Title

Bernd Dehning

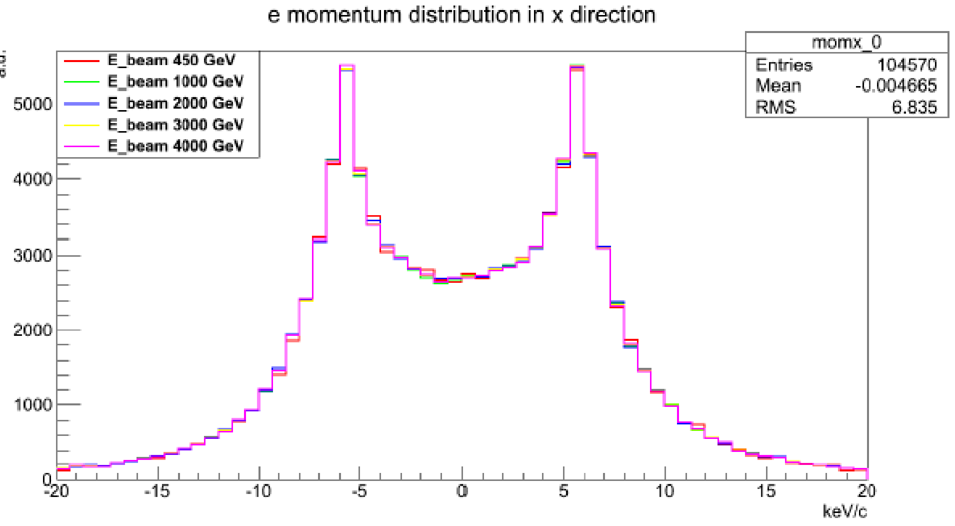
CERN BE/BI

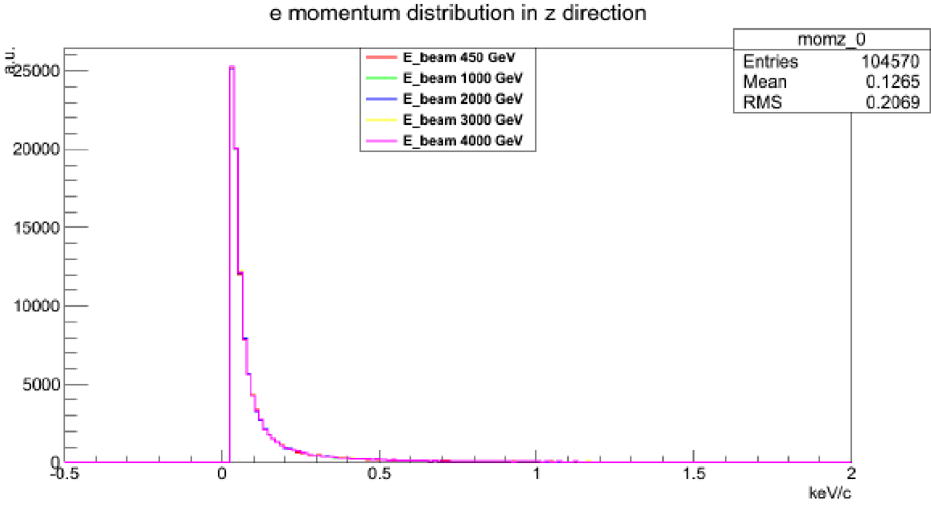
Session Talks

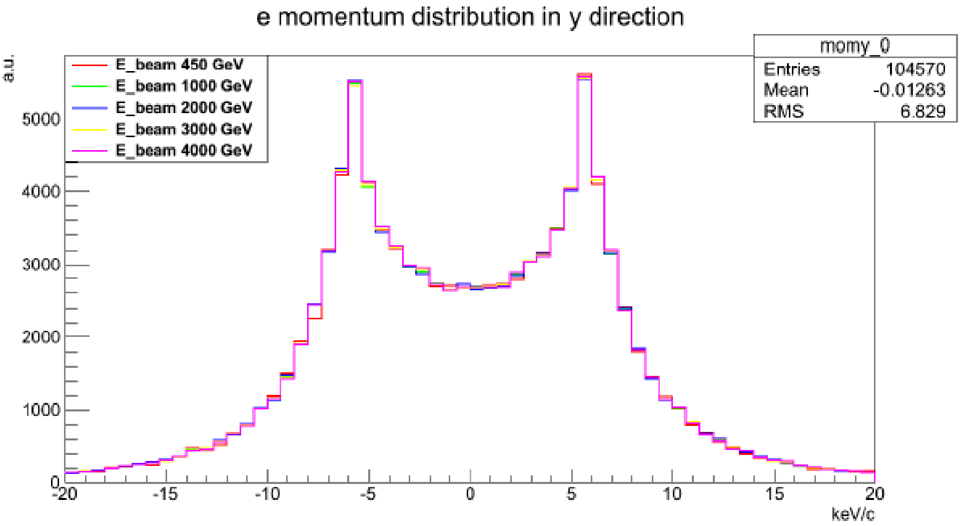
- Ionisation profile monitors
  - Marcin PATECKI : Electron tracking simulations in the presence of beam and external fields
  - Randy THURMAN-KEUP: IPM EM simulations
  - Jacques MARRONCLE: IPM developments for IFMIF
- Luminescence monitors and Gas jets
  - Peter FORCK: Experience with Luminescence monitors at GSI
  - Thomas TSANG: Experience with hydrogen gas jet and residual gas monitors at BNL-RHIC
  - Adam JEFF: Gas Jet Monitors

CERN: Marcin Patecki

Electron momentum distribution



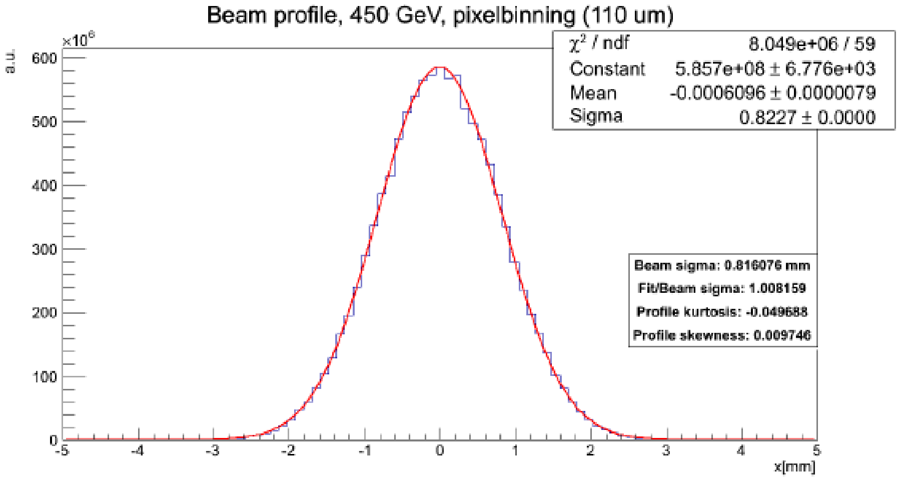


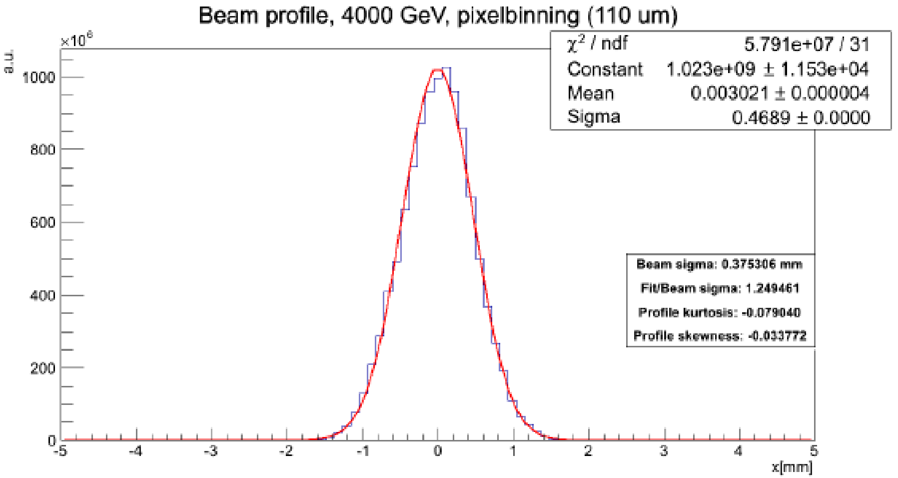


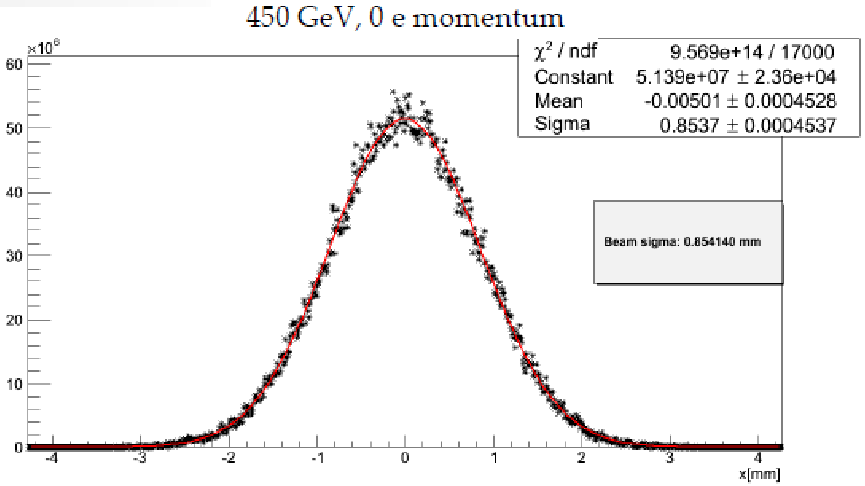
- No energy dependance;
- The same distribution in x and y direction;
- Significantly lower momentum in longitudinal direction.

