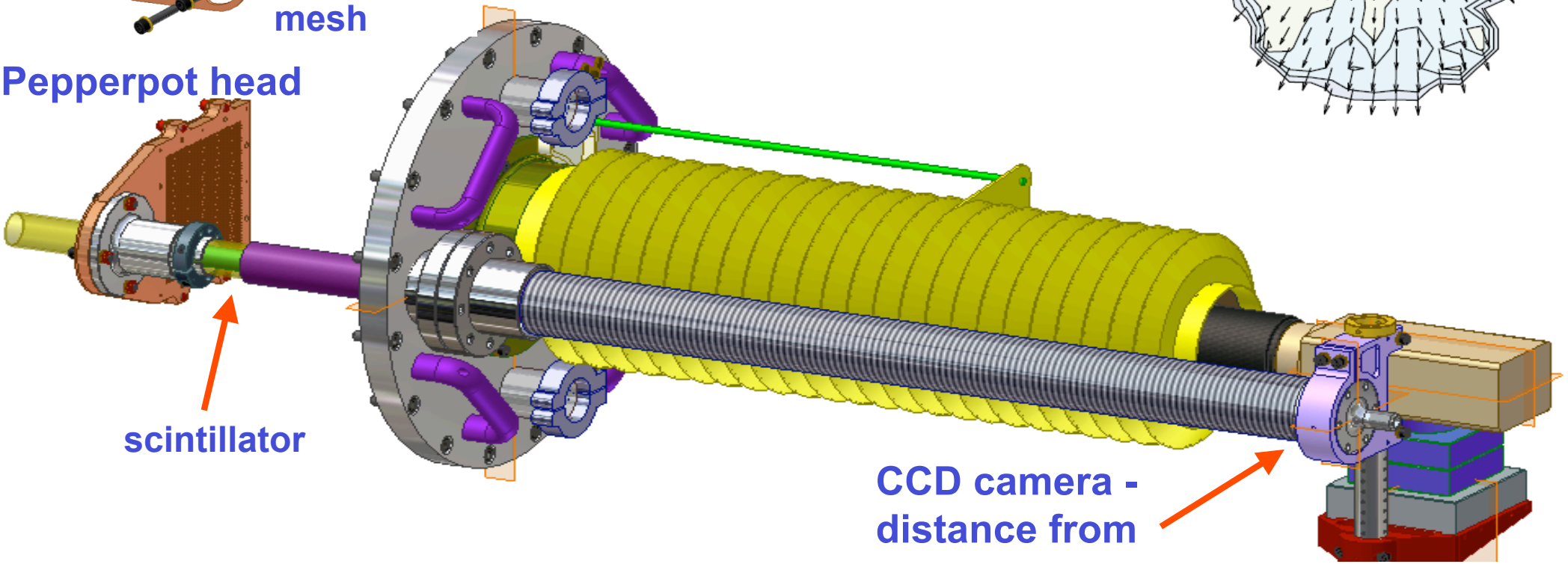
Impossible to reconstruct transversal density distribution for non cylinder symmetric beam (slit extraction) from uncorrelated emittance measurements

The pepper pot emittance measurement device



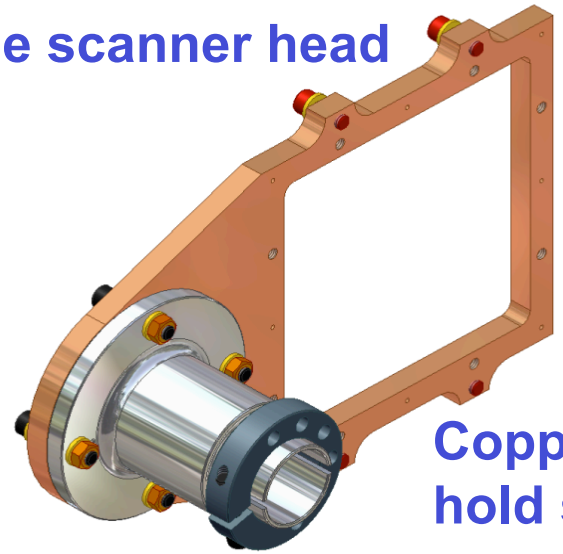
- 4 D phase space sampling
- 3 mm resolution, ±60 mm range
- 5 mrad resolution, ±100 mrad range
- good agreement with slit slit results



