BEAM LOSS MONITORING AND RELATED PROJECTS

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QUASAR and THz Group Workshop 2010

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Overview

- Introduction to beam loss monitoring:
  - Definition of loss
  - BLM Goals and requirements
- CLEX
- Optical fiber beam loss monitor:
  - Sensor
  - Detectors
- CLIC
- Beam loss monitor at CLIC:
  - Fluka and Geant4
  - Importance of simulations
  - Requirements

What is a loss? Why should it be detected?

What is a beam loss?

Particle is considered lost if it doesn't follow designed trajectory and interacts with matter.

Regular losses

- not avoidable
- typically localized on collimators or aperture limits
- during operational running
- due to different mechanisms as beam interactions, collisions, transversal and longitudinal diffusion, residual gas scattering, halo scraping…

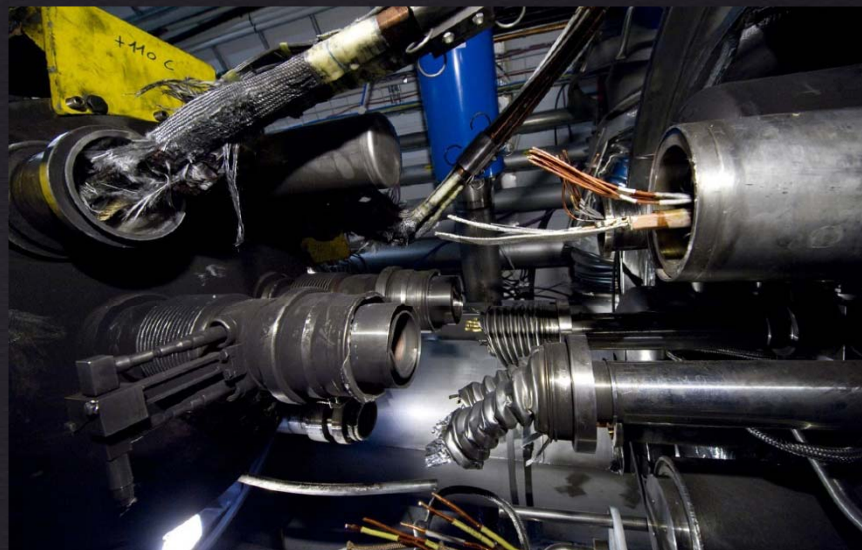
Irregular losses

- misaligned beam or a fault condition
- not predictable
- high damages for the accelerator and the electronics and dangerous for personal safety
- should be avoided!

Irregular losses as an horror movie

19th September 2008, CERN:

a faulty electrical connection between two of the accelerator's magnets resulted in mechanical damage and release of helium from the magnet cold mass into the tunnel.



Goals and requirements of a BLM

Goals

- Identify the loss level and measure losses.
- Localize losses.

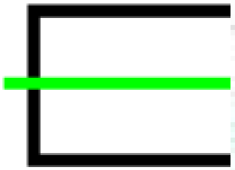
The ideal BLM

- High dynamic range to be used for both regular and irregular losses.
- Able to resolve time structure of losses.
- Not sensitive to radiation caused not by beam losses.
- Able to resolve spatial resolution of beam losses.
- Able to separate regular (usually low) from irregular (typically high and fast) losses.

How to choose a BLM

- Sensitivity
- Ease of calibration
- Radiation hardness
- Reliability
- Costs (incl. Electronics)
- Physical size
- Localization of beam losses

Why is the right choice of a BLM so important?



