Beam Loss Monitors:

Overview of BLM Technology

1. Introduction
2. Dynamic range, sensitivity
3. Limitations in
   a) time and/or
   b) spatial resolution
4. Challenges associated to measurements of losses (in different machine types)
5. Radiation hardness
6. A comprehensive summary of the current state-of-the-art methods
7. Needs for further development

Kay Wittenburg
3rd oPAC Topical Workshop on Beam Diagnostics
Vienna, 8-9 May 2014

HELMHOLTZ ASSOCIATION

DESY

1. Introduction

Beam loss monitor systems are designed for measuring beam losses around an accelerator or storage ring. **A detailed understanding of the loss mechanism**, together with an **appropriate design of the BLM-System** and an **appropriate location of the monitors** enable a wide field of very useful **beam diagnostics and machine protection** possibilities.

- **Regular (controlled, slow) loss**

  Those losses are **typically not avoidable** and are localized on the collimator system or on other (hopefully known) aperture limits. They might occur continuously during operational running and correspond to the lifetime/transport efficiency of the beam in the accelerator. **The lowest possible loss rate** is defined by the theoretical beam lifetime limitation due to various effects.

- **Irregular (uncontrolled, fast) losses**

  The irregular losses may be distributed around the machine and not obviously on the collimation system. Can be avoided and should be kept to low levels but may reach very high levels in case of an accident.

It is clearly advantageous to have a BLM System which is able to deal with both loss modes. But this means -> High Dynamic Range System!

2. Dynamic Range, Sensitivity

- **Ionization chamber:** **70 µC/Gy**
  1 liter argon
  $S \approx$ active mass · charge per ionization energy $\approx V \cdot \rho \cdot e / E_{ion} \approx 1\,l \cdot 1.8\,g/l \cdot e / 26\,eV$
- **Long ionization chamber:** **20 µC/Gy**
  1 meter length, 1 cm radius, argon
  $S \approx$ active mass · charge per ionization energy $\approx \pi r^2 \cdot L \cdot \rho \cdot e / E_{ion} \approx 314\,cm^3 \cdot 1.8\,g/l \cdot e / 26\,eV$
- **PIN diode:** **6 µC/Gy**
  1 cm² surface, 100 µm depletion depth
  $S \approx$ active mass · charge per excitation energy $\approx A \cdot d \cdot \rho \cdot e / E_{ion} \approx 10\,mm^3 \cdot 2.3\,g/cm^3 \cdot e / 3.6\,eV$
- **Secondary emission monitor:** **500 pC/Gy**
  100 cm² surface, 0.01 average secondary emission yield (SEY)
  $S \approx$ surface · SEY · electron charge · density of primaries per dose $\approx A \cdot SEY \cdot e \cdot (\rho/(dE/dx))$
  $\approx 100\,cm^2 \cdot 0.01 \cdot e \cdot 1/(2\,MeV \cdot cm^2/g)$
- **Aluminum cathode electron multiplier:** **5 µC/Gy**
  10 cm² surface, 0.01 average secondary emission yield (SEY), tube gain 10^5
  $S \approx$ surface · SEY · electron charge · density of primaries per dose · gain $\approx A \cdot SEY \cdot e \cdot (\rho/(dE/dx)) \cdot G$
  $\approx 10\,cm^2 \cdot 0.01 \cdot e \cdot 1/(2\,MeV \cdot cm^2/g) \cdot 10^5$
- **PMT with organic scintillator:** **200 C/Gy** ← Radiation damage problematic!
  1 liter scintillator, 60% collection efficiency, 30% photocathode efficiency, tube gain 10^5
  $S \approx$ active mass · photon yield per energy · collection efficiency · photocathode efficiency · gain · electron charge
  $\approx V \cdot \rho \cdot Y \cdot C \cdot P \cdot G \cdot e = 1\,l \cdot 1\,g/cm^3 \cdot 1/(100\,eV) \cdot 0.6 \cdot 0.3 \cdot 10^5 \cdot e$
- **Bare PMT (Čerenkov light):** **4 mC/Gy**
  10 cm² surface, 1 mm thick, 30% photocathode efficiency, tube gain 10^5
  $S \approx$ active volume · density of primaries per dose · photon yield per length · photocath. efficiency · gain · electron charge
  $\approx A \cdot d \cdot \rho \cdot (\rho/(dE/dx)) \cdot Y \cdot P \cdot G \cdot e \approx 1\,cm^3 \cdot 1/(2\,MeV \cdot cm^2/g) \cdot 260/cm \cdot 0.3 \cdot 10^5 \cdot e$
- **PMT with Čerenkov fiber:** **2 µC/Gy**
  1 meter length, 100 µm radius, 2% collection efficiency, 30% photocathode eff., tube gain 10^5
  $S \approx$ active volume · density of primaries per dose · photon yield per length · coll. eff. · photoc. eff. · gain · electron charge
  $\approx \pi r^2 \cdot L \cdot \rho \cdot (\rho/(dE/dx)) \cdot Y \cdot C \cdot P \cdot G \cdot e \approx 31\,mm^3 \cdot 1/(2\,MeV \cdot cm^2/g) \cdot 260/cm \cdot 0.02 \cdot 0.3 \cdot 10^5 \cdot e$

Flexible gain → linearity and calibration problematic!

ERL Instrumentation Workshop, Cornell University, 2-3 June 2008 Lars Fröhlich, DESY

In these two references one can find a lot of details on various BLM types!

K. Wittenburg, **Beam loss monitors,** CAS2008
Specialised Beam Diagnostics School in Dourdan, France, CERN-2009-005

Lars Fröhlich, **Beam Loss Monitors**
ERL Instrumentation Workshop, Cornell University, 2-3 June 2008
http://tesla.desy.de/~lfroehli/download/ERL_instrumentation_ws_2008_BLMs.pdf

Detector Material	energy to create one electron [eV/e]	number of [e / (cm MIP)] (**depends on dE/dx, resp. density**)	Sensitivity S (for MIPs) [nC/rad]
Plastic Scintillator:	250 – 2500	10^3 - 10^4	$\approx 17 \cdot 10^3$ (· **PMT$_{gain}$**) (1 ltr.)
Inorganic Scint.	50 - 250	10^4 - 10^5	$\approx 100 \cdot 10^3$(· **PMT$_{gain}$**) (1 ltr.)
Gas Ionization:	22 – 95	≈100 (Ar,1 atm., 20^{0}C)	≈ 500 (· **Elec$_{gain}$**) (1ltr)
Semiconductor (Si):	3.6	10^6	≈ 50 (· **Elec$_{gain}$**) (1 cm² PIN-Diode)
Secondary emission:	2-5%/MIP (surface only)	0.02-0.05 e/MIP	$\approx 2 \cdot 10^{-3}$ (· **PMT$_{gain}$**) (8cm²)
Cherenkov light	10^5 - 10^6	≈10 (H_2O) -200 (fused silica)	≈ 270 (· **PMT$_{gain}$**) (1 ltr.)

$\approx 0.2 \cdot 10^{-3}$ (· **PMT$_{gain}$**) for 1 m Cherenkov fiber

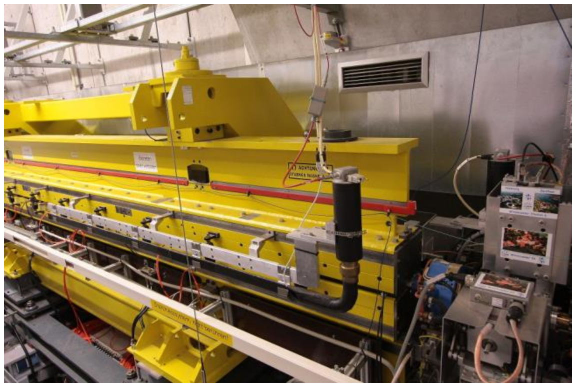
Including Gain and
1 Gy = 100 rad

>10^8 Difference in Sensitivity between different types

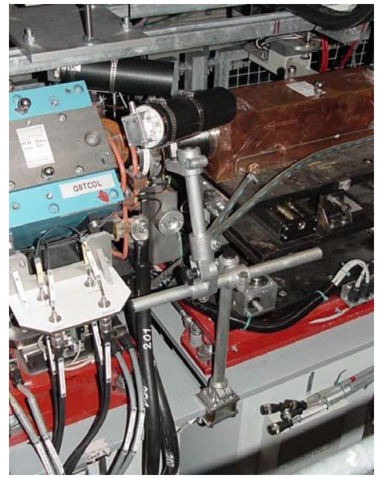
2. High dynamic loss monitoring by

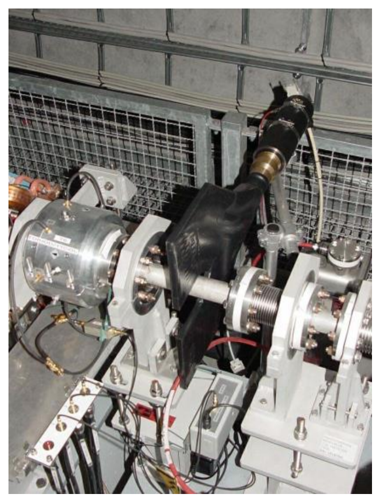
Different BLM types/materials

FLASH

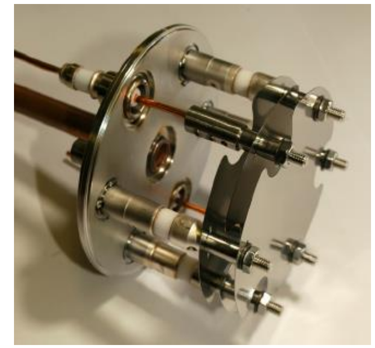


FLASH





LHC



SNS

Area	IC	ND	PMT
DTL	11	12	6
CCL	50	8	6
SCL	76	23	
HEBT, LDmp, IDmp	59		
Ring	71		
RTBT	40		

2. High dynamic loss monitoring by

Different BLM types/materials

Diamond and Sapphire

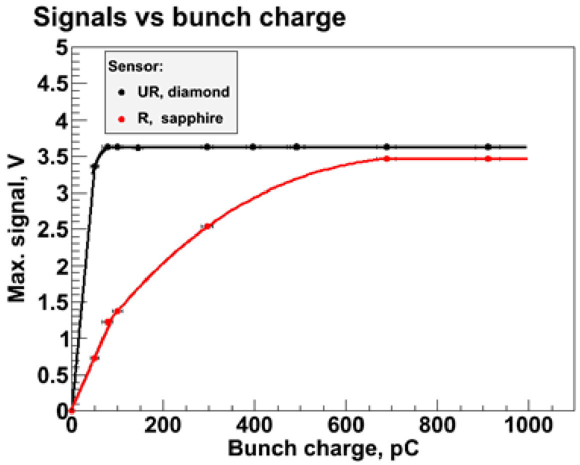


Figure 5.4.5: Fits for the maximal average signal for a diamond a sapphire sensors.

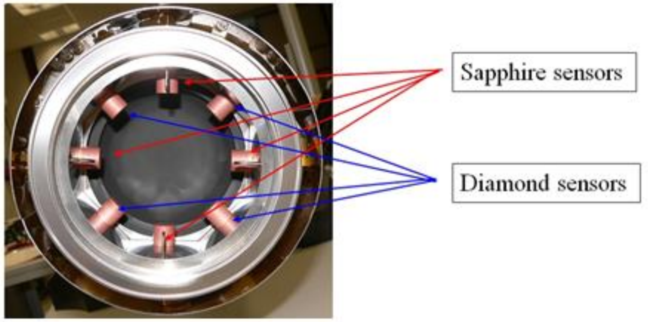


Figure 5.2.1: View to the BHM module from the dump. The pick-ups of the magnetic-coupled BPM can be seen in front of the cups with sapphire sensors.

