Working Group F Summary: Beam Diagnostics and Instrumentation for High-Intensity Beams

Manfred Wendt
for the Working Group F contributors

WG F: Overview

- **10 Presentations in 2 sessions, 3½ hours total**
  - **Y. Hashimoto:**
    Multi-Ribbon Profile Monitor Using a Carbon Graphite Foil for the J-PARC
  - **M. Hori: A Time-Resolved SEM monitor with large Dynamic Range**
  - **W. Blokland: Non-Invasive Beam Profile Measurements using an E-Beam Scanner**
  - **P.-A. Duperrex: Current and Transmission Challenges for High-Intensity Beams**
  - **E. B. Holzer: Commissioning and Optimization of the LHC BLM System**
  - **C. Gabor: Status Report of the RAL Photo-Detachment Beam Profile Monitor**
  - **P. Forck: Beam Induced Fluorescense Profile Monitor Development**
  - **J. M. Carmona: First Measurements of Non-Intercepting Beam Profile Monitor Prototypes for Medium to High Current Hadron Accelerators**
  - **K. Satou: IPM Systems for J-PARC RCS and MR**
  - **M. Wendt:**
    Beam Instrumentation for High-Intensity, Multi-GeV Superconducting Linacs
  - **Thanks to the speakers(!), and to all participants!**
- **Discussions session joint with WG-E (Computational Challenges), ~ 1 hour**
  - **A. V. Aleksandrov: Challenges of Reconciling Theoretical and Measured Beam Parameters a the SNS Accelerator Facility**

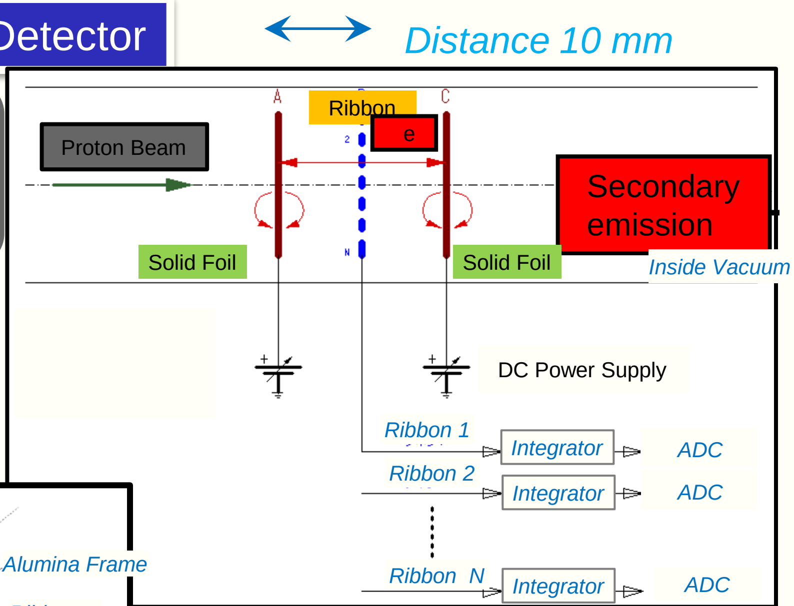
Overview

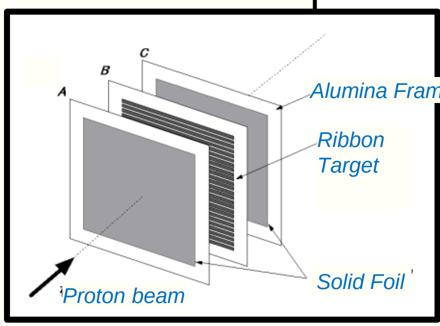
- **Classification**
  - 7x transverse beam profile
    - 2x invasive (SEM)
    - 5x non-invasive (photo-detachment, e-beam deflection, rest gas)
  - 1x beam intensity and beam current transmission
  - 1x beam losses and machine protection
  - 1x general overview
  - 1x theoretical vs. measured beam parameters
- **Some Highlights**
  - Invasive profile monitor R&D with minimum residual losses
  - Calibration and fitting advances for non-invasive monitor data
  - Environmental and practical issues on cavity current monitors
  - LHC BLMs detect unexpected loss patterns (dust particles?)
  - Simulations and beam monitoring are orthogonal (no trade).

Y. Hashimoto: Multi-Ribbon Carbon SEM

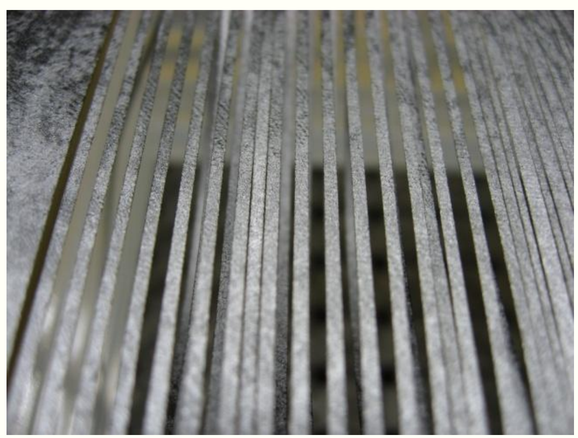
Ribbon Type Detector

Emissivity (secondary electron/proton) 2.1 % (P_E= 3 GeV)