pipe

particles

ndaries

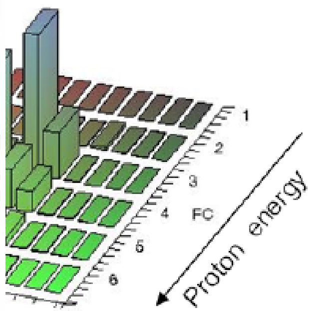
YdZ

$)P(x, y, z, X, Y, Z)dXdYdZ$

le

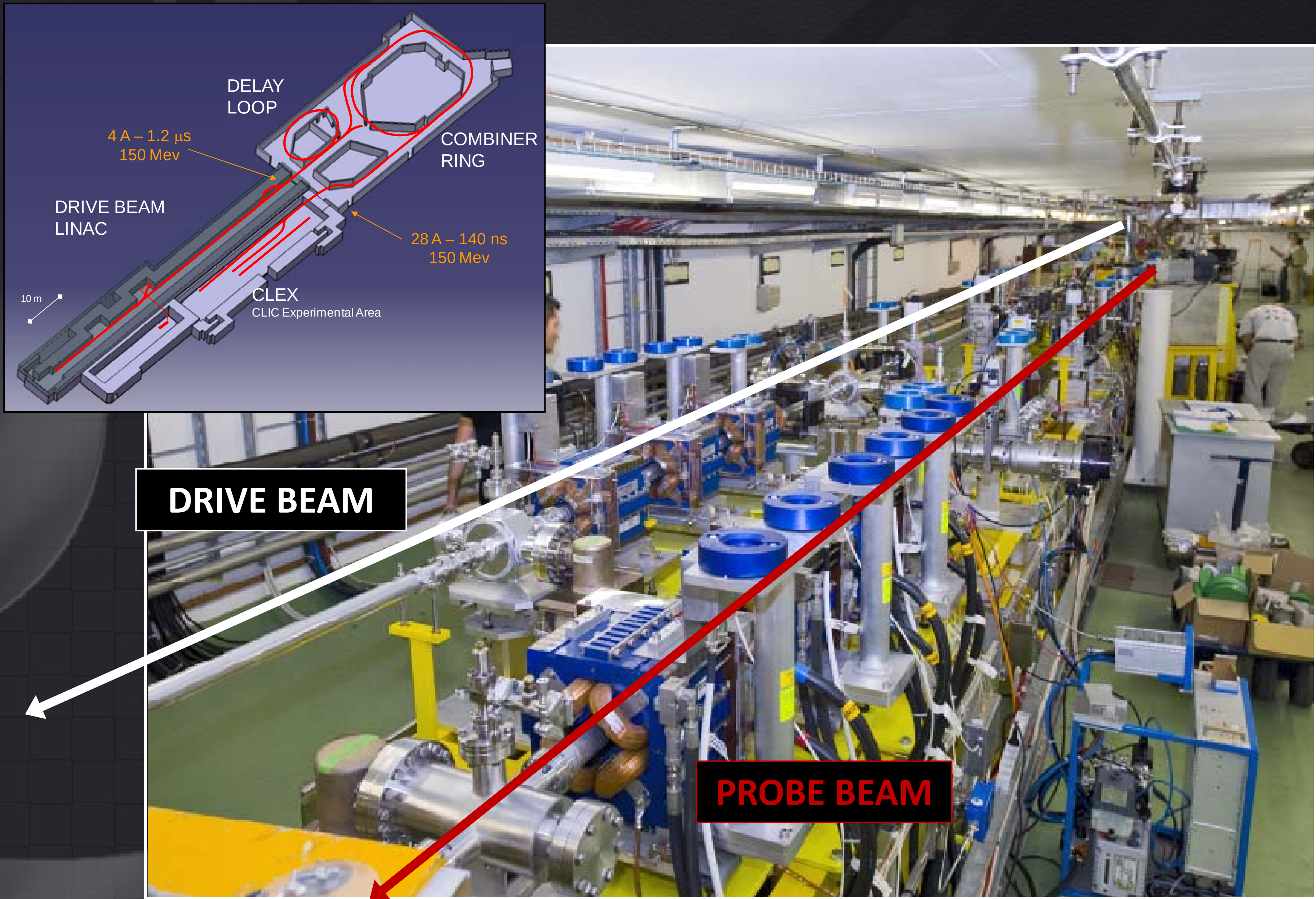
Ref: Bea

eutrons



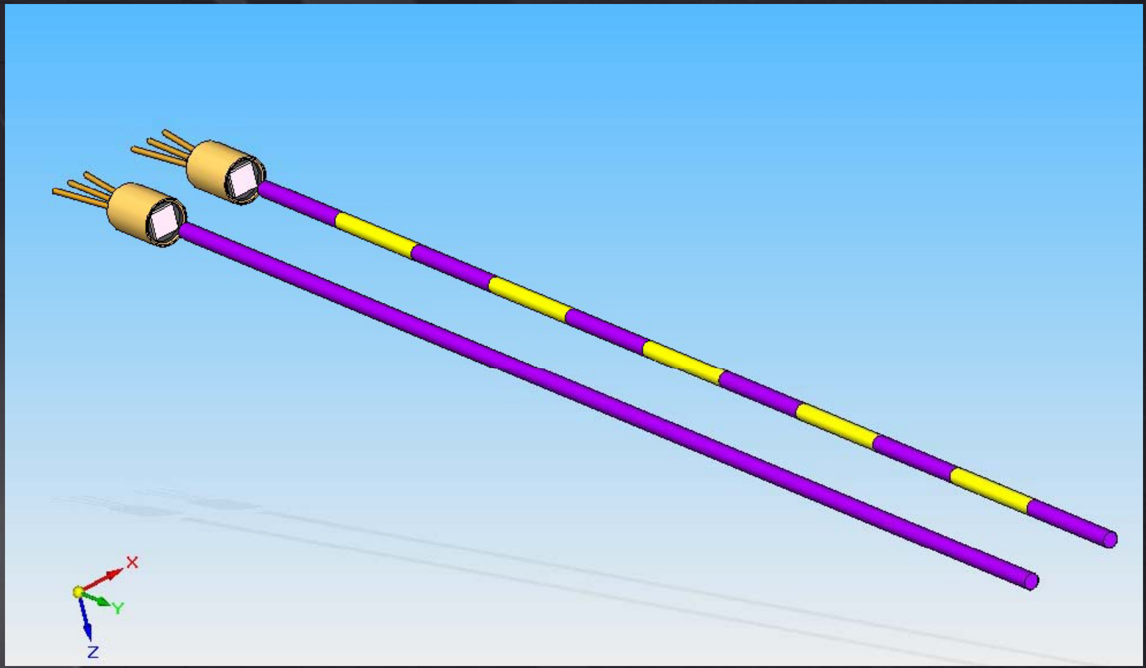
Quasars & BLMs

CTF3-Clex


DELAY
LOOP
4 A – 1.2 µs
150 Mev
COMBINER
RING
DRIVE BEAM
LINAC
28 A – 140 ns
150 Mev
10 m
CLEX
CLIC Experimental Area
DRIVE BEAM
PROBE BEAM

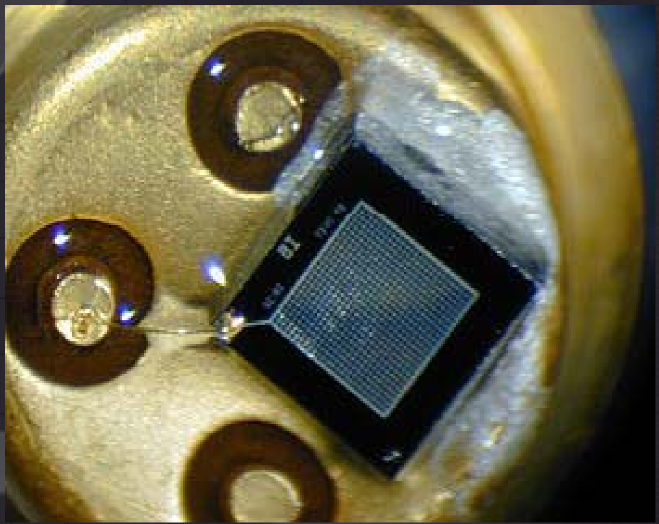
Optical fiber sensor by Cerenkov effect

A. Intermite



Main challenges:

- Sensitivity of 1 pC
- Resolution of 1.4 m
- Possibility to measure cross losses
- Evaluation and location of losses



Results:

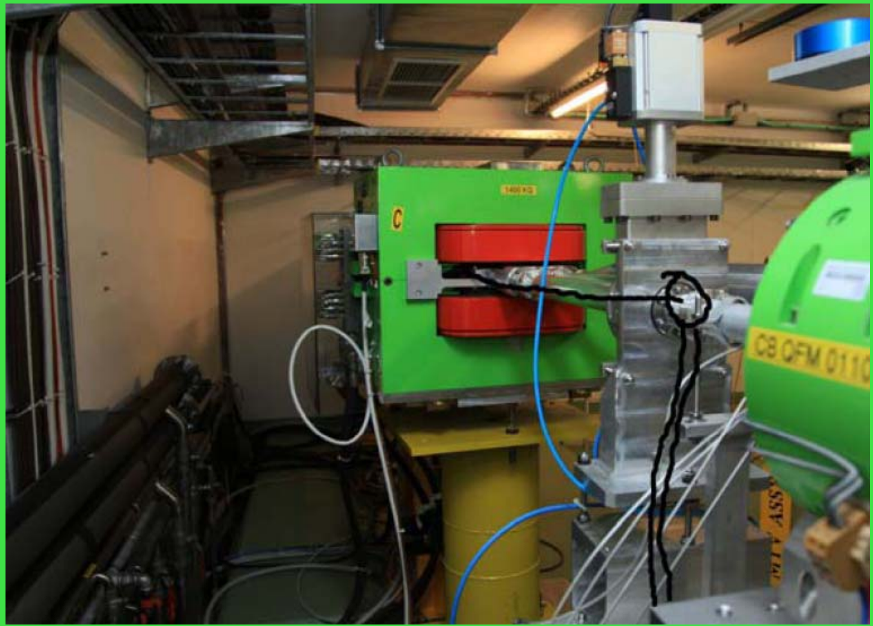
- ✓ Theoretical studies of Cerenkov Effect
- ✓ Design of the sensor
- ✓ Resolution up to few cm
- ✓ First arm assembled
- ✓ Theoretical study of different detectors
- ✓ Test and characterization of different SiPM

Future plans

A. Intermite

Alice, Daresbury

CERN

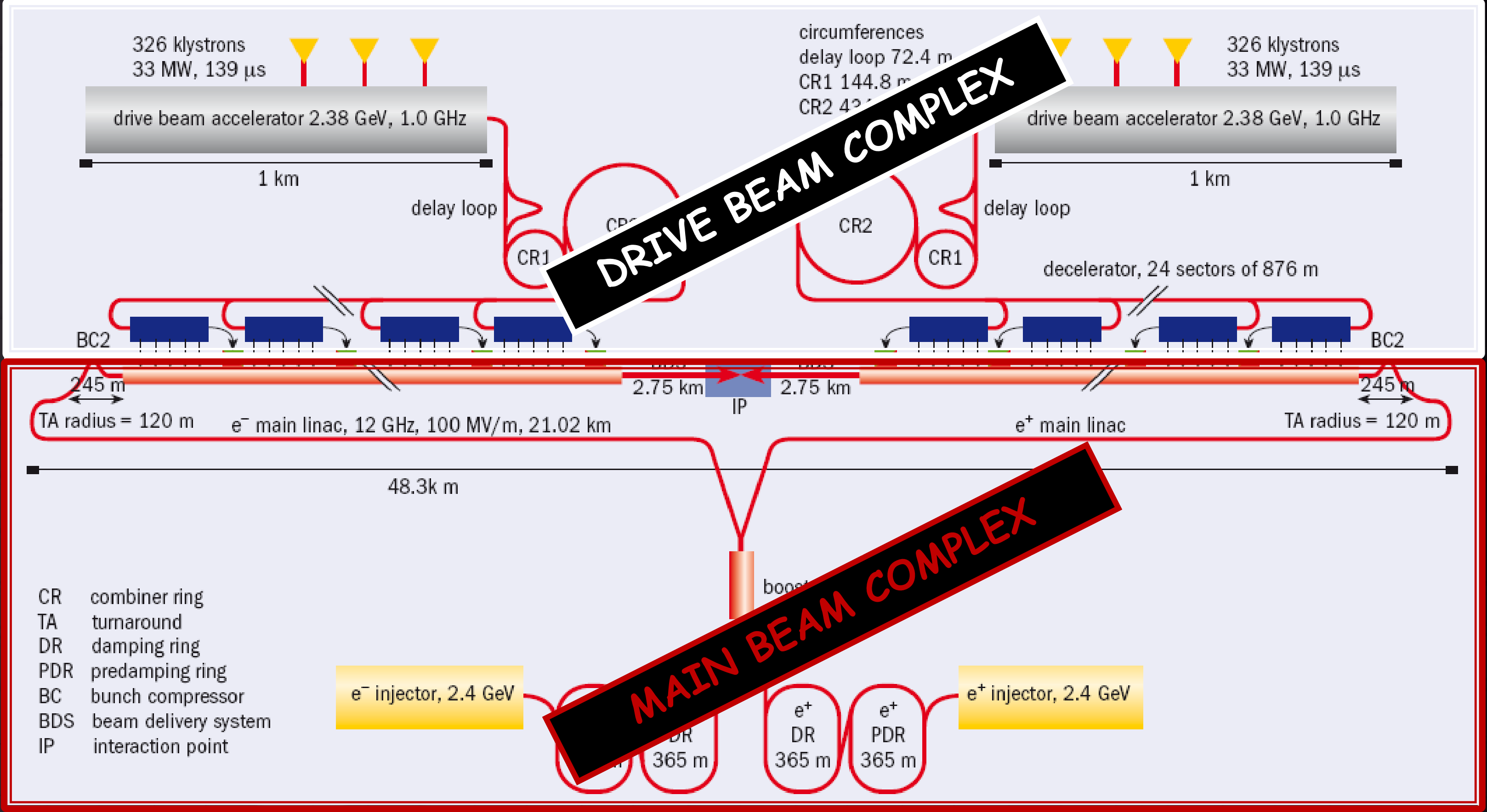


- ✓ Mechanical part assembled
- ✓ Remote control, partially ready
- ✓ Be window in place