Alexandr Ignatenko
Thesis, 2014
Brandenburgische Technische Universität Cottbus-Senftenberg

Diamond (UR)	Sapphire (R)
Low charges <50 pC (6.6e-02)*x + (3.1e-16)	Low charges <90 pC (1.4e-02)*x + (3.5e-02)
Medium charges >50 pC & <113 pC (2.0e-06)*x3 + (-6.7e-04)*x2 + + (6.99e-02)*x + (1.27e+00)	Medium charges >90 pC & < 690 pC (2.5e-09)*x3 + (-8.7e-06)*x2 + + (9.0e-03)*x + (5.5e-01)
High charges >113 pC (0)*x + (3.62e+00)	High charges > 690 pC (0)*x + (3.47e+00)

Table 5.4.1: Parameters for the resulting fit functions.

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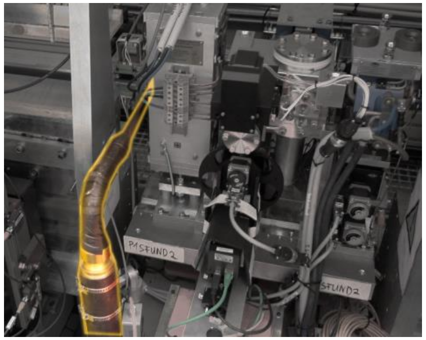
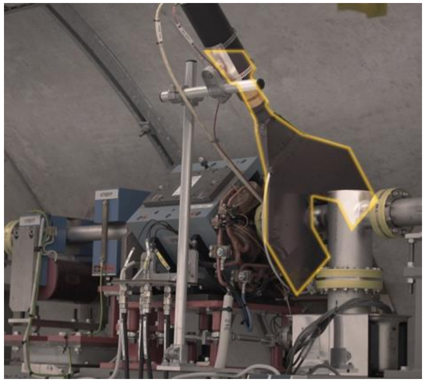
2. High dynamic loss monitoring by

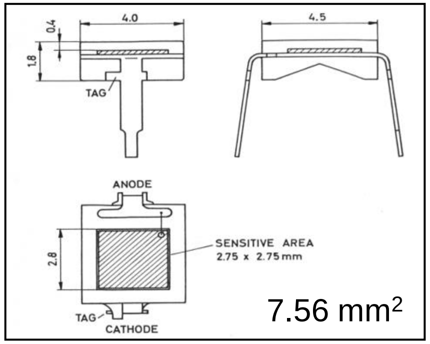
Small and Large

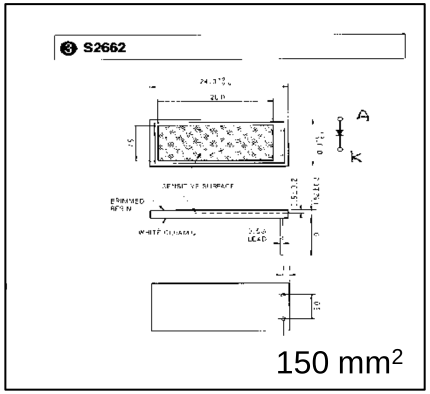
FLASH





HERA





Note that the flux density of photons into the light guide is "incompressible" !

<u>=> The cross section of the scintillator should not be larger than the cross section of the light guide -> I did not proof this rule, any experience with that?</u>

2. High dynamic loss monitoring by

Noise to saturation

Detector:

PMTs:
Noise at max Gain ≈1 mV
Saturation ≈ 1 V
+Active gain variation ≈ 10^3
⇒ Dynamic range ≈ 10^6

Ionization chamber (LHC)
Leakage current < 1 pA
Saturation ≈1 mA
⇒ Dynamic range ≈ 10^9

Electronic:

RF Amplifiers
Dynamic range ≈ 10^4
Log Amp. ≈ 10^5

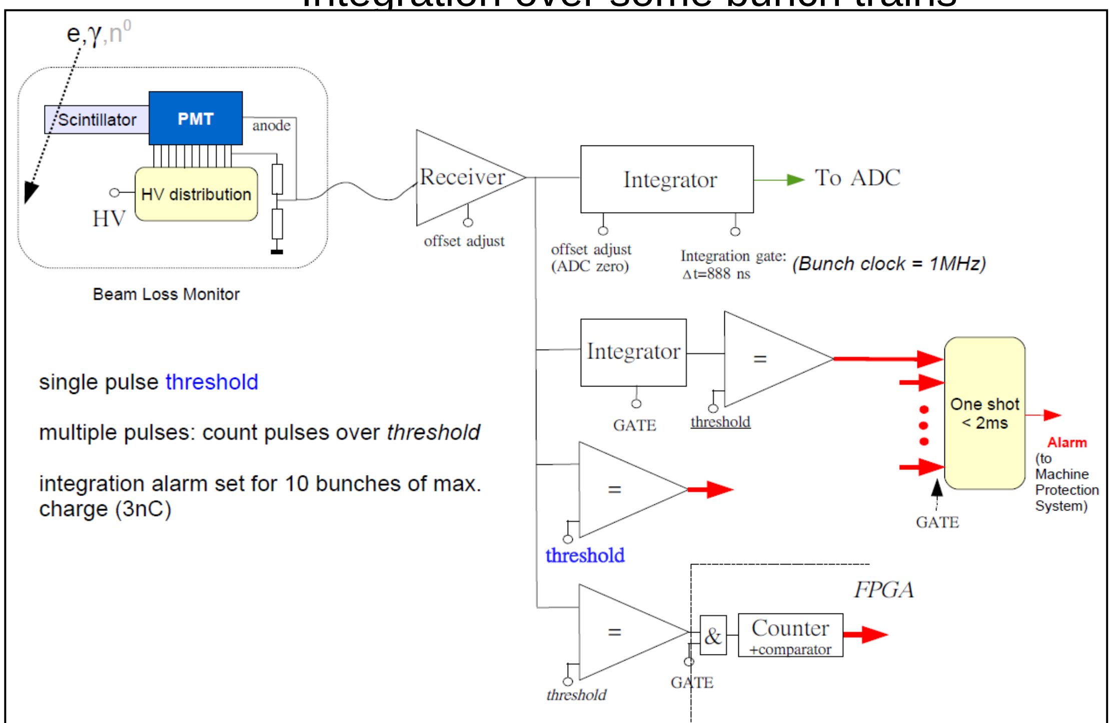
ADC
12 bit ≈ 4 x 10^3
16 bit ≈ 6 x 10^4
24 bit ≈ 2 x 10^7 (SNS: VME ADC but 10 bits noise)

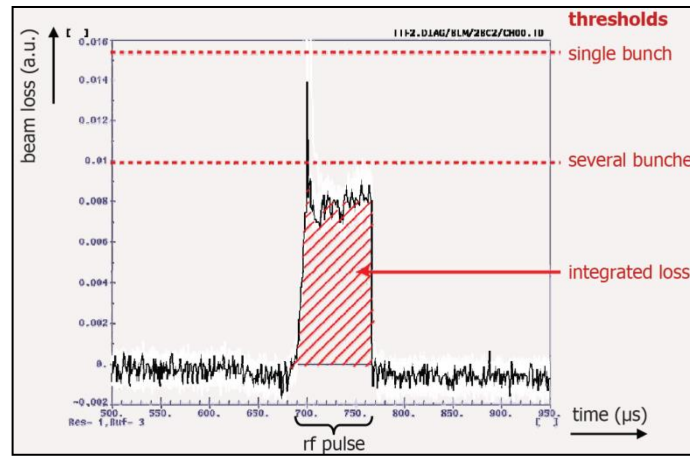
Counting
Dark count rate ≈1 Hz
Signal: Bunch rep. rate ≈10 MHz
⇒ Dynamic range > 10^9 (averaging!)

3a. Limitations in time resolution

3a. Limitations in time resolution

- Typical reaction time of
  - Rings: 1 - few turns -> > ≈ 10 µs -> Defines the detector time response
  - Linac: Bunch distance (≈ 100 ns at bunch train or ≈ ms at single bunch) but important:
    - Bunch by Bunch resolution -> Defines the detector time response
    - Integration over bunch train
    - Integration over some bunch trains





Alexander Kaukher
DESY
7th DITANET Topical Workshop on Beam Loss Monitoring
December 7, 2011

3a. Limitations in time resolution

> **≥ turn by turn:**

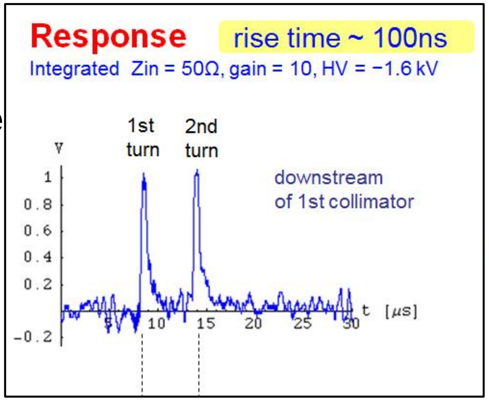
- Ionization chambers

+ Low bandwidth ADC allows high dynamic range

- Counting (many bunches)

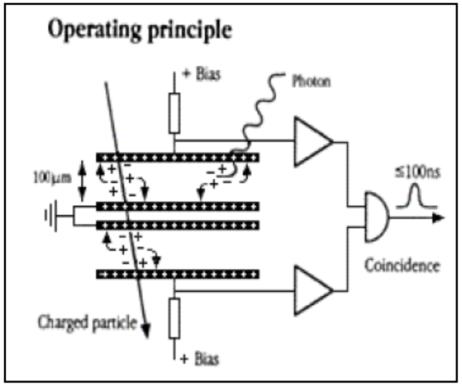
Allows super high dynamic range

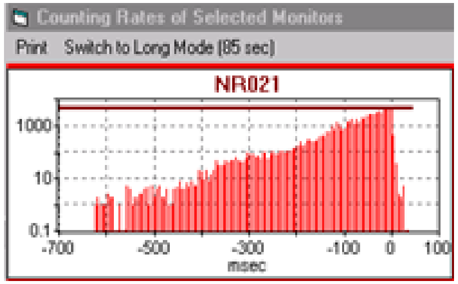
(4) Experience at the J-PARC MR



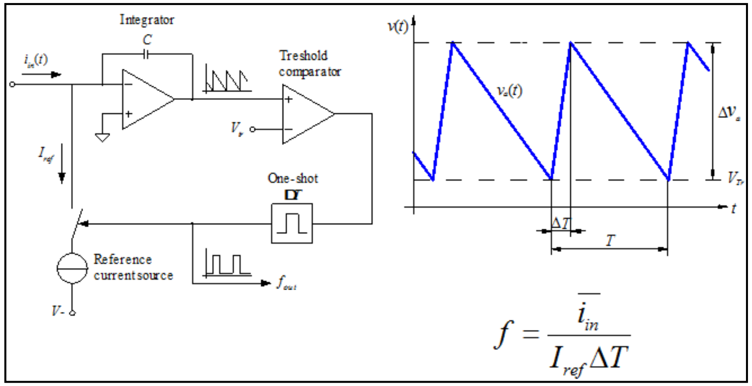
T. Toyama et al., HB2008

Pin Diodes at HERA





Counting circuit for LHC Ion Chamber



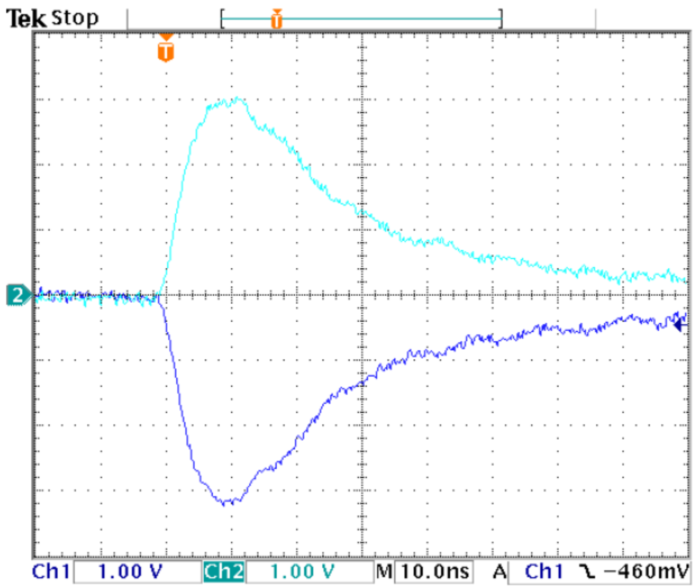
$$f = \frac{\overline{i_{in}}}{I_{ref}\Delta T}$$