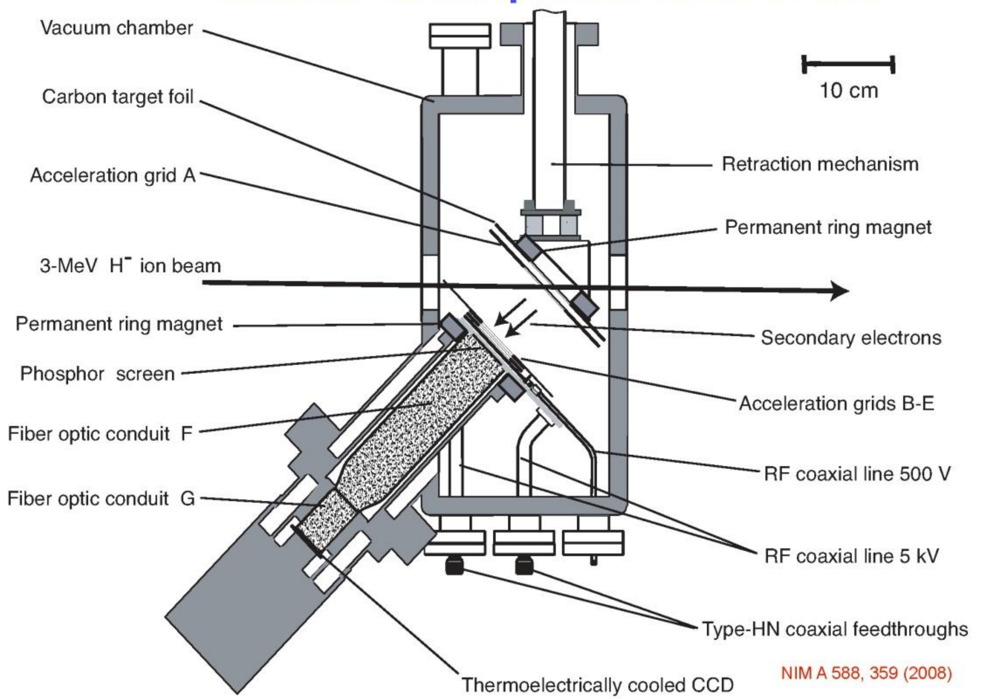
2 µm ribbons of 1mm width and 2 mm pitch



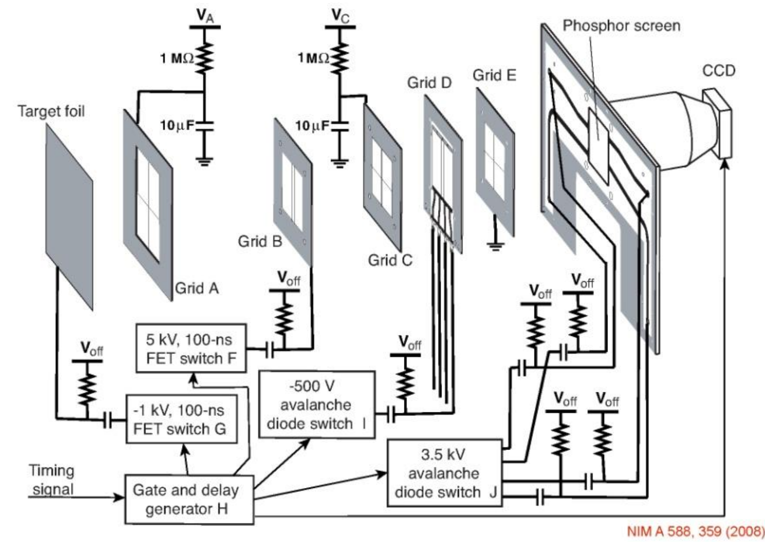
- **Graphite Ribbon**
  - **1.6 – 2 µm thick**
  - **Up to 200 mm long, <1 % un-uniformity**
  - **0.8 keV beam loss at 3 MeV beam energy**
  - **Tested: 1×10^{13} ppb**
  - **Design: 4×10^{13} ppb up to 8 bunches**
  - **Beam halo detection by core signal suppression (factor 2000)**