- ✓ Location fixed
- ✓ Losses simulations: Marco and Sophie

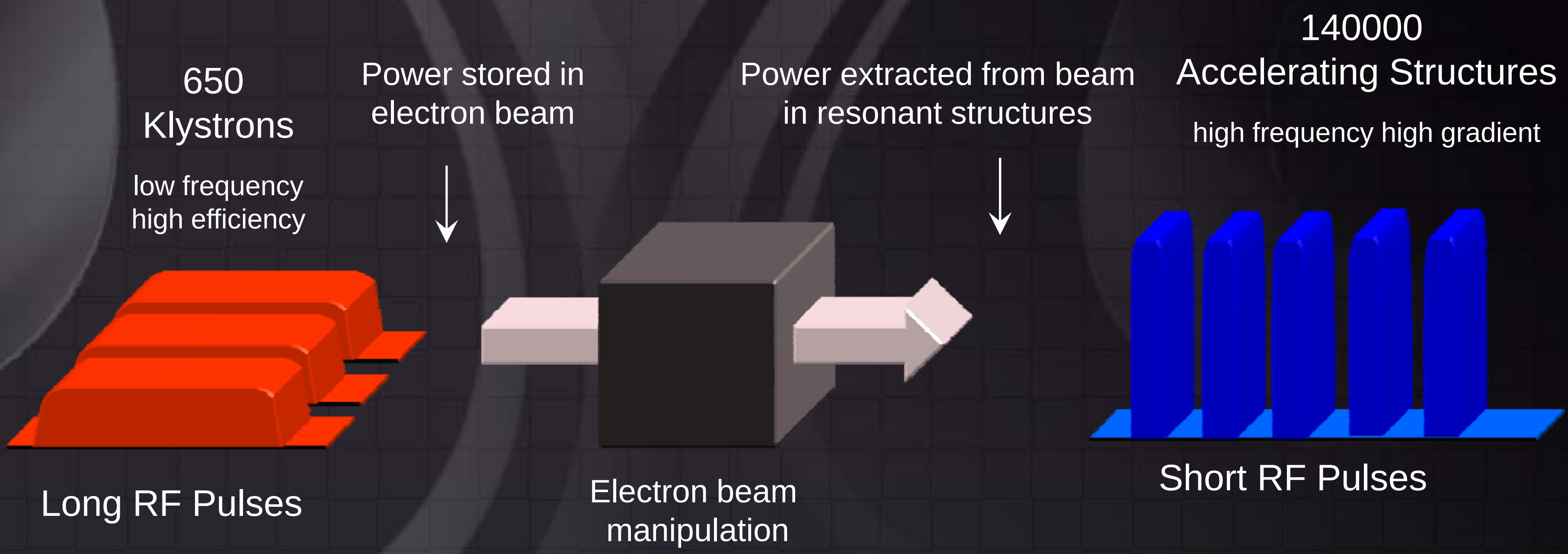
CLIC layout

Compact Linear Collider



The CLIC scheme

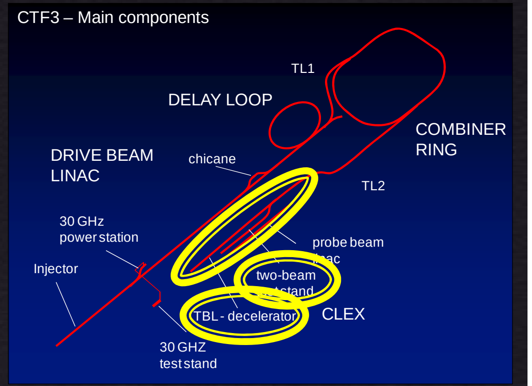
The CLIC RF power source can be described as a “black box”, combining *very long RF pulses*, and transforming them in *many short pulses*, with *higher power* and with *higher frequency*

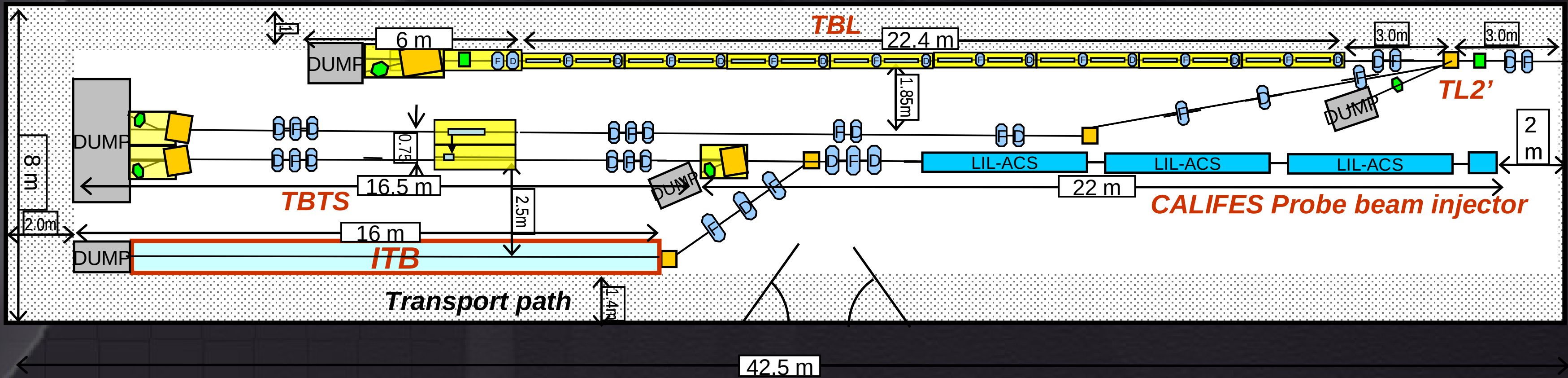


Lines subject to investigation in 2010

CLEX area:

- TBL → study the drive beam stability during the deceleration
- TBTS → test the two-beam acceleration scheme





TBL Challenges

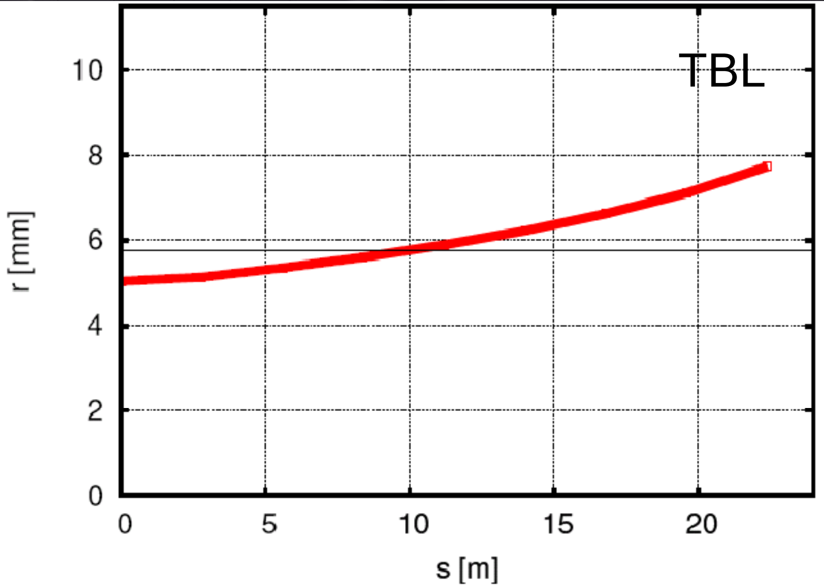
Demonstration of stable beam transport for heavily decelerated beam (CLIC feasibility)

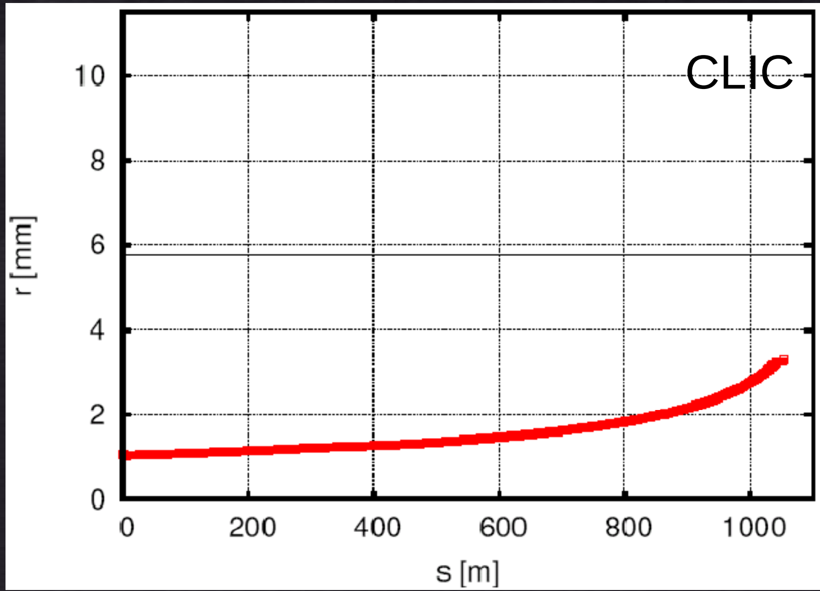
First prototype for the CLIC decelerator (test - bench and benchmarking)

This is one of the R&D items required from the International Linear Collider Technical Review Committee to demonstrate feasibility of CLIC.

TBL-CLIC problem

Due to lower initial and final energy (+ 20 % increase due to longer cell length), the TBL has a much larger beam size than CLIC in the case of perfect machine and injection.