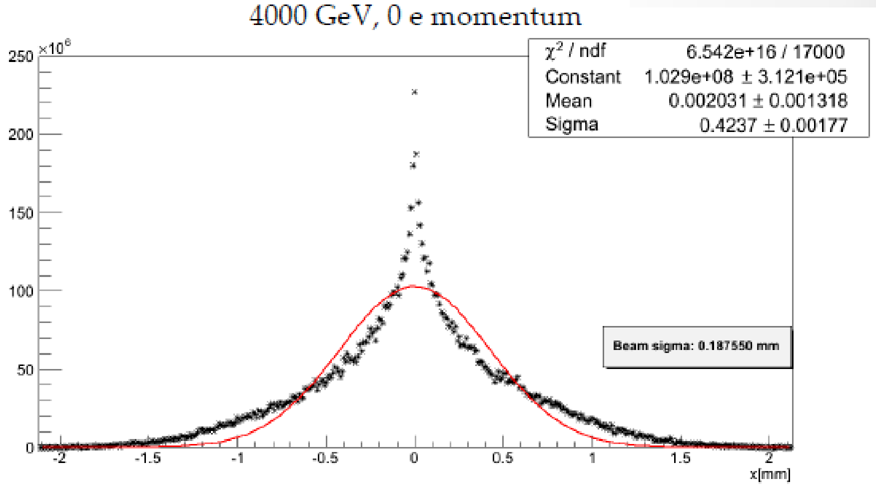
CERN: Marcin Patecki

Initial momentum effect


Beam profile, 450 GeV, pixelbinning (110 um)

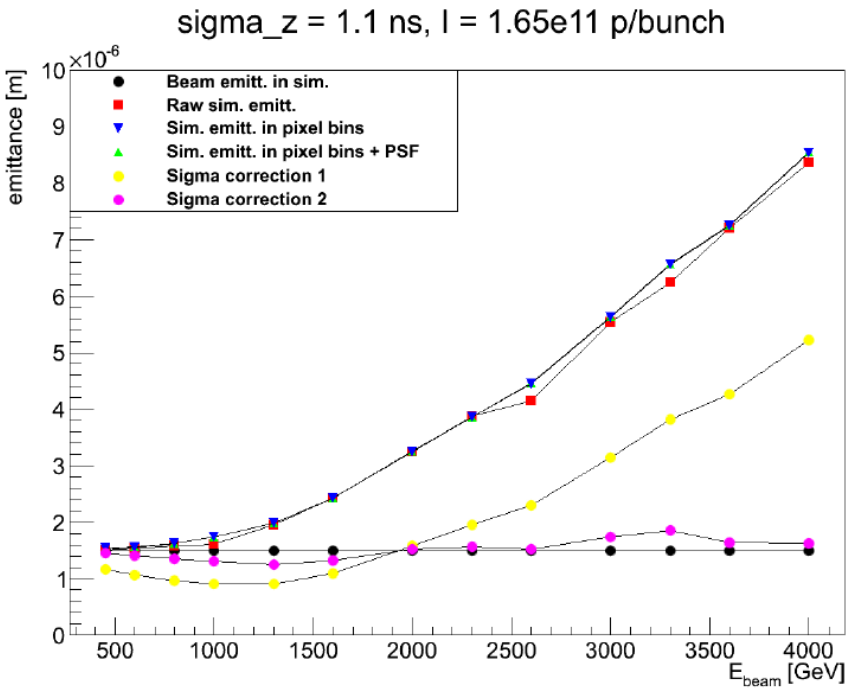

Beam profile, 4000 GeV, pixelbinning (110 um)

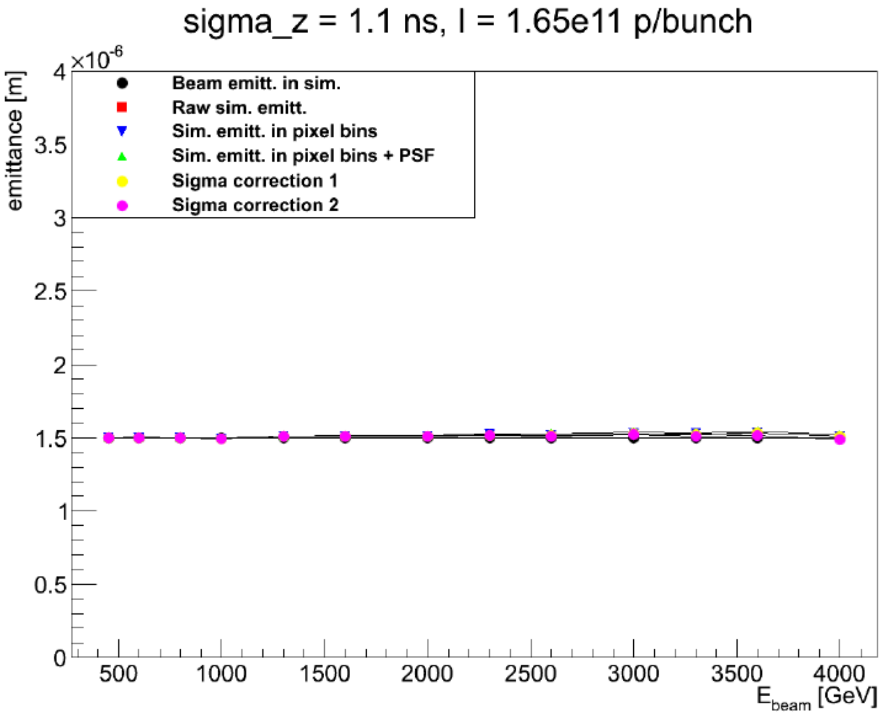

450 GeV, 0 e momentum


4000 GeV, 0 e momentum

CERN: Marcin Patecki:

Emittance and Space Charge 0.2 T and 1T

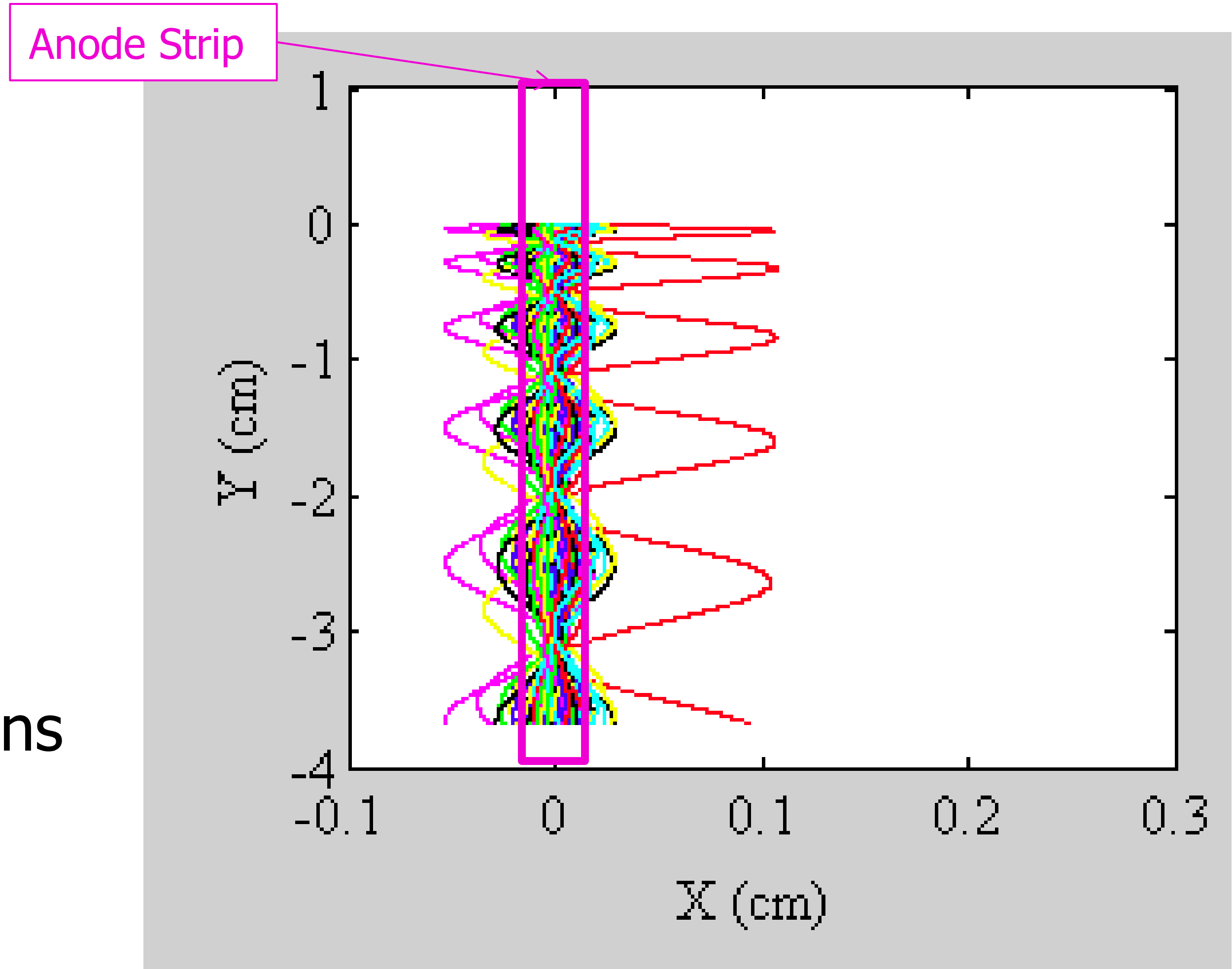




Gated-on IPM

Particles originating from single point (resolution contribution)