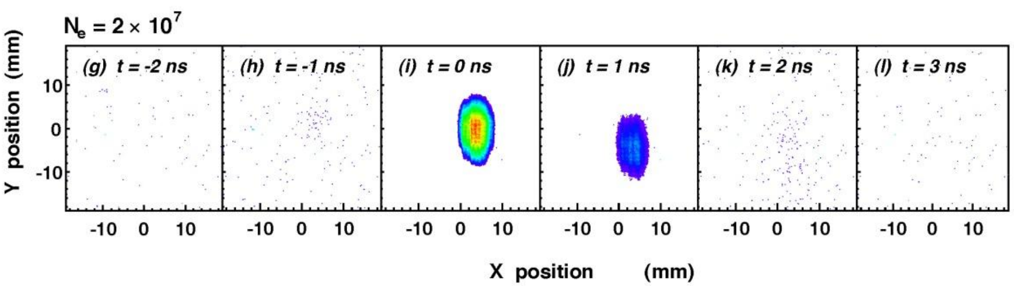
M. Hori: Time resolved SEM

Detector developed for Linac4 R&D



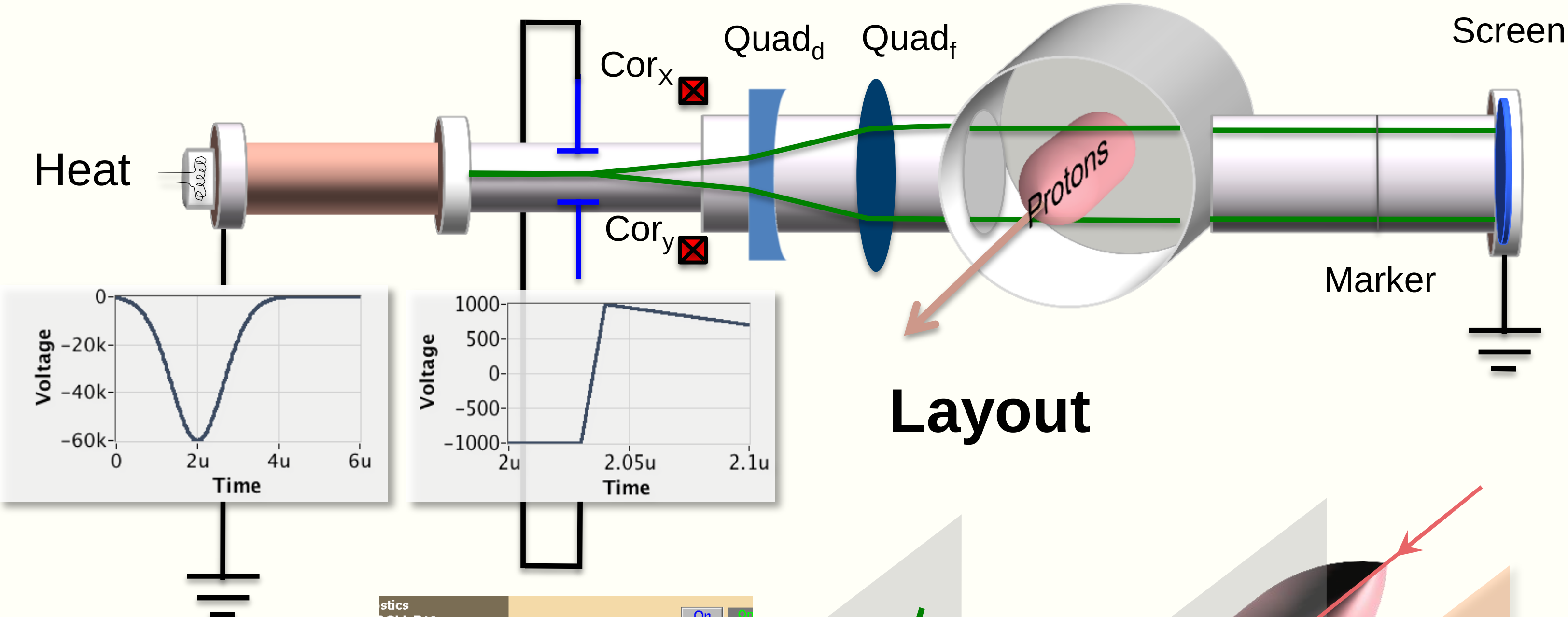
Electronic gating and acquisition system





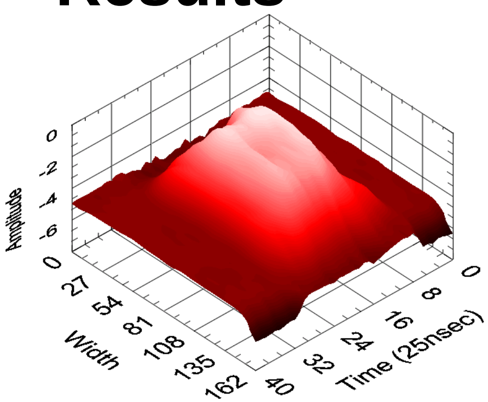
- **3D SEM**
  - **2 mm spatial resolution**
  - **<1 nsec time resolution**
  - **10^8 dynamic range**
  - **n_p=10 protons / pulse sensitivity**