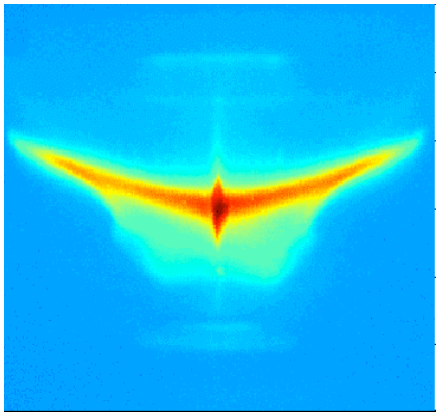


The 2D profile measurement device

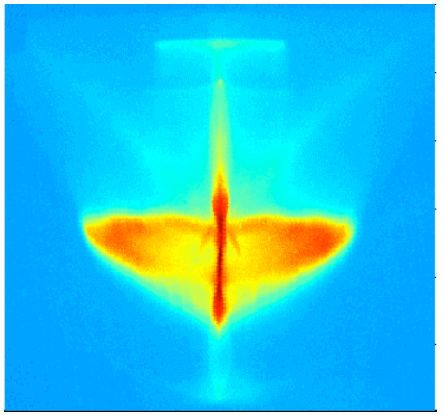
Profile scanner head



Copper frame to hold scintillator

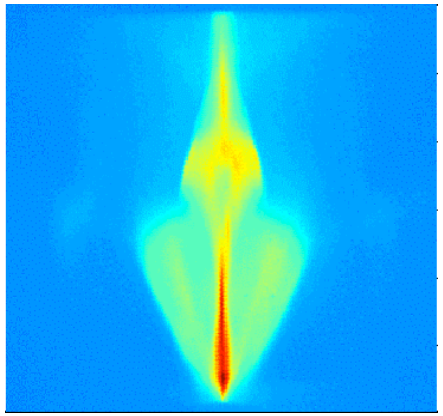


5 kV Ext

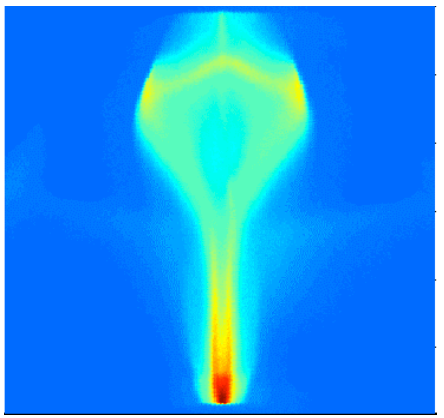


6 kV Ext

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

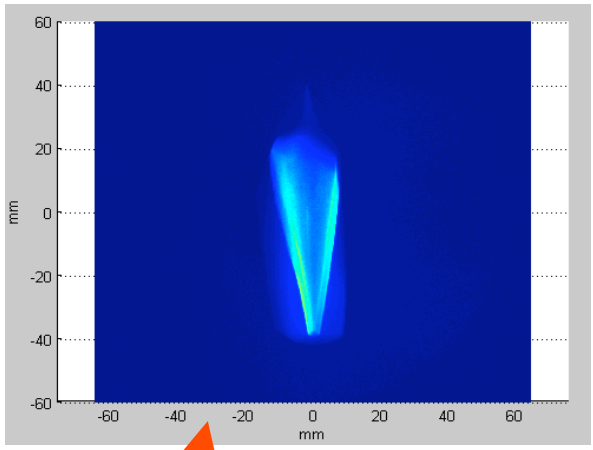


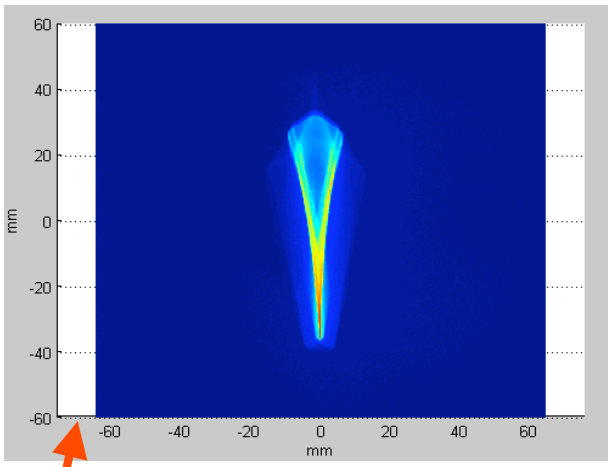
7 kV Ext

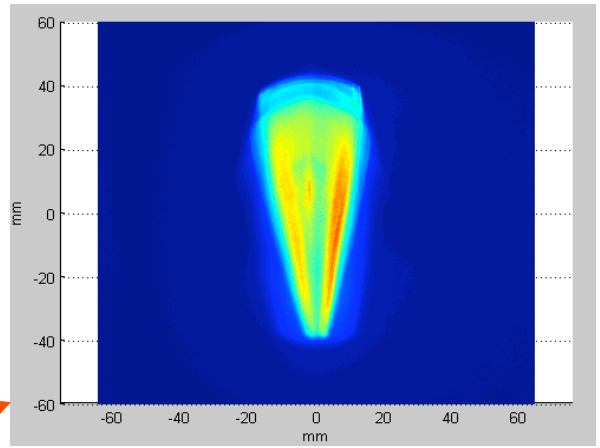


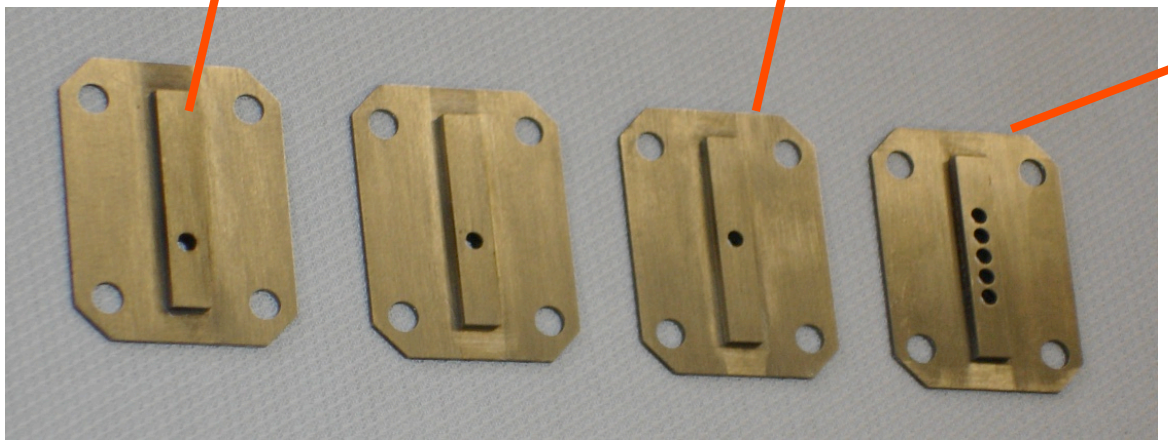
8 kV Ext

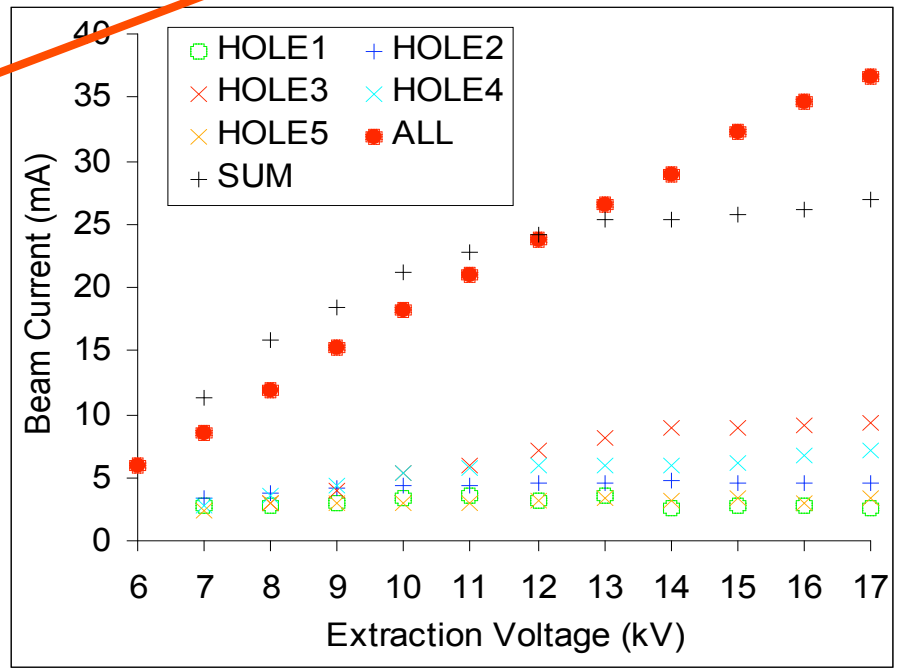
Extraction of individual beamletts





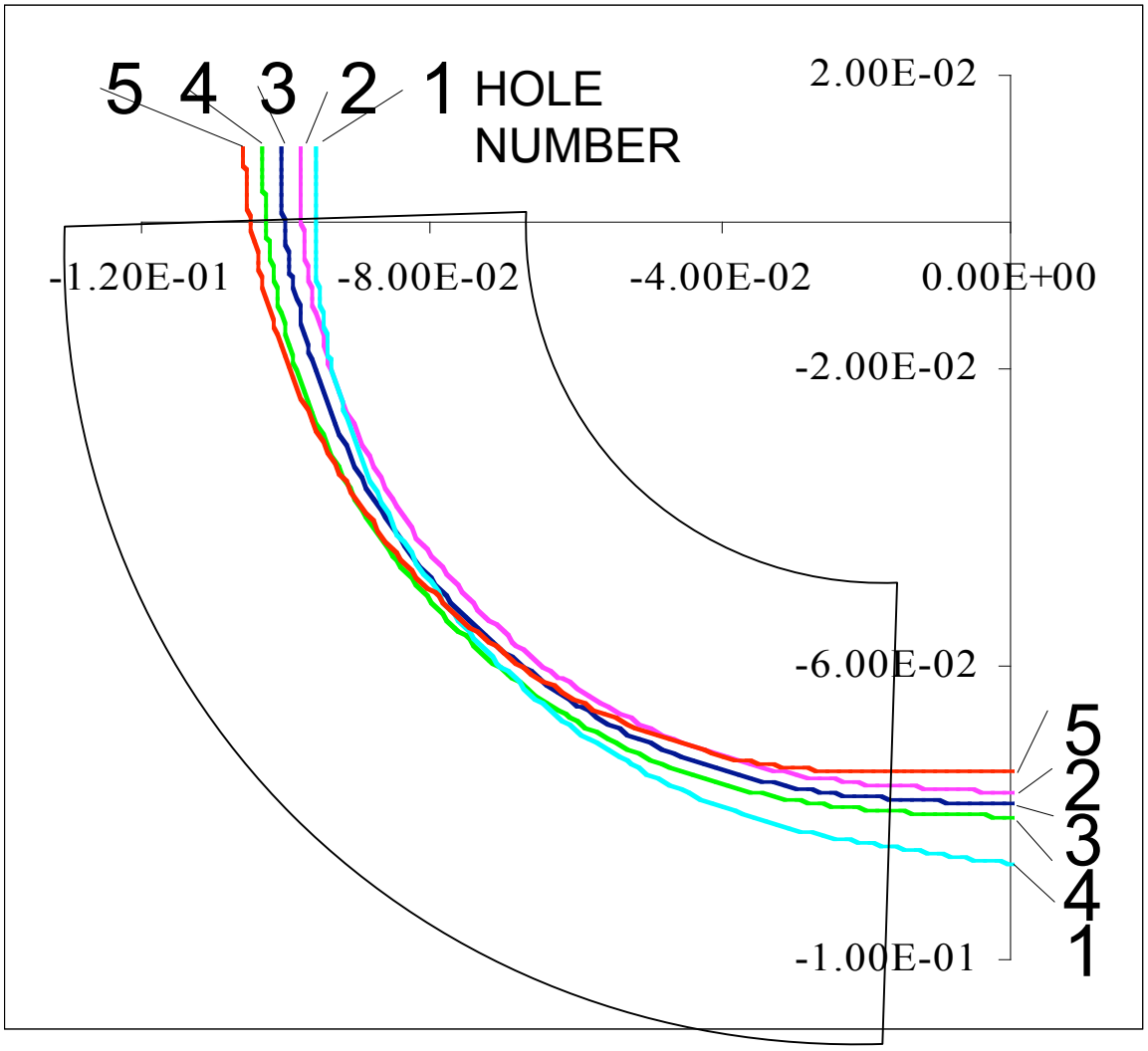


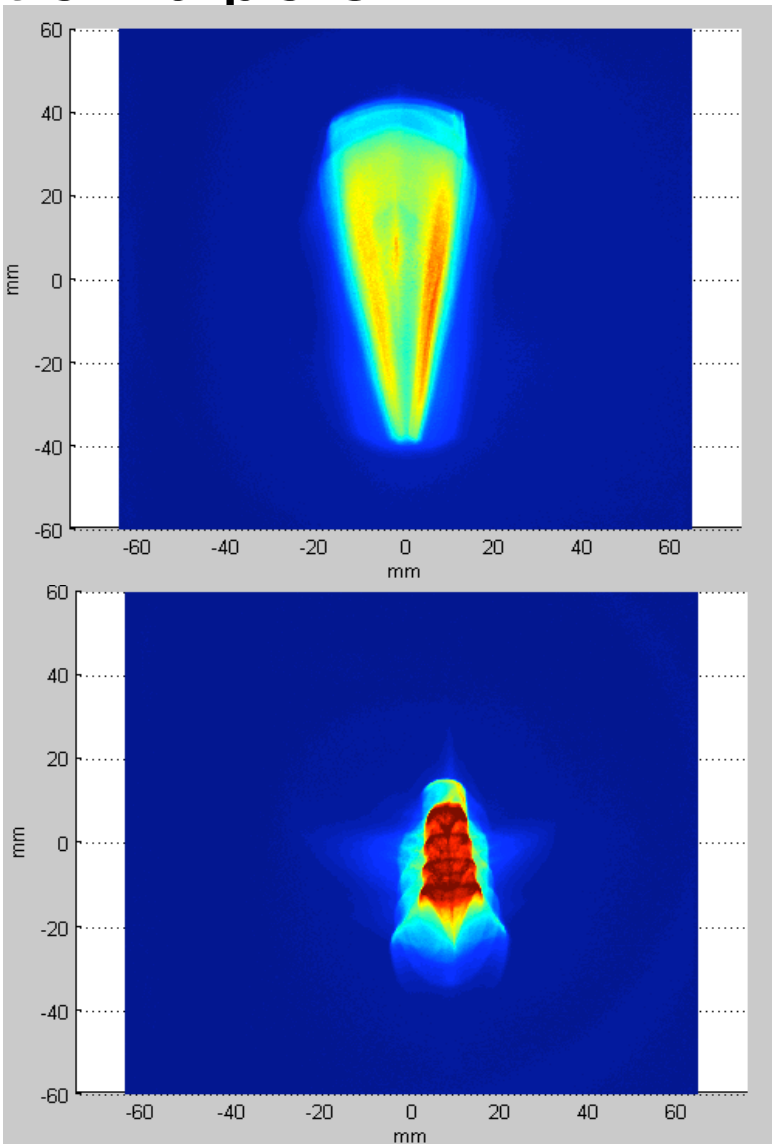




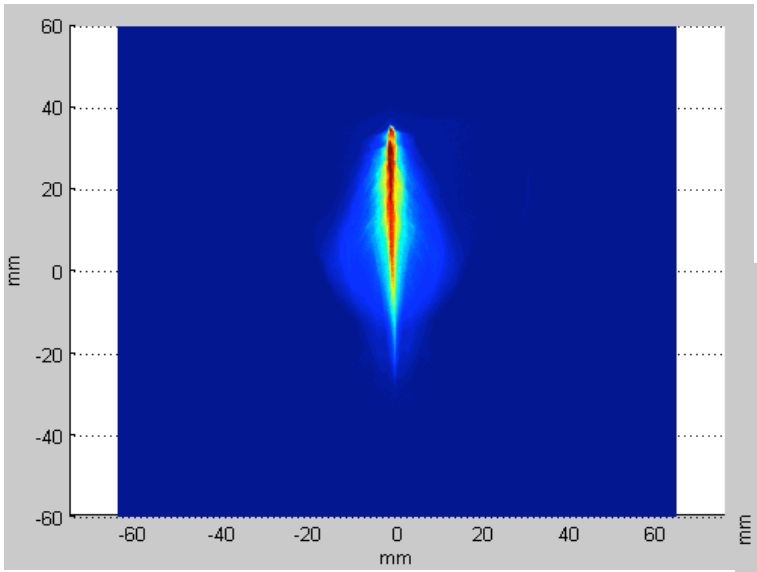
➢ beam transport in dipole heavily distorts the beam profile. Individual beamletts overlap behind the post acceleration