Elapsed time ~ 1.7 ns

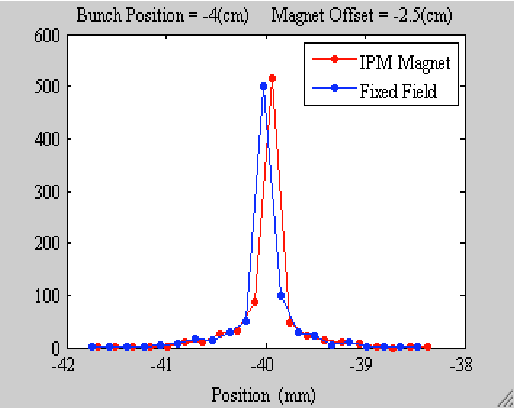


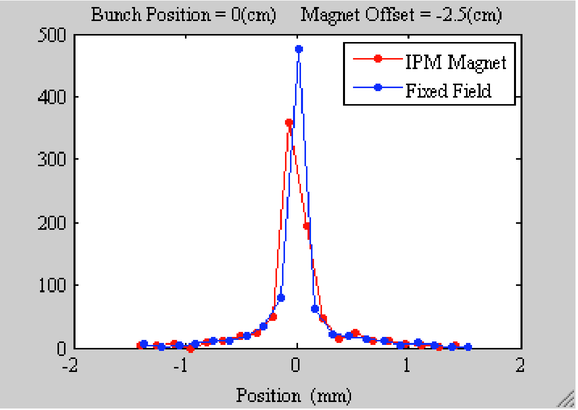
Gated-on IPM

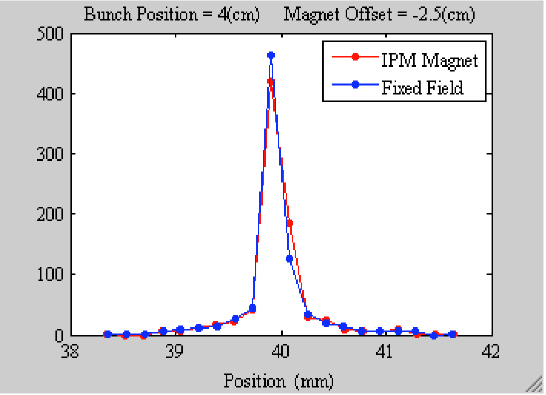
Particles originating from single point

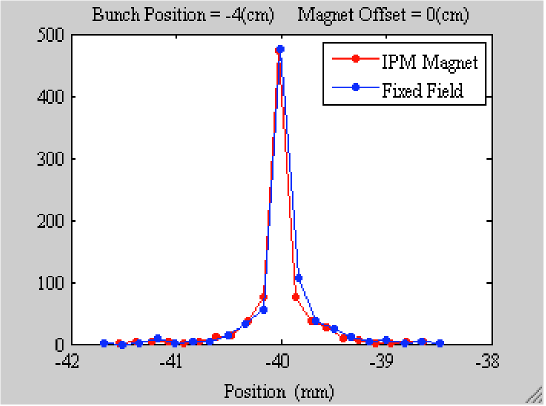
(resolution contribution)

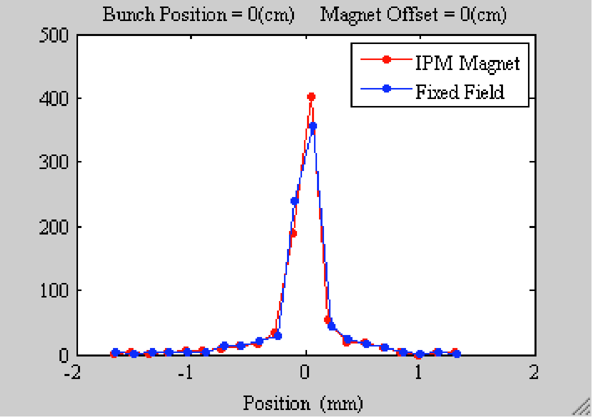
Bunch offset refers to x

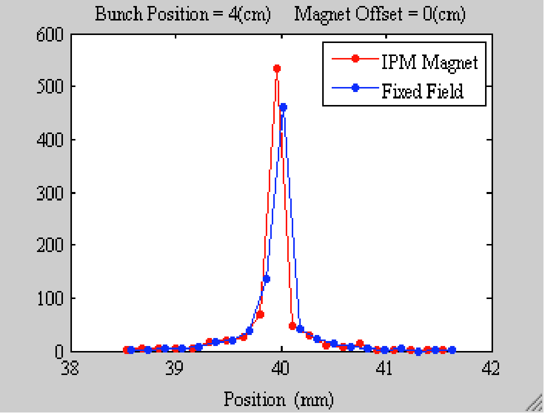




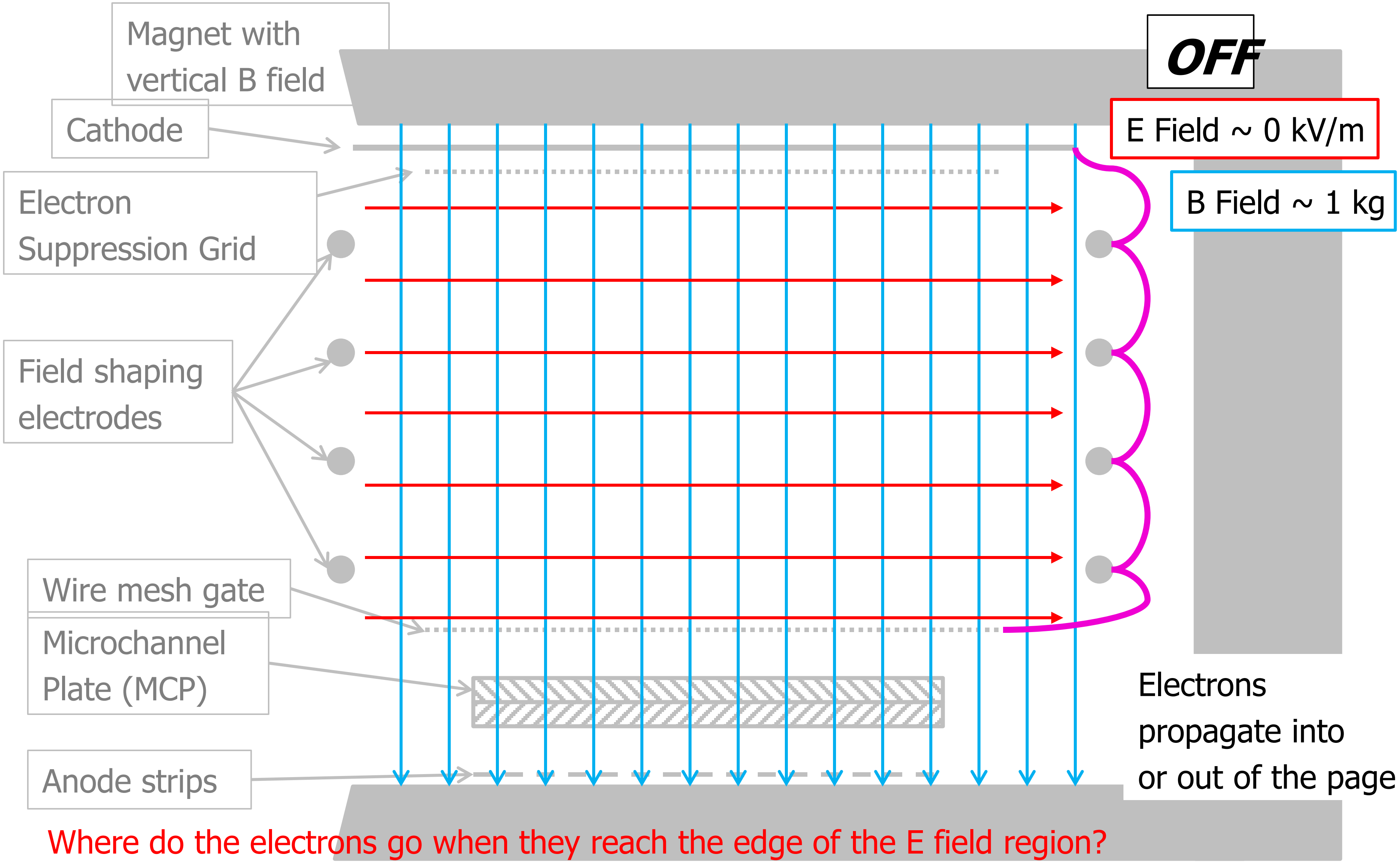








Gated-off IPM



Magnet with vertical B field

Cathode

Electron Suppression Grid

Field shaping electrodes

Wire mesh gate

Microchannel Plate (MCP)

Anode strips

OFF

E Field ~ 0 kV/m

B Field ~ 1 kg

Electrons propagate into or out of the page

Where do the electrons go when they reach the edge of the E field region?