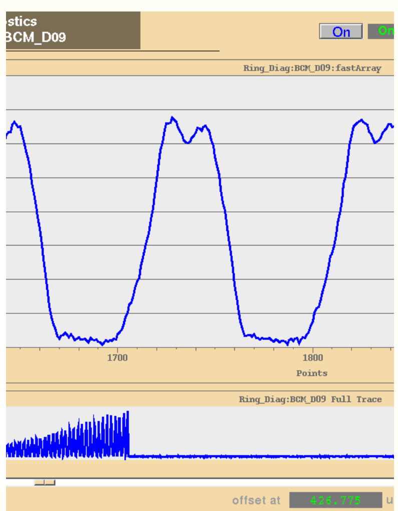
W. Blokland: Electron Beam Scanner

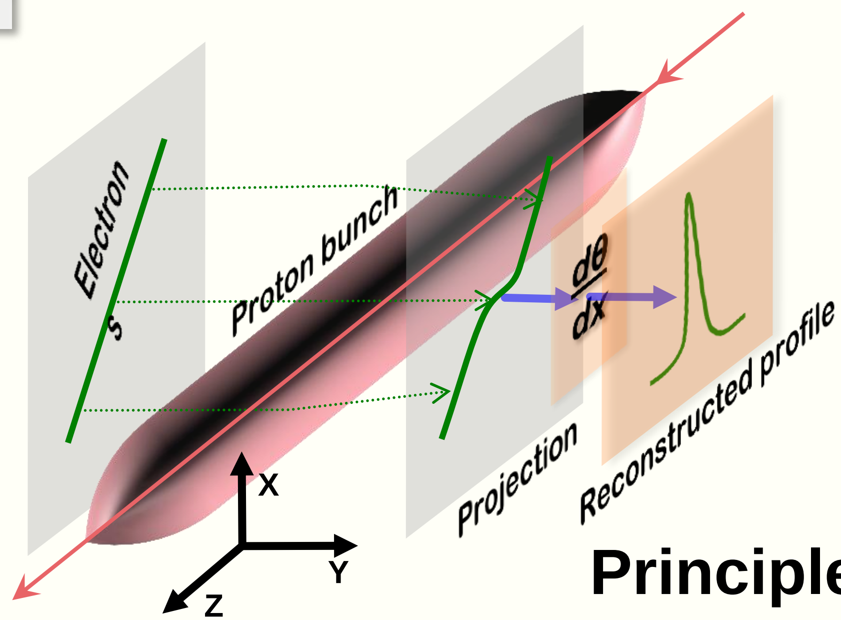


Layout

Results

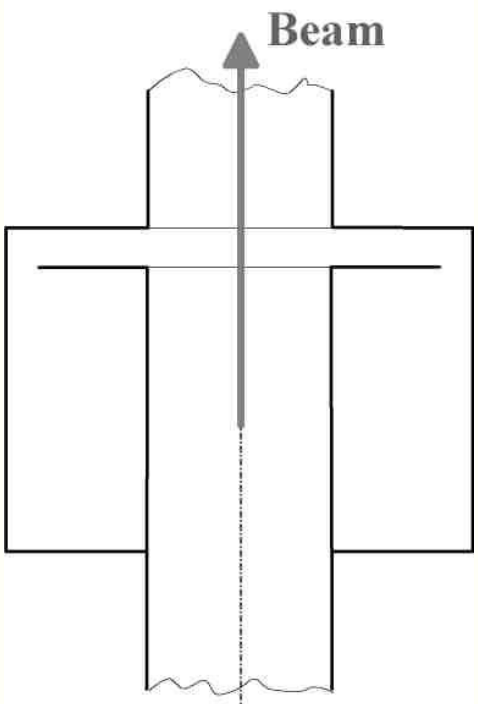


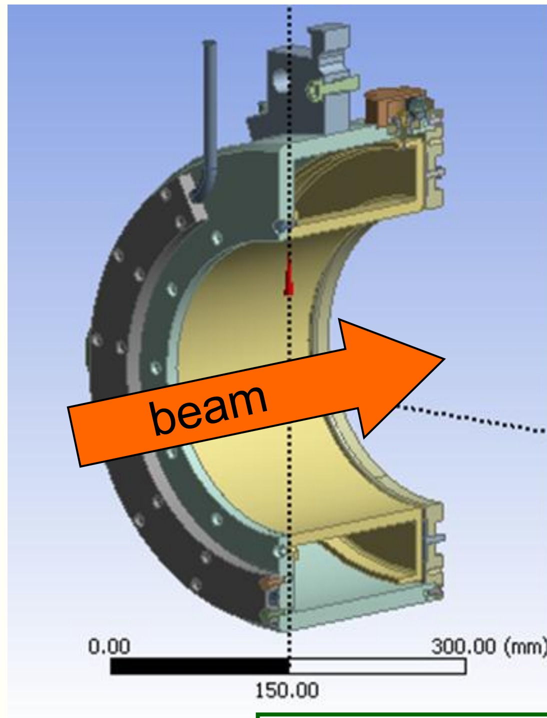


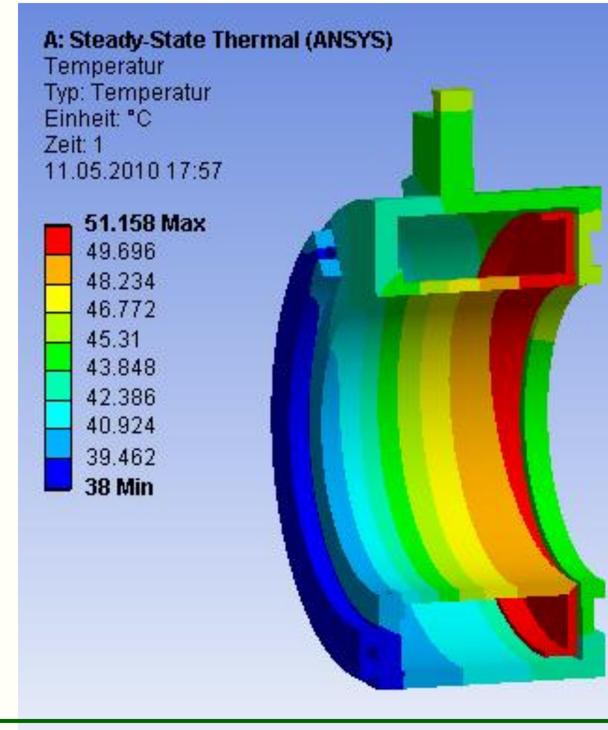


Principle

P.-A. Duperrex: Beam Intensity & Transmission







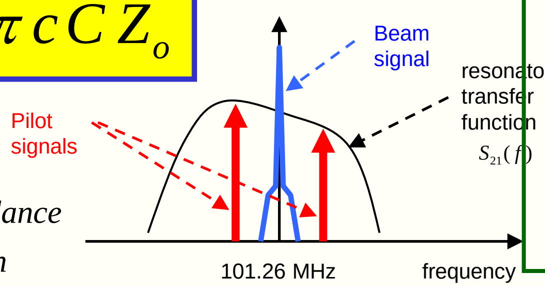
$$\tan\left(\frac{2\pi L}{\lambda_m}\right) = \frac{\lambda_m}{2\pi\, c\, C\, Z_o}$$

L : resonator length

C : capacitor shunt

Z_o : characteristic impedance

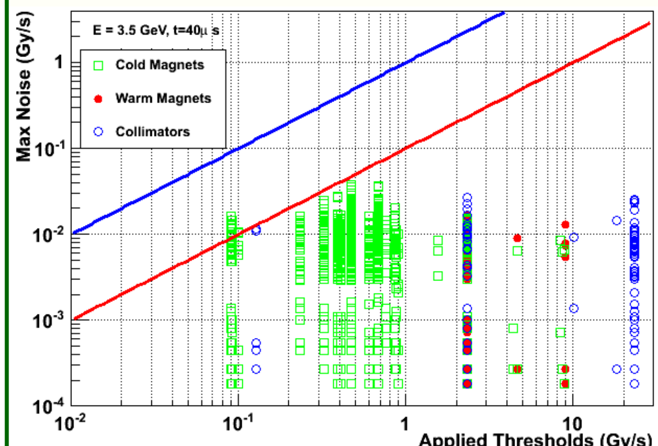
λ_m : resonant wavelength

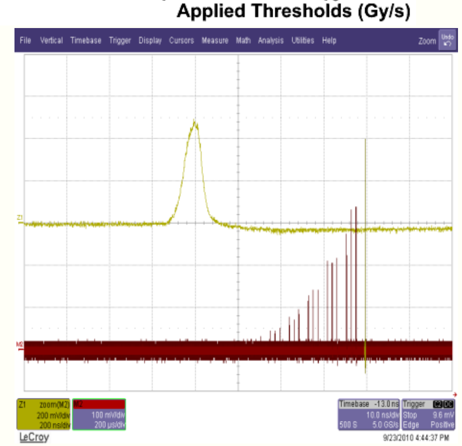


- **Coaxial Resonator CM**
  - **Simple, ruggedized, rad hard**
  - **Temperature drifts**
  - **No absolute measurements**

E.B. Holzer: LHC BLM Interlock

- Complex protection interlock
  - 3600 ICs & 300 SEMs
  - Interlock with multiple integration intervals / “families” of monitors
  - Continues / regular self tests
- Performance
  - No evidence of a single beam loss event been missed
  - No avoidable quenched passed BLM protection
  - All exceptionally high losses caught hardware failures never caused a degradation of reliability
  - No dumps on noise
  - Few hardware failures, mostly detected by offline checks
- Experience
  - More redundancy in loss measurement than expected
  - To be improved: Better long cables or rad-hard read-out electronics for S/N improvements.
  - Unexpected beam aborts!
    Hypothesis: Dust in the machine?!