3a. Limitations in time resolution

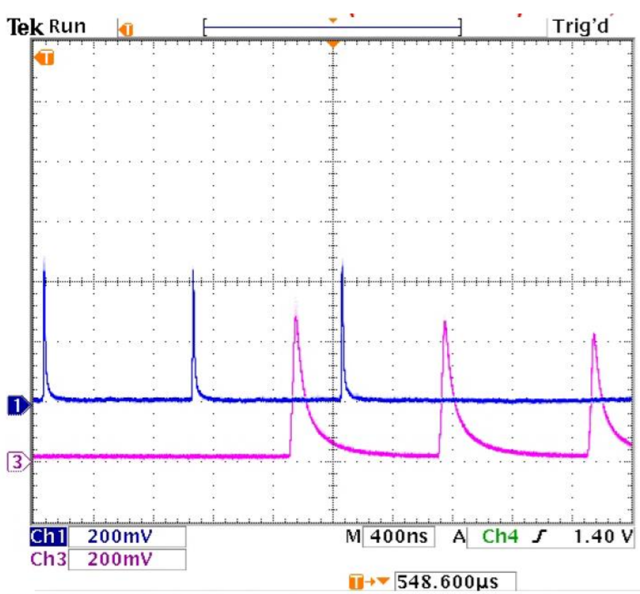
> < 100 ns:

- PMT (or APD) + Cherenkov or Scintillator
- SEM + GHz Amplifier (or SEM-PMT)
- Solid State Detectors + GHz Amplifier

+ GHz ADC (limited dynamic range)!!!



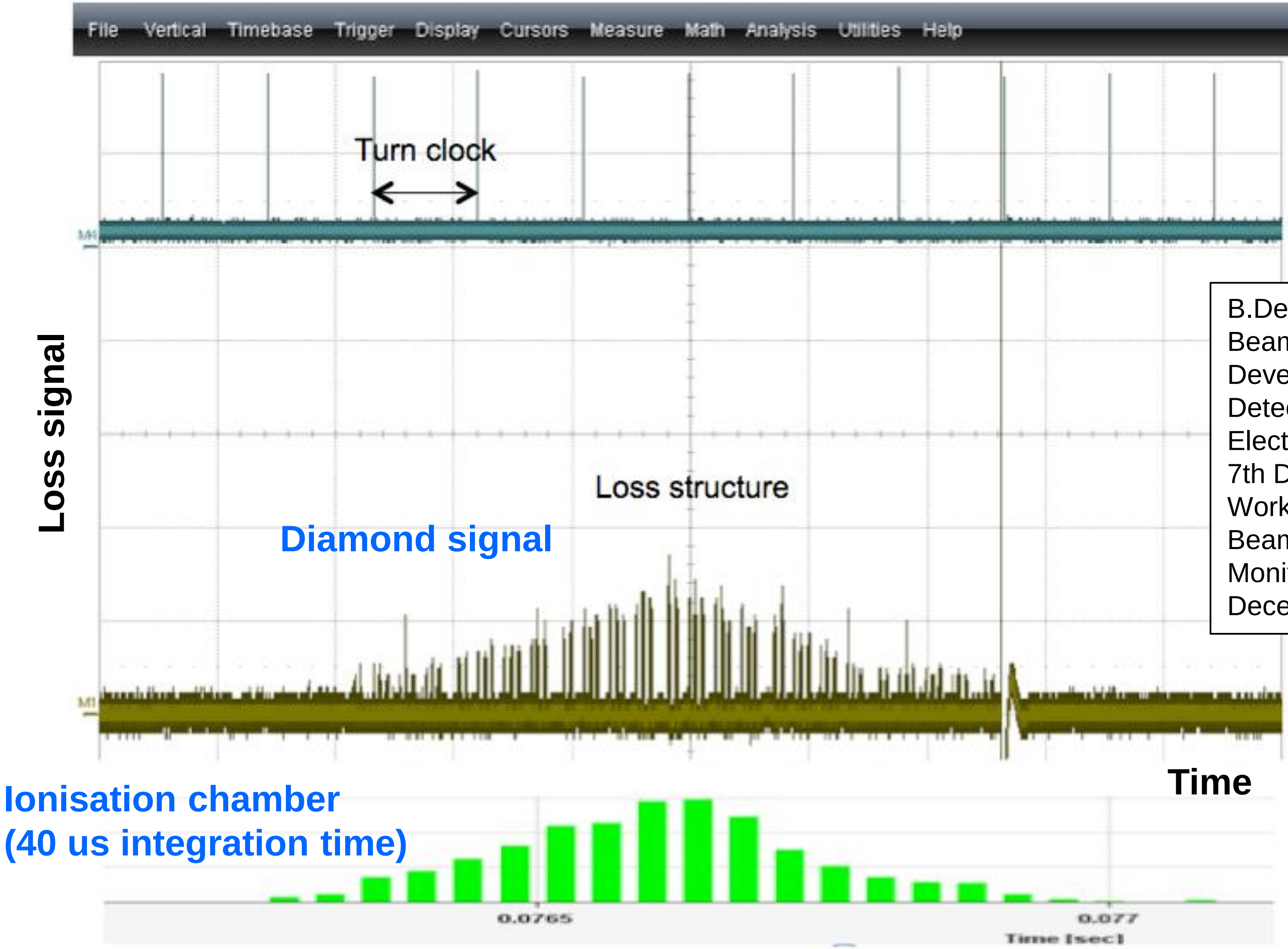
The signal width from the R5900 PMT is as short as 20 ns, even after 50m twisted pair cable.



Signals from 3 bunches at FLASH:

BLM #1 (top,BC-408, HV=500V) and BLM #3 (quartz fibers, HV=700V).

3a. Limitations in time resolution

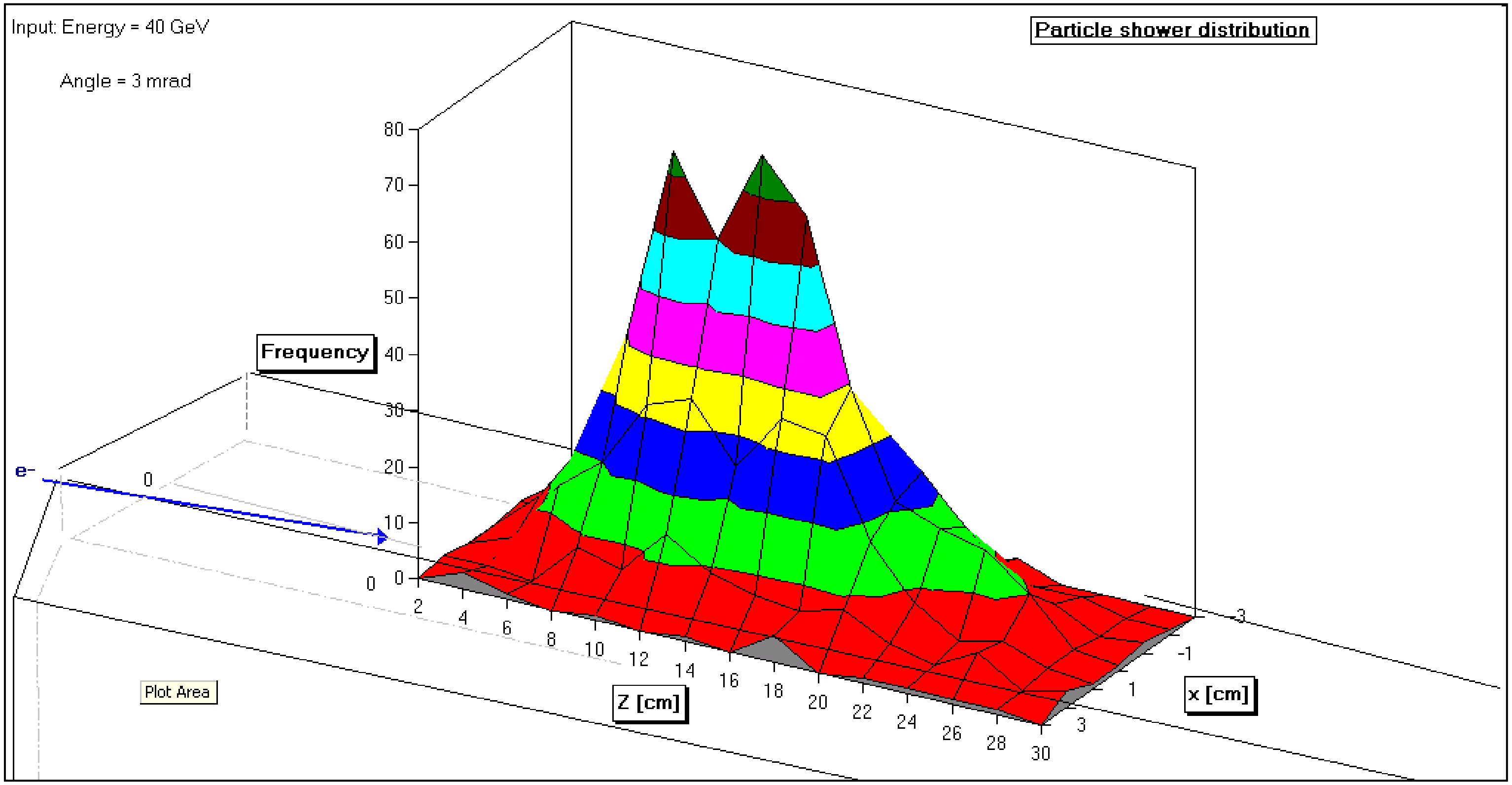


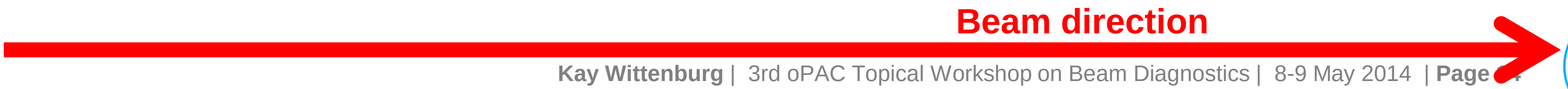
B.Dehning
Beam Loss: New Developments, Detectors and Electronics ;
7th DITANET Topical Workshop on Beam Loss Monitoring
December 7, 2011

3b. Limitations in spatial resolution (where to put BLMs)

3b. Limitations in spatial resolution (where to put BLMs)

Electron beam = small shower

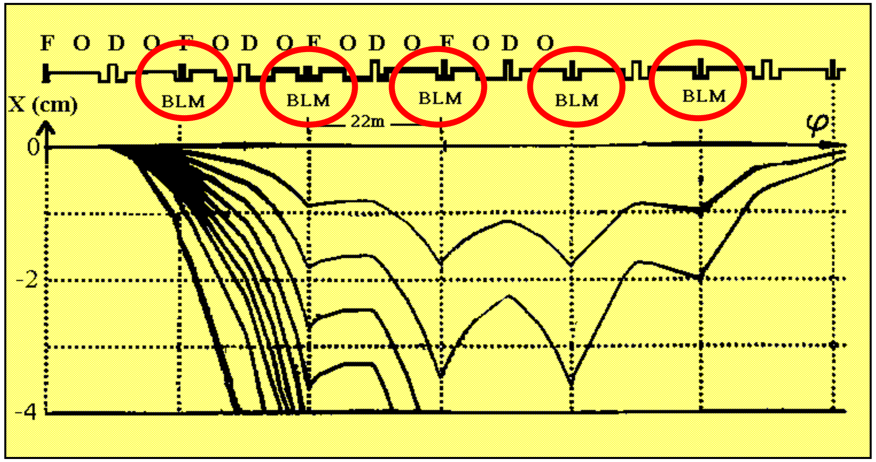




3b. Limitations in spatial resolution (where to put BLMs)

Important:
Beam Optics!
Tracking Codes

Trajectory of Electrons after Energy Loss



Electron Beam Loss Monitors for HERA
F. Ridoutt, W. Bialowons, K. Wittenburg; EPAC 1994

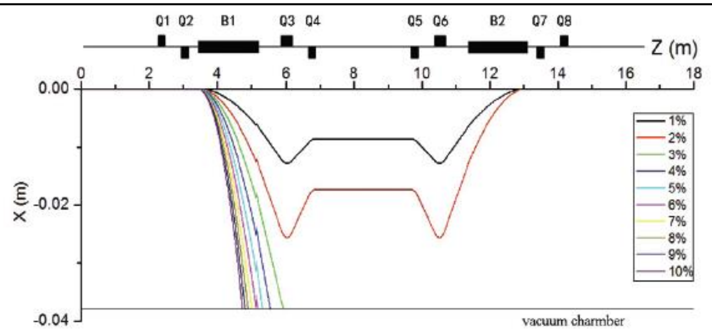


Figure 3: Deviation of the electron orbit with momentum difference from 1% to 10%.