Need 3-D E field calculation

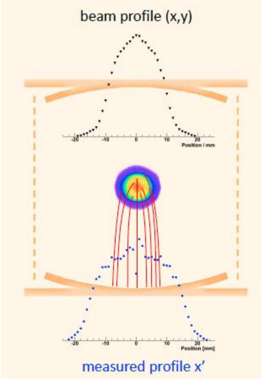
Space Charge effect

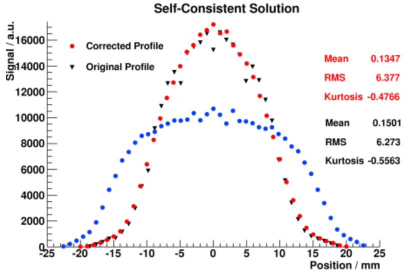
Ionization products experienced

- IPM electric field
- Beam electric field: **Space Charge**
  - ➞ GSI: low I ⇒ negligible effect
  - ➞ IPHI: high I, low E ⇒ big effect (profile distortion)

Theoretical

Profile reconstruction with an algorithm



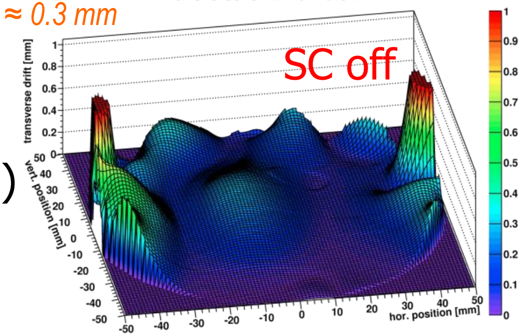


How to counteract SC

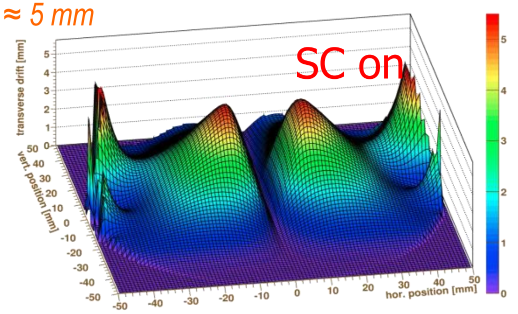
- magnetic field for guidance ➞ no space available
- increasing the electric field ➞ limitation due to deviation
- applying correction with an algorithm (developed by Jan Egberts)

Transverse Ion Drift in the IPM

$\Delta_{max} \approx 0.3$ mm



$\Delta_{max} \approx 5$ mm



Space Charge Algorithm

1- Hypothesis

- D^+
- round beam
- beam charge distribution described by a generalized Gaussian Distribution (GGD)
- I_{beam}

2- Approach $\vec{P}_{Corrected} = M \times \vec{P}_{Measured}$

-
- Matrix components M_{ij} represent the probability that an ion collected on strip j has been create at the position i
  → beam distribution (GGD) & ions trajectories
- Set of matrices computed for various parameter combinations
  - I_{beam}: 1 to 125 mA → 35
  - σ: 5 to 15 mm → 21
  - β: -0.25 to 0.25 → 3

  total matrices: 2205

3- First parameter to initiate iteration process

- fit of the experimental profile using a GGD to **extract**
  - I_{beam}: given by Current Transformers
  - → $\sigma_0 = \sigma_{exp}$
  - → $\beta_0 = \beta_{exp}$
- iterations $\vec{P}_1 = M(\sigma_{exp}, \beta_{exp}) \times \vec{P}_{Measured} \Rightarrow \sigma_1$ and β_1 extraction from $\vec{P}_1$ fit

  $\vec{P}_2 = M(\sigma_1, \beta_1) \times \vec{P}_1 \Rightarrow \sigma_2$ and β_2 extraction from $\vec{P}_2$ fit

  …

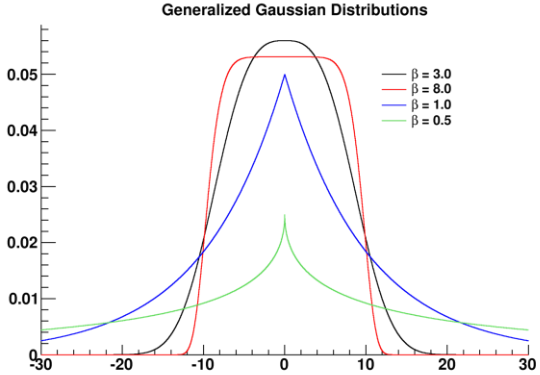
  $\vec{P}_n = M(\sigma_{n-1}, \beta_{n-1}) \times \vec{P}_{n-1} \Rightarrow \sigma_n$ and β_n extraction from $\vec{P}_n$ fit

  until parameters converge ($\sigma_n \approx \sigma_{n-1}$; $\beta_n \approx \beta_{n-1}$) → self consistent solution

Generalized Gaussian distribution

- μ: profile center
- Two degrees of freedom
  - σ: 2nd moment
  - **β:** kurtosis, 4th moment

$$p_{\alpha,\beta,\mu}(x) = \frac{\beta}{2\alpha\,\Gamma(1/\beta)}\, e^{-\left(\frac{|x-\mu|}{\alpha}\right)^{\beta}}$$



IPM: HEBT

Large aperture: 15 × 15 cm^2

Very high radiation background: 7 kSv/h neutrons on beam axis

⇒ Materials: ceramics (RO4350B), copper, resistors (CMS), Kapton (ribbon cable)

+ SAMTEC 80 micro coaxial cables (PVC, LCP, FEP ; halogen)

Degraders (16×2): 230 MΩ ➞ Lorentz-3D for electric field uniformity

FEE based on integrators; rate ≈ 10 Hz

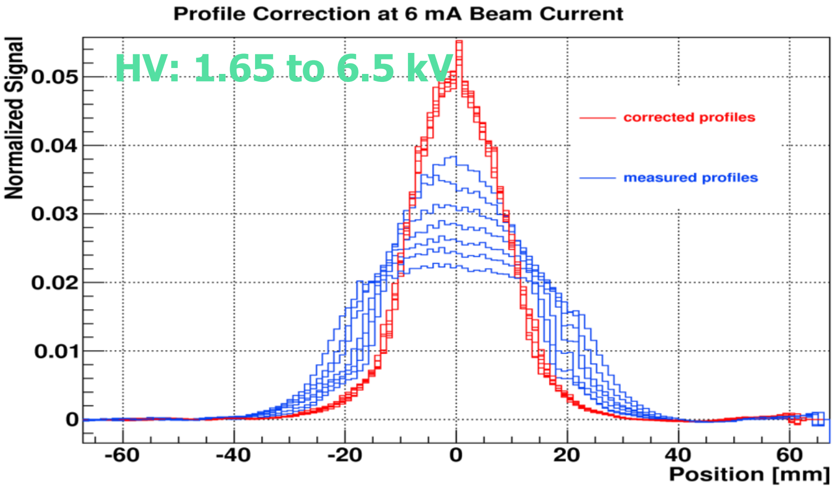
HV_{max} = 16 kV

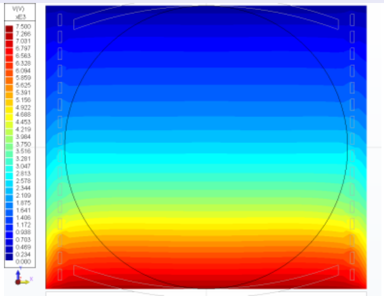
Tests done at Saclay on SILHI source: Dec. 2011 - Feb. 2012

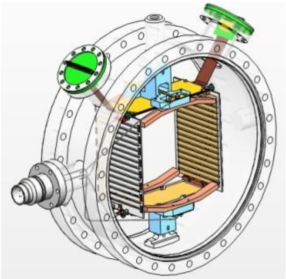
proton E_{max} = 95 keV, I_{max} = 100 mA, dc: up to cw

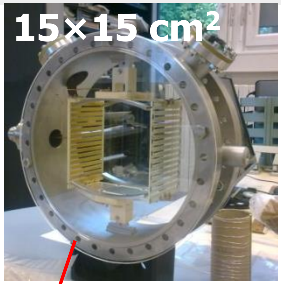
Main test: SC algorithm

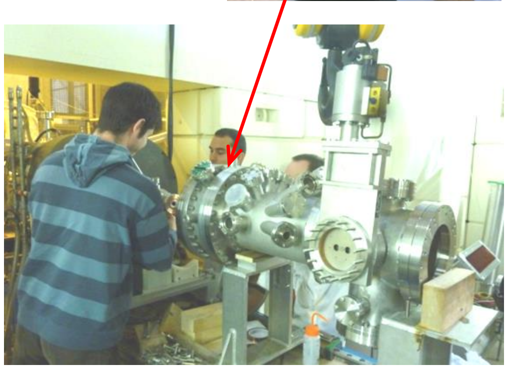
- frozen beam characteristics (conditions)
- only variation of extracting field



