Summary of WG-E

Beam Diagnostics and Instrumentation for High-Intensity Beams

HB2012, Beijing

R. Doelling, N. Hayashi, V. Scarpine

List of 12 Talks

W. Blokland – Recent Developments on High Intensity Beam Diagnostics at SNS

P. Saha – Online Monitoring for the Waste Beam in the 3 GeV RCS of J-PARC

T. Xu – The Beam Diagnostics of CSNS

L. Nebot Del Busto – Detection of Unidentified Falling Objects at LHC

R. Singh/O. Chorniy – Measurement and Interpretation of the Betatron Tune Spectra of High Intensity Bunched Beam in the SIS18

V. Scarpine – Instrumentation Development and Beam Studies for the Fermilab Proton Improvement Plan Linac Upgrade and New RFQ Front-End

B. Walasek-Hohne – Optical Transition Radiation for Non-relativistic Ion Beams

P. Kowina – Momentum Spread Determination of Linac Beams Using Incoherent Components of the Bunch Signal

F. Becker – Beam Induced Fluorescence – Profile Monitoring for Targets and Transport

T. Maruta – Longitudinal Beam Diagnostics with RF Chopper System

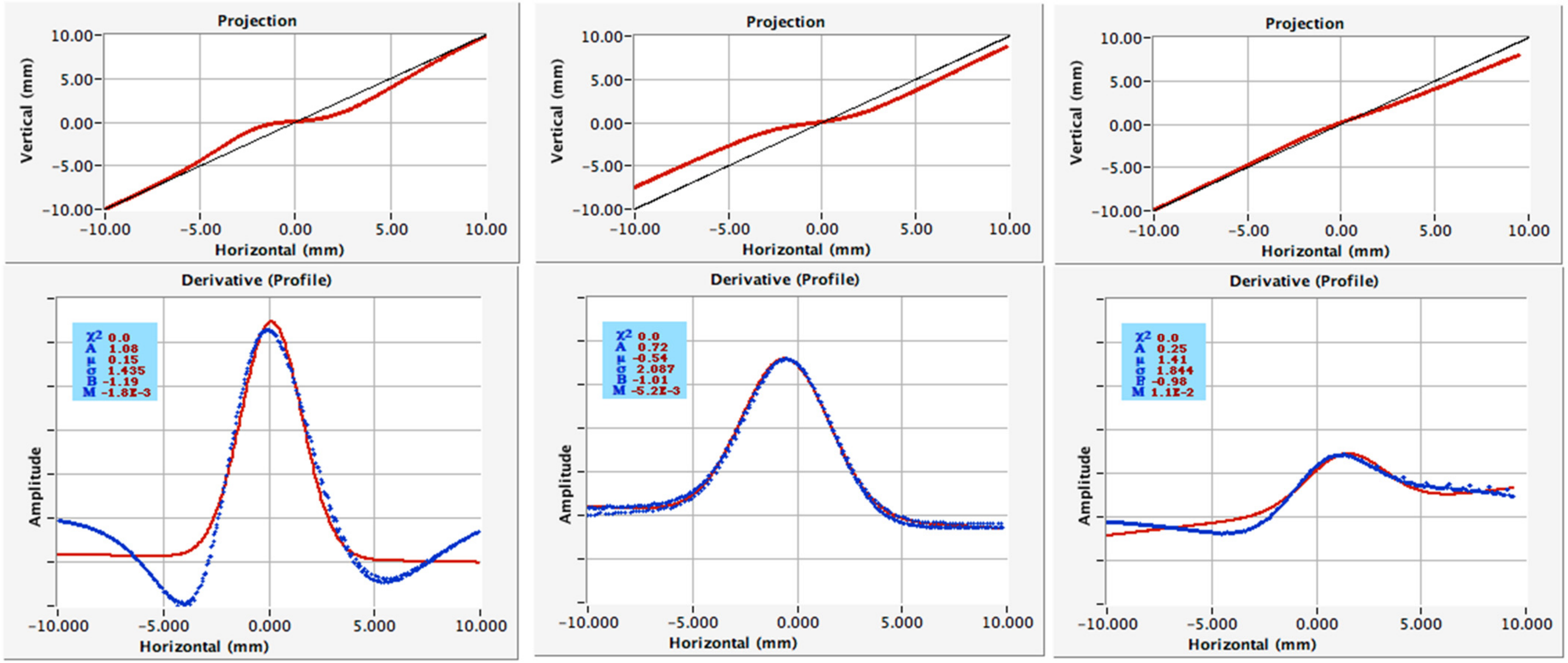
E. Holzer – Fiber Based BLM System R&D at CERN

P. Duperrex – On-line Calibration Schemes for RF-based Beam Diagnostics

Talk and Poster Statistics

- 3 profile - transverse
- 3 profile - longitudinal
- 3 losses
- 3 current/bpm
- 2 energy/momentum
- 1 emittance
- 2 overview
- 3 others

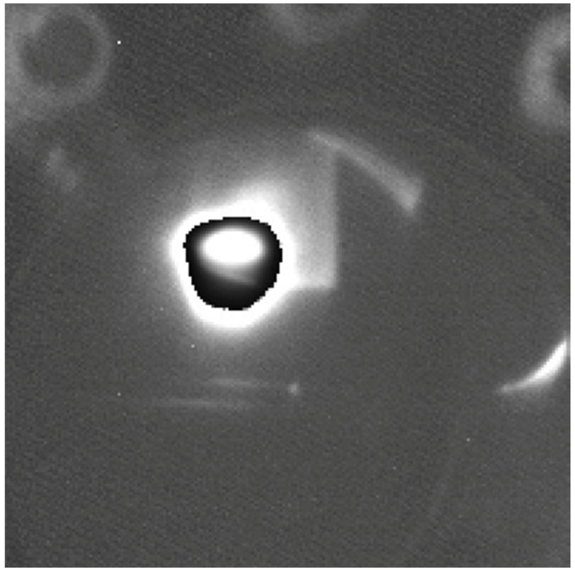
Electron Beam Scanner: Scan Length



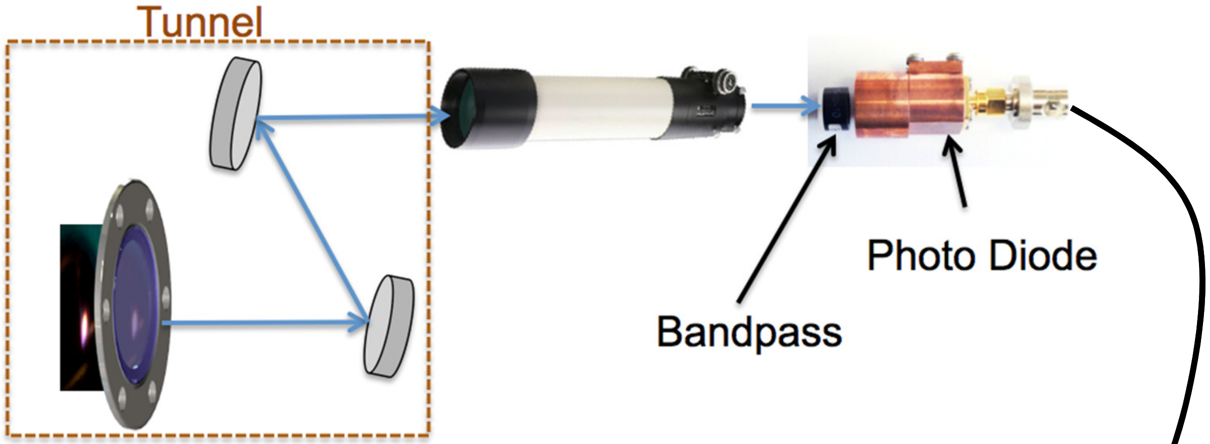
20 ns long scan | 3 ns long scan | Off-center, 7ns long scan

- Simulation to see what happens when the electron scan duration is longer than the proton bunch duration (ProjectX: Main Injector: 3 ns bunch)

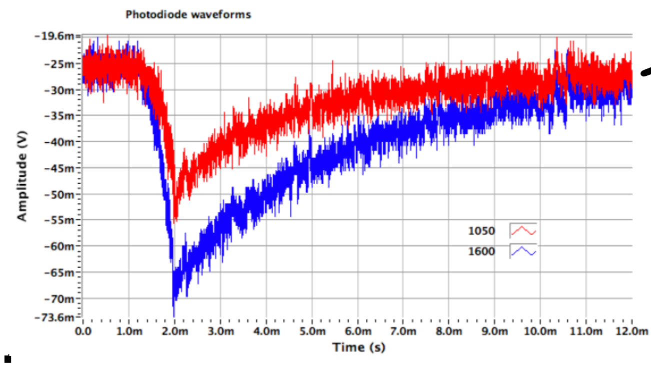
Foil Imaging System: Temperature



Control Room Display

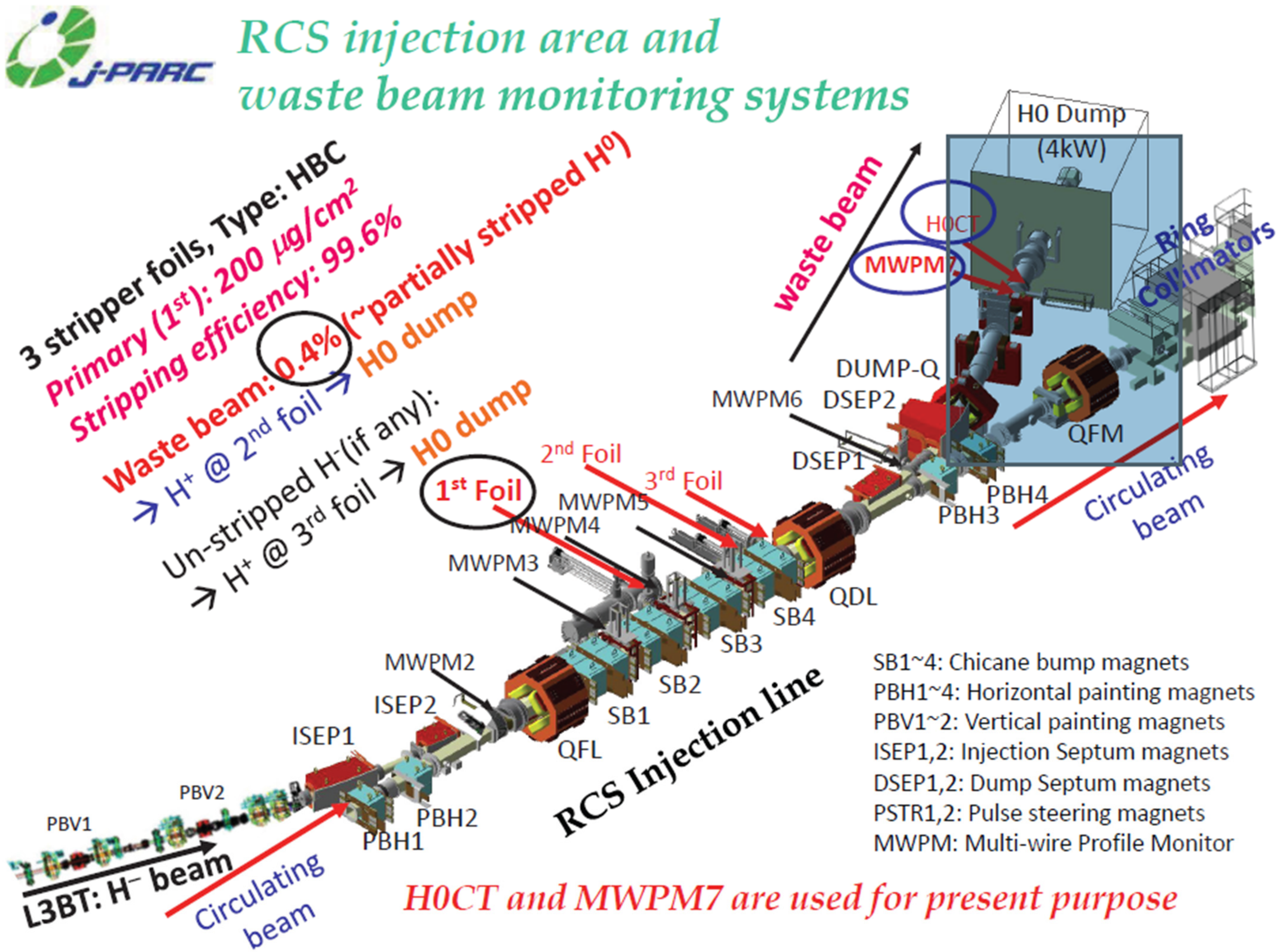


Temperature Measurement



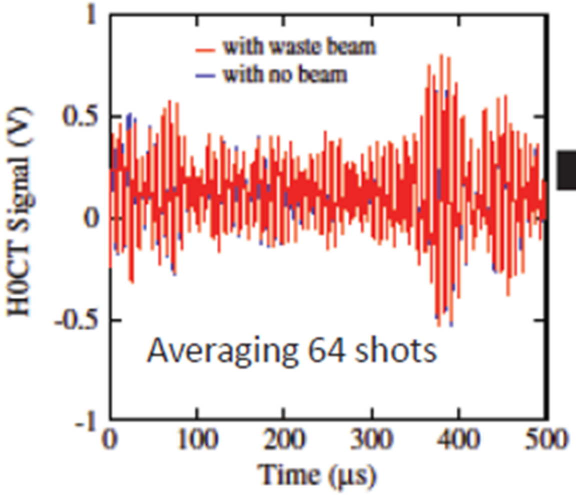
- **Display in Control Room to view foil**
  - **Does have some air turbulence and vibrations**
- **Temperature measurements**
  - **Photo Diode and Bandpass Filters in shielded eye-piece**
  - **Program created to input optical path characteristics to calculate temperature**
  - **Must limit light to spot on foil and scan foil area and counter turbulence**