A New Theoretical Design of BLM System for HLS II
Yukai Chen, Lijuan He, Juexin Li, Wei-min Li, Yuxiong Li
IPAC 2013

Beam direction

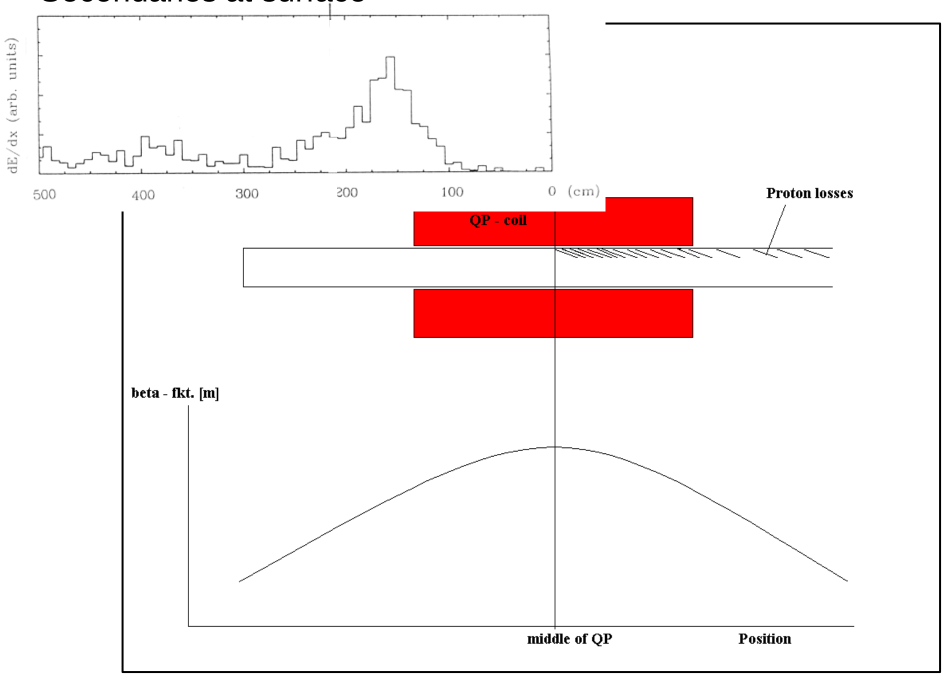
3b. Limitations in spatial resolution (where to put BLMs)

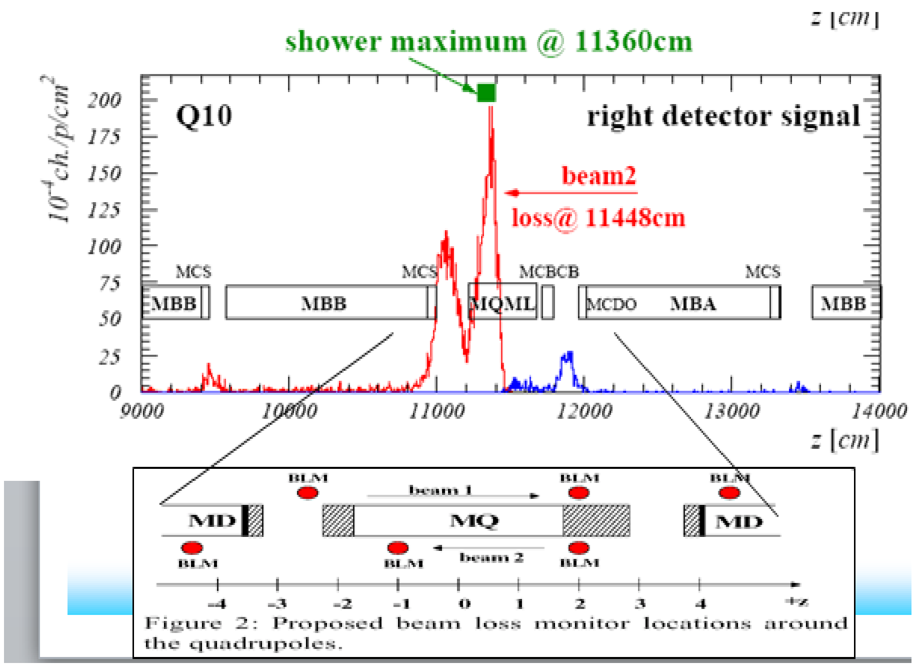
A local orbit distortion creates losses at high beta (in general at aperture limitations)

High Energy Proton Beam = Large Shower

Important:
Particle Shower
Monte Carlo Codes

Secondaries at surface



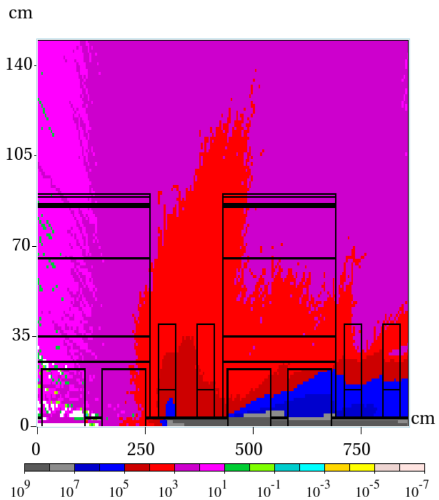


Beam direction

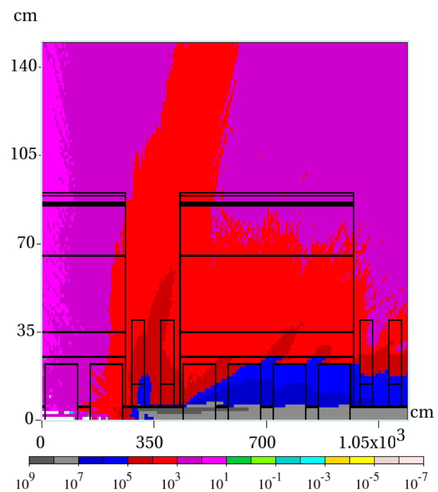
3b. Limitations in spatial resolution (where to put BLMs)

Low Energy Proton Beam = Shielded Shower

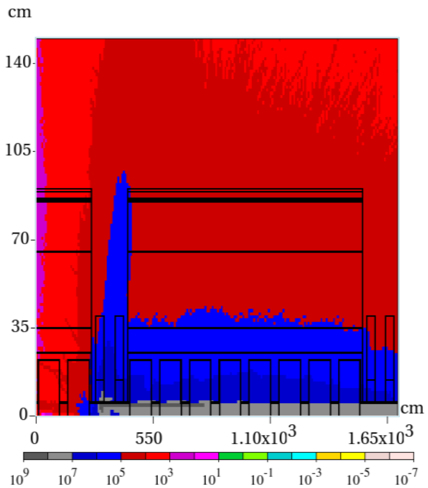
Important:
Loss signal has to be calibrated by energy
Monte Carlo Codes



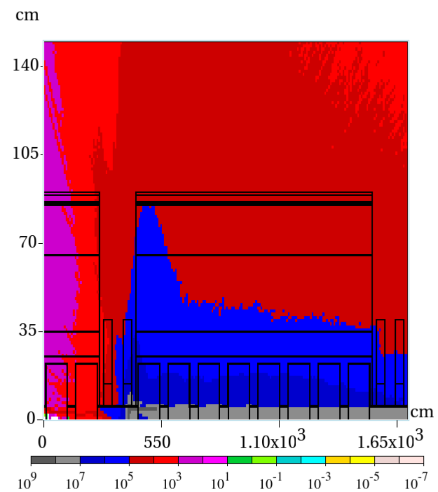
Loss in the middle of first quadrupole magnet, in xz plane, with 150 MeV energy.



Loss in the middle of first quadrupole magnet, in xz plane, with 200 MeV energy.



Loss in the middle of first quadrupole magnet, in xz plane, with 1 GeV energy.



Loss in the middle of first quadrupole magnet, in yz plane, with 2 GeV energy.

Loss location = middle of first quadrupole
Loss angle = 1.5 mrad
Loss intensity = 10^12 protons/sec

Technical Note ESS/AD/0032

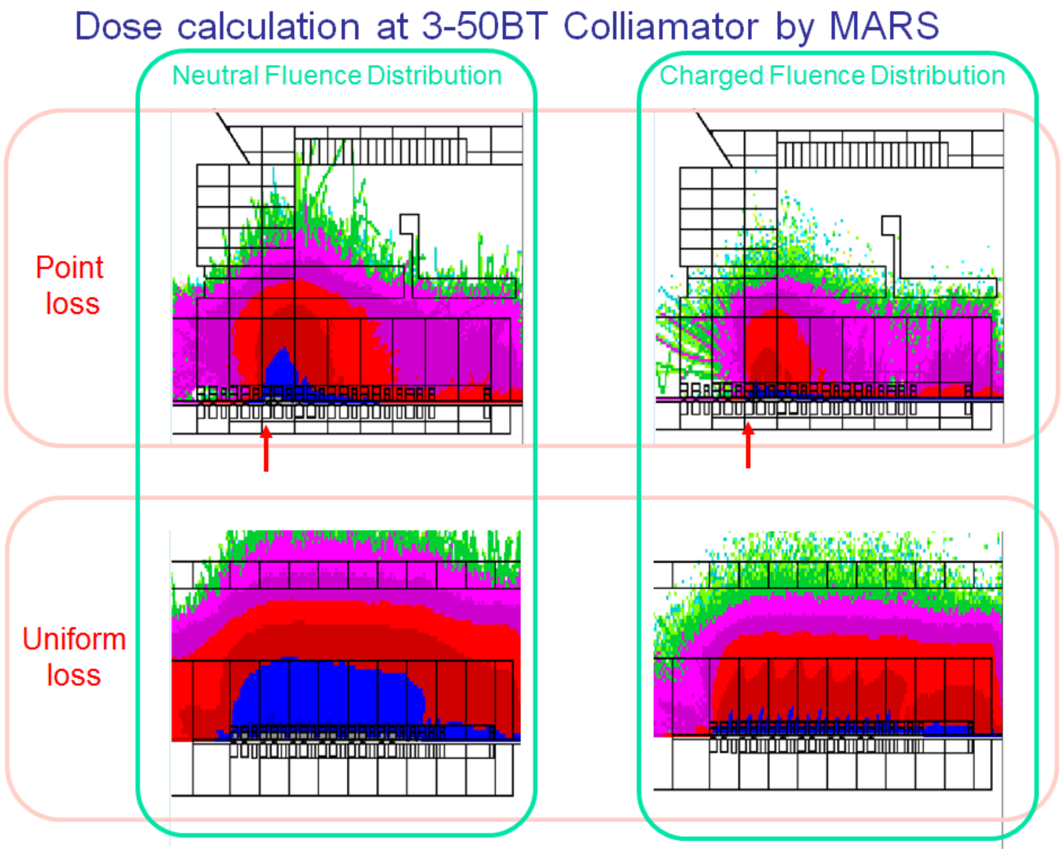
Beam direction

3b. Limitations in spatial resolution (where to put BLMs)

Local measurement
Vs.
Do losses appear somewhere?