Redesign of charge separation dipole

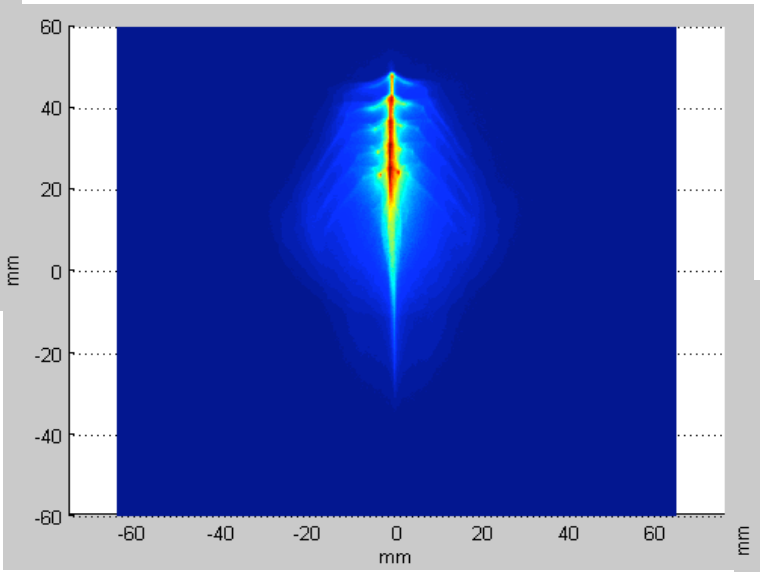




Beam profiles for different z positions

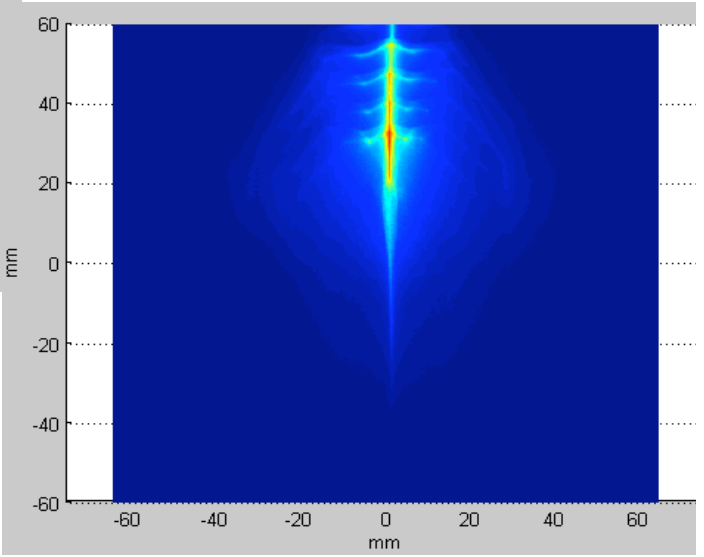


355 mm

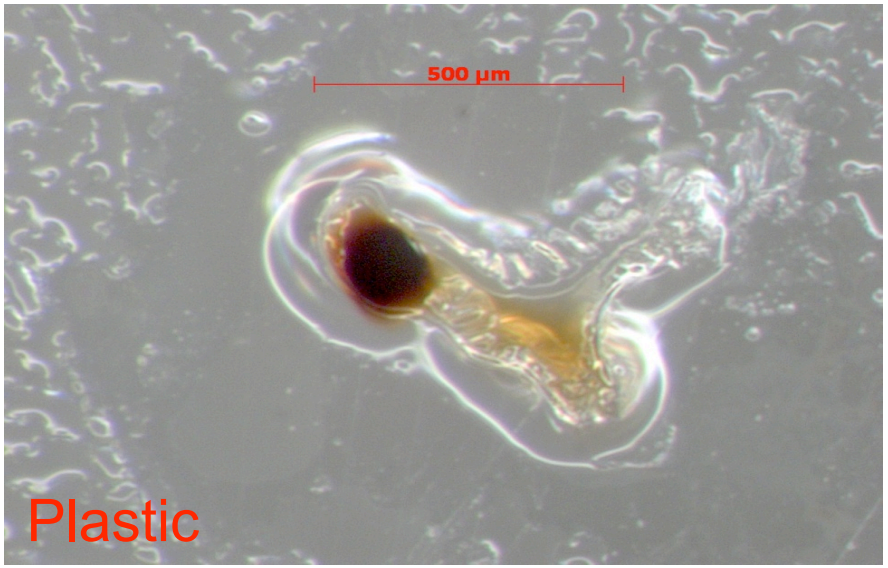


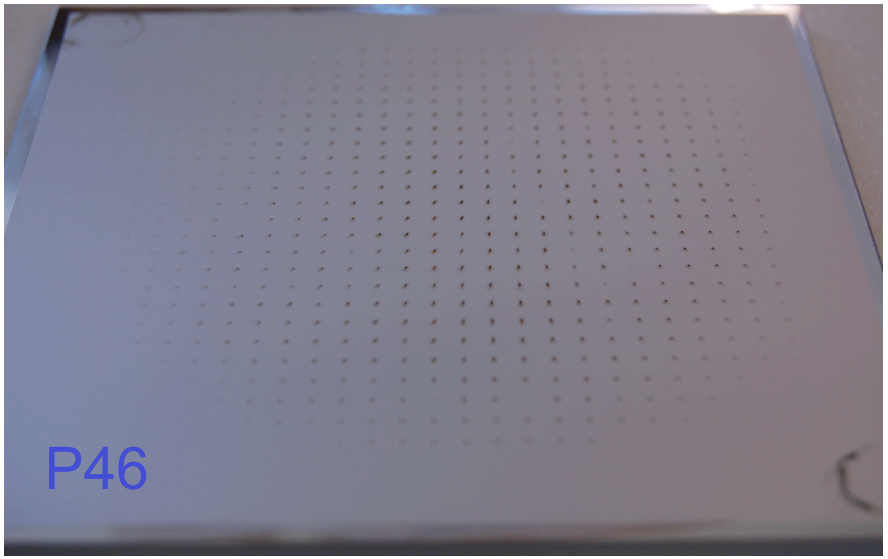
555 mm

755 mm

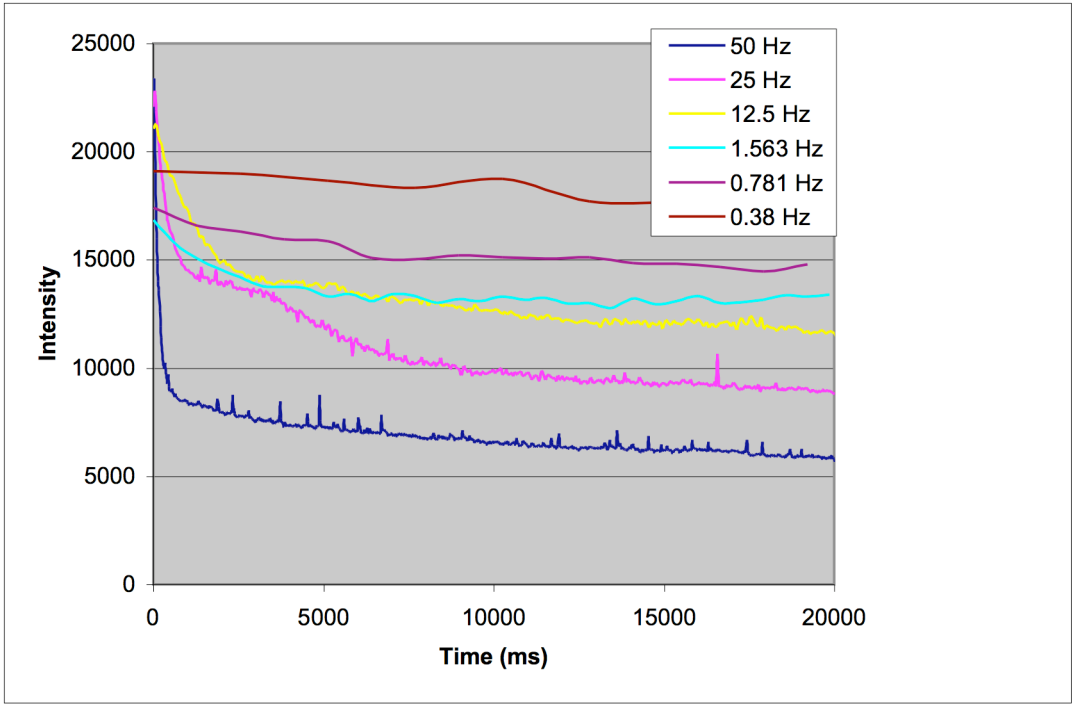


Scintillator lifetime and irradiation damage studies

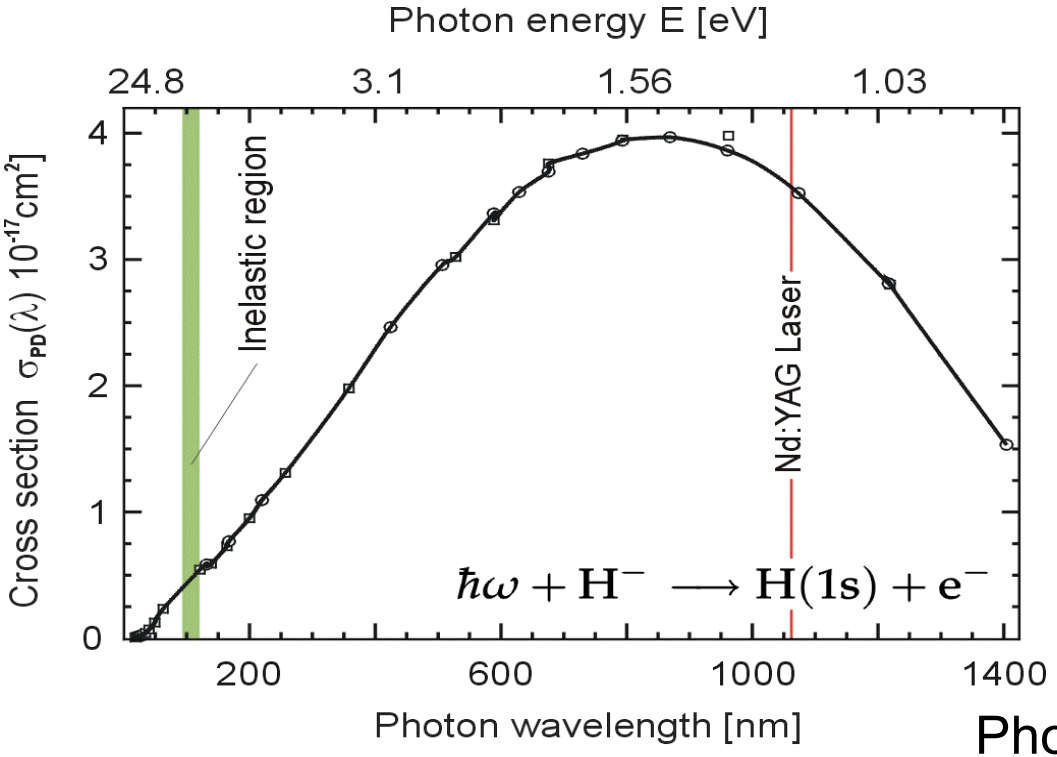




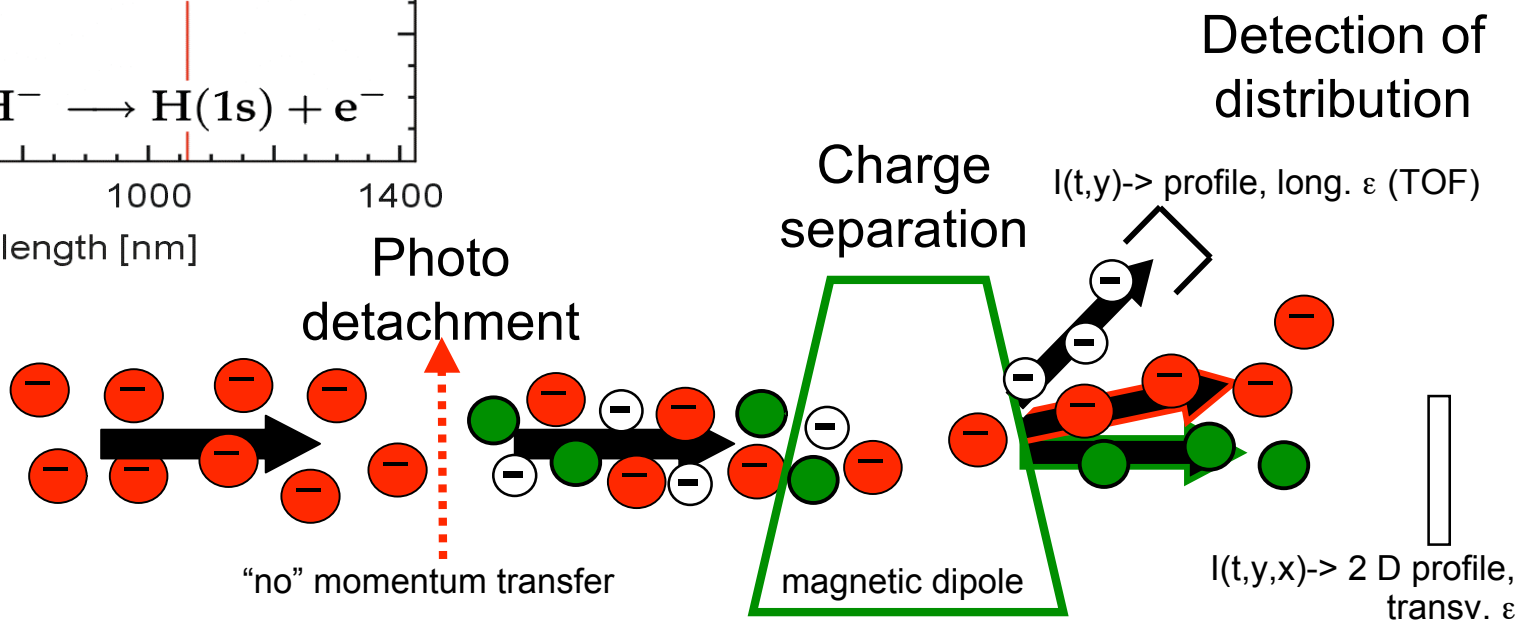
Various different scintillator materials tested (Plastic, P46, Ruby, YAG, Quartz,…) and all show radiation damage (decrease in light yield over time). Quartz seems to be most stabile and is most often used for the experiments.