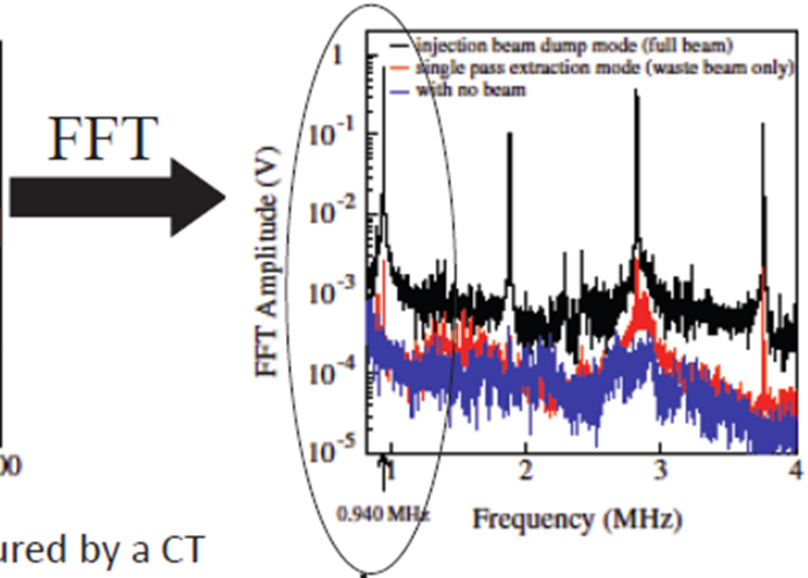
RCS injection area and waste beam monitoring systems



H0CT and MWPM7 are used for present purpose

Measurement technique

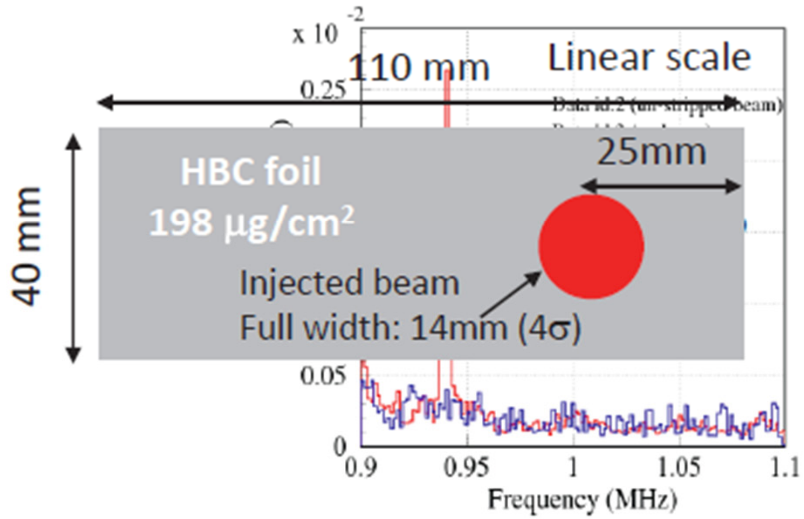


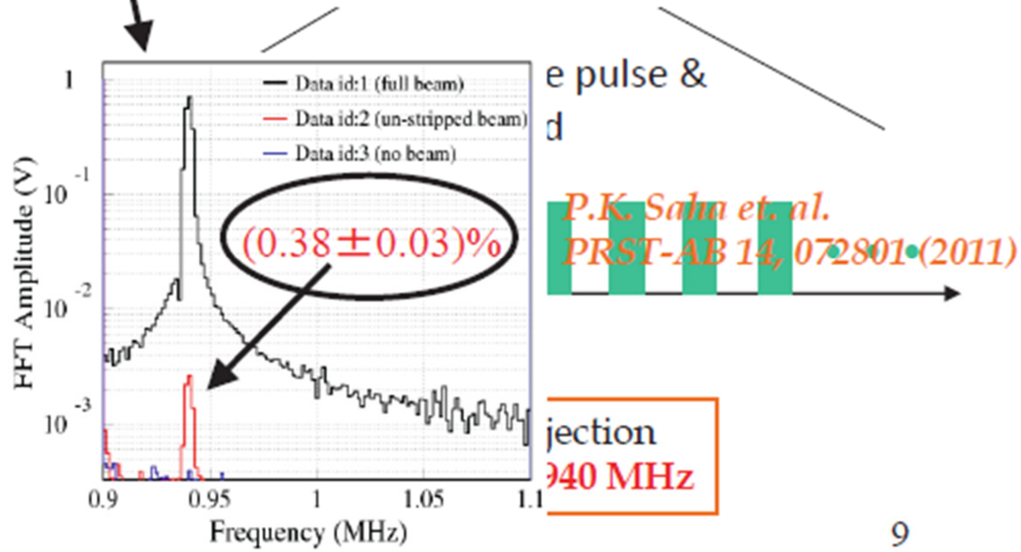


Typical waste beam signal measured by a CT

Very identical w/ beam and w/ no beam

→ Hard to extract real information





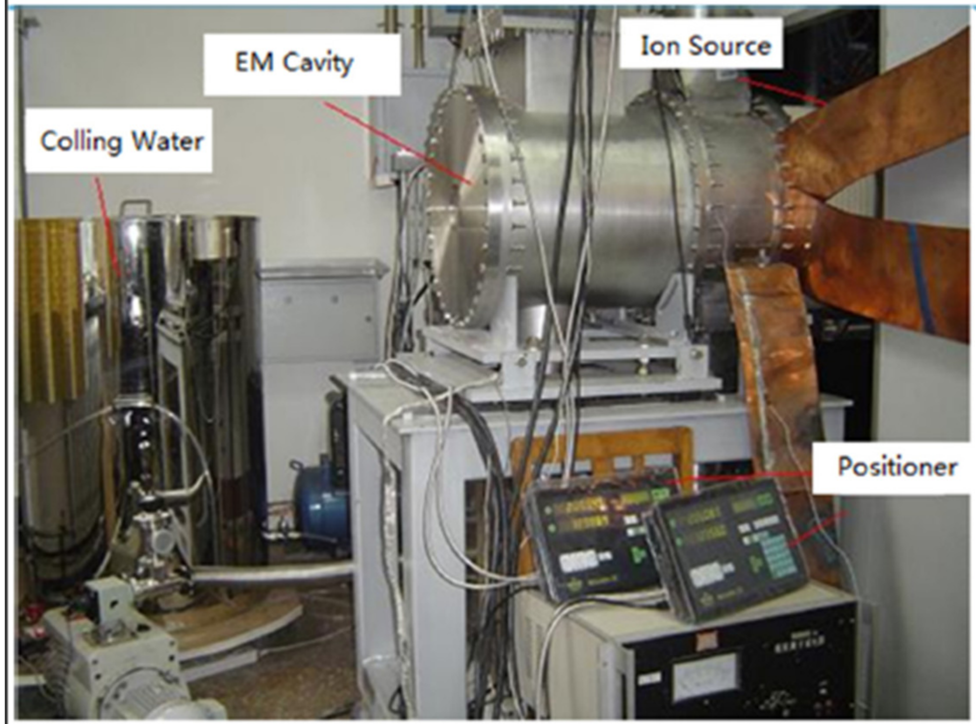
CSNS CHINESE ACADEMY OF SCIENCES

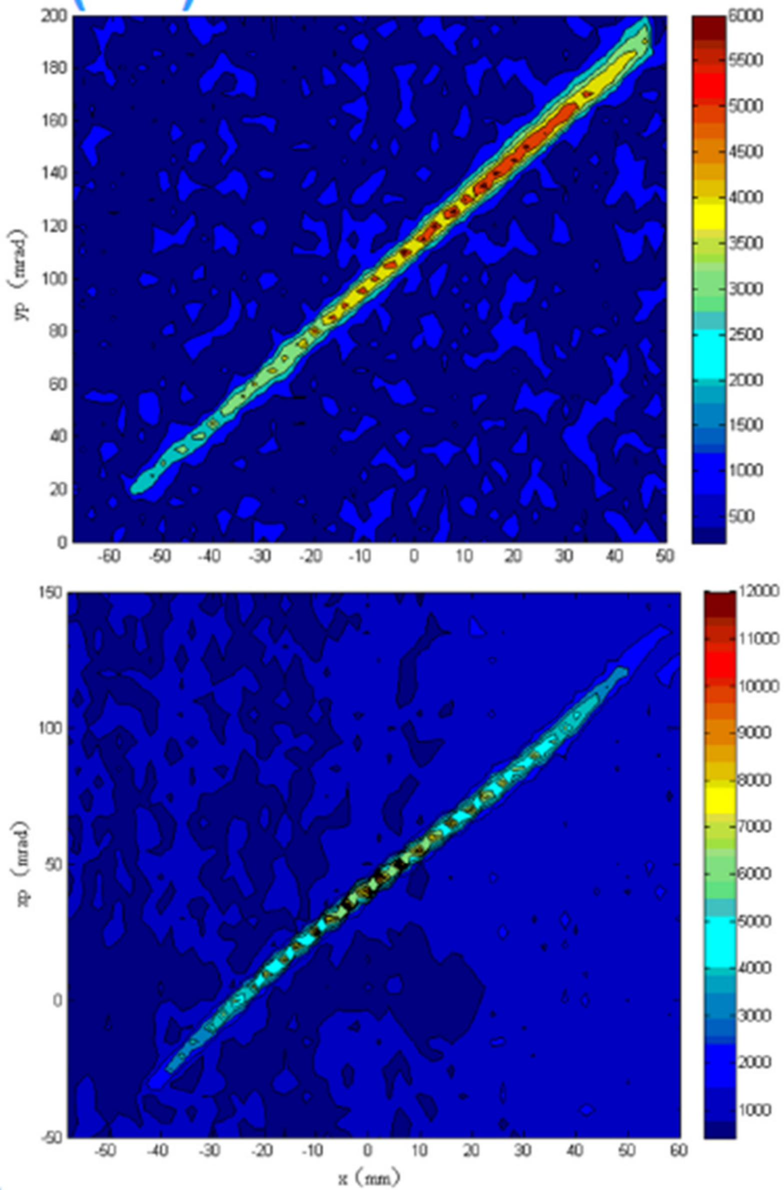
CHINA SPALLATION NEUTRON SOURCE

The progress of CSNS beam diagnostics

- RFQ Beam test (a halo study beam line after RFQ is built)
  - Strip line BPM
  - BCT
  - WS
  - BLM/FBLM
  - Phase measurement
- Ion source beam test
  - EM
- WCM
- Readout system

The progress of CSNS beam diagnostics (EM)



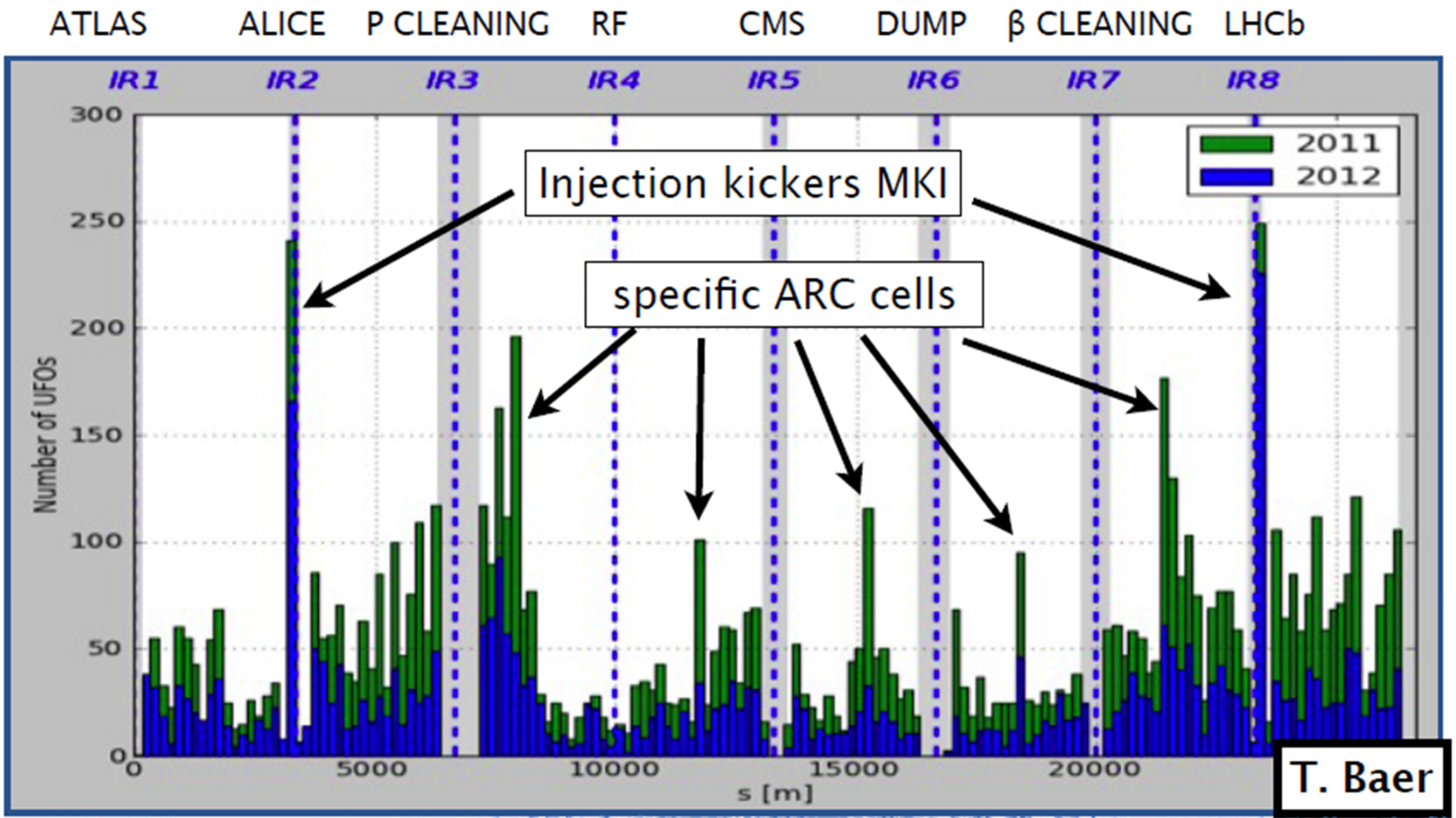


The ion source emittance is measured.