Neutrons are everywhere in the accelerator tunnel in case of losses:

Few neutron detector BLMs are sufficient



Beam direction

3b. Limitations in spatial resolution (where to put BLMs)

Neutron Detector

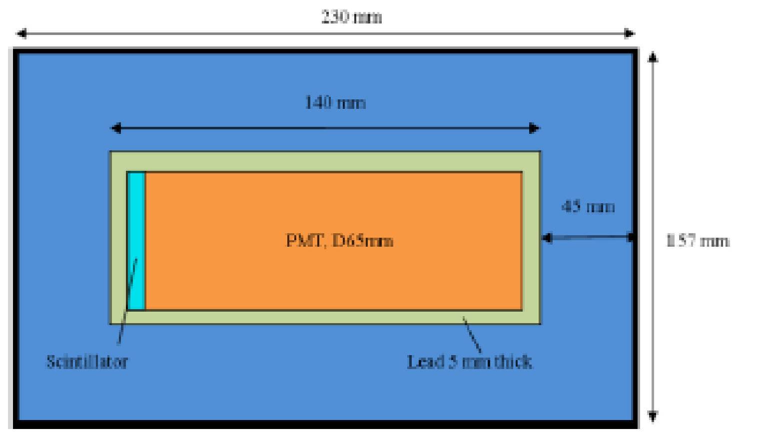


Figure 1: Neutron Detector is a 230x157x150mm box. PMT is inside x-ray shielding (lead) and is surrounded by polyethylene neutron moderator.

- 35 mm poly moderator
- Li (n,alpha)
- Scintillator detects the alphas
- PMT
- $10^4 - 10^8 n/cm^2/s$
- 0.03eV - 3MeV

4) Challenges associated to measurements of losses

Just a small selection:

a. Very low energy machines

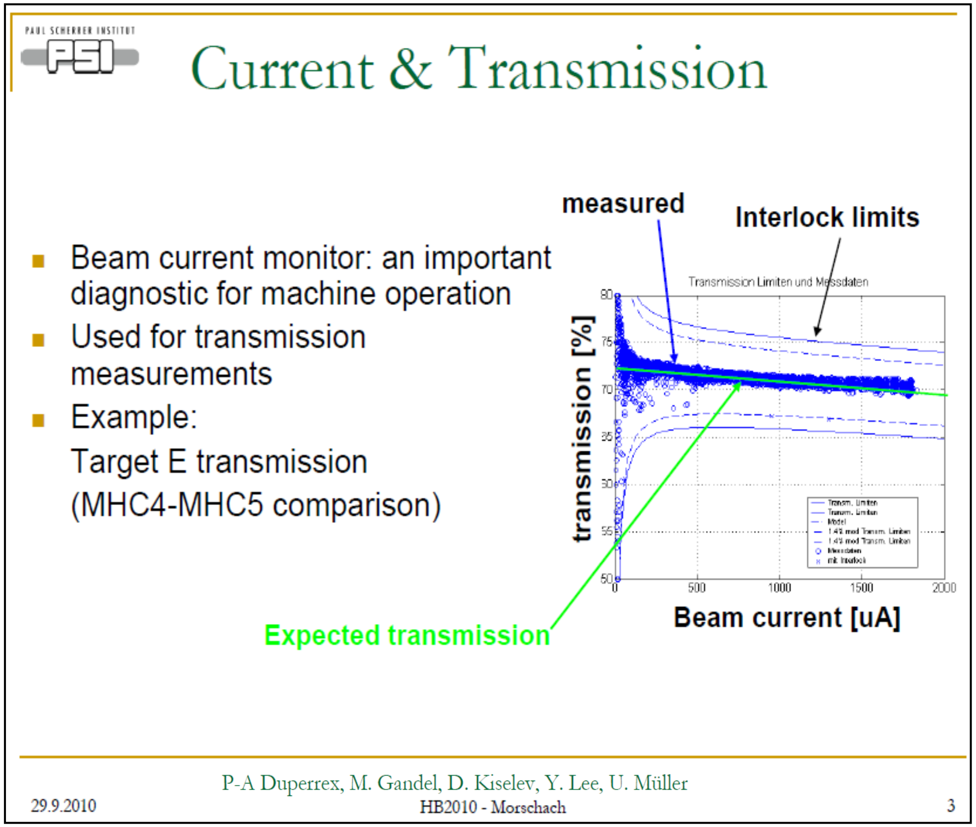
b. High background

4a) Challenges associated to measurements of losses at low energies

The problem: No or very few secondaries outside the vacuum chamber

Solutions:

- **Differential current measurement**
  - **Limited position resolution**
  - **LINAC/transport only**
- BLMs very close to beam pipe
  - Risk of wrong position
- BLMs sensitive to neutrons
  - Limited position resolution
- Very sensitive BLMs
- Use of BLMs at collimators



4a) Challenges associated to measurements of losses at low energies

The problem: No or very few secondaries outside the vacuum chamber

that complements ionization chambers. A specifically designed device, the halo monitor ring (HMR), is implemented upstream of each cryomodule to detect beam loss directly. Together

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- Differential current measurement
  - Limited position resolution
  - Linac/transport only
- **BLMs very close to beam pipe**
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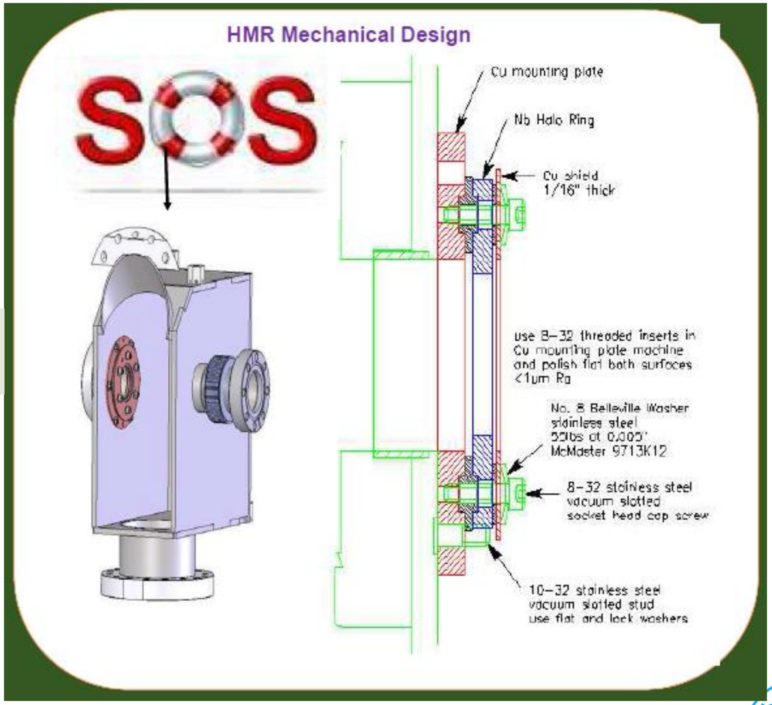
- Use of BLMs at collimators

Beam Loss Monitor System for the Low-Energy Heavy-Ion FRIB Accelerator

Zhengzheng Liu, Tom Russo, Bob Webber, Yoshishige Yamazaki, Yan Zhang

IBIC 2013 poster



-> Also: Cryogenic BLMs (not at low energy)

4a) Challenges associated to measurements of losses at low energies

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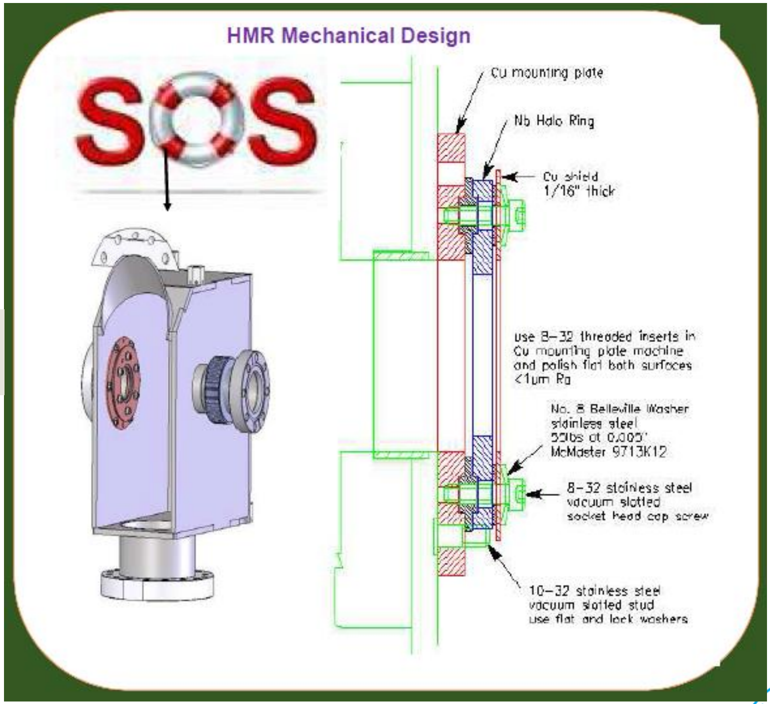
- Very sensitive BLMs
- Use of BLMs at collimators

that complements ionization chambers. A specifically designed device, the halo monitor ring (HMR), is implemented upstream of each cryomodule to detect beam loss directly. Together with fast response neutron scintillators, the new integrated BLM system satisfies both machine protection and sensitivity requirements.