Beam diagnostics using laser detachment

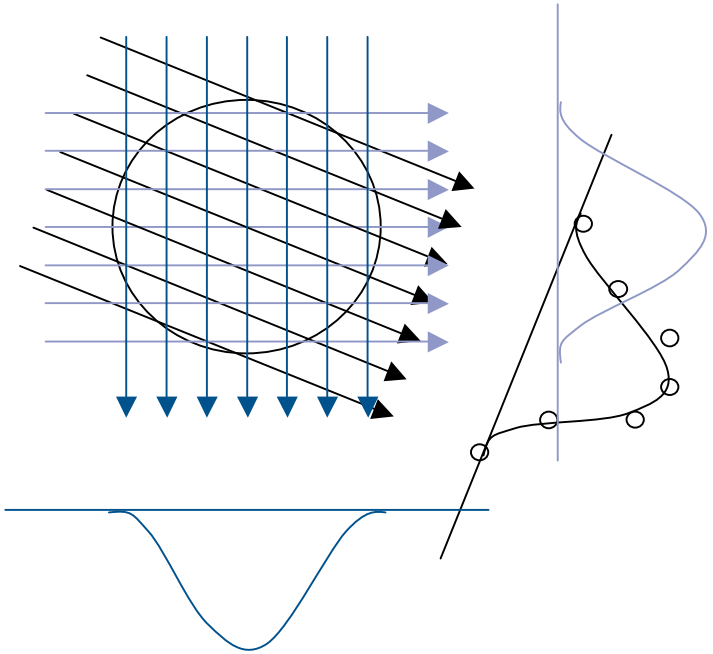


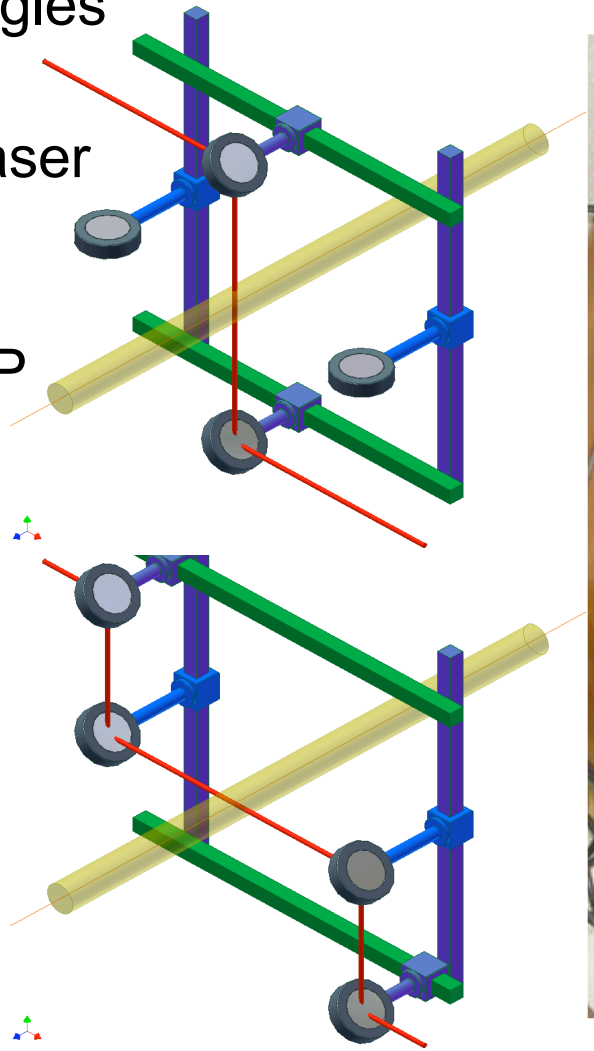
- Interaction between laser and H- beam produces neutrals and free electrons.
- magnetic dipole field separates the detached electrons and neutrals from the ion beam



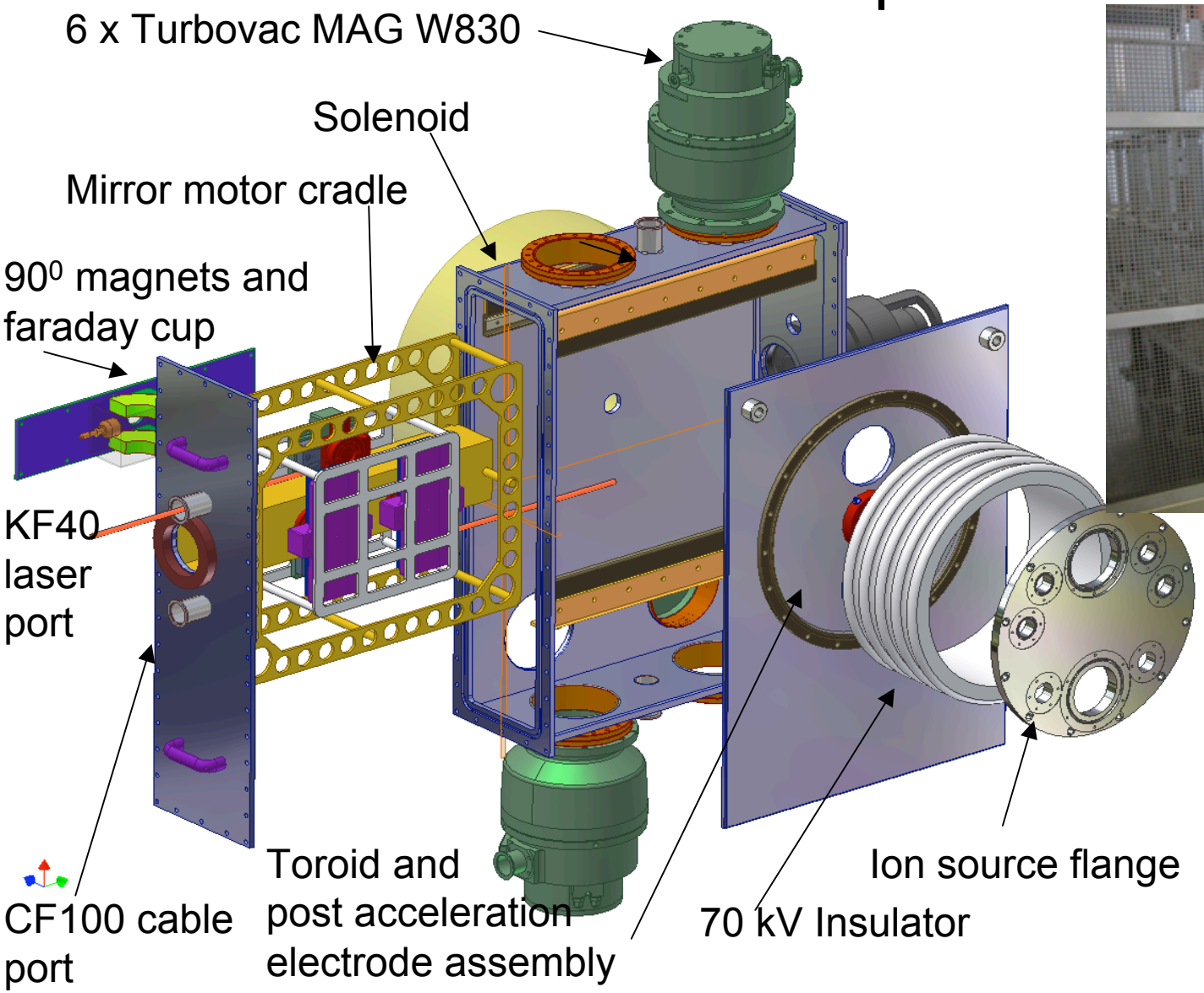
H^- beam tomography using laser detachment

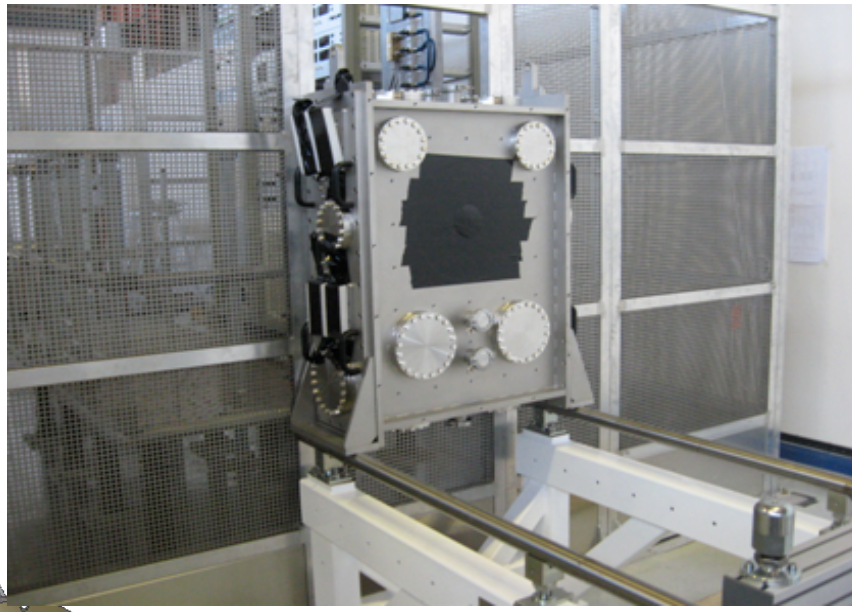
- Beam profiles for different angles have to be taken.
- requires the ability to move laser beam around the ion beam.
- 2 D density profile can be reconstructed using ART or FBP