It need to do more measurement to improve the whole system.

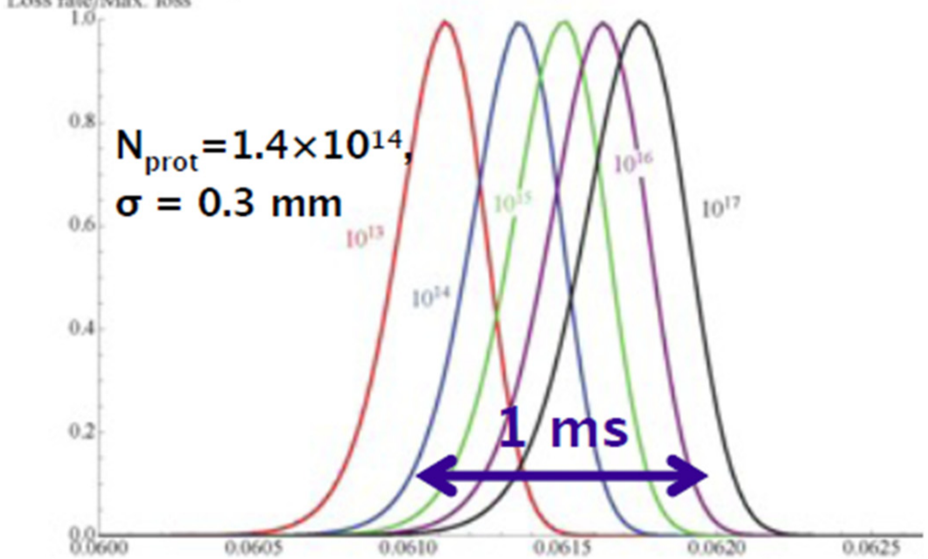
UFO observations I

Observation all around the LHC ring

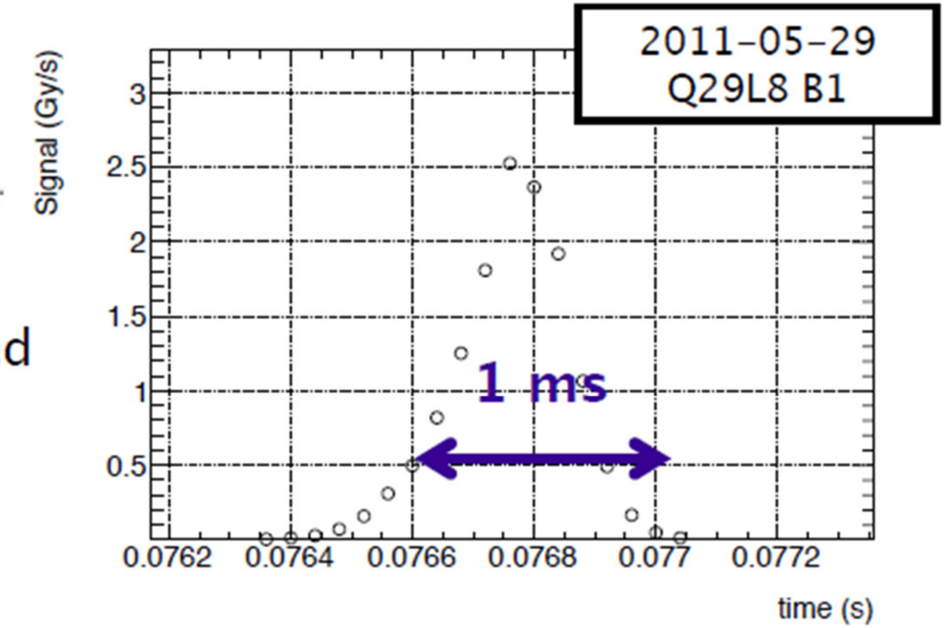


Predictions and observations

F. Zimmermann



Qualitative agreement between temporal loss rate predicted and measured. Comparable loss duration

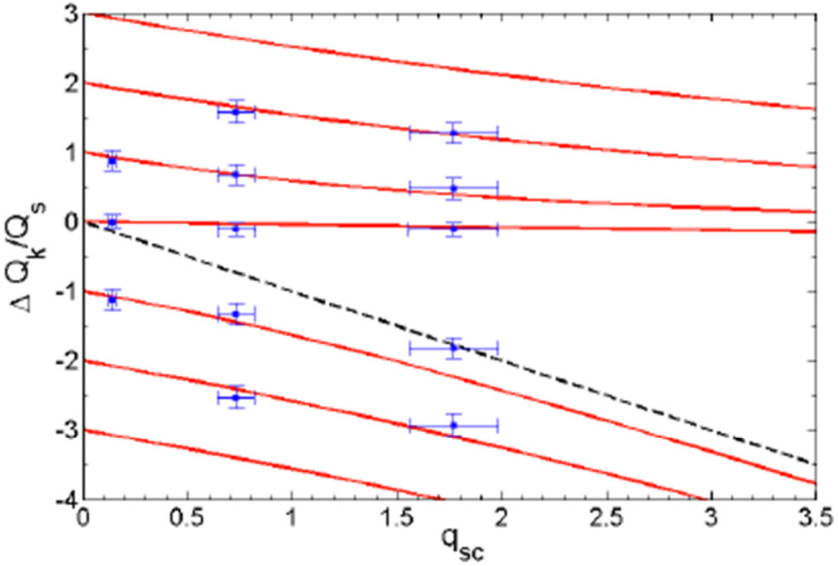


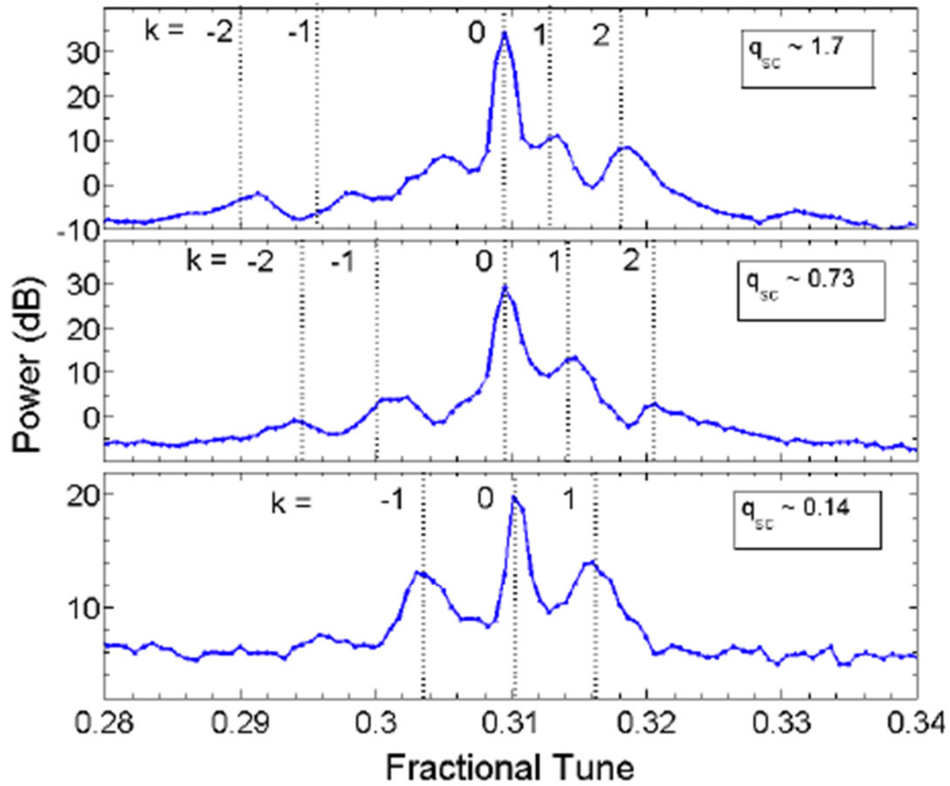
According to the model, the observed asymmetries contain information about the particle (mass).

Fit of the peaks position by head-tail modes

Horizontal tune spectra with Uranium beam

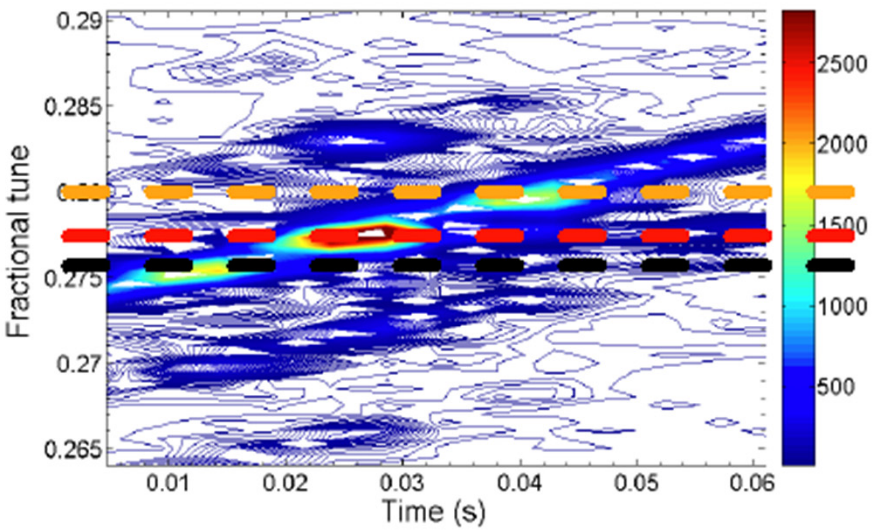
Head-tail tune shift:



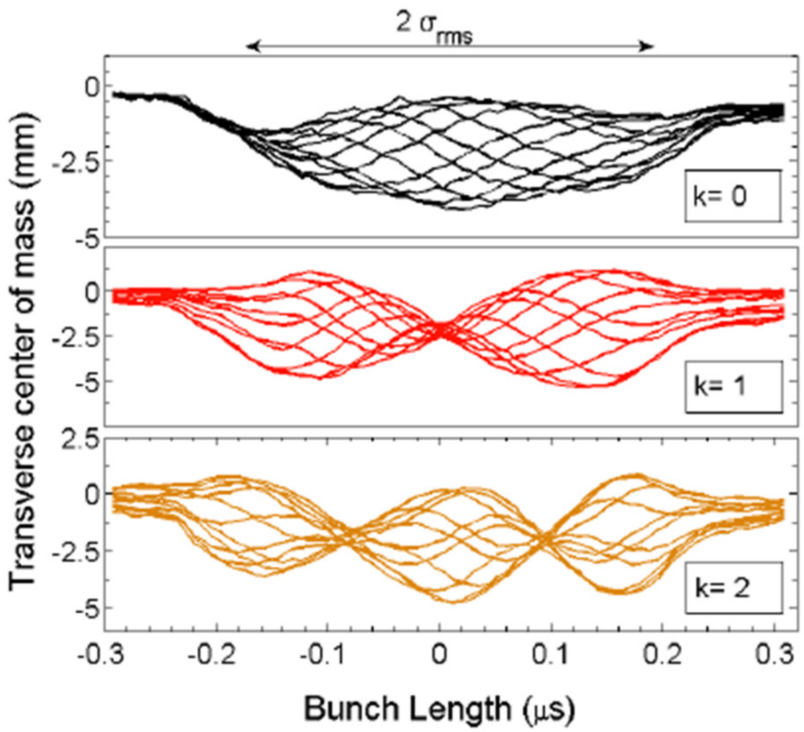


Excitation of particular head tail modes

- In order to excite particular modes we apply the frequency sweep.
- As soon as modulation frequency coincide with any mode frequency, the corresponding form of the mode was observed.