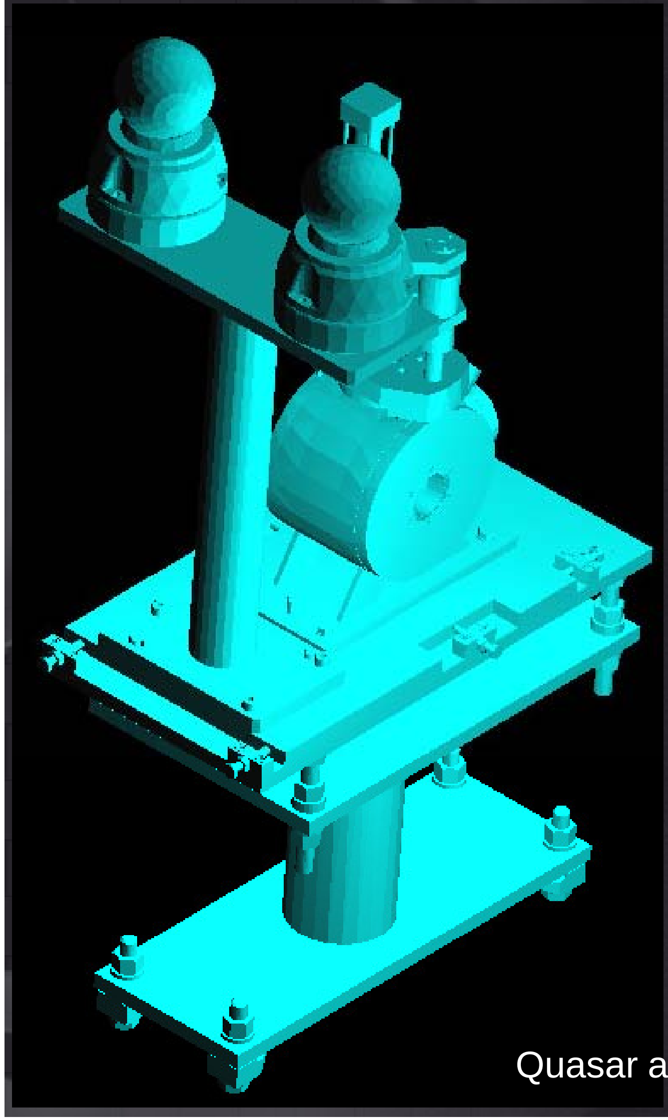


For this scenario it is significantly more difficult to achieve a low-loss transport through TBL, but should be possible depending on incoming beam.

Vital instrumentation to verify loss levels:
Optical fiber beam loss monitor under development by Angela Intermite.

"HOT" components under investigation-1

OTR screen installations

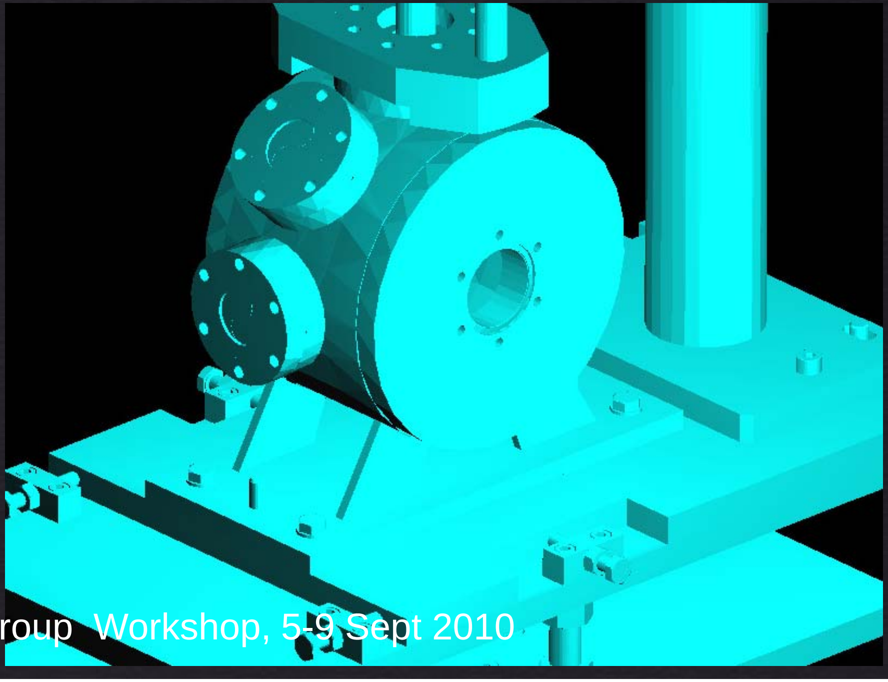


Challenges:

- Find the best position to put the sensors.
- Simulate the whole experiment.

Results:

- Beam Loss position known with very high precision.
- B.L. timing also known very well.
- High detailed models under development.



Marco Panniello

“HOT” Components under investigation-2

PET installations. (Power Extraction system and Transport):

Challenges:

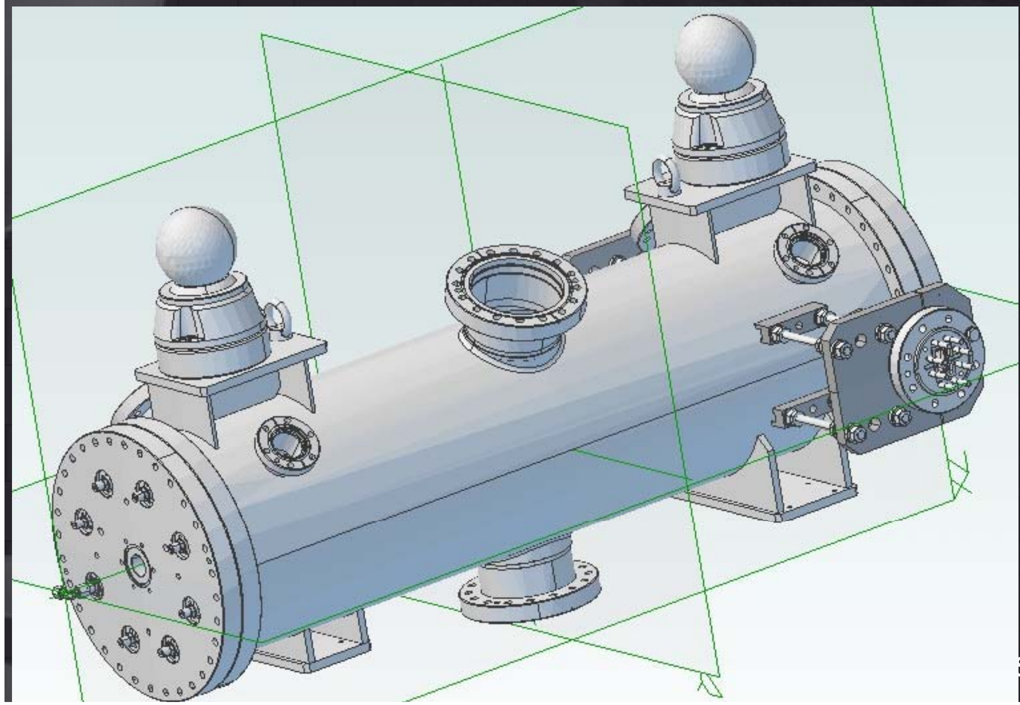
- Feasibility to perform the sensors experiment finding “hot spots” for losses.
- Simulate the whole experiment.