Mechanical set up and vacuum vessel

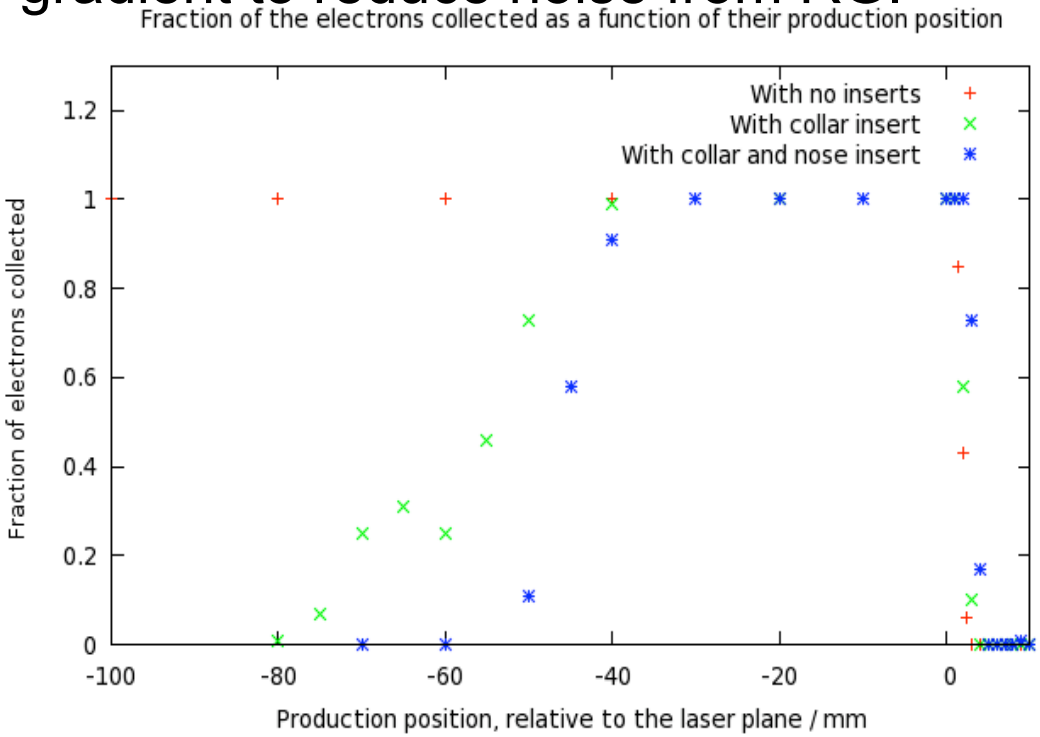


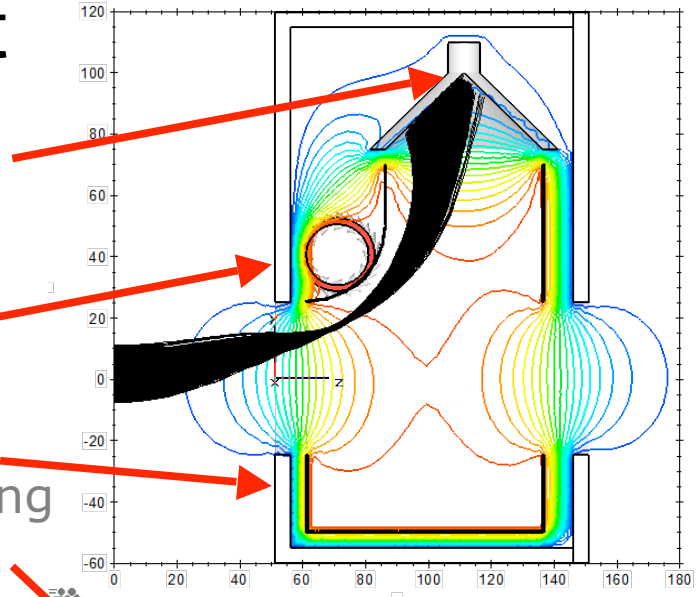


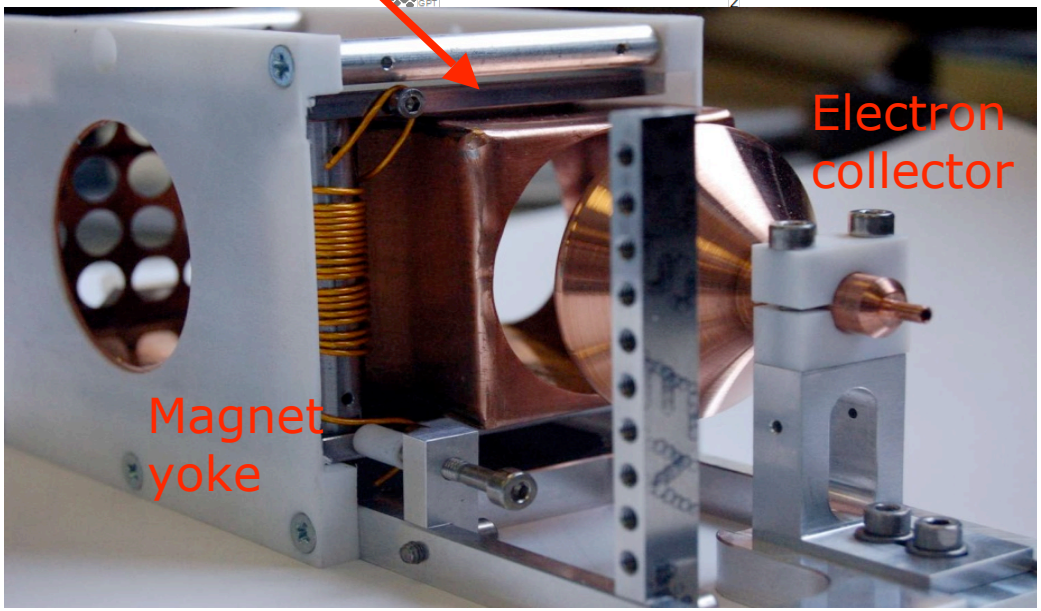
First vessel manufactured and vacuum tested, vessel internals in manufacture, first beam tests expected for end of September.

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

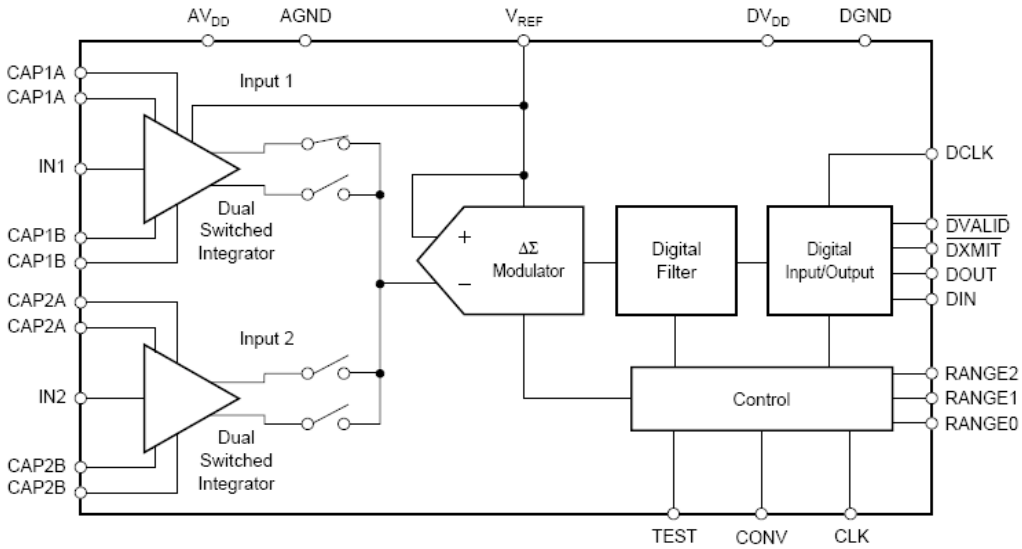




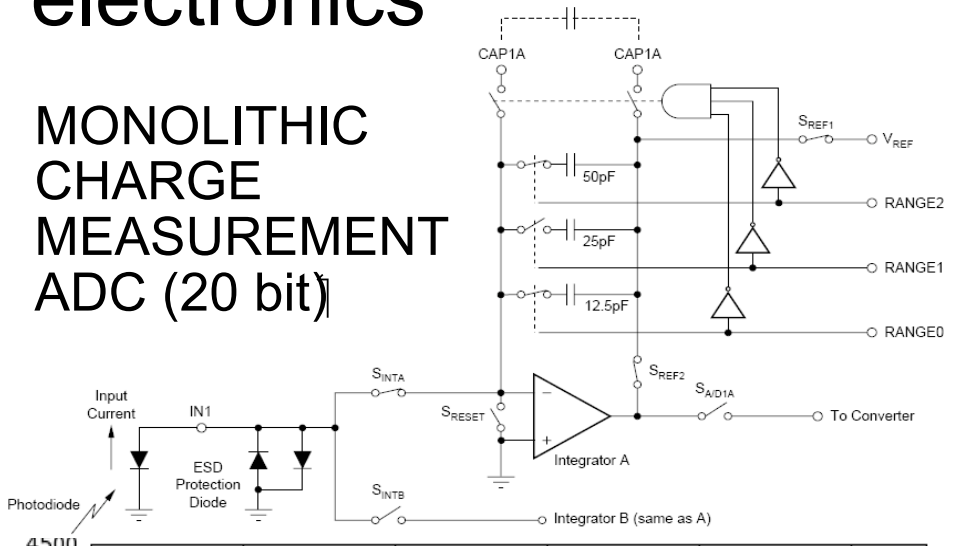


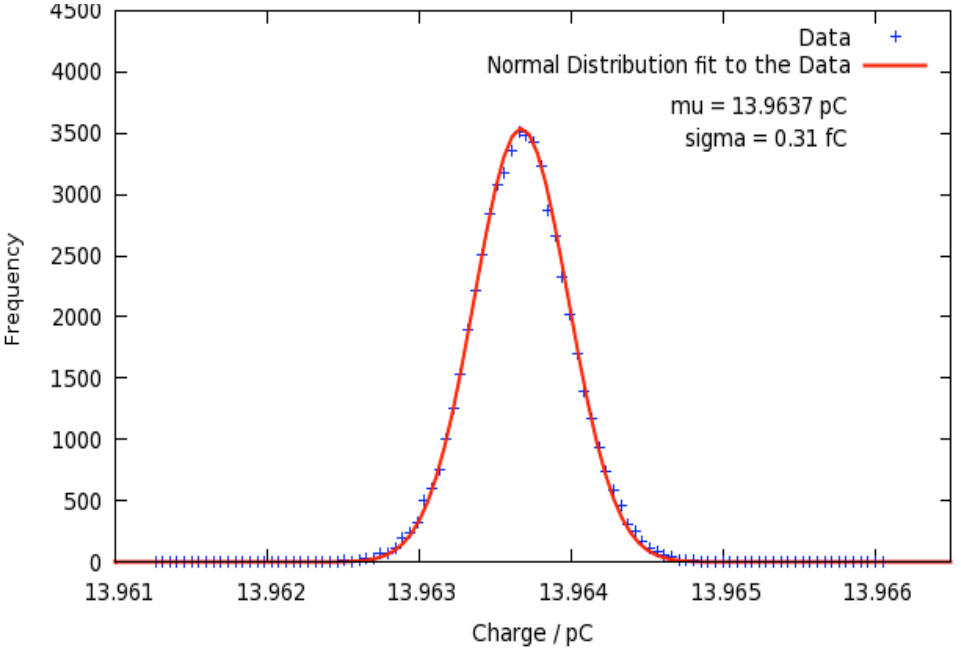
Status of detector electronics

Burr Brown DDC 112



MONOLITHIC CHARGE MEASUREMENT ADC (20 bit)