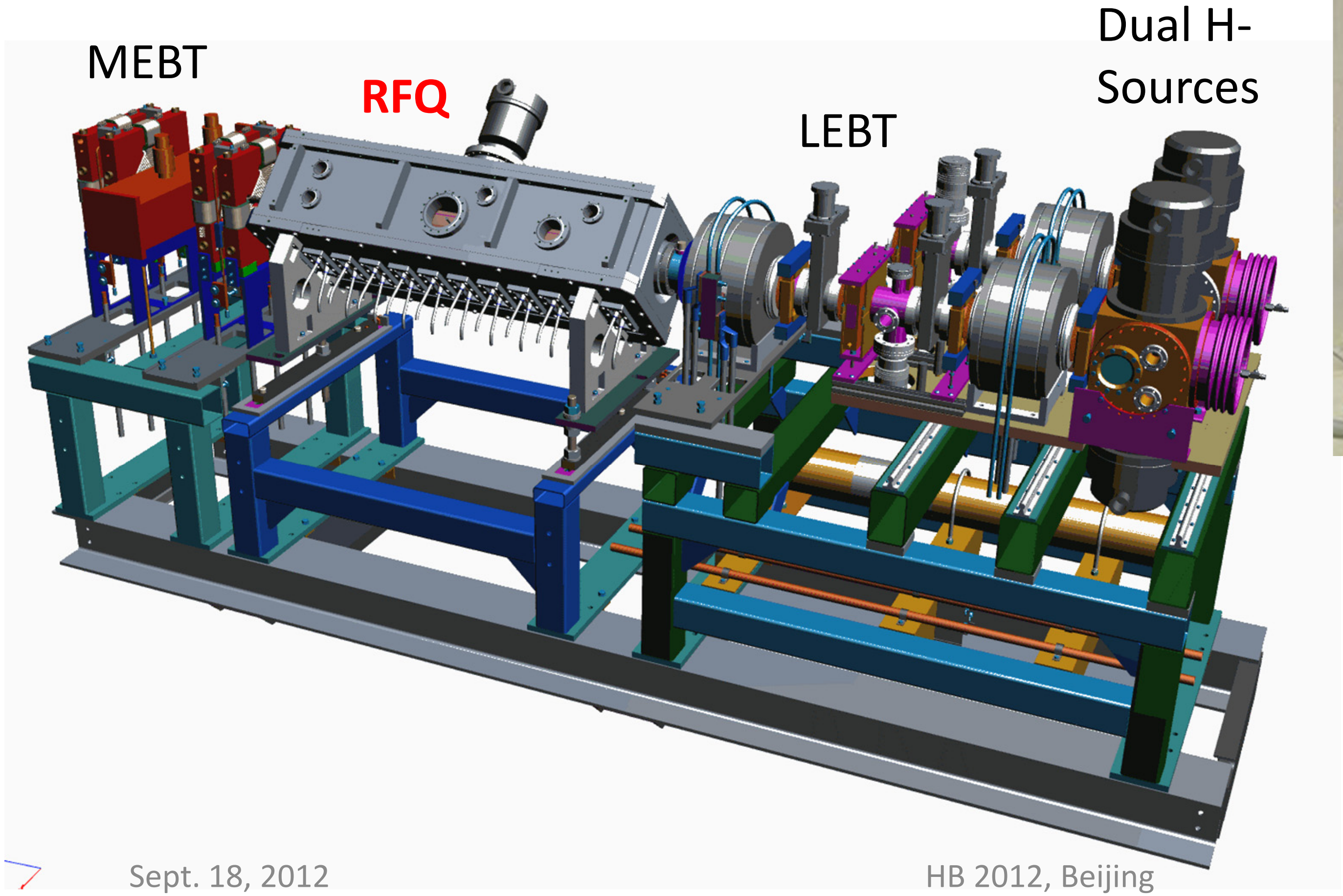
Bunch signal recorded by TOPOS (each curve is bunch signal)



Fermilab PIP Front-End Upgrade

Upgrade Fermilab linac front-end :

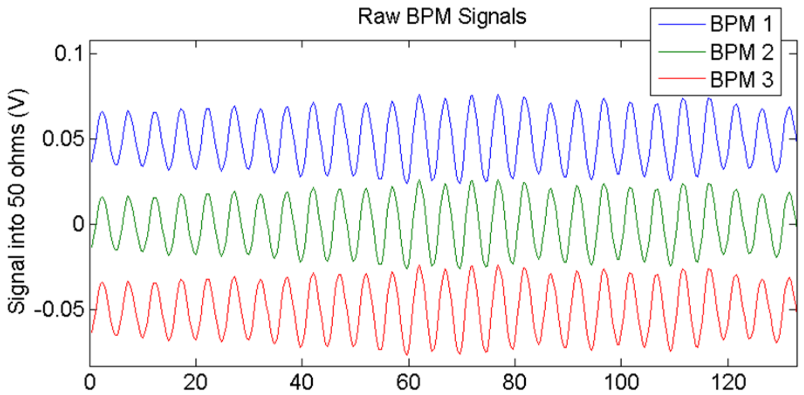
- Replace present sources and Cockcroft-Walton
  - Liability; large source of down-time
- Dual H- sources – 65 mA @ 35 KeV
- New 201.25 MHz, 750 KeV, 4-rod RFQ

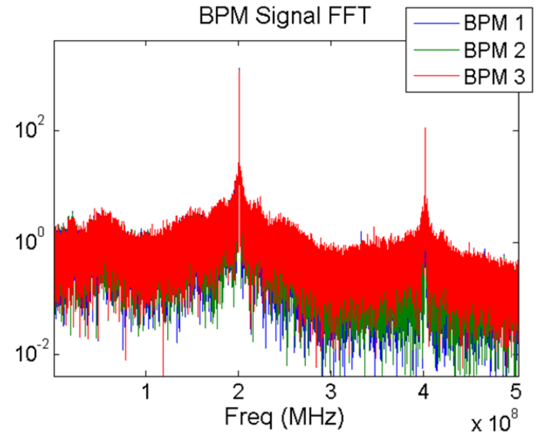


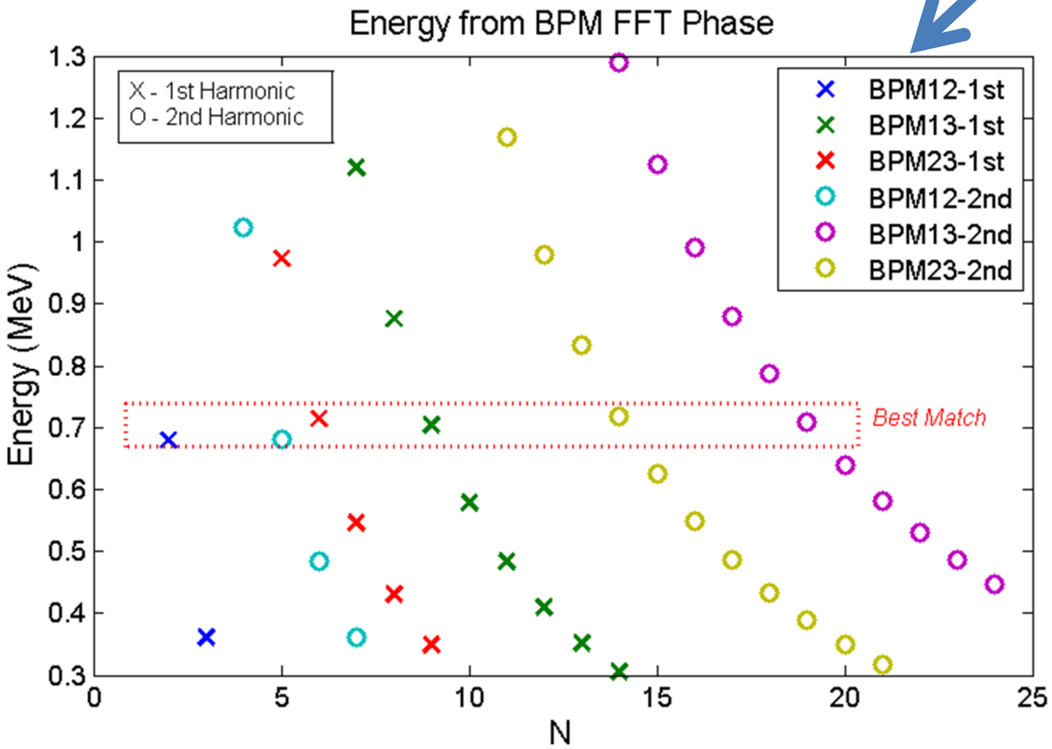
(2) Direct Scope Measurements

All three BPM signals into high-BW scope – *no filters, no phase monitor*

– Capture many bunches → FFT → unwrap phase from 201.25 MHz FFT



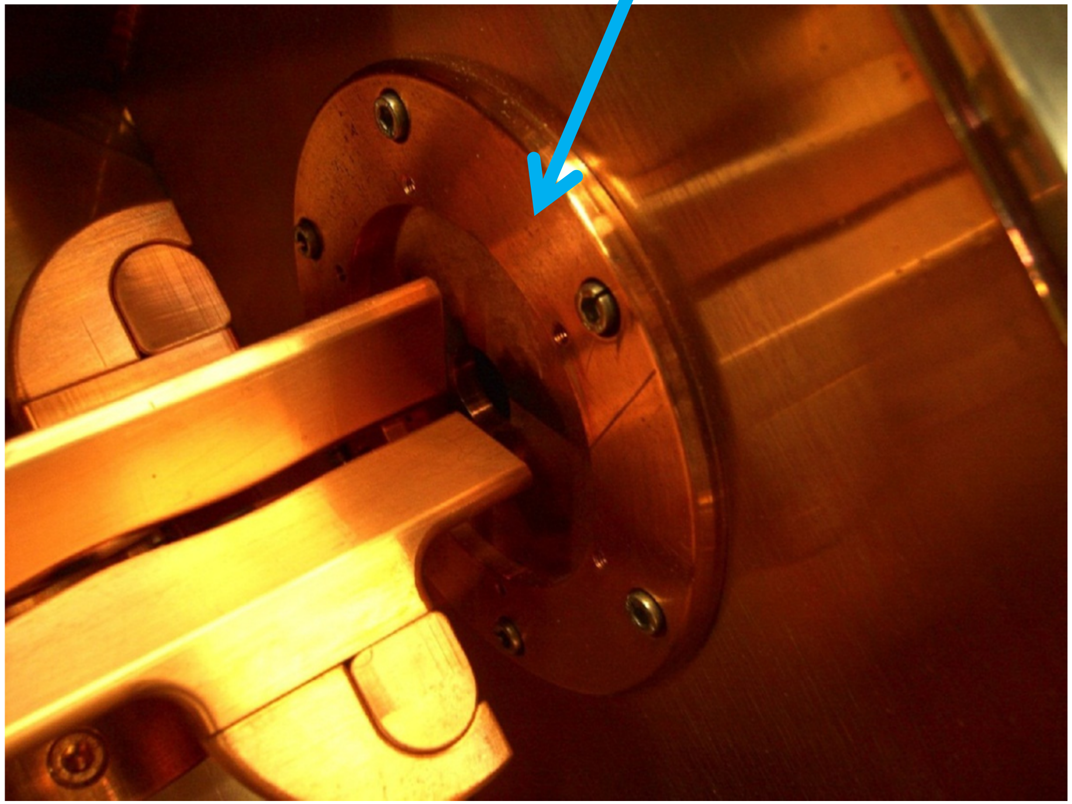


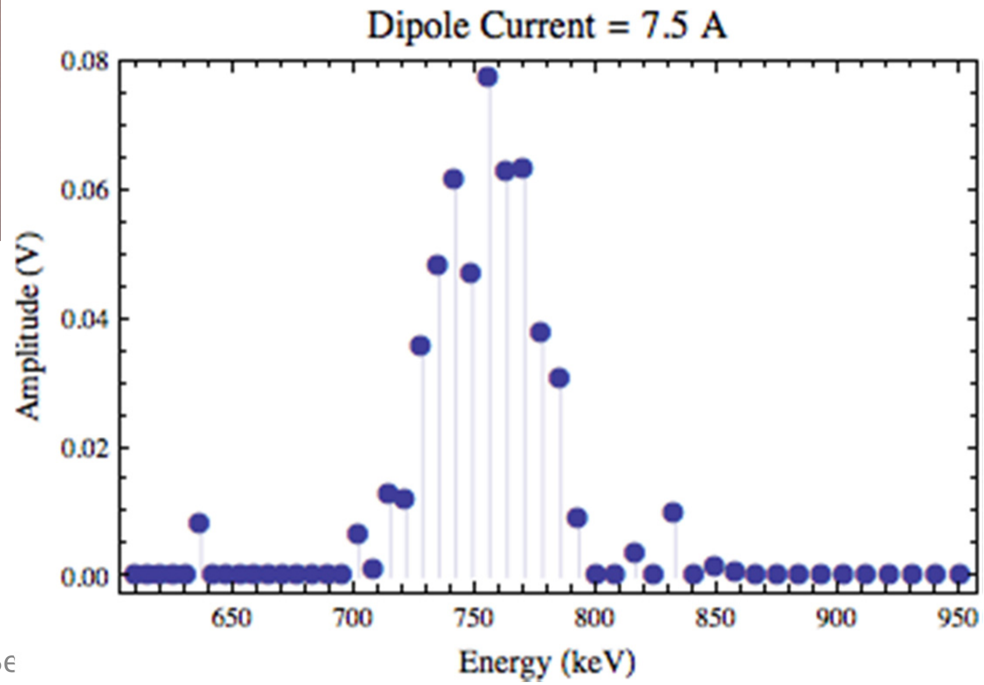


Energy still Low

RFQ Power (KW)	Energy (BPM 1 to 2) keV	Energy (BPM 1 to 3) keV	Energy (BPM 2 to 3) keV
212	0.716	0.705	0.701
220	0.716	0.704	0.699
233	0.716	0.705	0.700
206	0.717	0.706	0.702
182	0.706	0.706	0.707
162	0.669	0.710	0.556