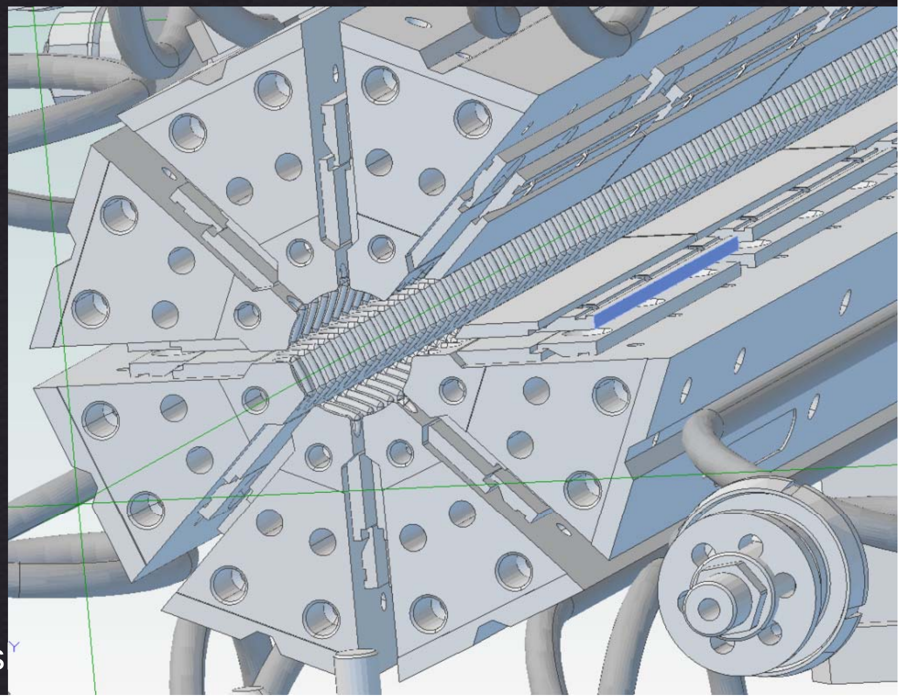
Results:

– Beam loss peaks difficult to find because of their wide and flat distribution.

– Beam loss. Timing can be dependent on the efficiency of the device to decelerate the beam.

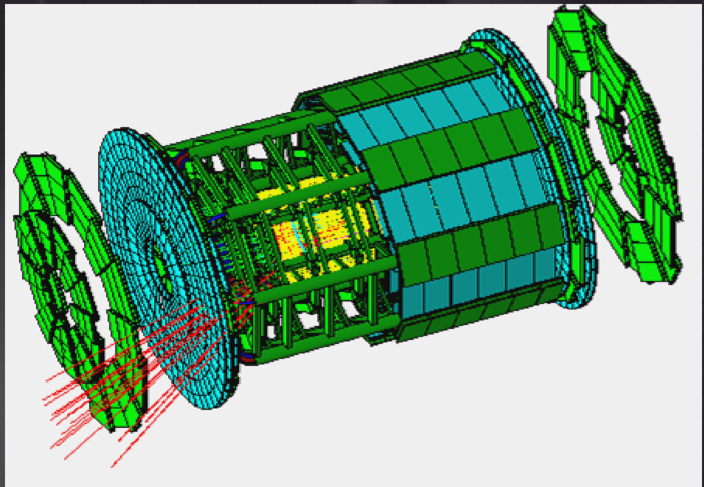
–Very complicate models, even without high detail level.



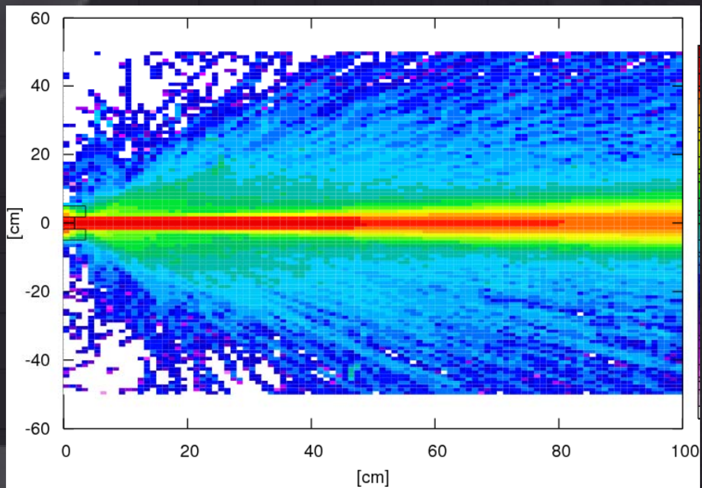


TOOLS

Free software packages which can be used to accurately simulate the passage of particles through matter. These software are “Montecarlo” codes.



Geant4:
- Not user-friendly.
- Needs more extensive programming skills.