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IBIC 2013 poster

4a) Challenges associated to measurements of losses at low energies

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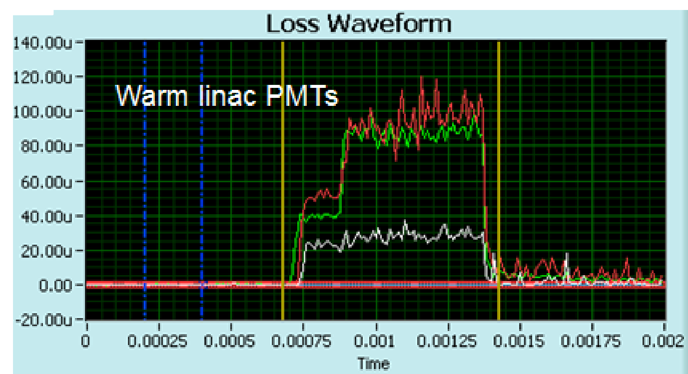
- Differential current measurement
  - Limited position resolution
  - Linac/transport only
- BLMs very close to beam pipe
  - Risk of wrong position
- **BLMs sensitive to neutrons**
  - **Limited position resolution**
- Very sensitive BLMs
- Use of BLMs at collimators

Challenges: Low energy part of linac

- low energy beam (<20MeV)
  - IC not sensitive enough
  - ND sensitive, but hard to calibrate (no sufficient experimental data for reliable simulation)
  - Still the biggest issue



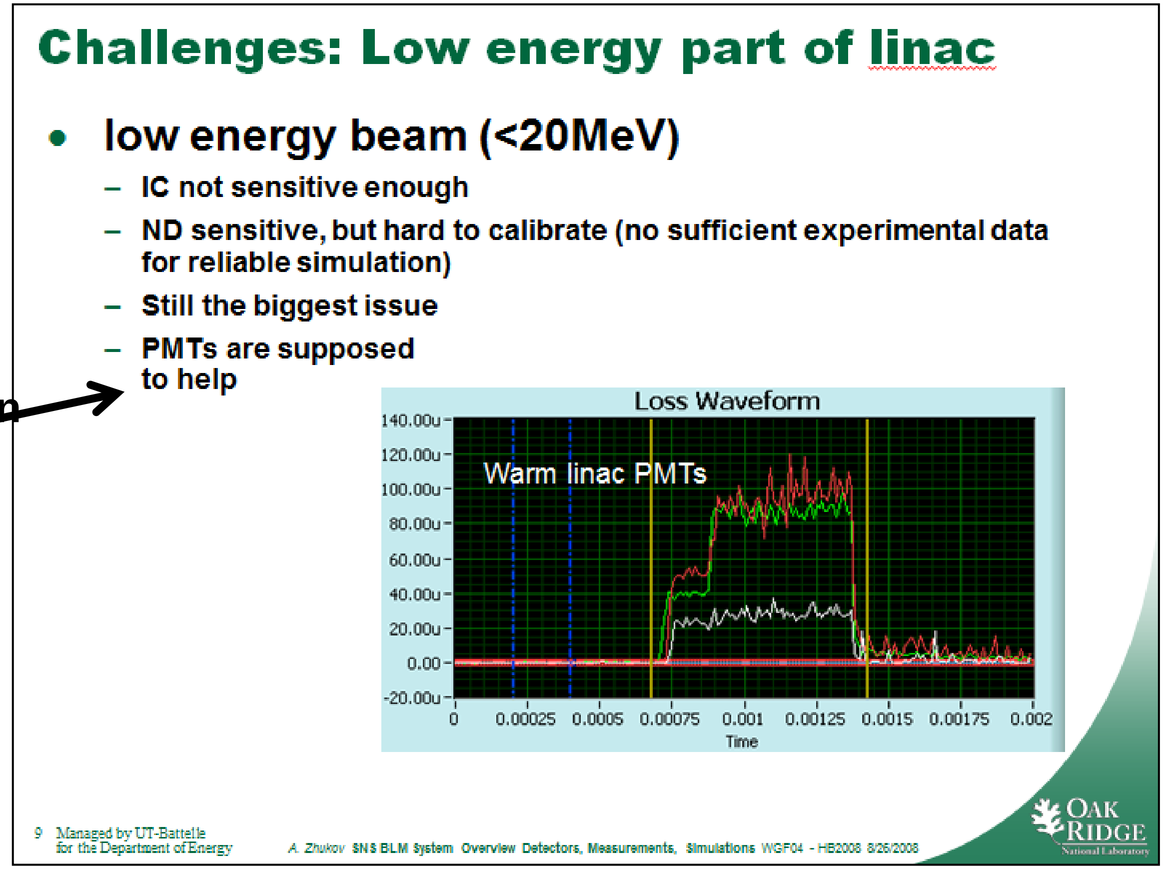
9 Managed by UT-Battelle for the Department of Energy   A. Zhukov SNS BLM System Overview Detectors, Measurements, Simulations WGF04 - HB2008 8/26/2008

4a) Challenges associated to measurements of losses at low energies

The problem: No or very few secondaries outside the vacuum chamber

Solutions:

- Differential current measurement
  - Limited position resolution
  - Linac/transport only
- BLMs very close to beam pipe
  - Risk of wrong position
- **BLMs sensitive to neutrons**
  - **Limited position resolution**
- **Very sensitive BLMs**
- Use of BLMs at collimators



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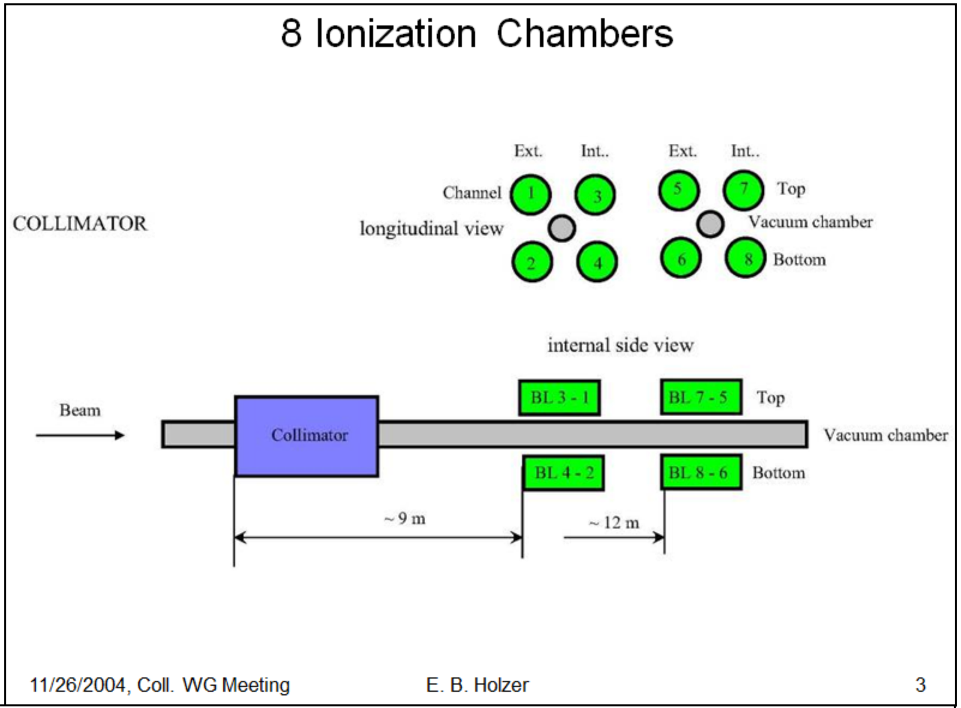
  - **Known loss location**
  - Aperture limit
  - Highest loss rate (hopefully)
  - Machine + Collimator Protection



- “Tails” in distributions are from the beam.
- BLM signal is linear with proton intensity.
- Left-right asymmetry of the shower depends on the collimator gap size and gap position.
- Slight top-bottom asymmetry?
- BLM signal depends on the impact position on the jaw.
- Compares ~ OK with simulations (TT40).

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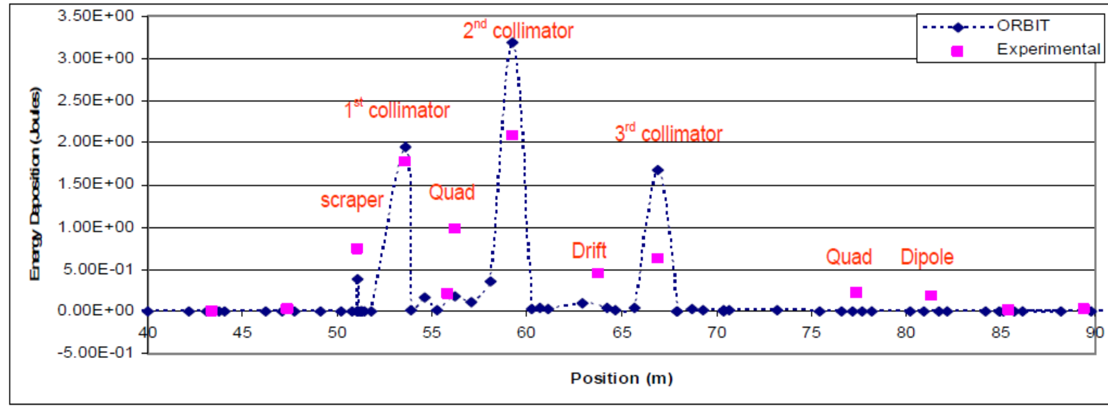
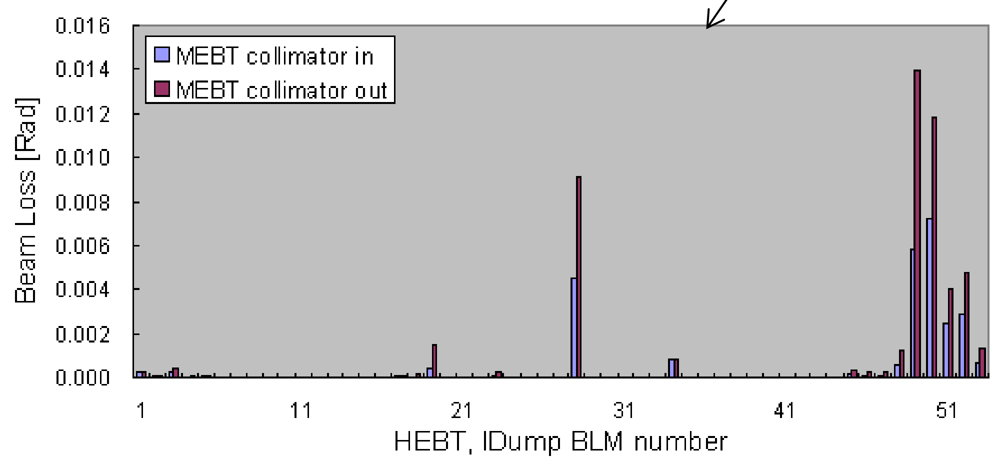
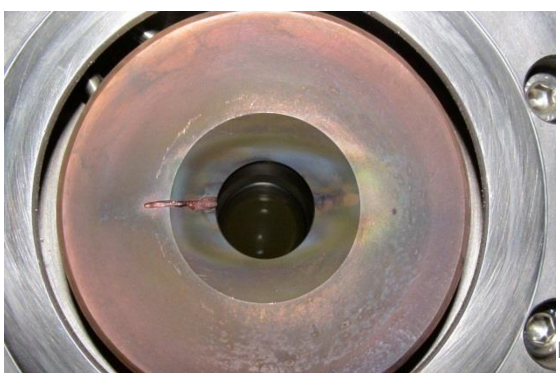


Figure 4. Benchmark of the beam loss pattern for a single minipulse of beam collimated in a two-stage system. The pink boxes are the measured BLM readings, converted to energy deposition, and the blue diamonds are the ORBIT simulation results.

SNS PAC07 LINAC10



Plot of measured beam loss along the HEBT and IDump (Injection Dump) with the MEBT collimator in and out. Data shows significant reduction in beam loss in the HEBT and IDump with the MEBT collimation.