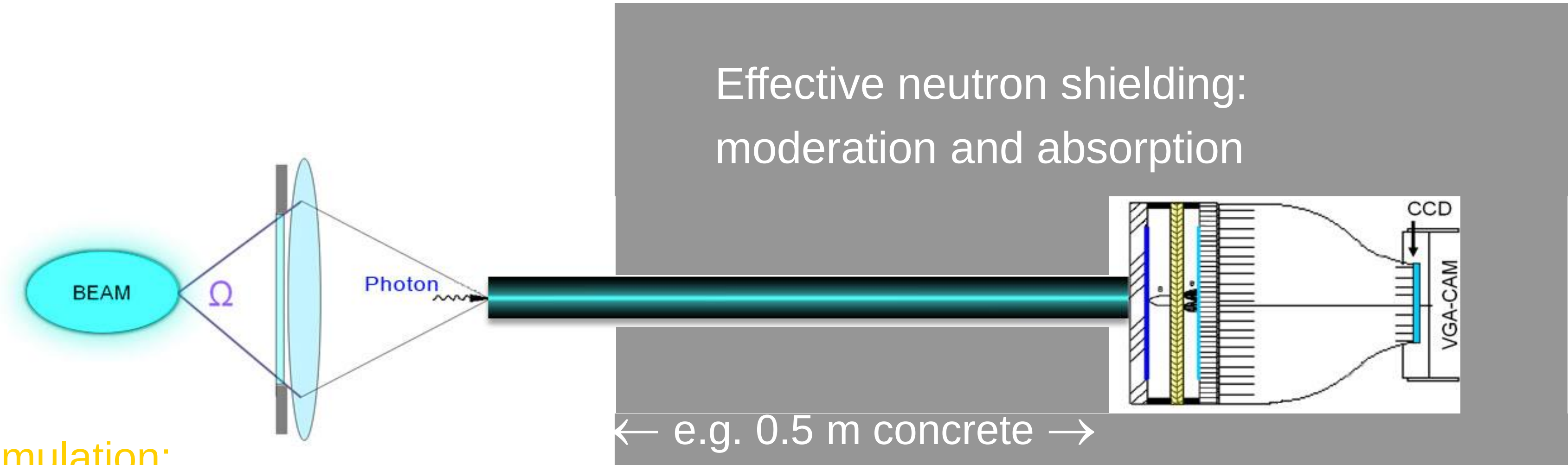








GSI: Peter Fork: **Shielding Concept for Background Reduction**



Effective neutron shielding:
moderation and absorption

← e.g. 0.5 m concrete →

FLUKA simulation:

Shielding of 1x1x1 m^3 concrete block:

900 MeV/u BIF monitor 2m to beam dump

⇒ γ & n reduction 95 %

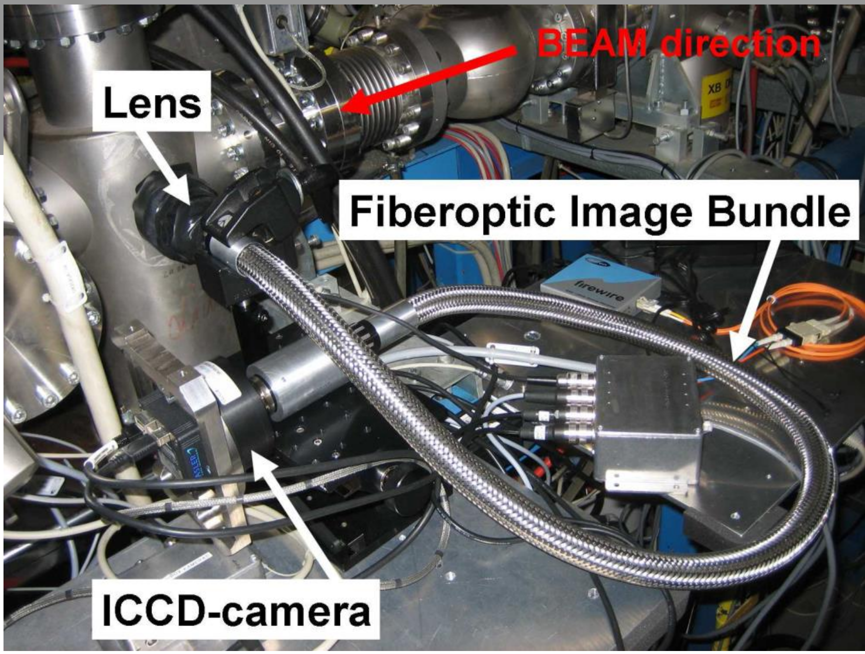
Fiber-optic bundle with ≈1 million fibers:

- Commercial device for reduction of background and CCD destruction
- Image Intensifier and CCD in shielded area
- larger distance but same solid angl

Experimental results:

- No significant image distortion
- Low scintillation by n & γ inside bundle

  un-shielded: ≈30 % increase of background



GSI: Peter Fork: Spectroscopy – Variation of Gas Pressure

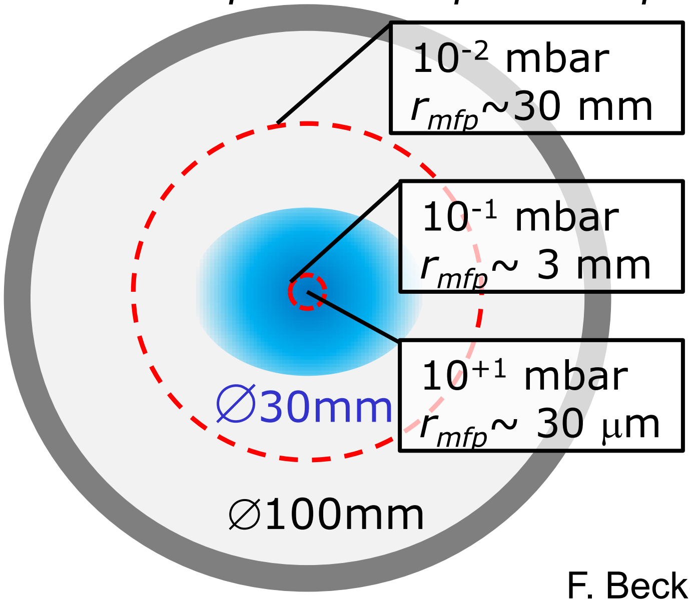
Task: To which pressure the methods delivers a correct profile reproduction?

Investigated: 10^{-3} mbar < p < 100 mbar

Secondary electron might excite residual gas:

- ⇒ mean free path at 10^{-3} mbar: $r_{mfp} >> r_{beam}$
- ⇒ mean free path at 10 mbar: $r_{mfp} << r_{beam}$