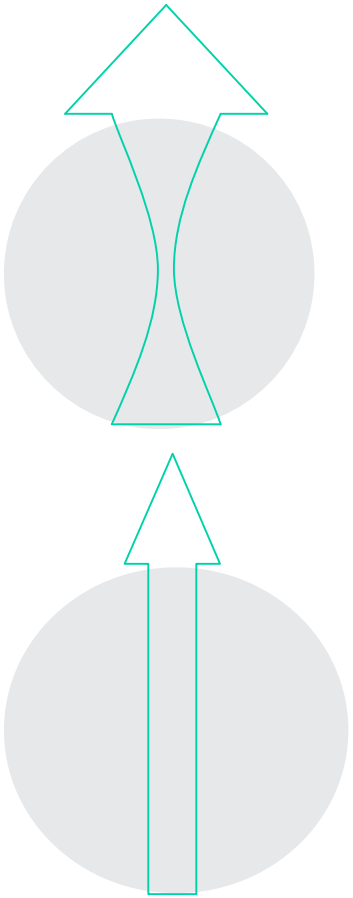


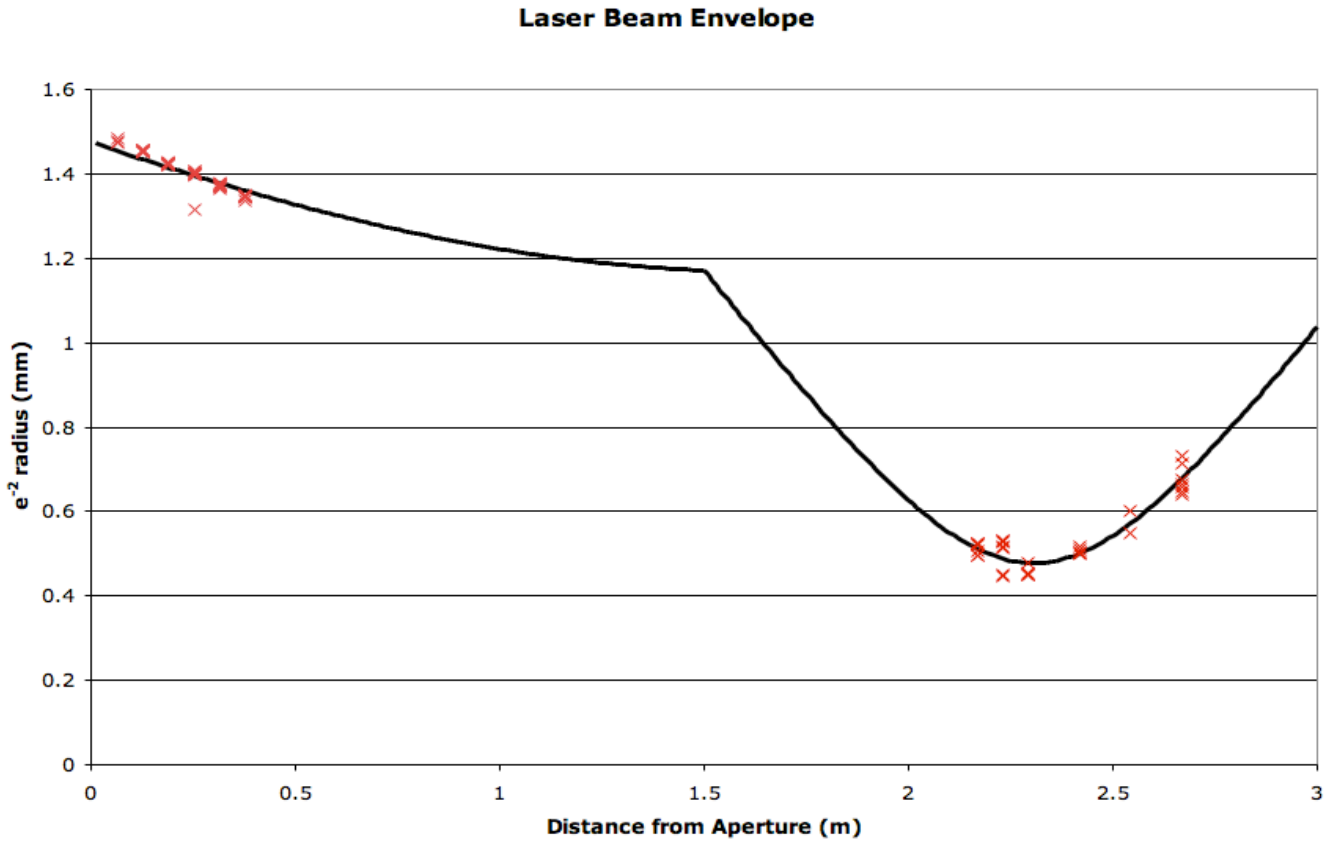


- Front end electronics built and tested
- Test charge measured with resolution of 0.31 fC (≈2000 electrons)
- Compares favourably with expected signal size of ~10^5–10^7 electrons

Laser beam characterisation

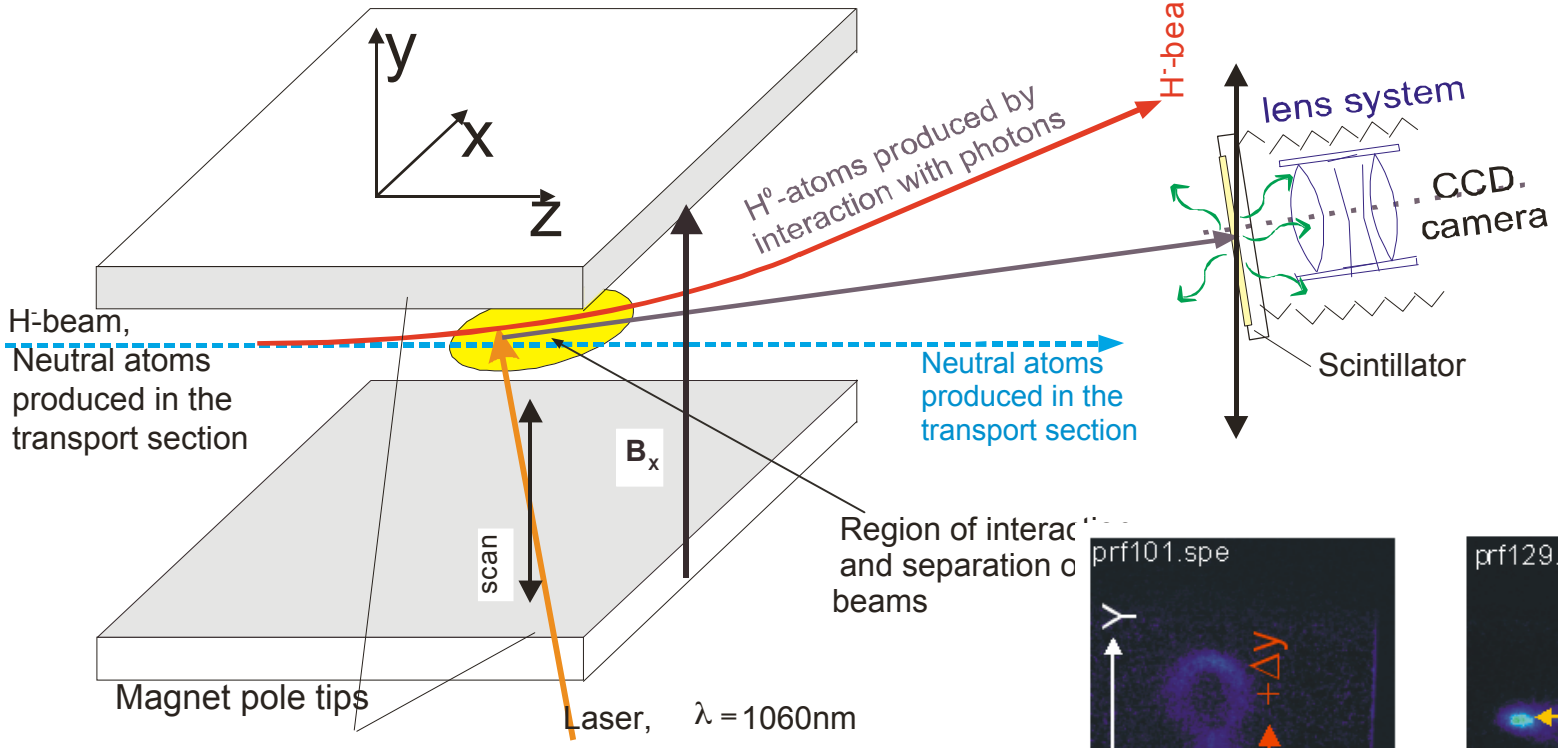
- Laser envelope characterised with simple one lens system
- Minimum radius of 0.48 mm, 0.24% larger at ±25 mm, 3.79% at ±100 mm

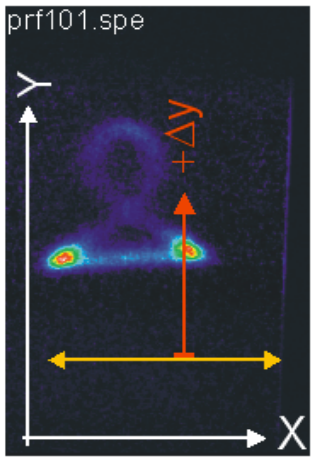




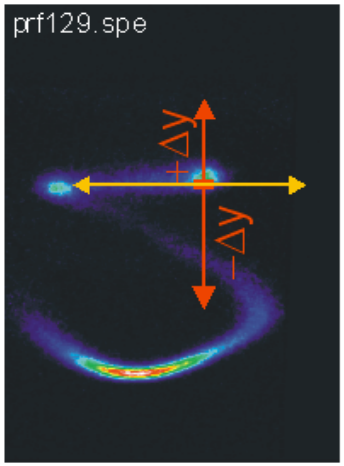
J. Pozimski, 42nd ICFA Beam Dynamics Workshop on High-Intensity, High-Brightness Hadron Beams, August 24-29, 2008 Nashville

Emittance scanner based on photo detachment: Pre experiment at University of Frankfurt – set up