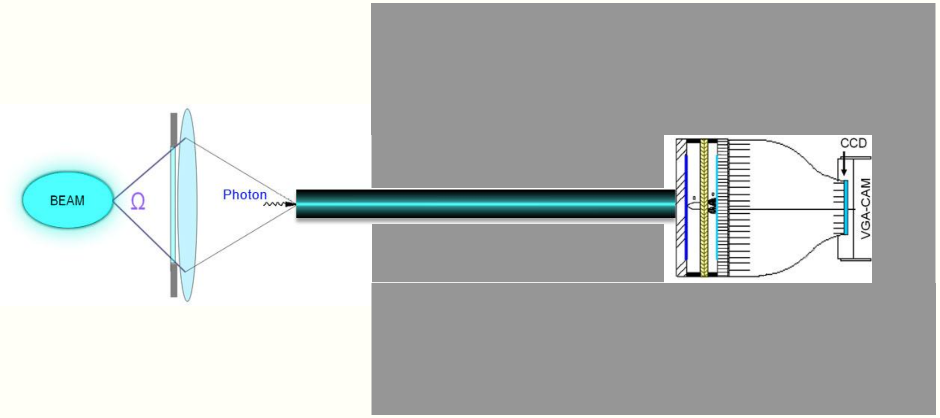




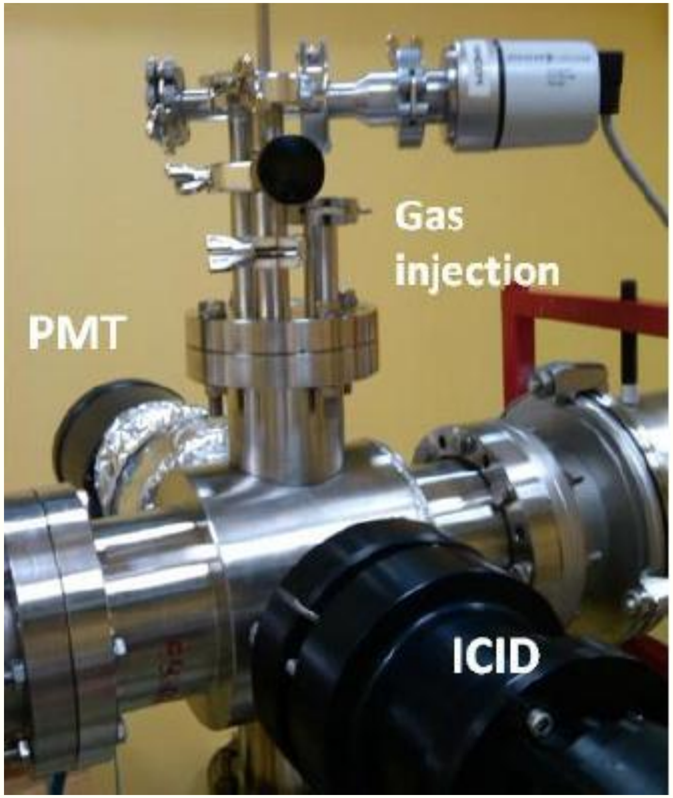
Beam Induced Fluorescense Monitor

- **P. Forck (GSI)**
- **4x2 @UNILAC operational**
  - **Intensified CCD camera**

  - **Option:**
    Fiber-optic bundle ⇒ shielding

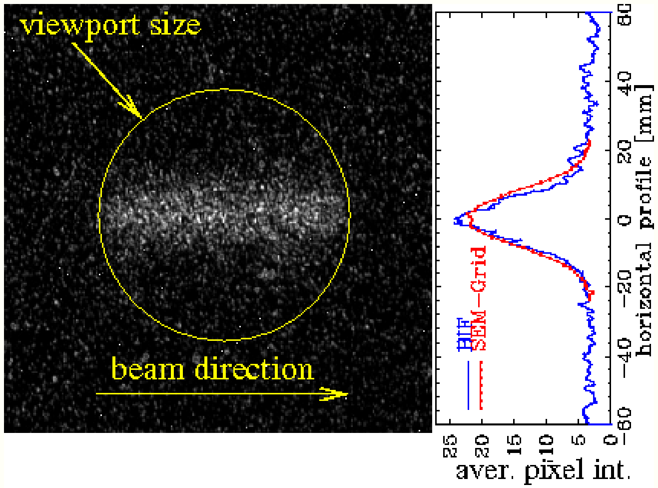


- **J.M. Carmona (CIEMAT/CAN)**
- **Prototypes:**
  - **Intensified radhard CID camera**
  - **Multianode PMT**

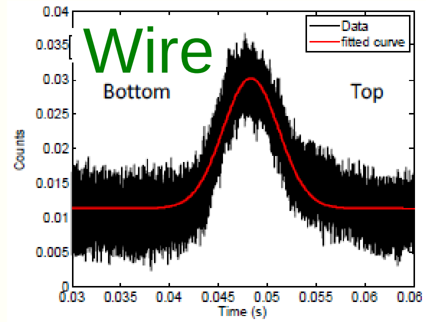


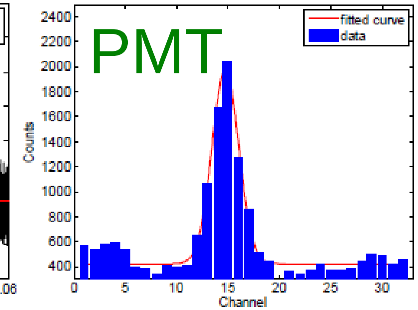
Fluorescense Monitor Signals

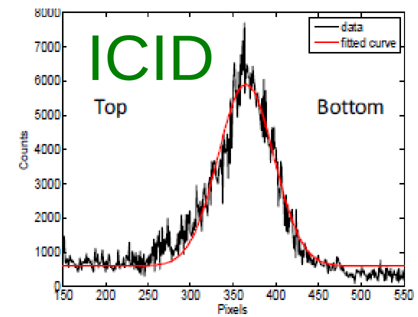
ICCD



- 4×10^{10} Xe^{48+} at 200MeV/u, p=10^{-3} mbar
- Signal ~ energy loss (Bethe-Bloch)
  Spectral analysis