End plate inside RFQ

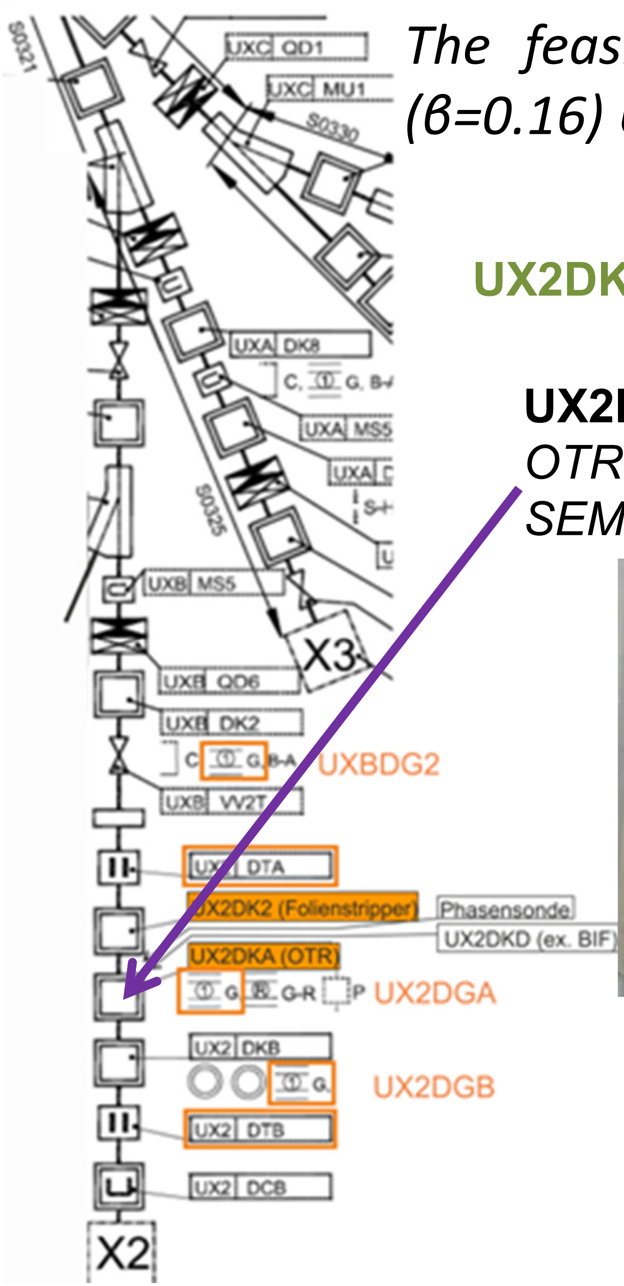




Energy now 756.5 +/- 0.5 keV

Experiment location

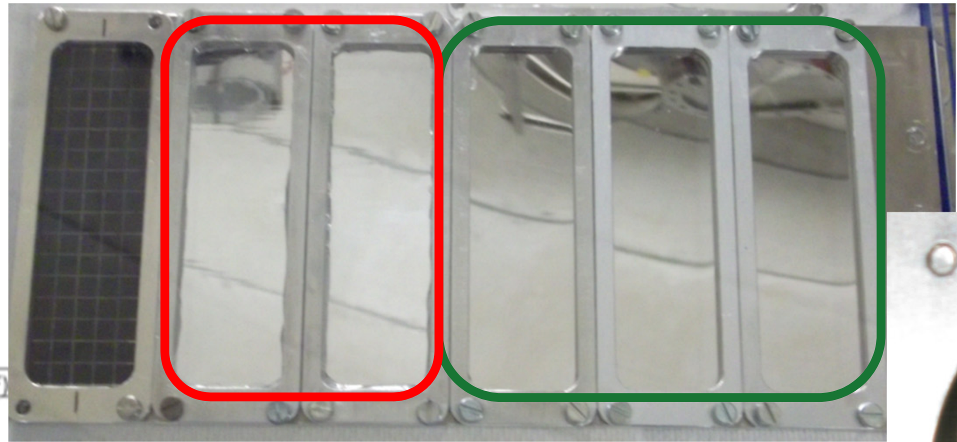
B. Walasek-Hohne – Optical Transition Radiation for Non-relativistic Ion Beams

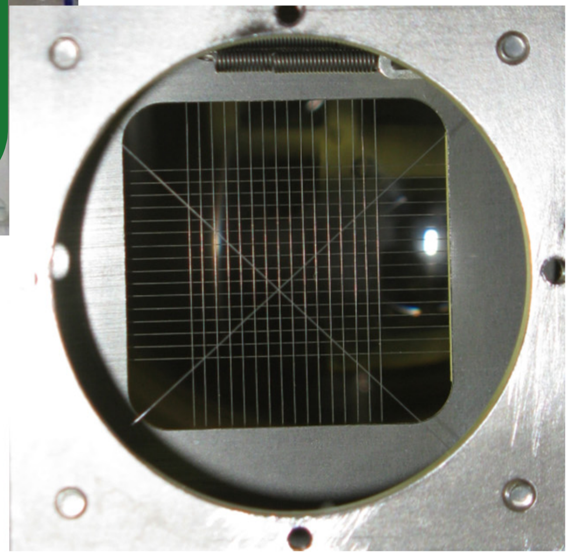


The feasibility of OTR has been evaluated with an 11.4 MeV/u (β=0.16) U^{28+} beam at the UNILAC (X2 beam line)

UX2DK2 (Stripping foil location), used materials: Carbon 570 μg/cm^2

UX2DKA diagnostic chamber:
OTR Targets: 10 μm aluminum on Kapton foil and 500 μm stainless steel
SEM-Grid (UX2DGA) for transversal profile comparison





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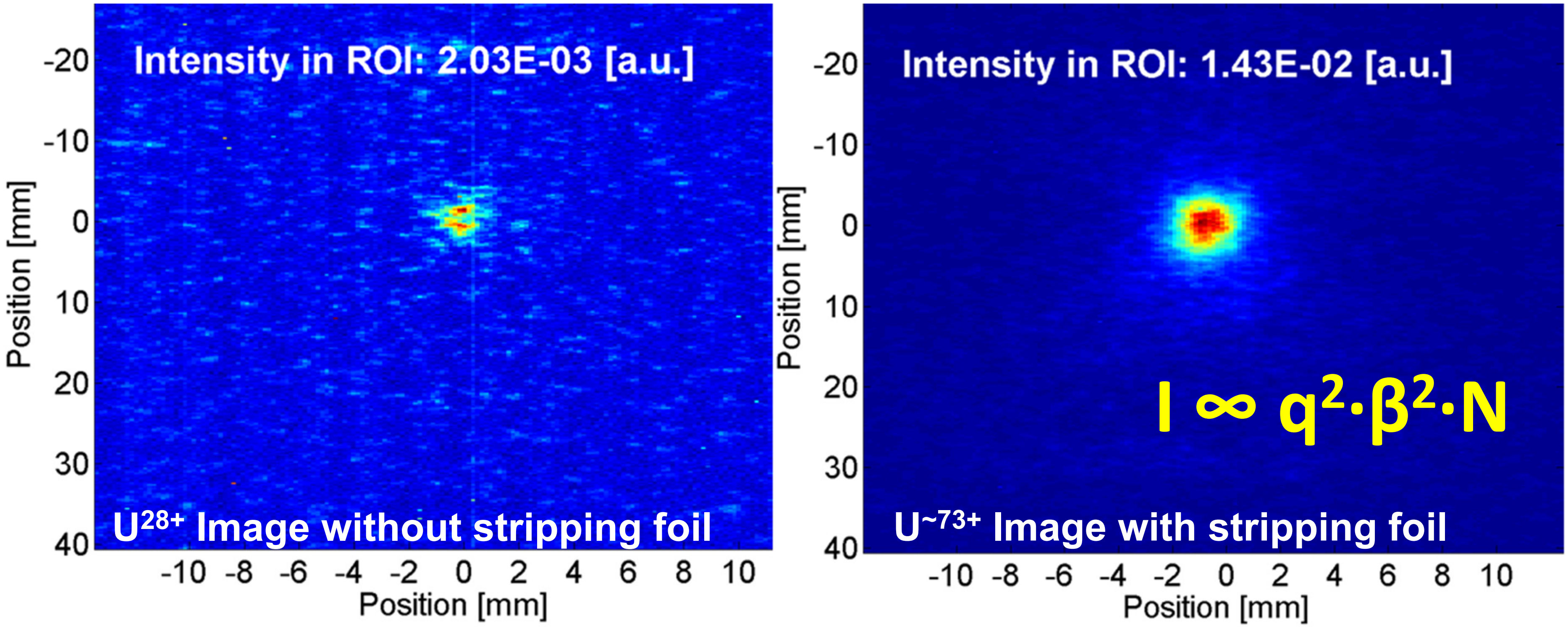
First results – q^2 dependency

Number of emitted OTR photons depends on q^2. Stripping foil increased mean charge state from q=28 to q~73. Expected signal growth by a factor of ~7.

Beam distributions for both charge states, but same ion number of ~$2.6\cdot10^8$



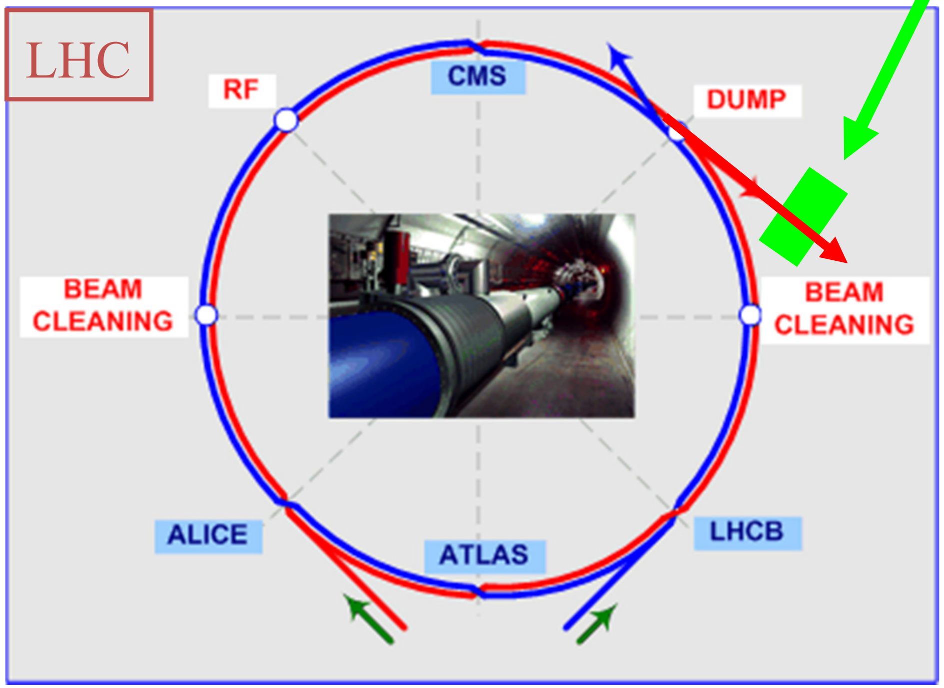
→ the ratio of the integral ICCD intensities roughly supports q^2 dependency:

$1.43\cdot10^{-2}/2.03\cdot10^{-3} \sim 73^2/28^2 \sim 7$

But: due to low signal strength, results are very sensitive to noise and chosen ROI

"Gedankenexperiment"

- Consider a quite large synchrotron with big number of circulating bunches like e.g. LHC.
- At injection revolution frequency is f_0 = 11.24 kHz which gives a period of T_{rev}=89 µs.
- Can we see any Schottky like signal if we do a measurement for let say 80µs only, i.e. each bunch pass our pick-up only once?
- If yes, the signal measured in the beam dump should have the same structure.
- What happen if we "skip" the synchrotron in the front of the dump?
- Is it only question of dispersion?

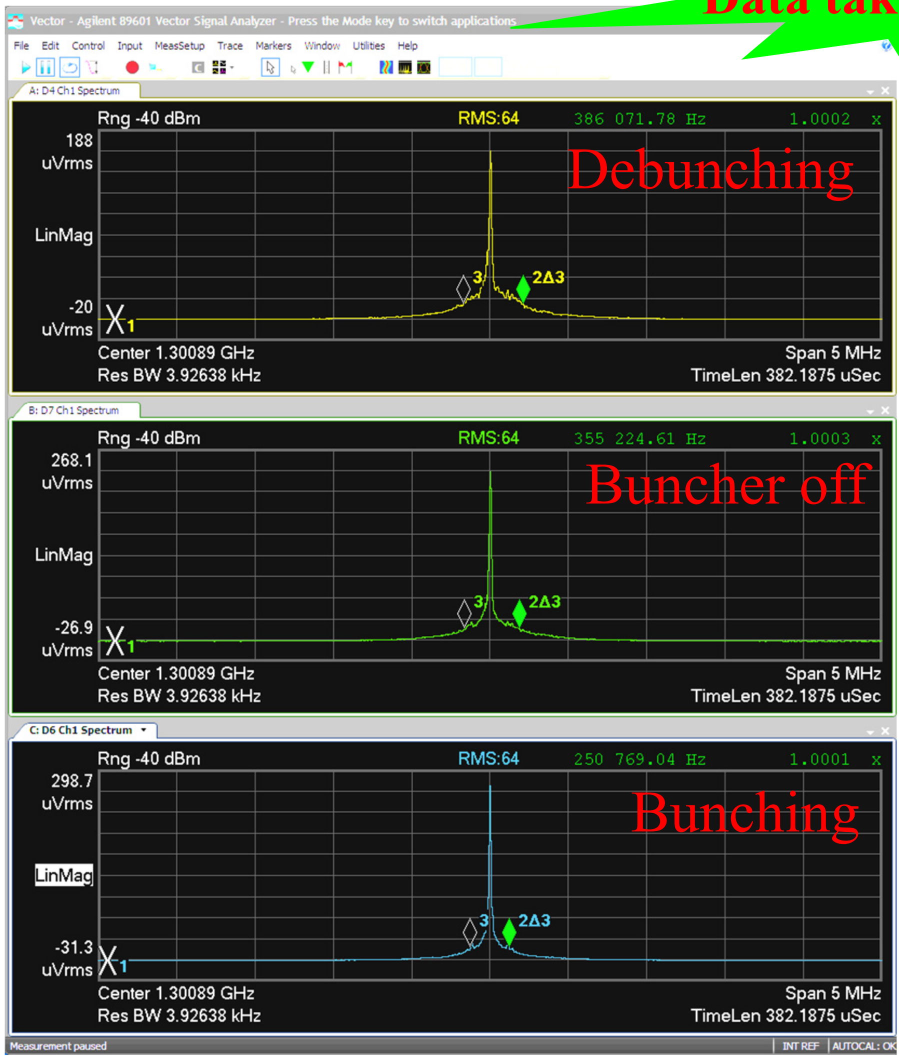


Parameters:
2808 bunches
E_{inj}=@450 GeV
f_0=11.24kHz
T_{rev}=89µs
γ_{tr}=55.67
α=3.2e-4
γ_{inj}=480
η=-=3.2e-4