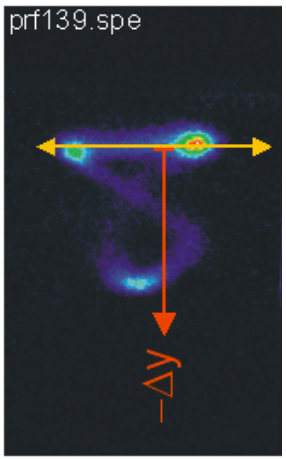




y=-7,8mm



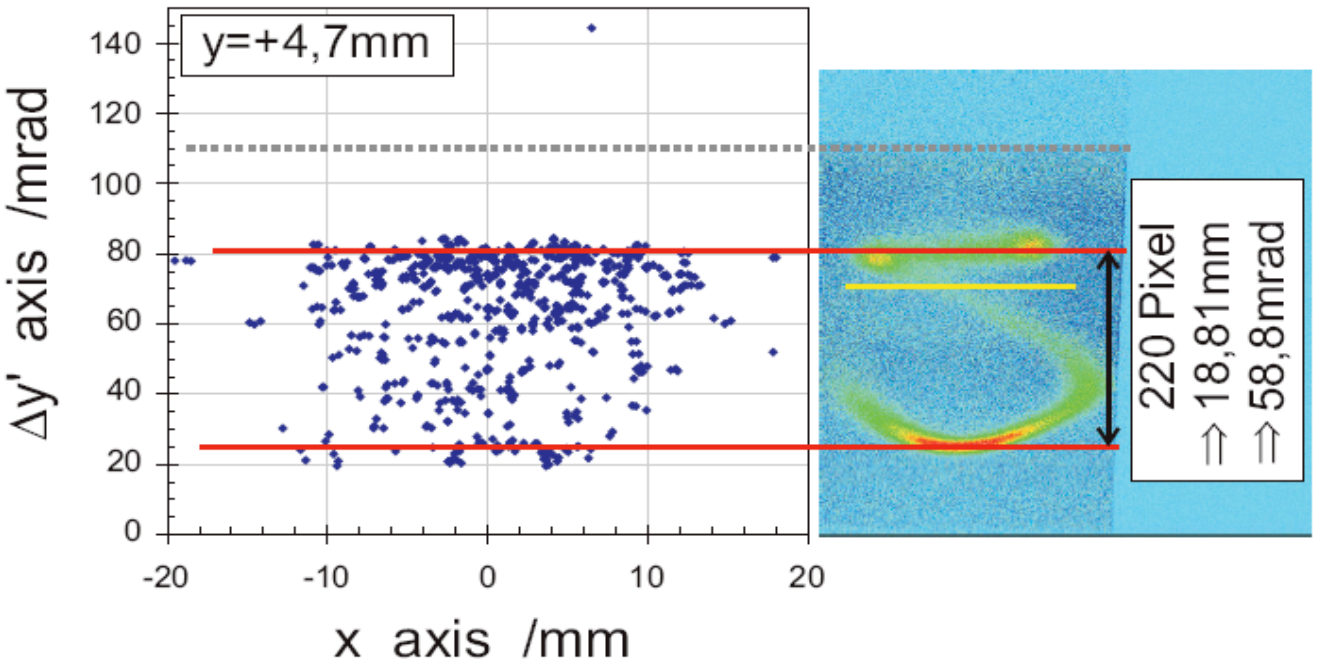
y=+4,7mm

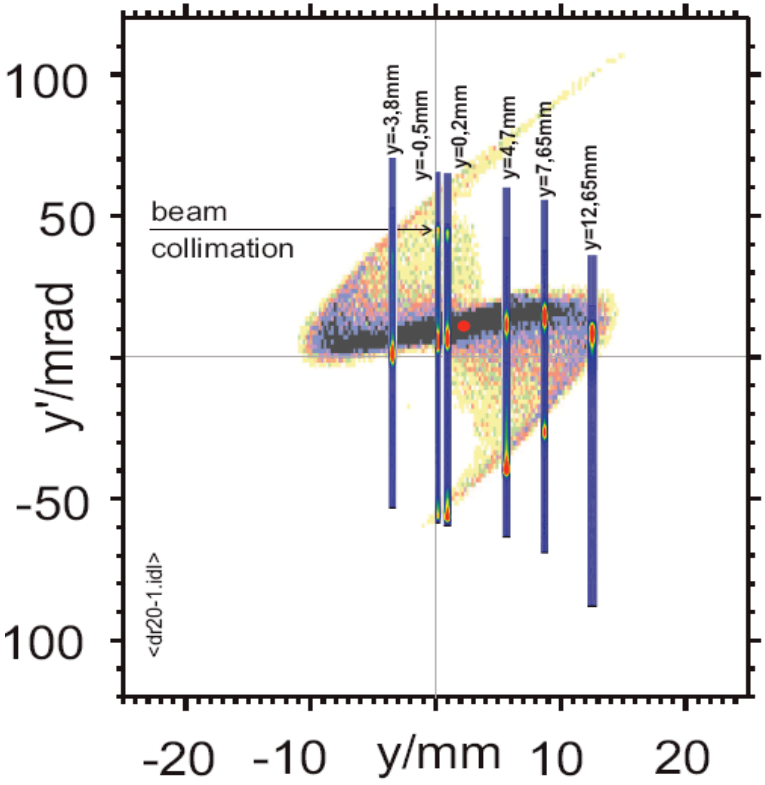


y=+8,4mm

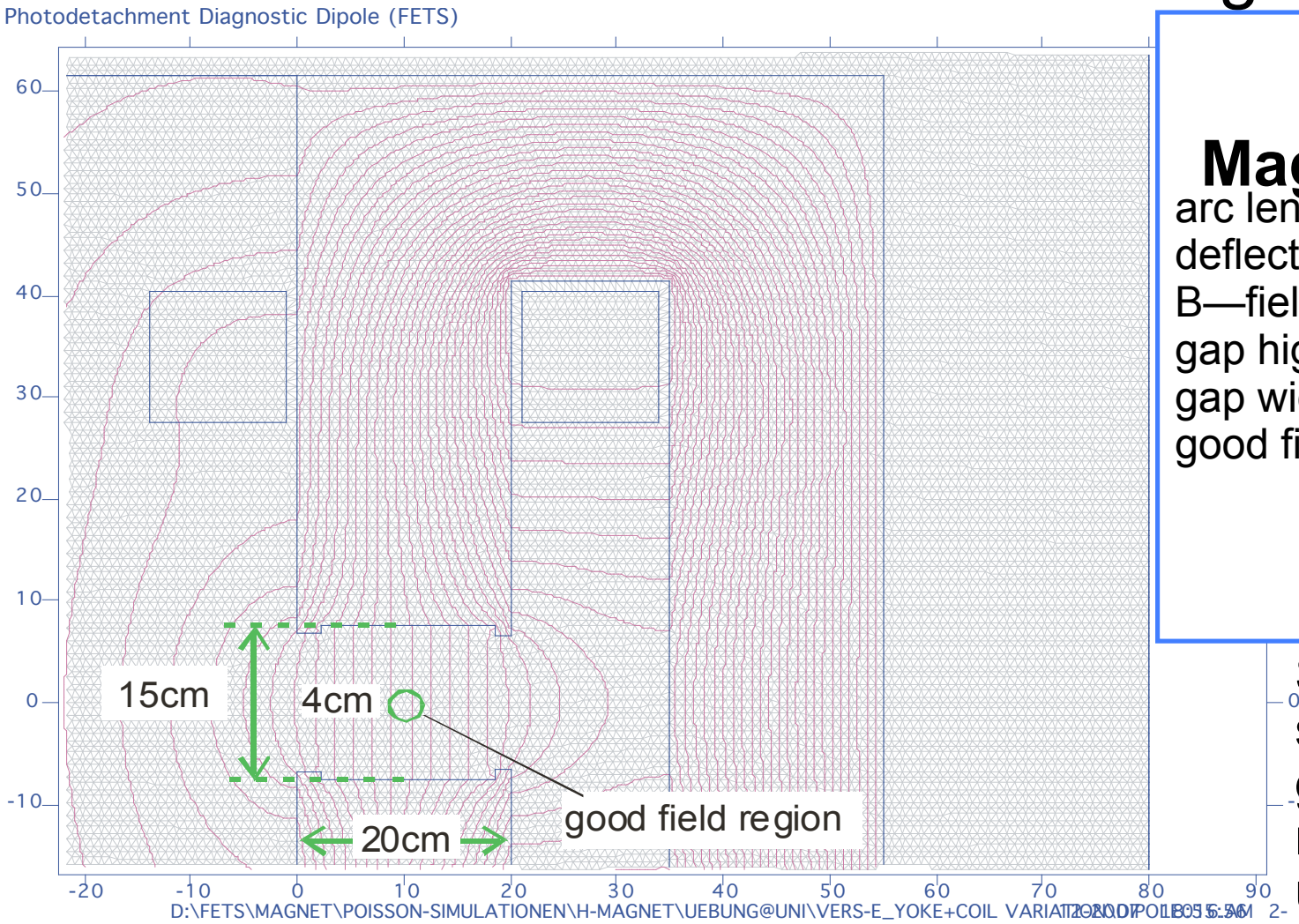
Emittance scanner based on photo detachment: Preexperiment at University of Frankfurt - results

- Comparison between simulations (left), PD measurements (centre) and slit-slit measurements show good agreement.





Determination of correlated transversal emittance measurements – laser scanning in x and y



Magnet parameters

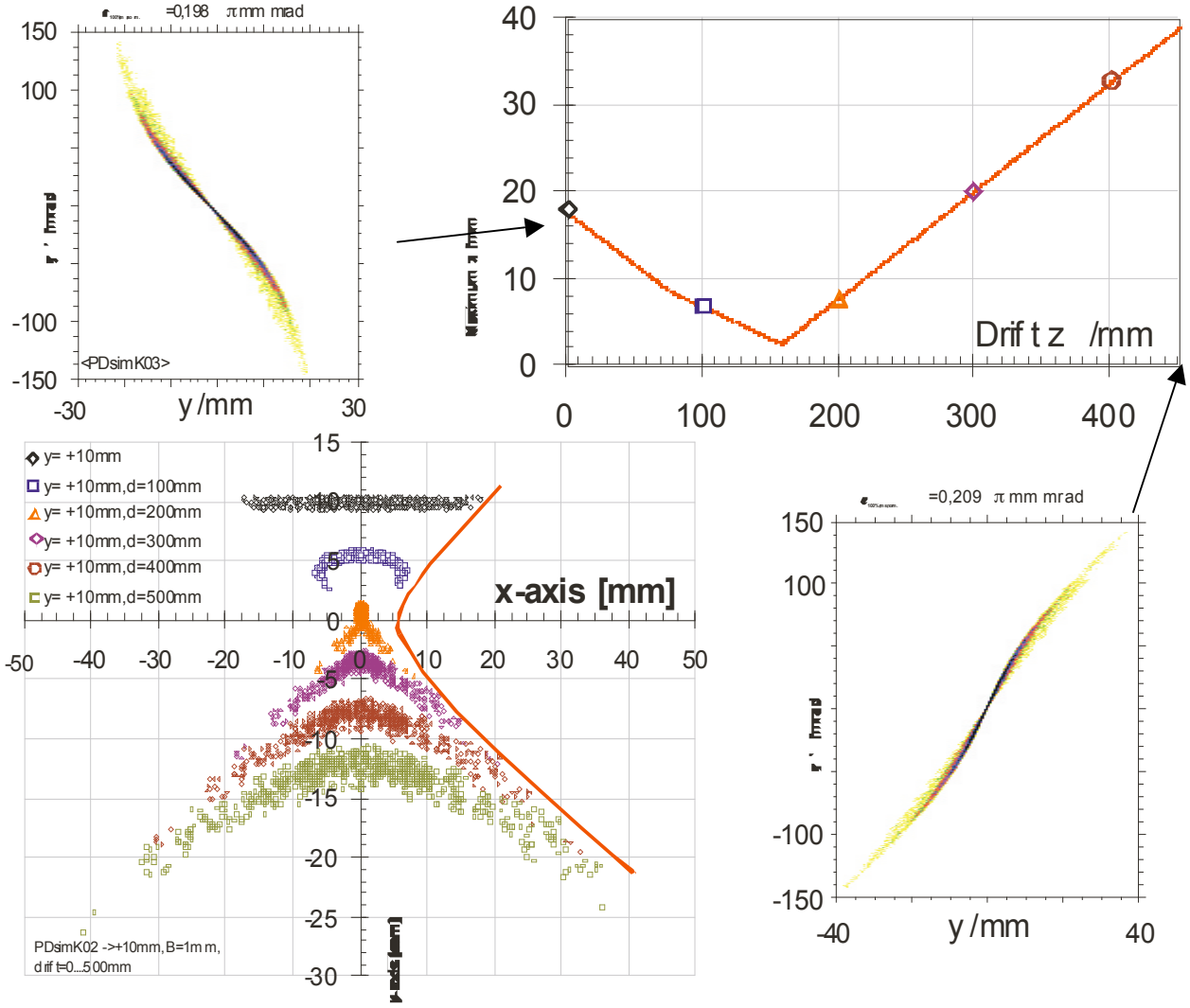
arc lenght:	500 mm
deflection angle:	60 deg
B—field:	0.522 T
gap high:	150 mm
gap width:	200 mm
good field region:	d=40 mm