Profiler	FWHM (95% C.I.)
Wire Scanner	2.44±0.03 cm
PMT	2.4±0.3 cm
ICID	2.42±0.07 cm

deuteron
Beam Energy=9 MeV
Beam Intensity=15 uA
Pressure=7×10^{-4} mbar of N_2
ICID voltage=1580V, τ=20ms
PMT voltage=900V, τ=5ms

- Switching of image intensifier within 100nsec
  ⇒ short exposure window (also fast PMT readout)

Background from radiation (&reflections)

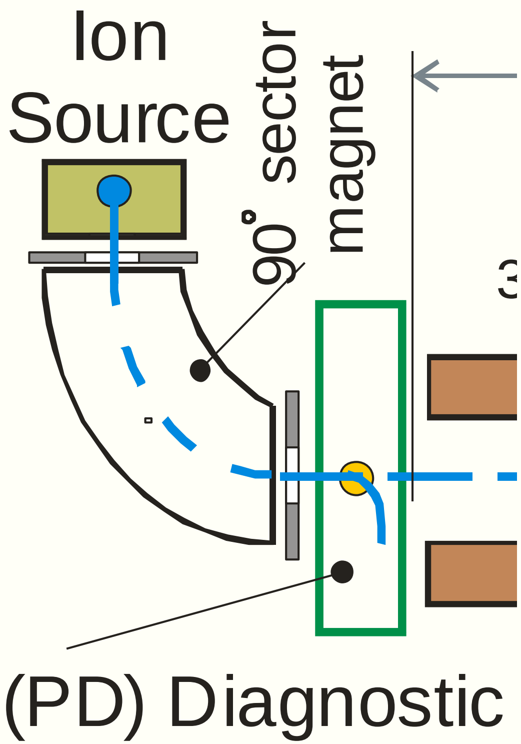
Background ~ E_{kin}^2
⇒ shielding required

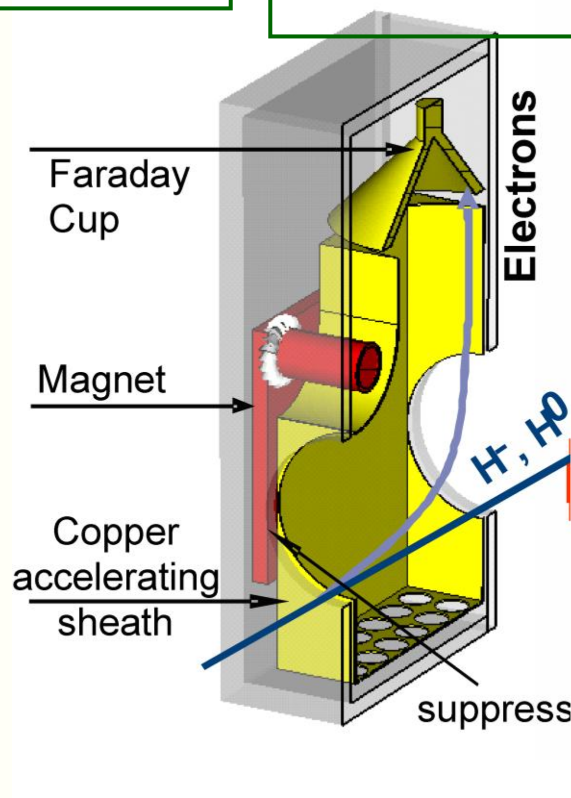
- No shielding
  – Doses of ~27.2 mSv/h for gammas and ~6.5 mSv/h for neutrons

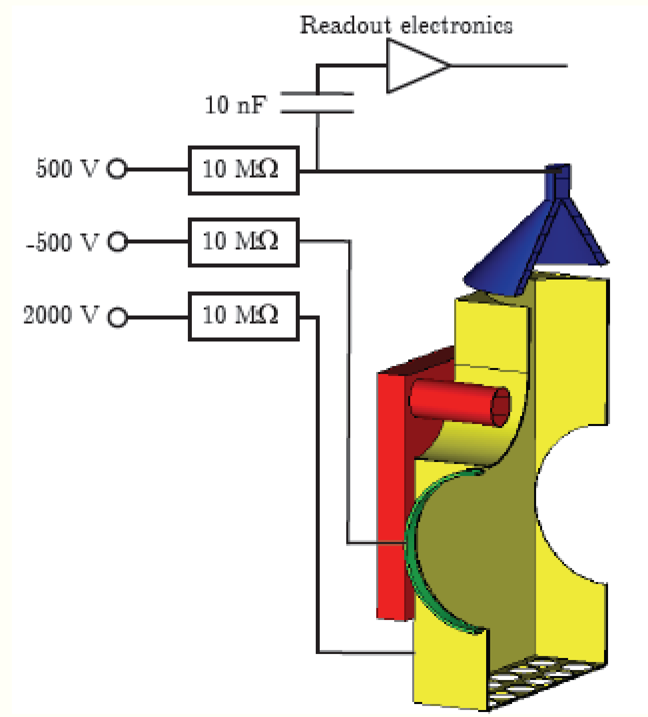
C. Gabor: Laser Wire for Low Energy H-

- **H- beam parameters:**
  - **60 mA, 70 keV, 2 msec, 50 Hz**

- **Problems**
  - **large background, due to H- beam losses (instable source)**
  - **Interference of the detection system to the H- beam**