Results of the "Linac Schottky" measurements

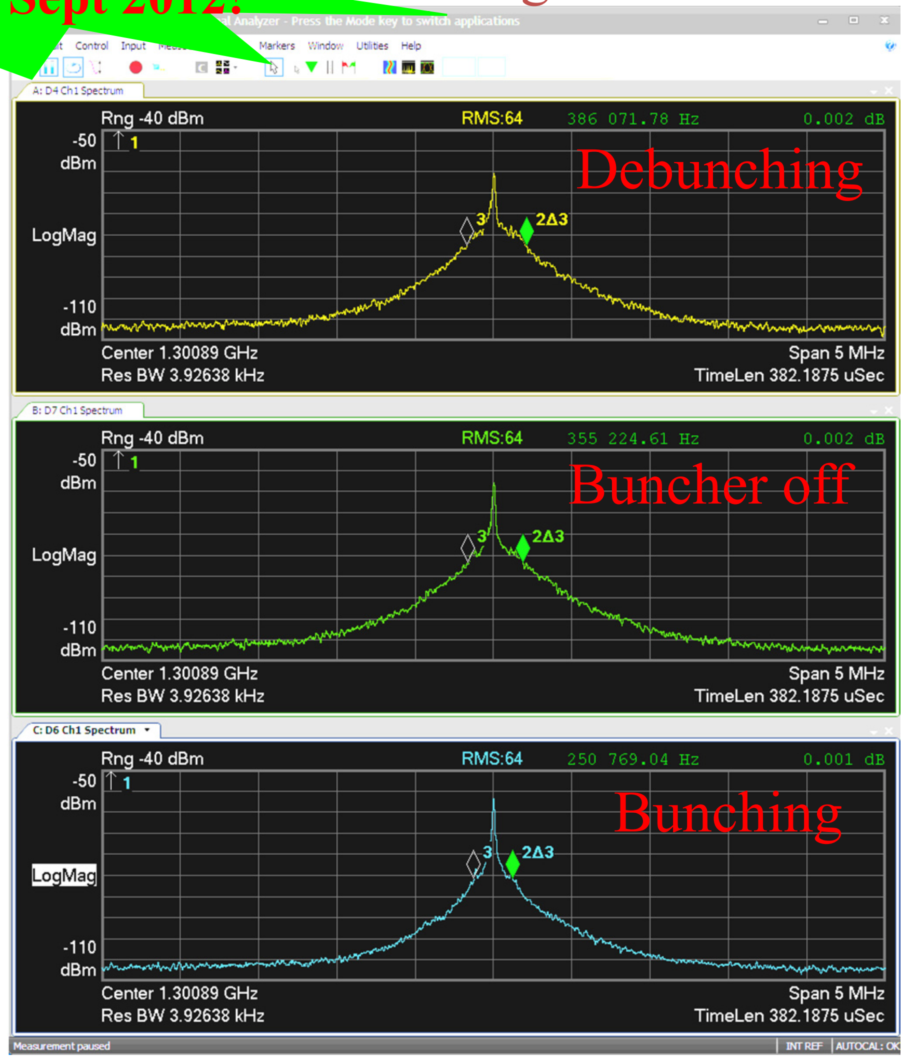
Data taken on 12th Sept 2012!

Linear scale



Decreasing momentum spread ↓↓

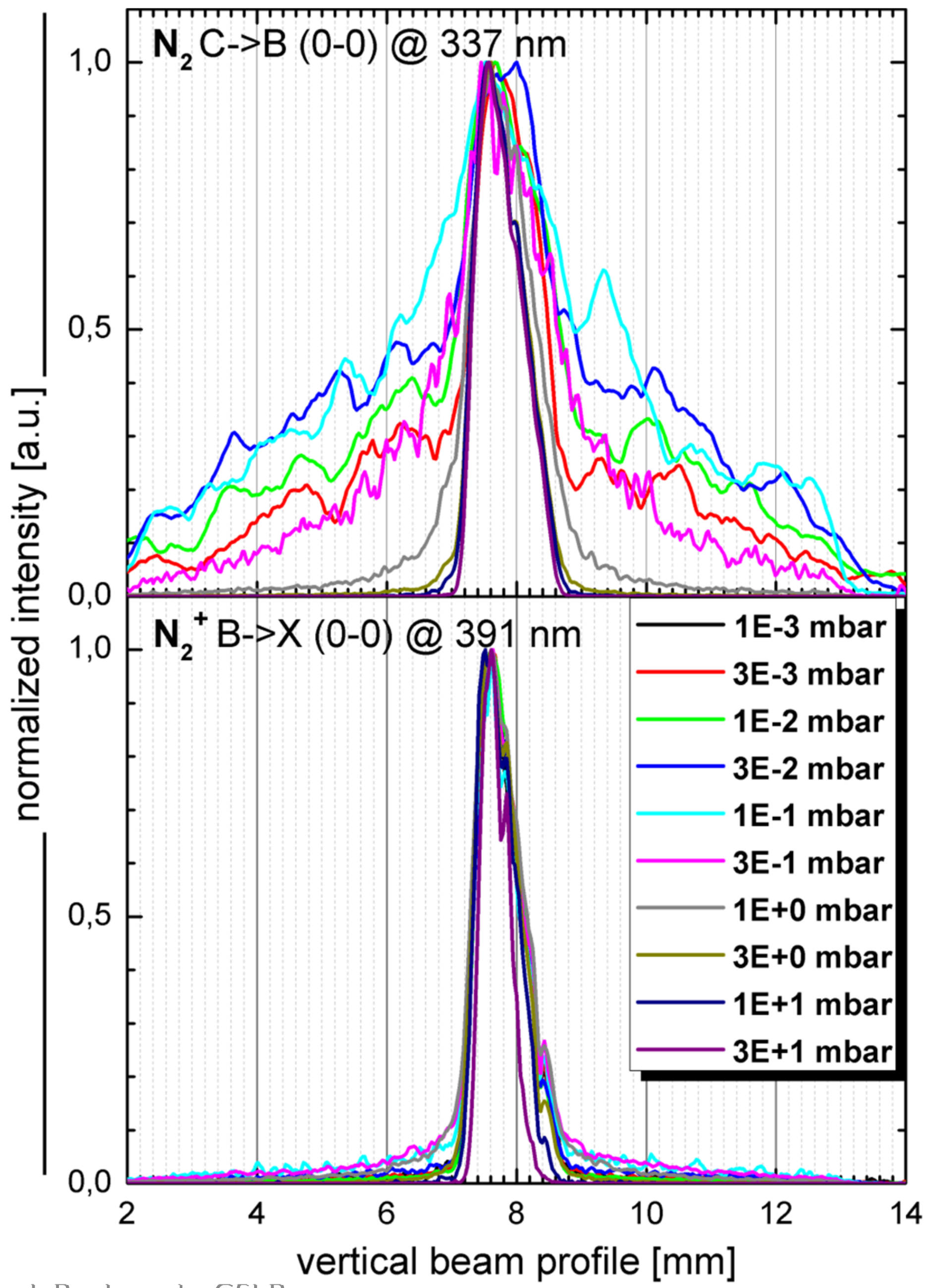
Logarithmic scale



Very preliminary data! => precise data analysis needed.

Transition Selective Profile Analysis N_2

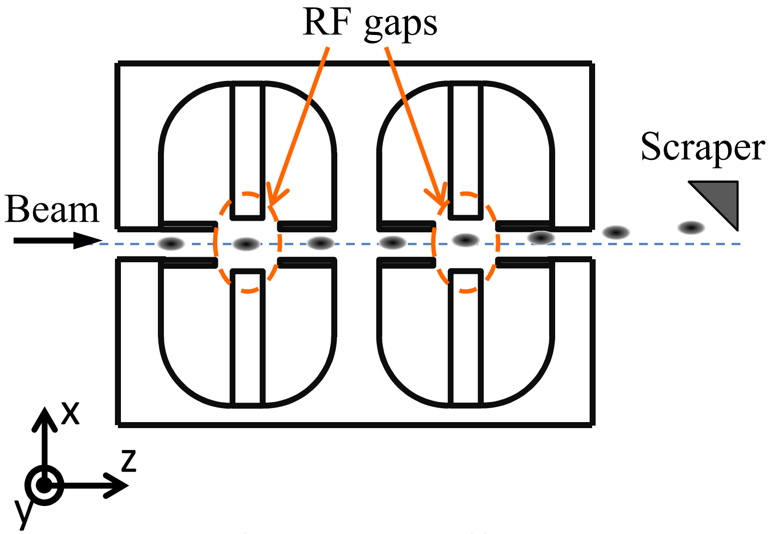
- Spectral acceptance (ROI) 8 nm to select transitions separately
- Profiles of neutral transition N_2 show in- and decreasing halo (one tick is 200 µm)
- Profiles of ionic transition N_2^+ unchanged from 10^{-3} to 30 mbar
- Fluorescence light in rare gases distributed among several lines but similar tendency is observed



N_2^+ B→X (0-0) should be selected

PLAY MOVIE HERE

Principle of the RF Chopper System

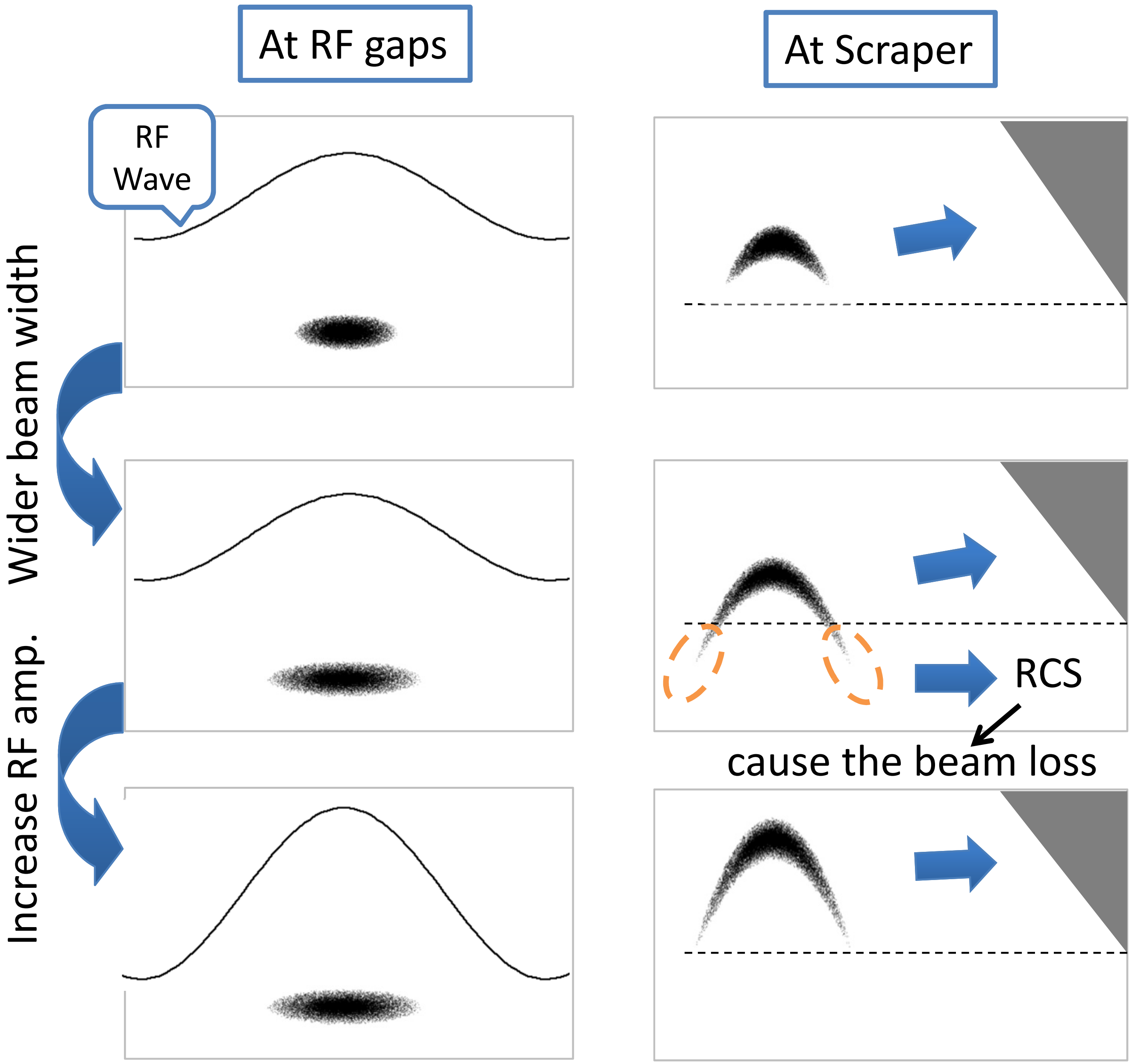


Beam is horizontally deflected by two RF gaps.