Space requirements for scanning in two planes gives unsatisfactory results for the dipole set up

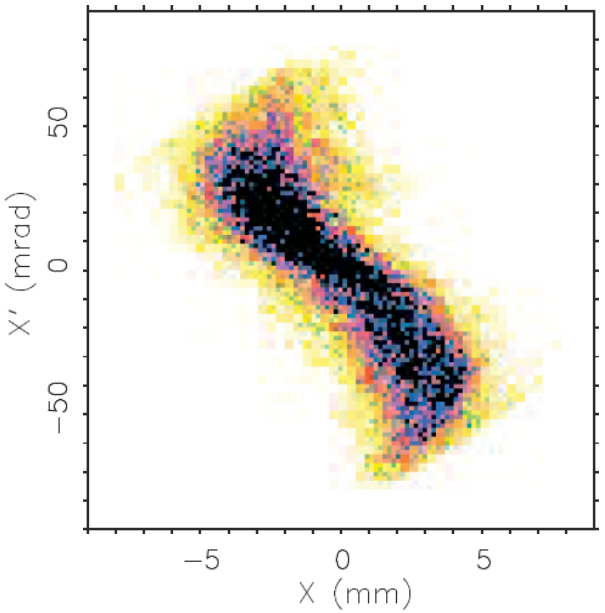
Determination of correlated transversal emittance measurements – movable detector

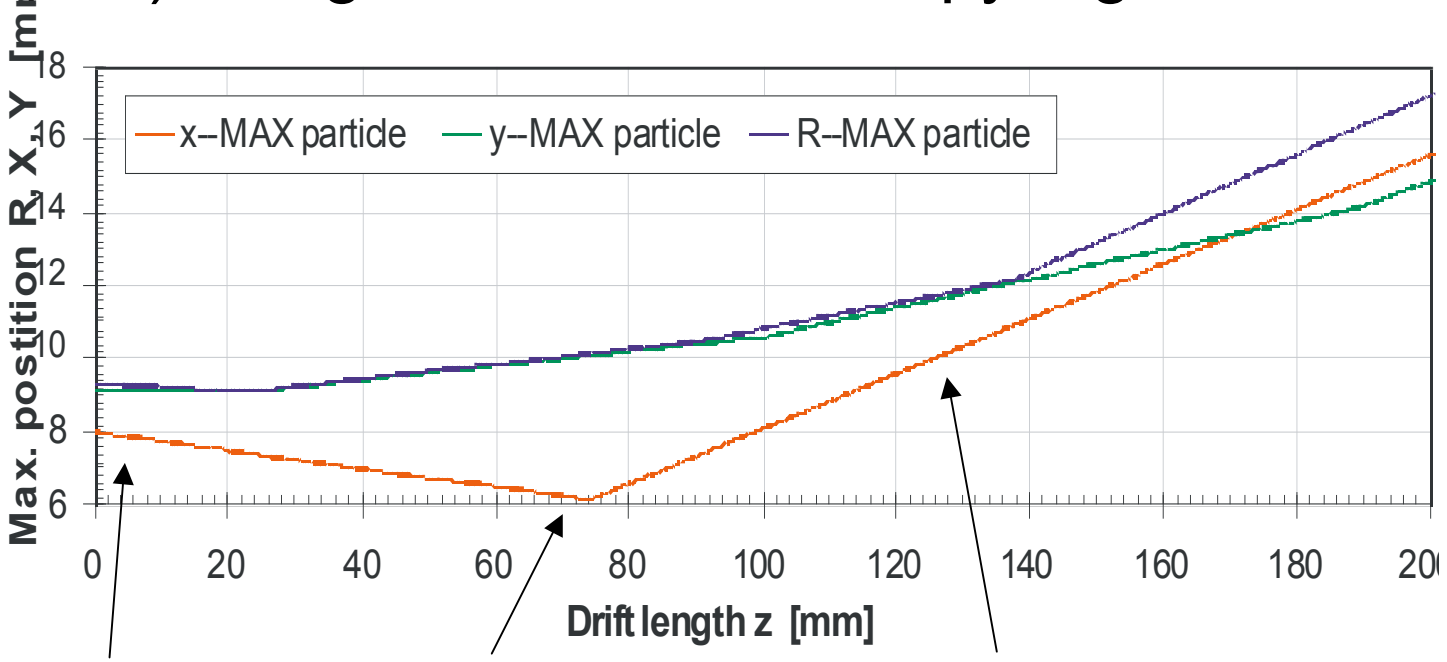
Utilizing the variation of the 2-D density distribution of the neutrals as a function of the drift length z offers the opportunity of determining both x' & y'

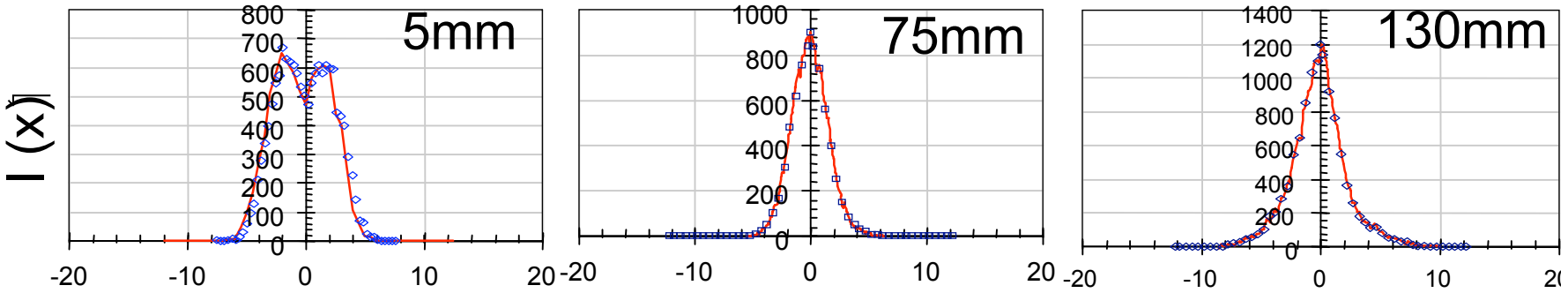
- would make dipole much more conventional
- Pepper pot mechanism could be reused or rebuild
- Simpler as 2D profile reconstruction.



New ideas for data analysis : Conversion of multiple I(x,z) profiles into the correlated phase space distribution I(x,x') using a Maximum entropy algorithm



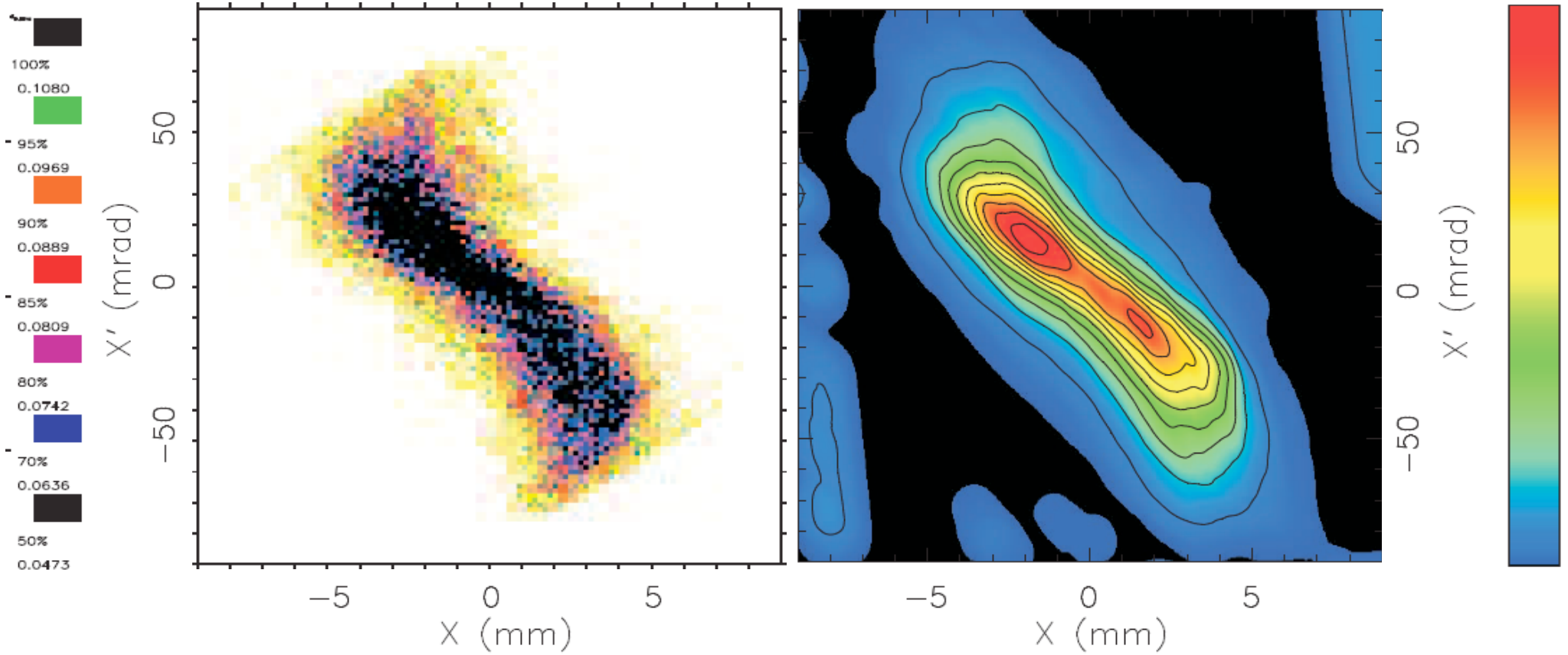




Conversion of 5 I(x, z) profiles into the correlated phase space distribution I(x,x') using a Maximum entropy algorithm

input Distribution

reconstructed Distribution



New ideas for data analysis : Conversion of multiple I(x,y,z) profiles into the correlated phase space distribution I(x,x',y,y')

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 well under way, components tested, first results of beam measurements expected for autumn this year.
- Development of LD emittance underway. Setup for mechanical 2D scanning problematic (dipole), but new improved data analyses might facilitate mechanical set up substantially.
- Reconstruction of emittance from multiple profile measurements using a Maximum Entropy algorithm very promising.

Acknowledgements : I would like to thank D. Faircloth, C. Gabor and D. Lee for the materials provided for this presentation.