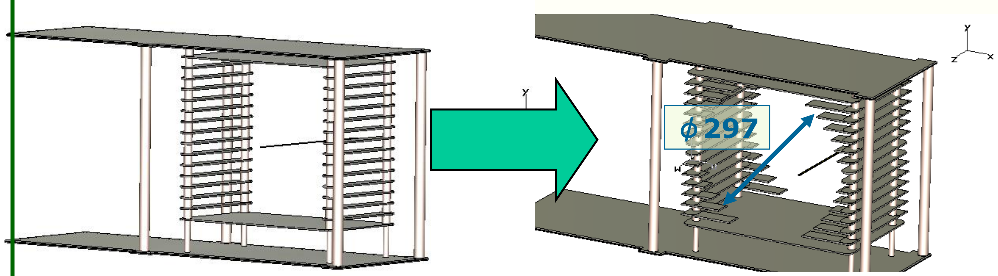




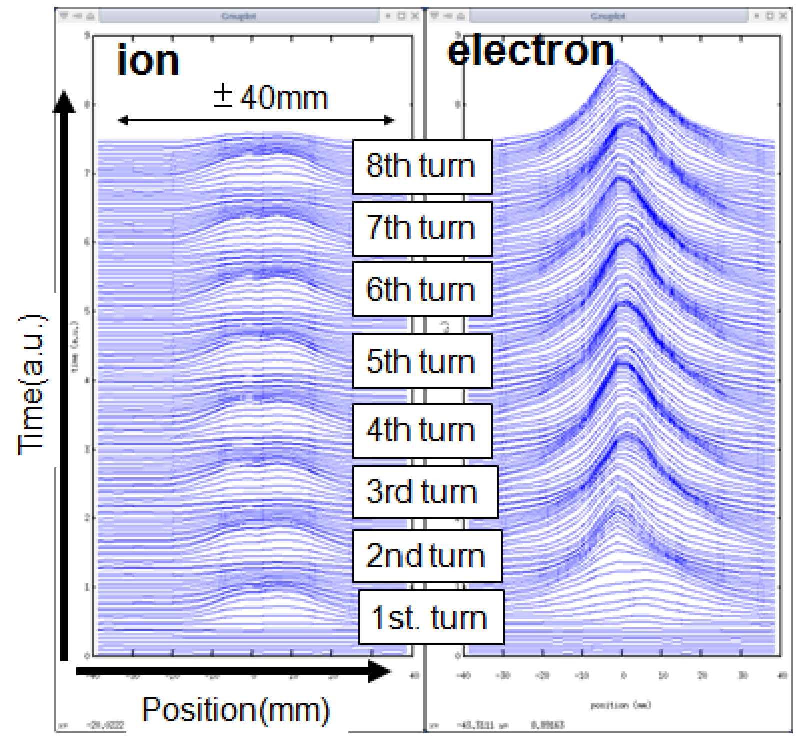
K. Satou: J-PARC IPMs

- Multi-strip anode read-out at MCP
- Electron generator arrays
  to check gain aging of MCP

- Problems:
  - Profile shrinkage (~2x) by external E-field (RCS-IPM)
    foreseen solution



  - Large and delayed signal in electron collection mode (MR-IPM)
    Reason not clear
    (Similar observation at other test setup)



M. Wendt: SRF Linac Beam Diagnostics

- **Essential beam instrumentation:**
  - **Beam trajectory**
    - **Beam position monitors (BPMs)**
  - **Beam phase, time-of-flight (TOF)**
    - **BPMs, WCMs, EO methods**
  - **Beam intensity**
    - **Toroid, wall current monitor (WCM)**
  - **Beam losses**
    - **BLM (ion chamber), TLM (*Heliax*)**
  - **Beam profile / emittance & halo**
    - **SEM (mulitwire), wire scanner, *Allison* scanner, slits, vibrating wire, laser diagnostics, e-beam scanner, IPM, etc.**
  - **Bunch profile & tails**
    - ***Feschenko* bunch shape monitor, laser diagnostics, etc.**

- **SRF issues:**
  - **High beam power -> low losses**
    - **Rule of thumb: <1 W/m**
    - **Residual losses of invasive diagnostics**
  - **Requires non-invasive diagnostics**
    - **Cavities: cleanroom class 10**
    - **Contamination from dissociated wire material, etc.**
  - **Cryogenic temperatures**
    - **Avoid moving parts in the CM**
  - **Cryo-string sectioning**
    - **Warm diagnostics sections**
  - **In the cryo-modules (CM): just BPMs, no other beam diag.! …perhaps BLMs!**

A. Aleksandrov: Theoretical vs. measured Beam Parameters

Accuracy of beam modeling in different parts of the SNS linac (informal)

	Transv. centroid	Transv. RMS	Long. centroid	Long. RMS	Halo
RFQ	NA	NA	NA	NA	No clue
MEBT	good	good	not so good	good	No clue
DTL	good	not so good	very good	NA	No clue
CCL	very good	not so good	very good	not so good	No clue
SCL	not so good	not so good	very good	NA	No clue