Observation: pressure dependent spectrum



10^{-2} mbar
$r_{mfp} \sim 30$ mm

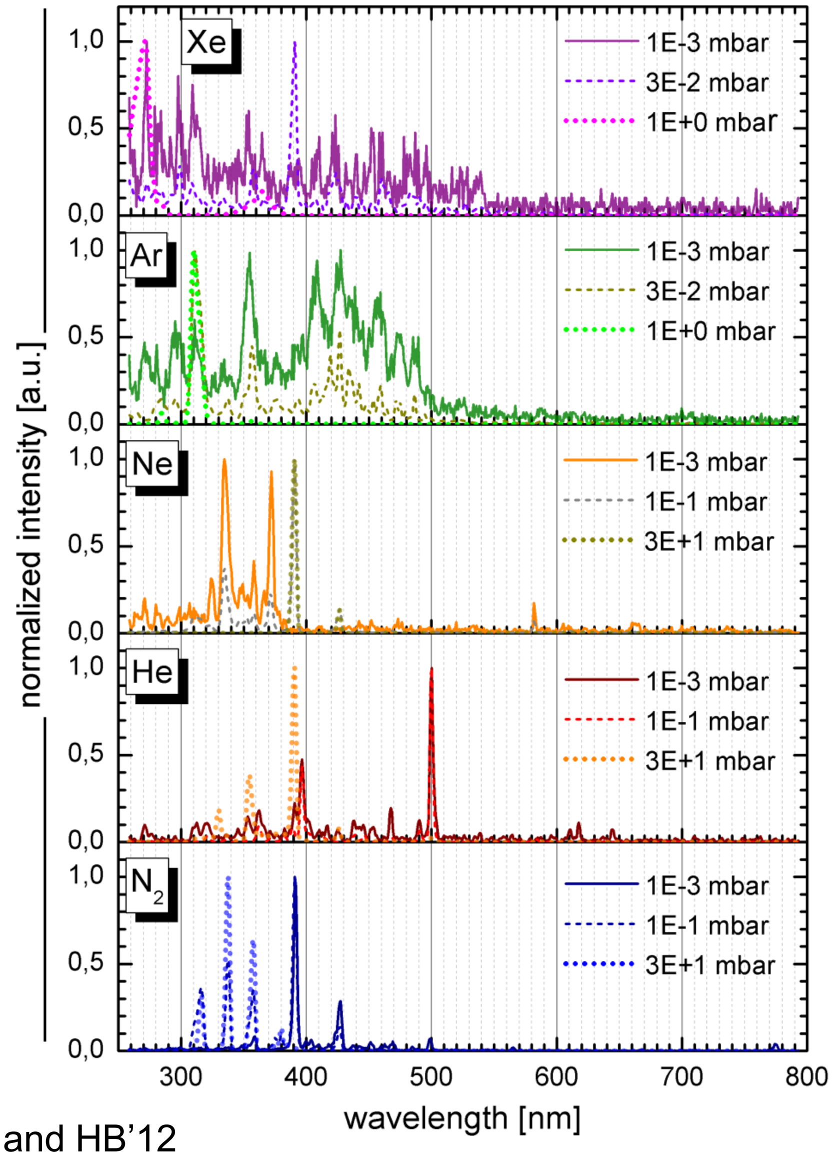
10^{-1} mbar
$r_{mfp} \sim 3$ mm

10^{+1} mbar
$r_{mfp} \sim 30\ \mu$m

∅30mm

∅100mm

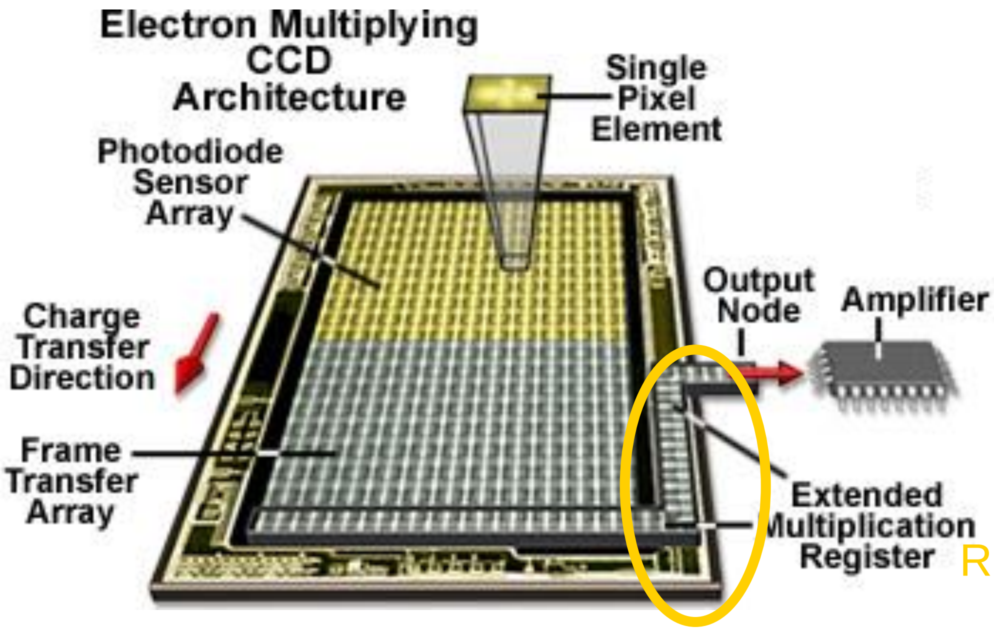
Beam: S at 3 MeV/u at TU-München TANDEM



F. Becker et al., IPAC'12 and HB'12

GSI: Peter Fork: Alternative Single Photon Camera: emCCD

Principle of electron multiplication CCD:



Multiplication by avalanche diodes:

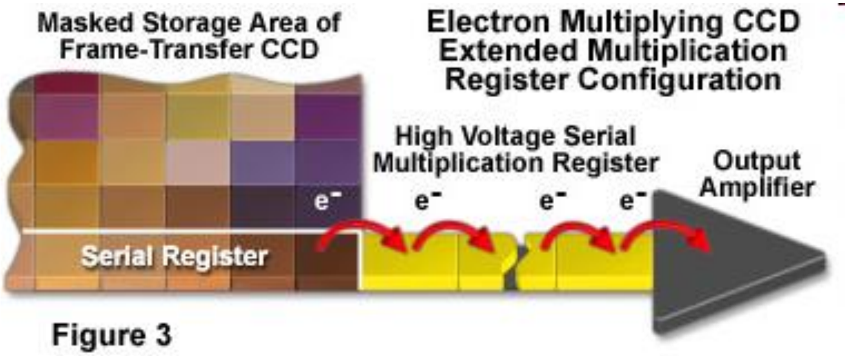
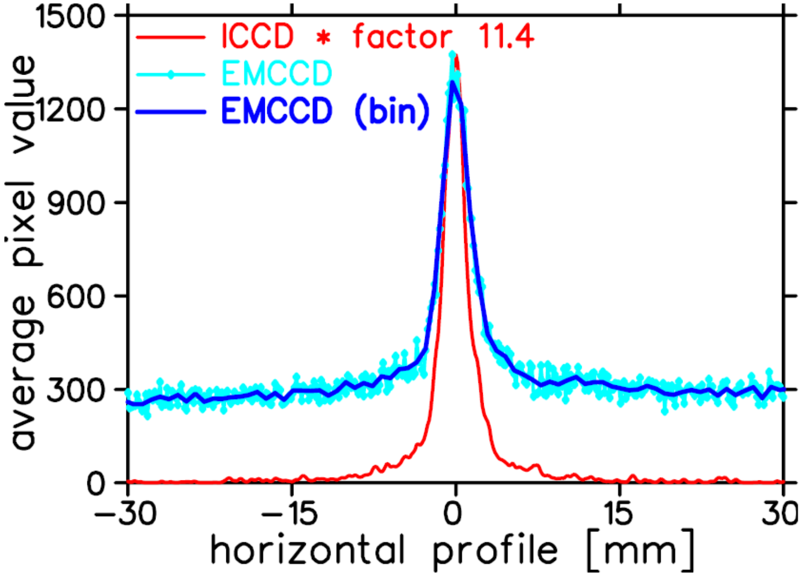