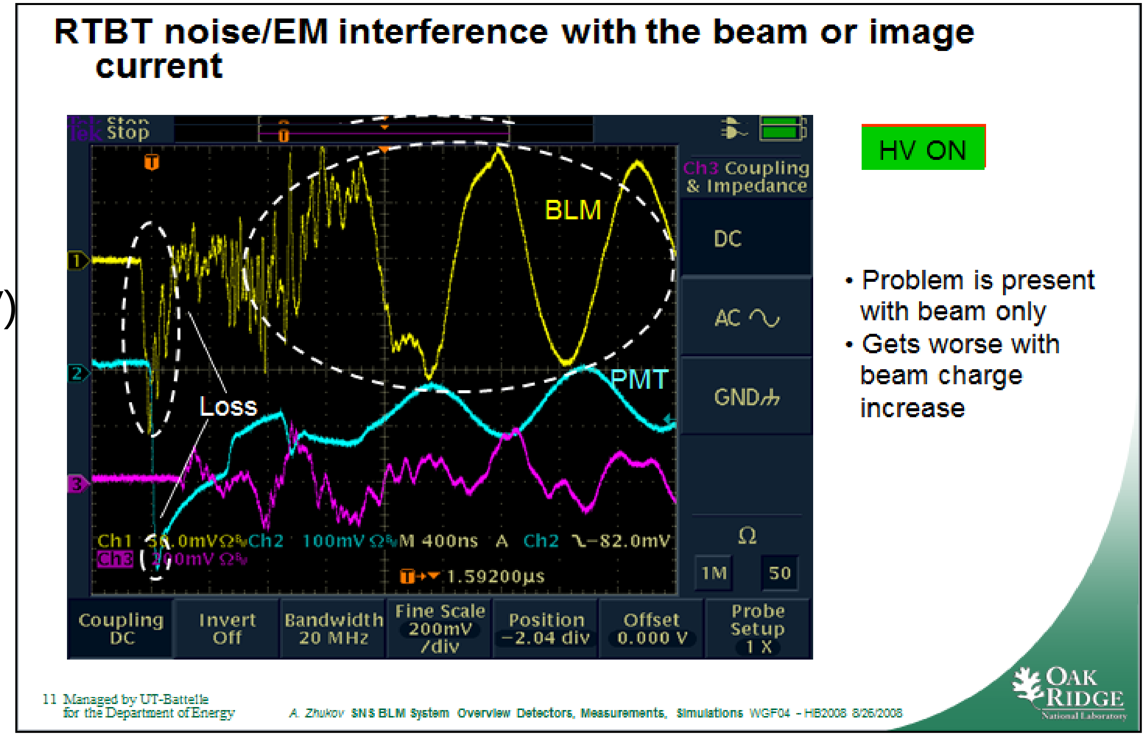
0.9 and 72 MEV Proton collimator at PSI Cyclotron (Pic. From R. Dölling-PSI)

4b) Challenges associated to measurements of losses at <u>high background</u>

The problem: Limits the dynamic range

1. EM Noise

<u>Reasons:</u>
- Shielding
- Ground loops
- RF
- PS ripple (from magnets, from HV)
- Kickers, septum
- Magic
- Ghosts
- Sabotage
- …



<u>Solutions:</u>

Blame the others!

(not very useful, I know…)

The problem: Limits the dynamic range

2. X-ray from cavities

Reasons:

- Released electrons from cavity
- Magic
- Ghosts
- Sabotage
- …

Solutions:

- **Subtraction by software**
- Use of a x-ray insensitive detector

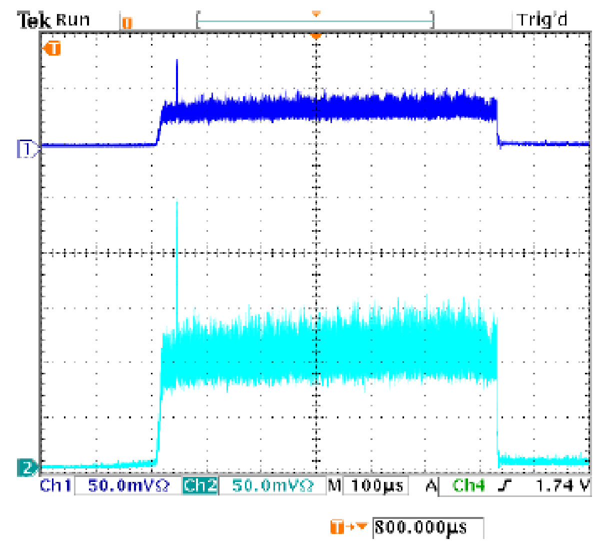
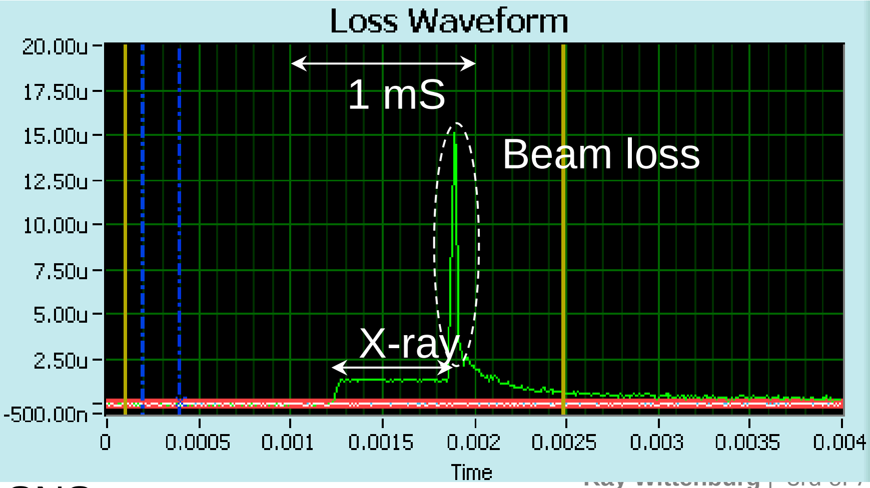


Figure 4: BLM signals from a single bunch and dark current at FLASH (April 2012): BLM with SQ1 synthetic fused silica (top, HV=700 V) and BLM with a scintillator (HV=550 V).

XFEL Beam Loss Monitor System
A. Kaukher, I. Krouptchenkov, D. Noelle (D. Nölle), H. Tiessen, K. Wittenburg
IPAC12



SNS

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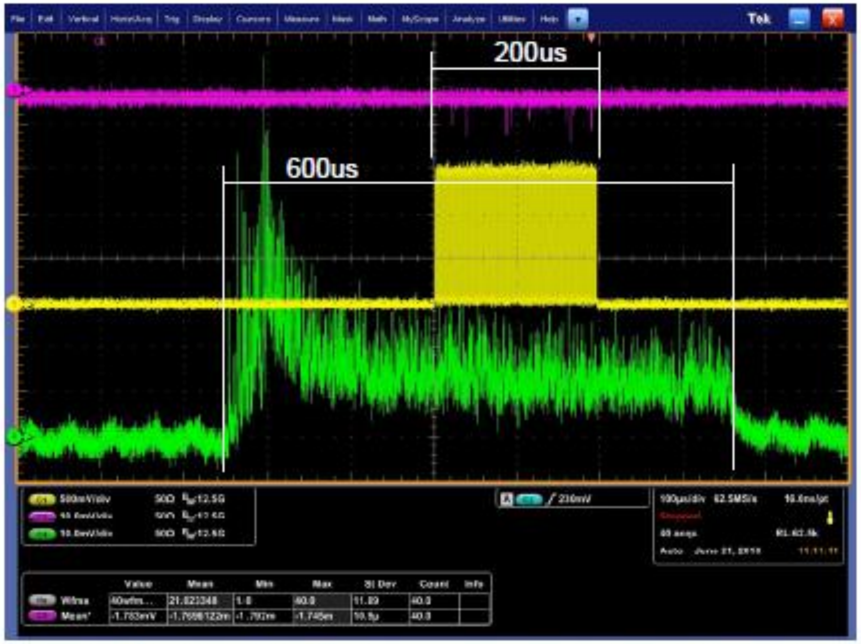


Figure 5: Signals from a gas proportional monitor (green) and plastic scintillation monitor (magenta) at SDTL13 section, during beam operation with chopped beam. The beam current signal with a current transformer is also shown (yellow).

Beam Loss Detected by Scintillation Monitor
Akihiko Miura, et al.
IPAC´11

4b) Challenges associated to measurements of losses at high background

The problem: Limits the dynamic range

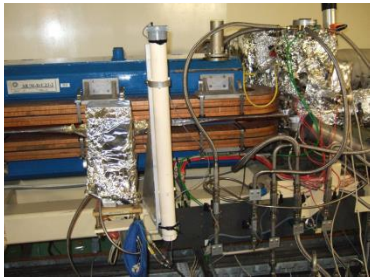
3. X-ray from Synchrotron radiation

Reasons:

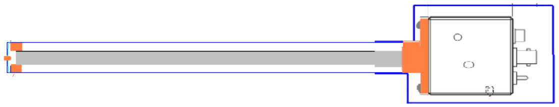
- SR is unavoidable

Solutions:

- Subtraction by software
- **Use of a x-ray insensitive detector: Cherenkov material: Quartz**
- Coincidence

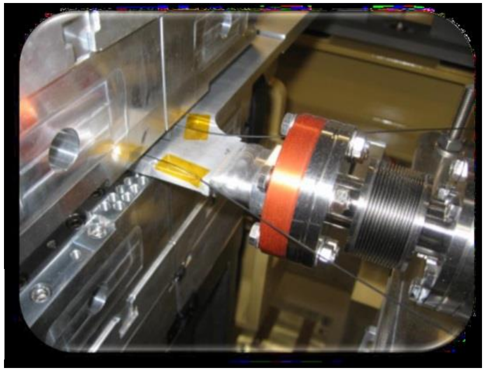


K. Scheid, ESRF, 7th DITANET Topical Workshop on Beam Loss Monitoring; 2011



S.L. Krameer NSLS II, 7th DITANET Topical Workshop on Beam Loss Monitoring; 2011

J. Perry, Jlab, PAC93



L. Fröhlich, FERMI, 7th DITANET Topical Workshop on Beam Loss Monitoring; 2011

4b) Challenges associated to measurements of losses at high background

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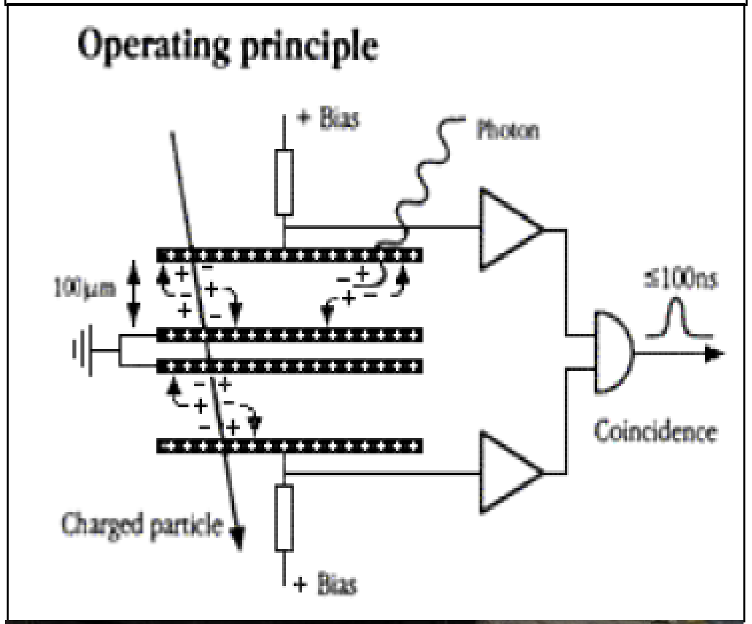
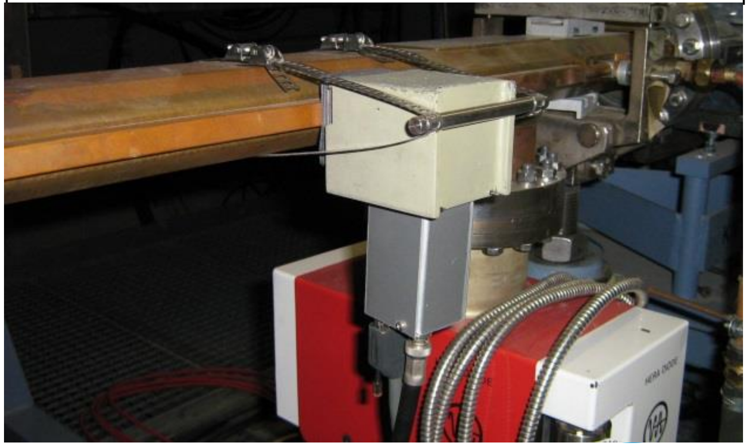
- SR is unavoidable

Solutions:

- Subtraction by software
- Use of a x-ray insensitive detector: Cherenkov material: Quartz
- **Coincidence: Counting**

Coincidence technique: SR-Photons stop in one <u>**or**</u> the other PIN diode and are not counted!