Deflection angle depends on

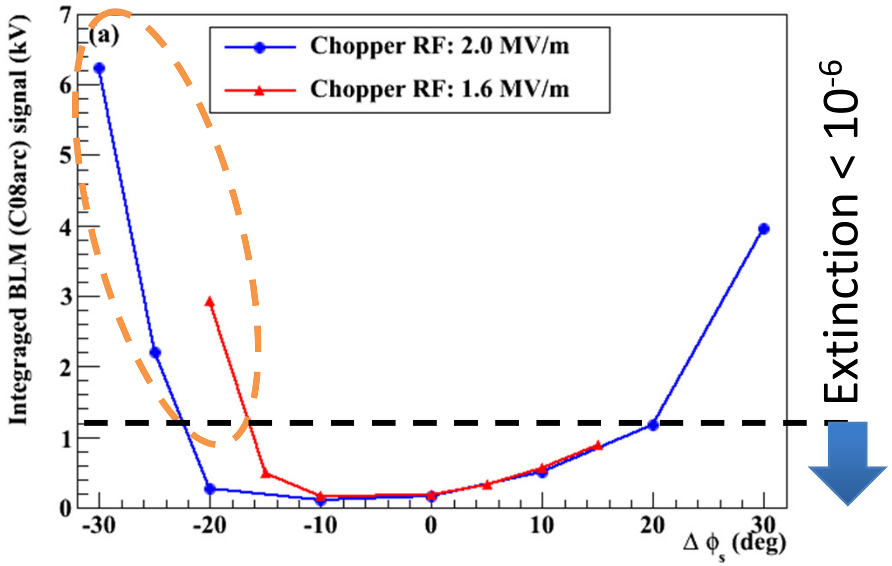
- RF amplitude
- (Inversely) Beam width on phase axis

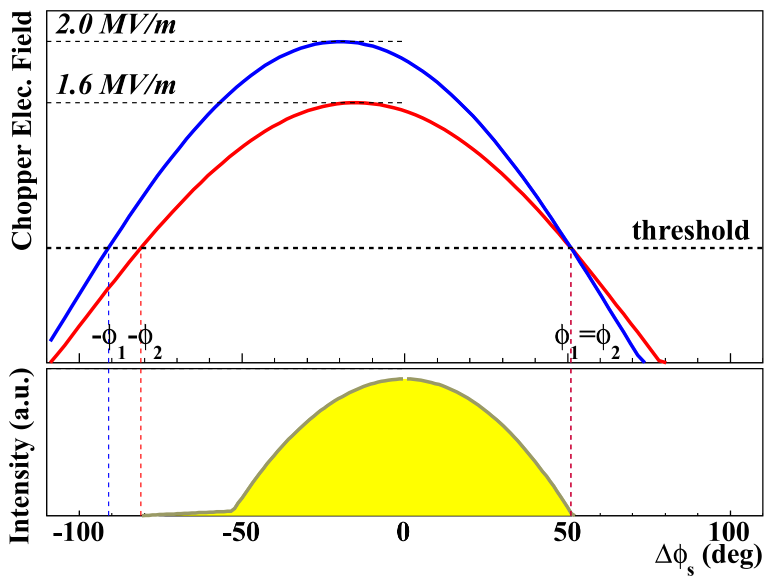
If beam becomes wider, higher RF amplitude is required to eliminate them.



Beam Size

Evaluate the longitudinal beam size from the phase and amp. scan result.





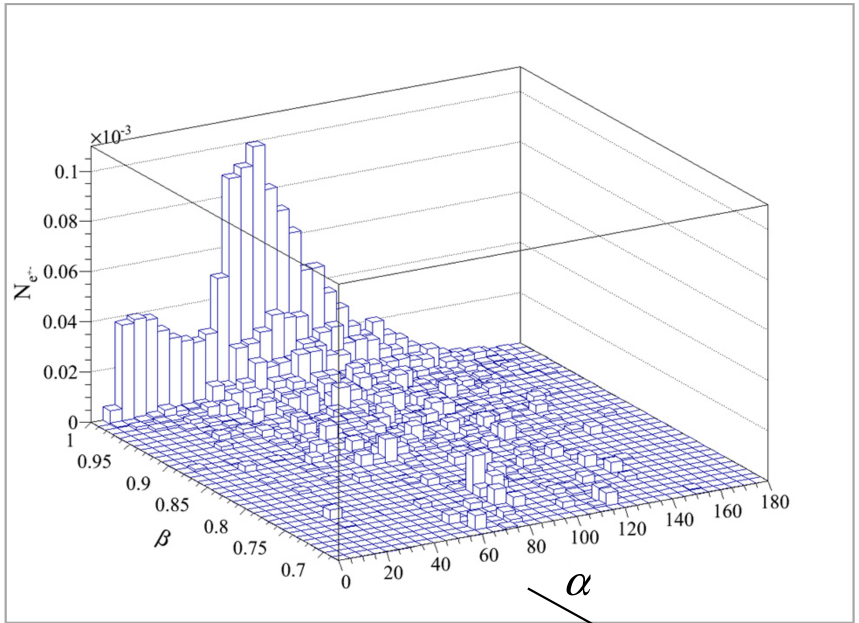
- Beam tail (fraction > 10^{-6}) is near to the edge of effective region at
  - 2.0 MV/m, -20 deg
  - 1.6 MV/m, -15 deg
- Threshold is same for 2.0 and 1.6 MV/m, intersection point is equivalent to threshold.
- beam width ($\delta\phi$) satisfies the equation,

$$2.0\cos(-20+\delta\phi) = 1.6\cos(-15+\delta\phi)$$

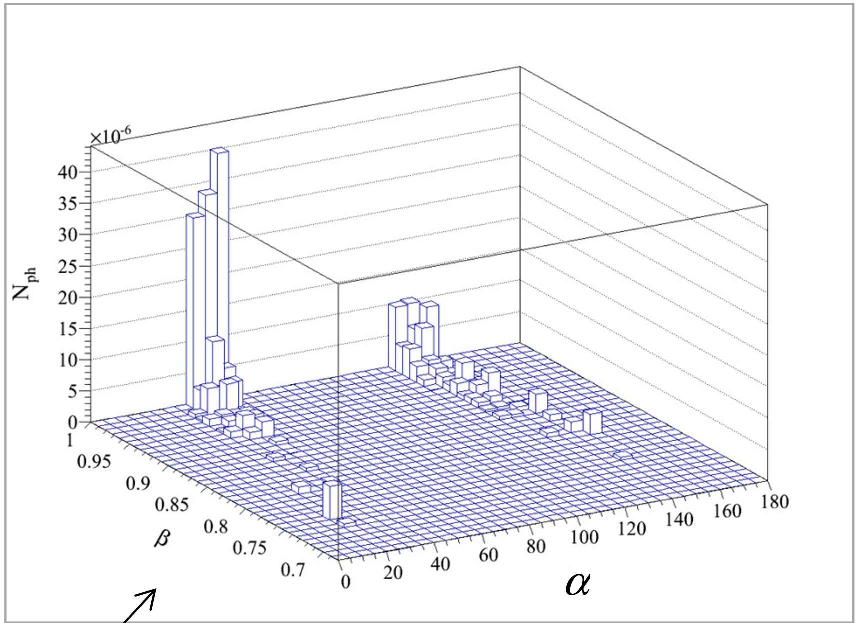
- The $\delta\phi$ is obtained to be 50 deg.

Photons Propagated in Fibers, Single Loss, 2.4 GeV DB

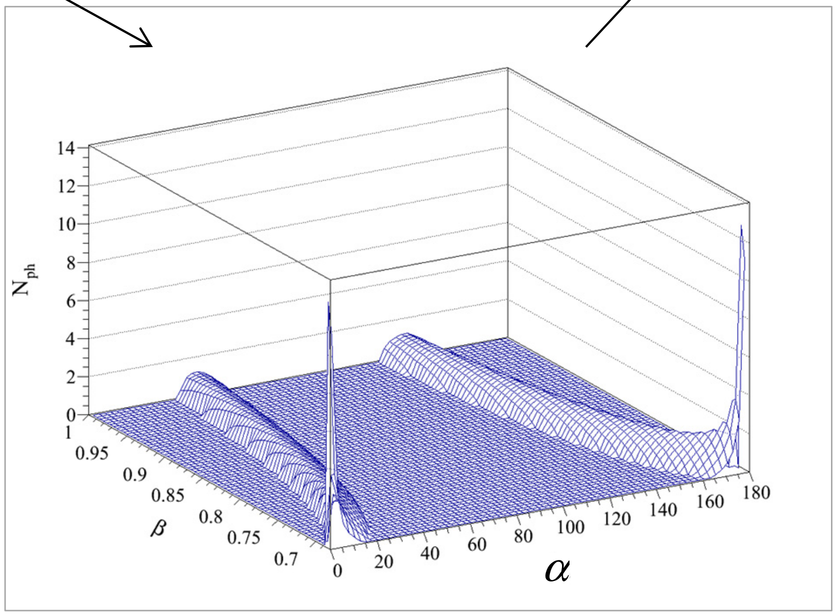
Particle Shower Distribution (FLUKA)



Corresponding Propagated Photons



Loss shower distribution, normalised to one lost beam electron



Propagated photon distribution, normalised to one lost beam electron

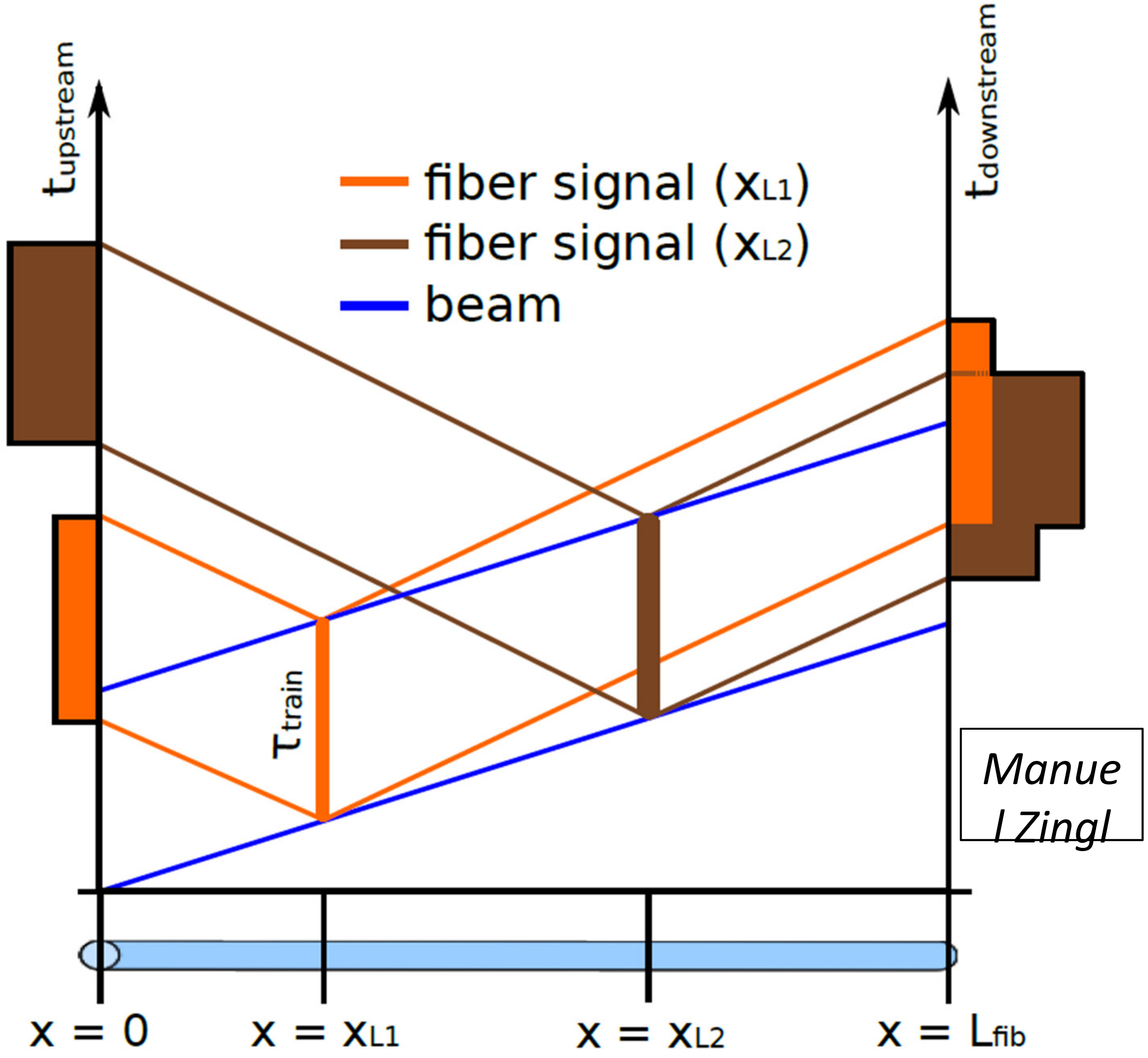
Photon yield N_{ph} for single charged particle as function of impact angle α and β=v/c

Fiber diameter 0.365 mm, NA 0.22

Two Loss Locations – Constant for All Bunches

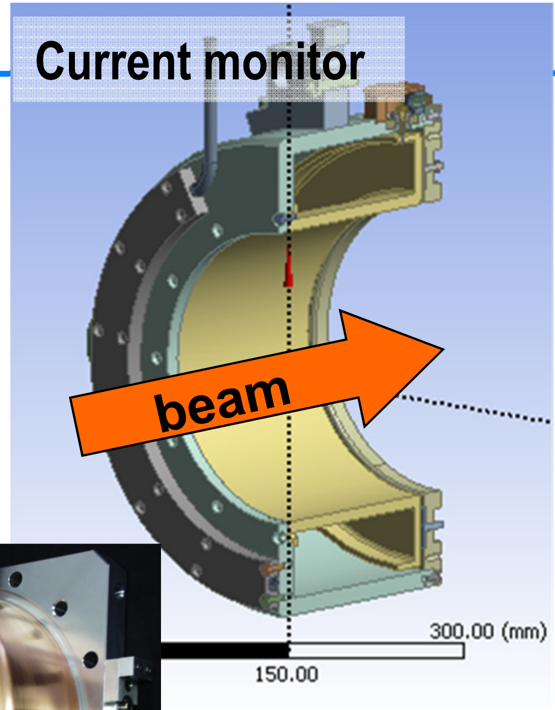
Starting point of the losses can be determined from the **signal rising edges**, with:

- < 1m longitudinal resolution
- ≈ 1ns time resolution

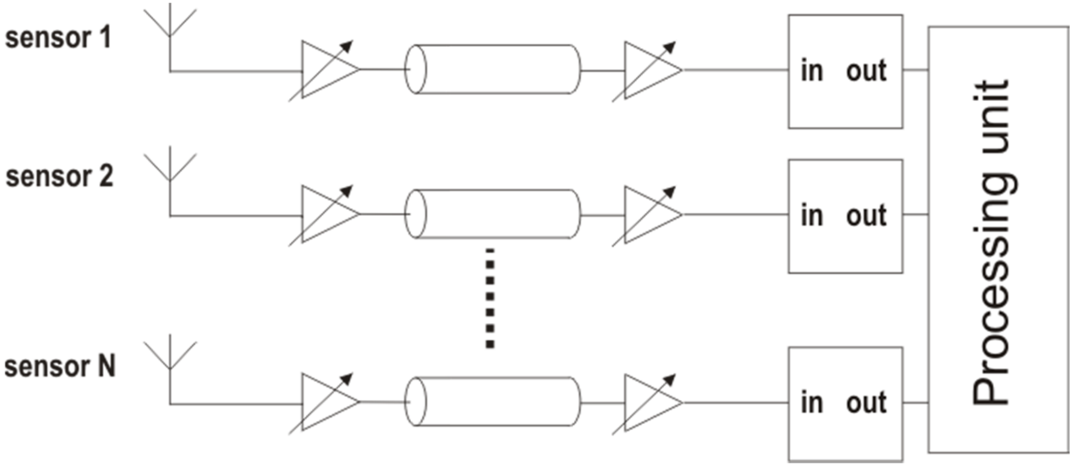


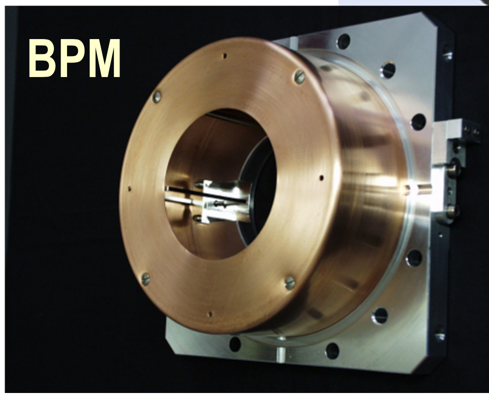
Manuel Zingl

Motivation



Some difficulties related to RF signal measurements:

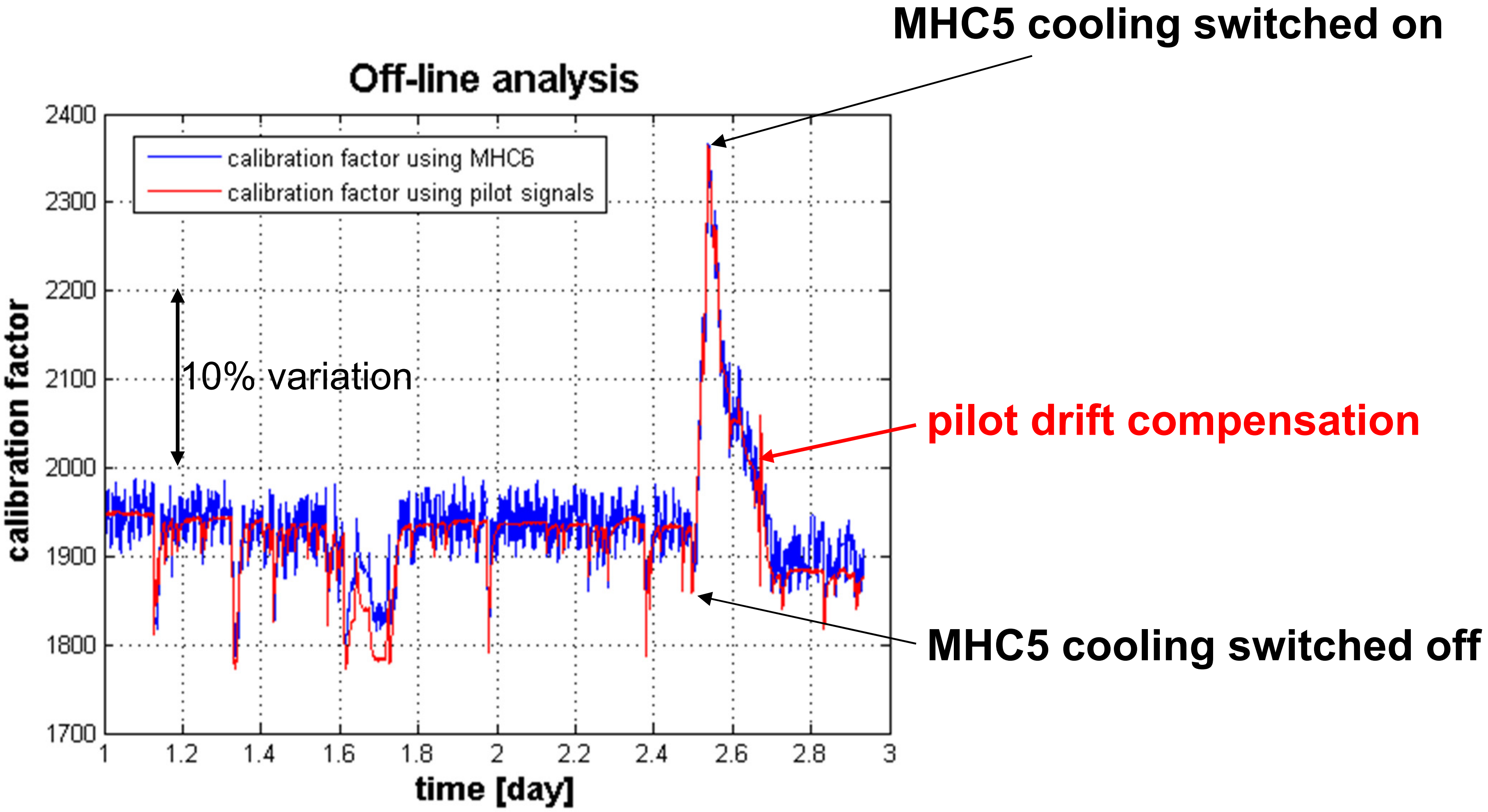




- Sensors 1 to N might have slightly different sensitivity.
- Difference in the overall gain between measurement chains introduces error.
- Temperature drifts may affect differently the electronic elements.
- Calibration may require some large effort, be time-consuming and possibly be required after repairs. Also repeated calibrations may be needed to confirm the gain.

⇨On-line calibration schemes may remove some of these difficulties.

Calibration: Off-line comparison



MHC6: another monitor on the same beam line, expected: $I_{MHC5} \cong I_{MHC6}$

⇨ **Possibility to use MHC6 for the MHC5 calibration**

The pilot drift compensation matches the calibration deduced from MHC6

Discussion session given questions

Starting with the question

**"Is it possible to know the beam (and the machine) in such detail,
that we are able, with the aid of simulation,
to fully understand the beam losses
and are subsequently able to reduce them in a predictable way?"**

speakers and poster contributors from working group E and all other interested parties were invited in advance, to present a short presentation (1 to 3 minutes with 0 to 3 slides), adressing some of the following topics (A-C), in the light of their own accelerator:

0) What machine? Already in operation?

Topic A (diagnostics performance)

providing the constraints (dynamic range, accuracy, spatial and temporal resolution) with which the beam parameters and beam losses can be measured (either with standard or more advanced tools)

1) What diagnostics are used for loss detection?

2) What diagnostics are used for transverse/longitudinal beam distribution (core and halo)?

3) What diagnostics are used for other projections of the 6D-phase space?

together with estimated numbers

We are of course not expected in an 80 minute discussion period, to reach a comprehensive and detailed statement from what is already a vast field (see e.g. http://cas.web.cern.ch/cas/France-2008/Lectures/Wittenburg-halo2.pdf). We should, however, aim to come to a consensus (within ~20 minutes) on what we believe to be both standard and feasible in the future.

Topic B („environment“ / how far we already come)

4) Is there a need to improve beam losses?

5) To what degree the beam losses are understood?
(Do you feel it is at all possible to get a sufficiently detailed understanding that will allow the prediction of beam losses?)

6) Are the diagnostics of 2), 3) used to improve the understanding of beam losses which occur during standard operation?
(or mainly for empirical tuning or trouble shooting?)

7) Is there a clear plan regarding how to proceed with improving beam losses and to what extent are diagnostics involved?

8) Are your beam dynamics colleagues aware of the performance capabilites and contraints of the beam diagnostics?
Is further improvement called for and
do they provide well-founded specifications?

Topic C (other)

9) Other points which complement the above.

Each contribution (we hope for approximately 15)
should be followed by a short discussion.
A general discussion will then follow if time permits.

Points discussed

Questionnaire A+B was delivered as a short version by GSI people together, Naoki Hayashi for JPARC, Rudolf Dölling for PSI. A somewhat longer overview answering mostly A for many CERN diagnostics by Eva Barbara Holzer .
→ few comments if prediction is/will be feasible
→ some statements/discussion what diagnostics are or may be needed

Somewhat more detailed slides on
- BIF monitor performance by Frank Becker
- On screen performance by Beata Walasek
- Halo measurement with adaptive mask by Hao Zhang

→ discussion on dynamic range of optical methods in one profile (not conclusive)

- fast current transformator and tune shift meas. by O. Chorniy
- wire monitor performance (and wire-induced loss as test case for simulations) by Rudolf Dölling
- better tail measurement available for tomographic reconstruction? asked by Davide Reggiani

- the unconventional IFMIF μ-loss-monitor strategy by P.A.P Nghiem
  → high dynamic range input for simulation (~dedicated halo monitor)

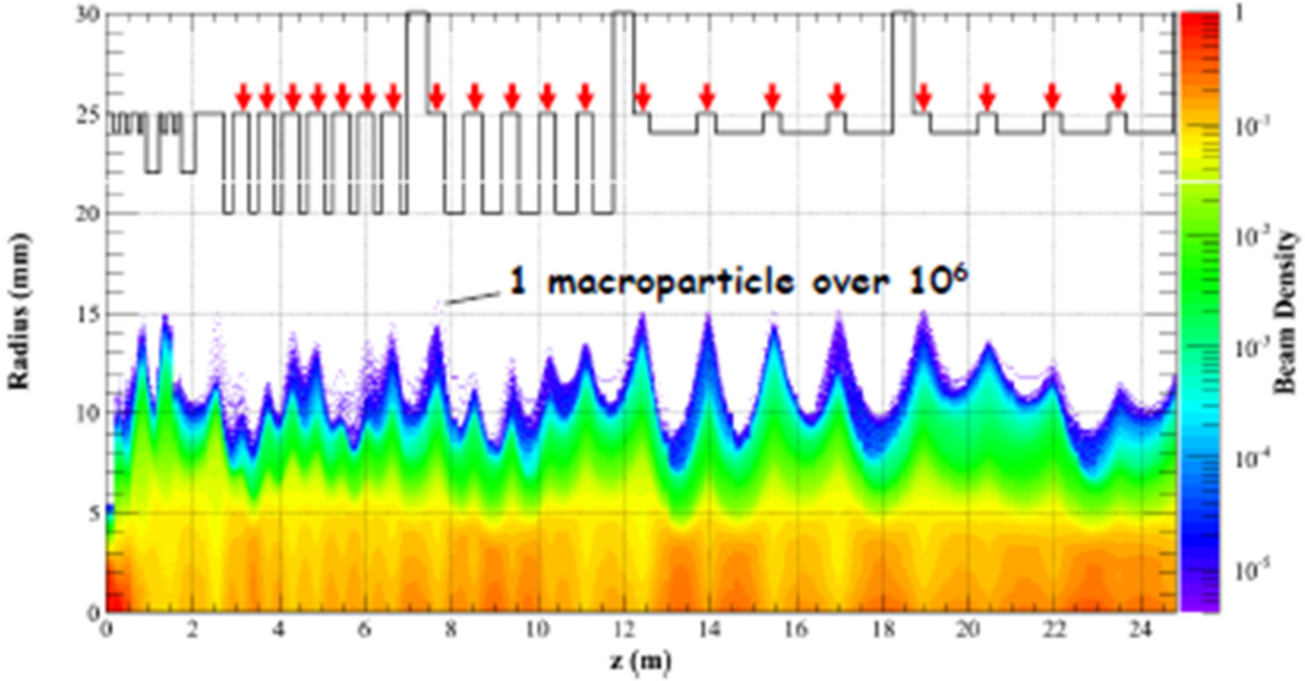
µ-Loss Monitor

Best correction: least residual µlosses Halo matching rather than core matching

⇒ Ideally as many µLM as foc. elements upstream (one-to-one correspondence)

⇒ Located at foc.elements where loss probability is the highest,
and the closest to the beam to allow locating losses

⇒ CVD diamond inside cryomodule



Performances: resolution 1/10 of maximum allowed losses

- was this (preparing something) useful ?
- compared to just discussing in one large or several smaller groups?
- discussing together with beam dynamics people is an advantage

  (one wonders, why not doing this at home more regularly)

- adjustment with WG-D discussion not ideal (our fault, we started late with this)
- ideas for HB2014 discussions? (method/topics/ timing)
- is a summary needed? (prevents us from joining other discussion sessions)