Figure 3



Results: Suited for single photon detection

x5 higher spatial resolution as ICCD

more noise due to electrical amplification

⇒ Acts as an alternative

Parameter of Hamamatsu C9100-13

Pixel: 512x512, size16x16μm^2

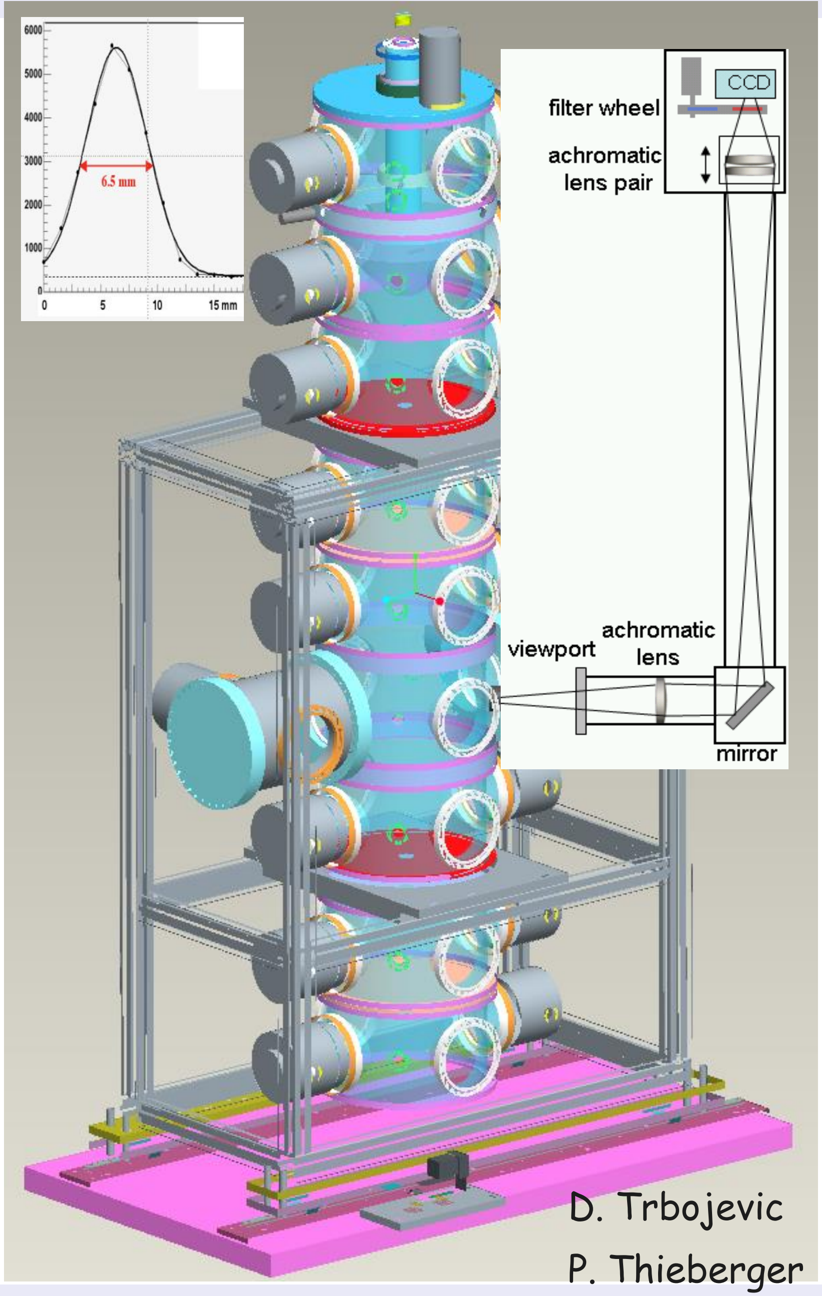
Maximum amplification: x1200

Temperature of emCCD sensor: -80 ^{O}C

Readout noise: about 1 e^- per pixel

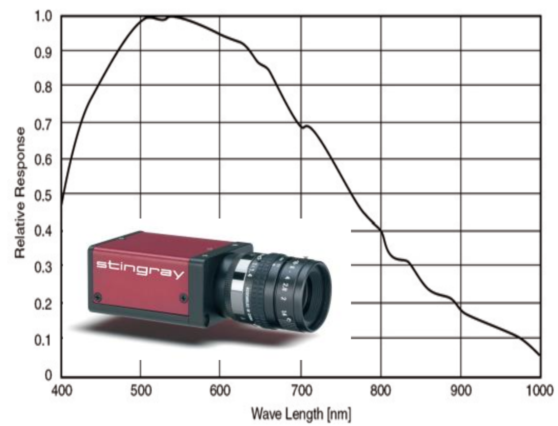
BNL: Thomas Tsang: The imaging system

BROOKHAVEN NATIONAL LABORATORY



D. Trbojevic

P. Thieberger



AVT Stingray F-145B/fiber

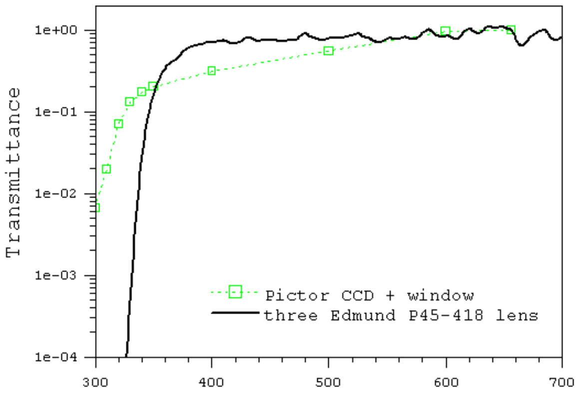
Sony ICX-285 CCD

1394b 800Mb fiber

1388 X 1038, 6.45um pixels

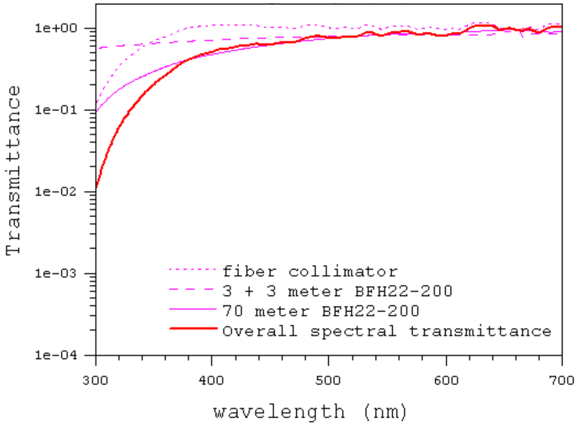
8, 12. 16-bit ADC

Exposure: 73 μs to 67sec



Transmittance

of achromat lens



transmittance of

fiber collimator and

70 meter BFH22-220 fiber

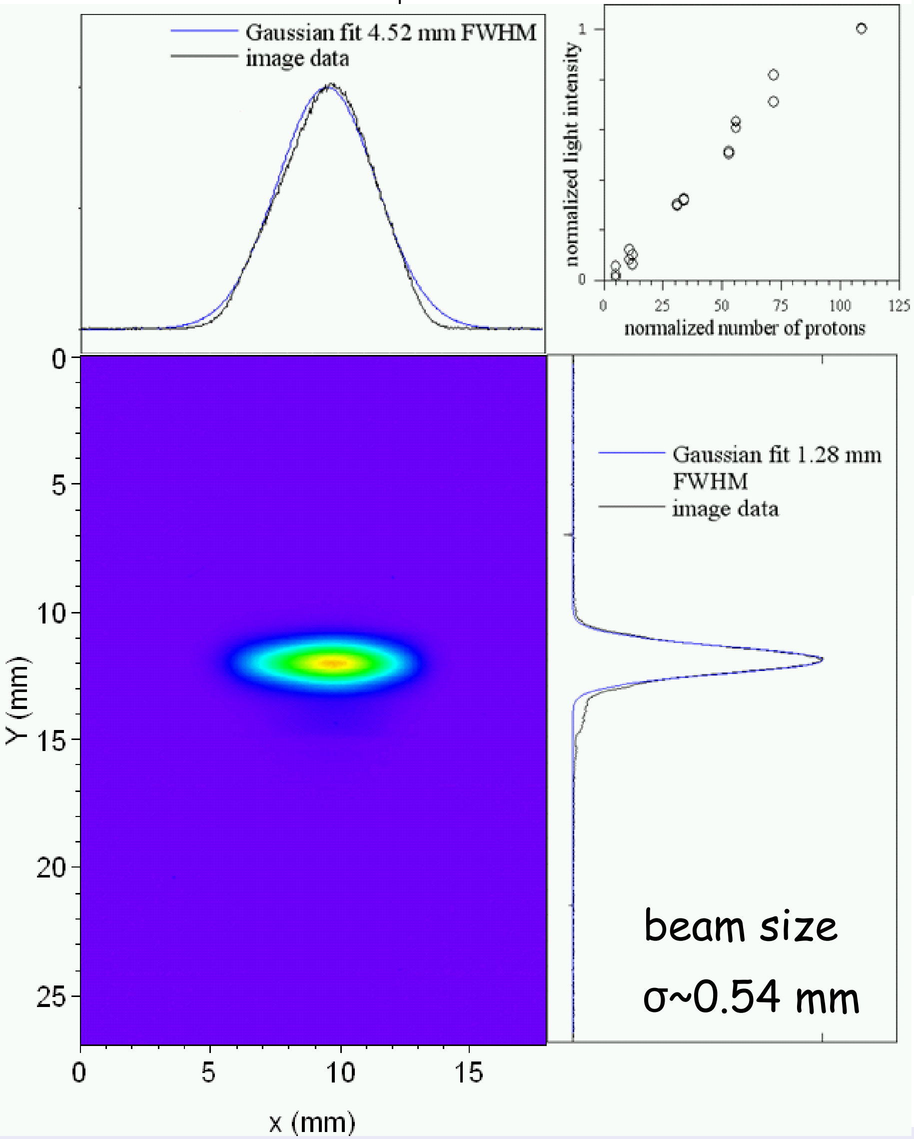
Overall (650 nm)

View solid angle: 1.4×10^{-3} sr

Optics:throughput: 0.58

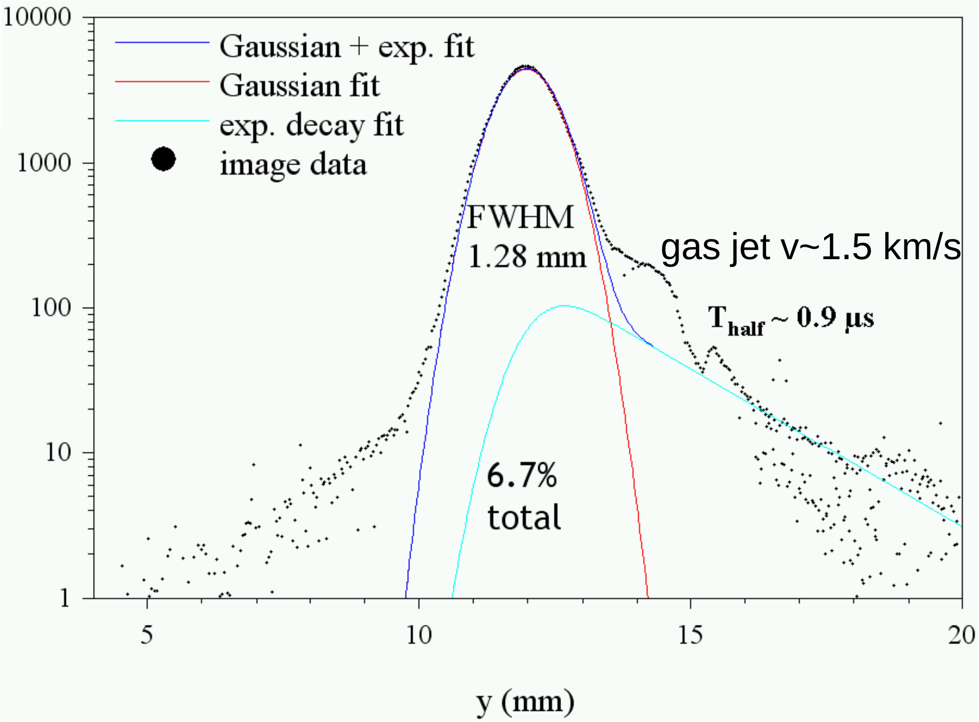
BNL: Thomas Tsang: Proton Beam and H-Jet beam size

100 GeV


H-jet beam width x√2~6.4 mm

beam size

σ~0.54 mm


gas jet v~1.5 km/s

6.7% total

Reveals the lifetime of a metastable state of Hydrogen, 0.9 µs lifetime

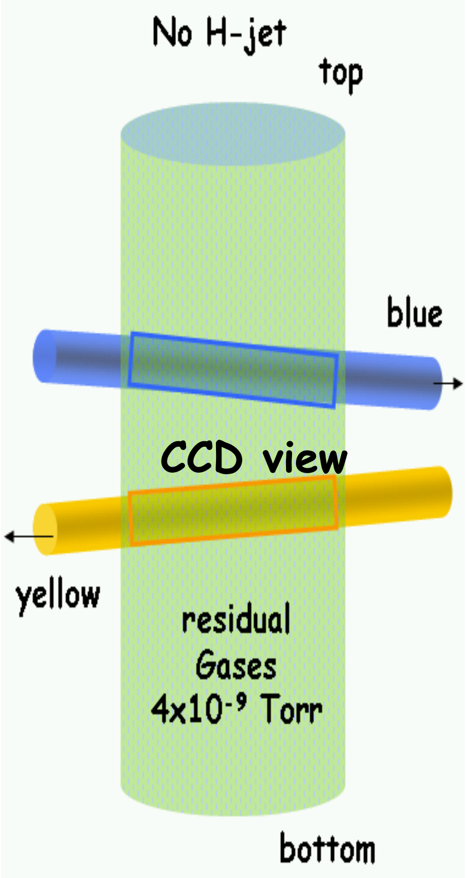
Fluorescence lifetime remains @ 10-20 ns