The Beam Loss Monitoring System at ELSA
Dennis Proft , IPAC12

Installation and Test of a Beam Loss Monitor System for the S-DALINAC
Robert Stegmann, IPAC12

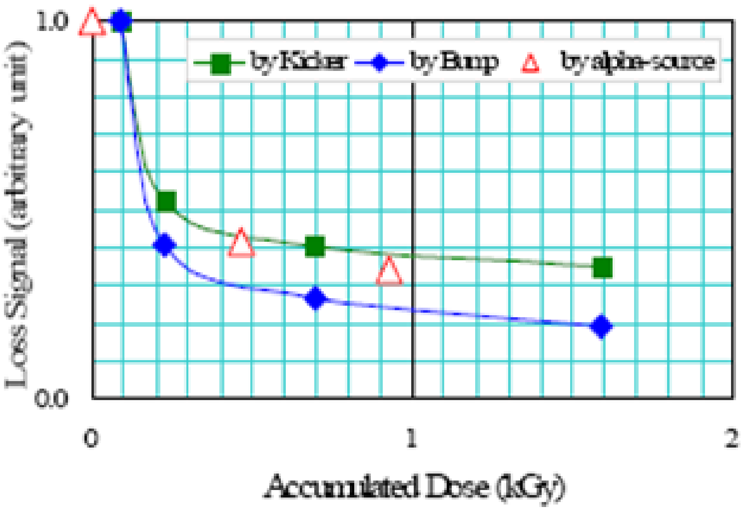
Beam Loss Monitors for the HERA Proton Ring
DESY HERA 90-11

5) Radiation hardness

5) Radiation hardness

S. Goulding, R.H. Pohl 1972

Reviewing relevant papers is an essential



Sample name	By γ-ray [kGy]	By proton beam loss [kGy]
Plastic Scintillator	1100	230

The radiation Dose which makes 1/e reduction of the original transparency

the time and place of observation! The literature on radiation damage in detectors could well lead to an equally valid conclusion.

6) A comprehensive summary of the current state-of-the-art methods

6) A comprehensive summary of the current state-of-the-art methods

- Cannot be answered since **all kind of methods are in use** (as seen from previous slides)
- T**here is no “best method”** since a useful method depends on various accelerator parameters
- Therefore: **Don’t trust on “state of the art”**, often a well established method can be the best (Ion chambers and Scintillators+PMT are the most common BLMs)
- However, **new problems need new solutions**:
  e.g. x-ray background-> Cherenkov rods and fibers, PIN-Coincidence
- Still searching for a **fast and sensitive detector with high dynamic range and high radiation damage threshold** -> Diamonds?
- **Simulations are important** to understand losses and the BLM response

6) A comprehensive summary of the current state-of-the-art methods

a) Simulation:

IBIC2013

Beam Delivery Simulation (BDSIM): A Geant4 Based Toolkit for Diagnostics and Loss Simulation
Monte Carlo Simulations of Beam Losses in the Test Beam Line of CTF3
S**imulation for Radiation Field Caused by Beam Loss of C-ADS Injector II**
Beam Loss Monitoring at the European Spallation Source

IPAC11

Comparative Studies into 3D Beam Loss Simulations
Monte Carlo Simulation of the Total Dose Distribution around the 12 MeV UPC Race-track Microtron and Radiation Shielding Calculations
Beamloss Study at J-PARC Linac by using Geant4 Simulation

b) Fiber based BLMs

IBIC13

Update on Beam Loss Monitoring at CTF3 for CLIC
Optical Fiber Based Beam Loss Monitor for Electron Storage Ring
Cherenkov Radiation for Beam Loss Monitor Systems

BIW12IBIC12

Development of Optical Fiber Beam Loss Monitor System for the KEK Photon Factory
Simulation and Measurement of Beam Loss in the Narrow-Gap Undulator Straight Section of the Advanced Photon Source Storage Ring

c) Diamond BLMs

IBIC12/13

Operation of Silicon, Diamond and Liquid Helium Detectors in the Range of Room Temperature to 1.9 Kelvin and After an Irradiation Dose of Several Mega Gray
A Prototype Readout System for the Diamond Beam Loss Monitors at LHC
Performance of Detectors using Diamond Sensors at the LHC and CMS

IPAC12

Advances in CVD Diamond for Accelerator Applications
BEAM HALO MONITOR FOR FLASH AND THE EUROPEAN XFEL
Investigation of the Use of Silicon, Diamond and Liquid Helium Detectors for Beam Loss Measurements at 2 Kelvin

7) Needs for further development:

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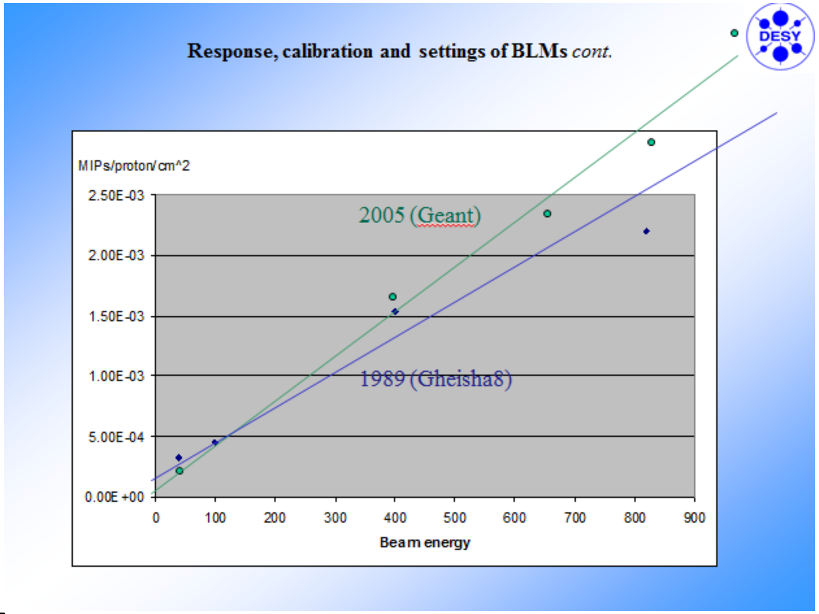
- **Calibration of BLM signal in terms of lost particles**
- Dealing with saturation, avoiding, detecting
- Extending the useful dynamic range and speed of loss measurements



Quite often, BLMs are used just to minimize losses. Mainly in superconducting hadron accelerators a calibration of the loss signal was done to define thresholds for quenches.

There is a need to calibrate the losses in terms of dose at high intense hadron accelerators to avoid activation, checking the 1W/m rule.
<u>-> Reliable integration of BLMs into MPS</u>

Beam lifetime measured by current and loss monitors agreed by factor 2 in HERAp. I've heard about the same at LHC.

BEAM LOSS LIMITS IN HIGH POWER PROTON LINEAR ACCELERATORS
L. Tchelidze, IPAC2013

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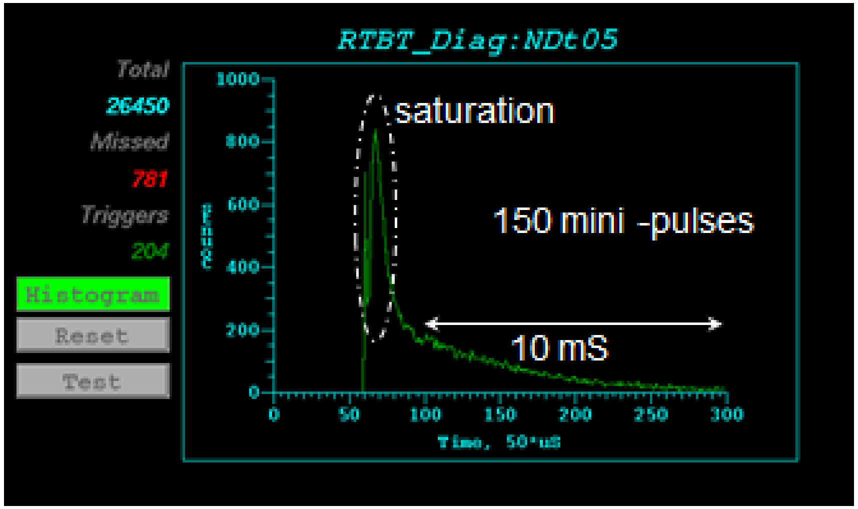
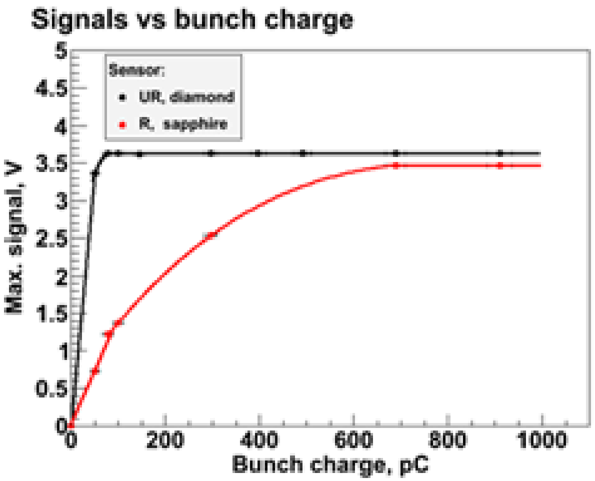


It is not always obvious if your detector, amplifier, ADC circuit is saturating. PMTs behave crazy at saturation.
It's known, but how to deal with it in operation?
Not much in literature available.



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- **Extending the useful dynamic range and speed of loss measurements**

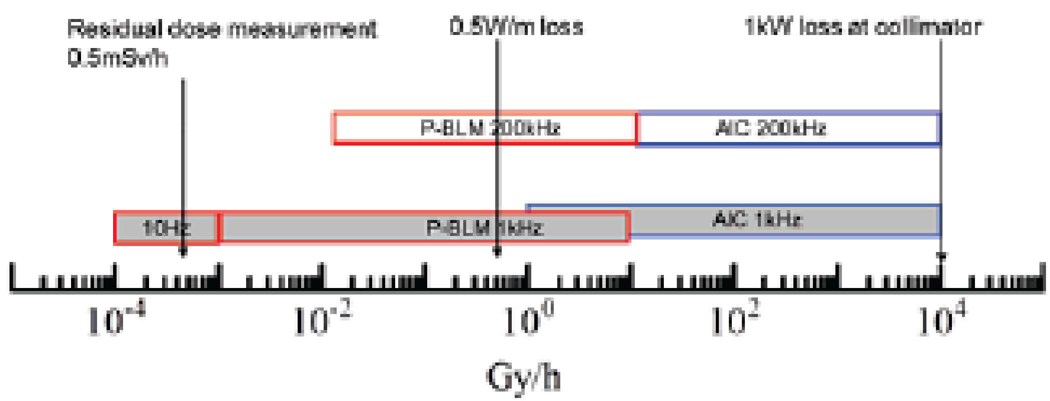
UPGRADE PLAN OF BLM SYSTEM OF J-PARC MR

Kenichirou Satou and Takeshi Toyama, J-PARC, KEK & JAEA, Tokai, Ibaraki, Japan.

SUMMARY

To measure the residual dose and intra-bunch beam loss phenomena, the BLM system is required to be upgrade. The essences of the upgrade plan are to extensively enhance the dynamic range and higher frequency band. The double monitor system, P-BLM and short-AIC, will improve the dynamic range up to 1E8. And, the introduction of the S-BLM makes it possible to study more complicated loss mechanism.

Improvement of the Dynamic Range by Short-AIC + P-BLM System



7) Needs for further development.

My final message:

One BLM System is not enough

for

your

accelerator!!!

Thanks for attention, questions?