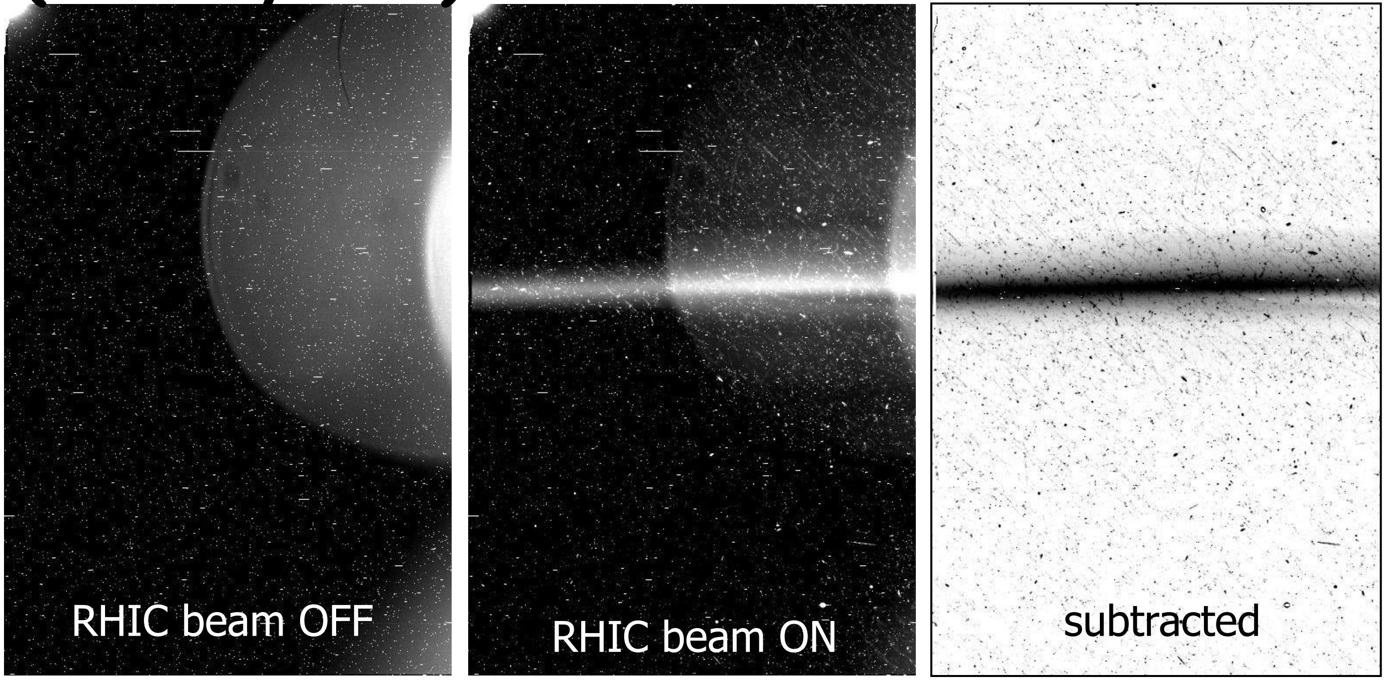
An image provides many information of

BNL: Thomas Tsang: Residual gas fluorescence monitor (RGFM)

Dec. 2, 2007

Deuteron-Au ion, 100 GeV/n, 69+69 bunch (blue – yellow)




RHIC beam OFF

RHIC beam ON

subtracted

no spectral filter, a few min. exposure

streak of Au ion fluorescence was observed

none for deuteron

BNL: Thomas Tsang: RGFM – ion beam summary

Modes	U-U ions		Cu-Au ions	
RHIC beam	U-Blue	U-Yellow	Cu - Blue	Au - Yellow
beam width, σ (mm)	**0.26**	**0.24**	**0.37**	**0.36**
vertical emittance ε (π mm mrad)	5.7-12.5	5.6-11.0	14-27	18-22
Fluorescence cross-section (cm^2)	**2.6×10^{-16}**		**1.8×10^{-17}**	**2.1×10^{-16}**

cross-section obeys the Z^2 dependence: Bethe-Block law

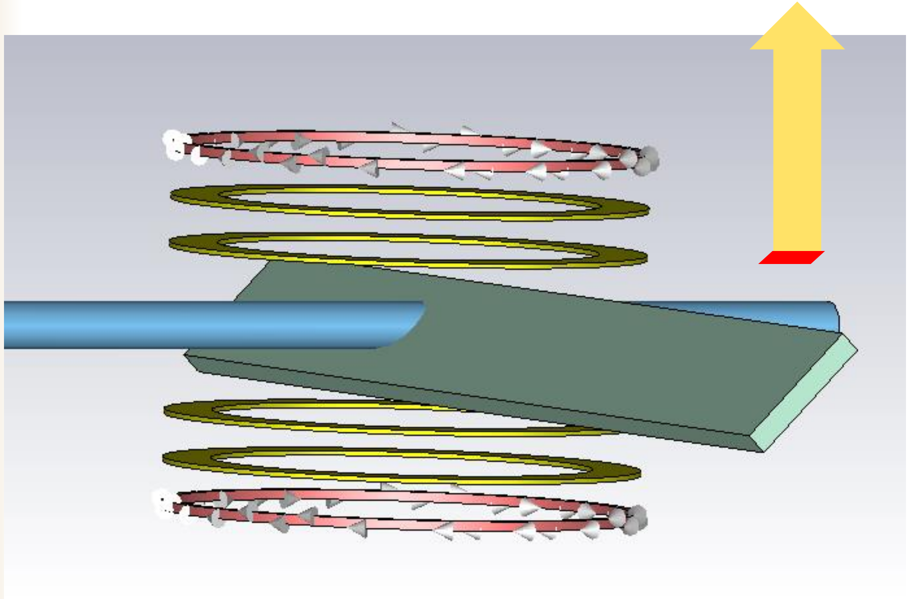
- provide simple visual inspection of beam
- hydrogen is the dominant residue gas constituent in all vacuum system
- RGFM is a passive, robust, truly ***noninvasive*** beam monitor

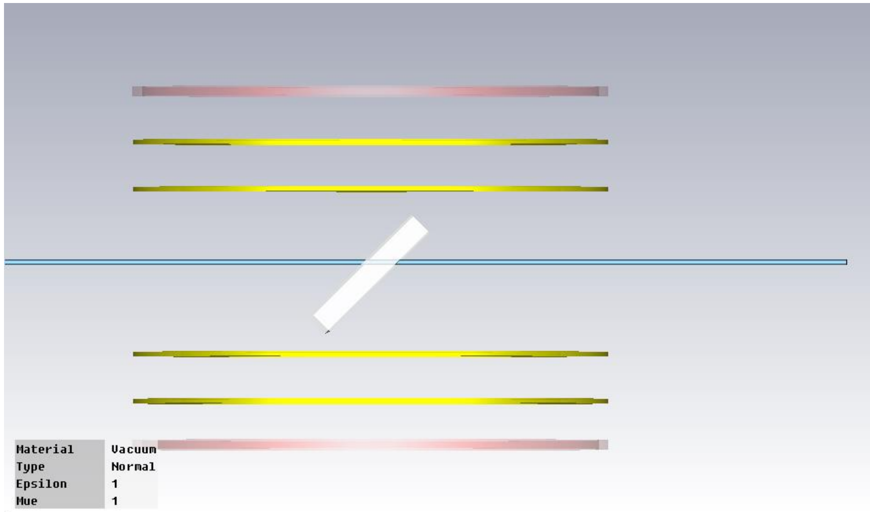
- beam-induced fluorescence is a weak process (1 bunch 3×10^8 U-ion gives ~7 photons)
- need longer exposure time to capture high s/n image
- need to monitor both vertical and horizontal planes
- need to avoid long term radiation damage to equipment

All images are batch processed by NIH ImageJ software

CRN: Adam Jeff: Principle of the Gas Jet Monitor

- Gas jet shaped into a plane inclined at 45° to beam
- Extract ions or electrons perpendicularly
- Collect on phosphor / MCP and image
- Gas jet collected on opposite side of beam pipe
- Resolution depends on jet thickness





Material	Vacuum
Type	Normal
Epsilon	1
Mue	1

CRN: Adam Jeff: Summary

Gas jet monitors are an interesting option for many accelerators and have significant advantages over traditional residual-gas monitors.

The added cost of the gas jet system is offset by measurement of both profiles at once.

Gas jets have been used over a huge range of intensities:

	Jet material	Jet pressure (Torr)	Jet thickness	Accelerator Vacuum (Torr)
ISR, CERN	Sodium Vapour	10^{-5}	0.7mm	10^{-9}
Los Alamos	Hydrogen	10	2-4 mm	10^{-5}
LEAR, CERN	Carbon	5×10^{-10}	1-5mm	10^{-12}
HIMAC, KEK	Oxygen	10^{-7}	1.3mm	10^{-11}
RHIC, BNL	Hydrogen	10^{-8}	10mm	10^{-10}
USR, FLAIR	?	?	?	10^{-11}
CLIC Drive Beam	?	?	?	10^{-9}

Some questions for discussion I

- LHC IPM limitation
    - Space charge effect
        - Mitigation:
            - increase B-field, CERN
            - Use correction: IFMIF
    - Camera system sensitivity to EMC
        - Mitigation:
            - Digital cameras (GSI)
    - Calibration of system
        - Mitigation
            - Electron emission plate (CERN, FNAL)
            - Calibrate electronic strips by capacitive test signal coupling (BNL, FNAL)
            - Use signal and optimise gain (move MCP or beam), application possible for strip and MCP possible

Some questions for discussion II

- New continues emittance monitor for the PS
  - Condition:
    - Relative high vacuum ~ e-8, (pressure bump possible)
    - Revolution period 6 us
    - Energy 1 to 26 GeV
    - Up few E13 intensity
    - Limited longitudinal space available
    - Dose in the order 100 to 1000 Gy / year
    - Beam size changes during ramp
  - Required accuracy relative (delta sigma / sigma) few %
  - Calibration of system is possible with wire scanners => Main requirement high reproducibility
- Options:
  - IPM (Using a gas jet?)
  - Luminescence (Using a gas jet?)
  - Beam scanner
  - Imaging by optical or strip system (Si detectors)
    - How to overcome the radiation effect
      - Usage of radiation tolerant preamplifiers (FNAL)
      - Usage of telescope or optical light guide (GSI)