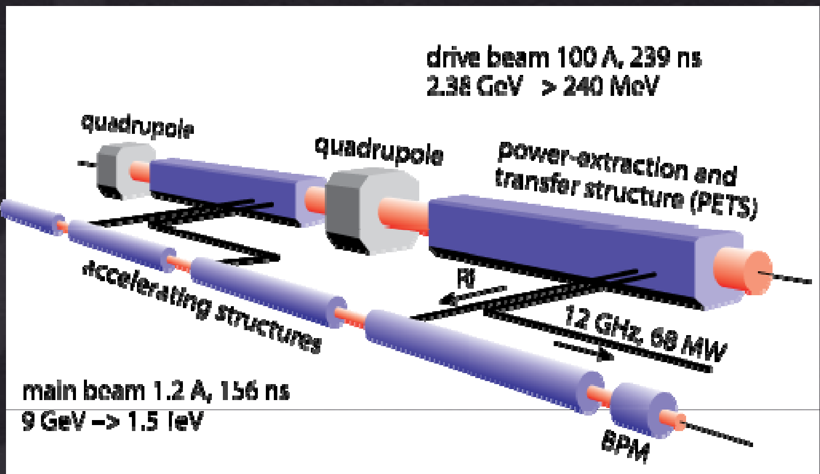


Fluka:
- User friendly thanks to good geometrical and GUI tools.
- Fewer programming skills required.

CLIC Study: 2 Beam Concept

– Study for future e+ e- collider nominal c.o.m. energy 3 TeV
– 48 km in length. Very high accelerating gradient **100 MV/m** requires sufficient RF power at 12GHz..
– Novel **two-beam-acceleration concept:** high current electron **drive beam** decelerates in special power extraction structures (PETs) and generated RF power transferred to the **main beam**

Main Beam
1.16e12 per bunch
train 50 Hz
9 GeV → 1.5 TeV



Drive Beam
1.54e14 per bunch
train 50 Hz
2.4 GeV→0.24 GeV

BLM Requirements – CLIC 2 beam modules

BLM Requirements:

✓Detector sensitivity determined by regular losses (normal operation)
Maximum limit from beam dynamic consideration: 10^{-3} of total intensity along each beamline.
Minimum limit is not known yet – in main beam expected < $2*10^{-4}$ of total intensity along main beamline(low).

✓Dynamic Range determined by irregular losses (failure mode)
Beam losses become destructive at the level where 1% of DB or 0.01% of MB hits a single aperture restriction. Limits from machine protection considerations

✓Spatial Resolution
Distinguish Between Losses originating from various sources

For choice of Detector Technology one should make estimates of the radiation field resulting from beam loss. Use Monte Carlo codes to 'score' particle fluences, absorbed doses near the beamline.

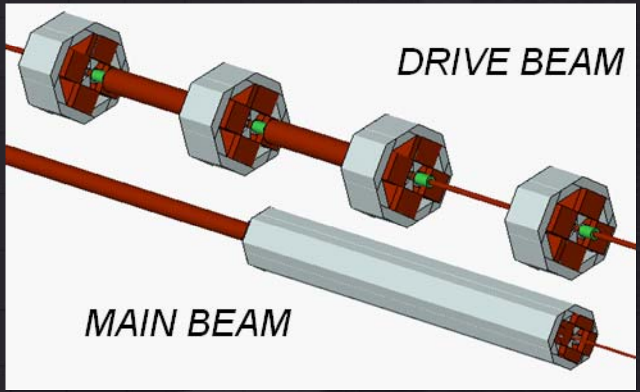
FLUKA Simulations

Simulations include representation of beam line components , concrete tunnel and concrete floor.

Simulations of ‘regular’ and ‘irregular’ losses for each beam.

Losses simulated at:

- location of aperture restrictions
- end of PETs (Drive Beam)
- end of Accelerating Structures (Main Beam)

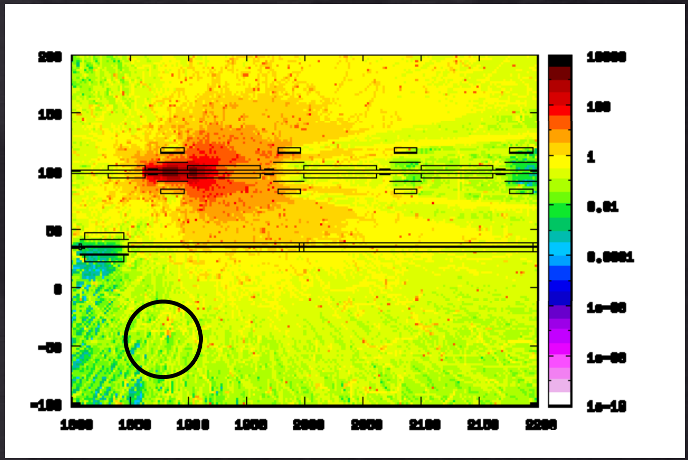


Representation of beamline components in FLUKA simulations.

FLUKA Simulations - Example Results

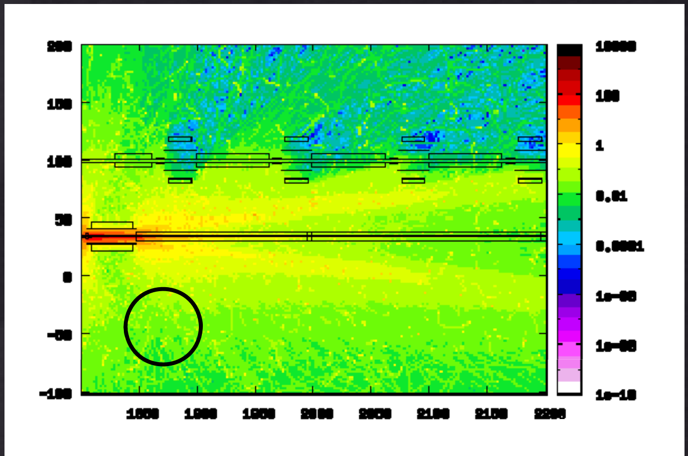
- Irregular losses originating from Main and Drive Beam
- Distinguish losses?: High Energy Drive Beam / Low Energy Main Beam.
- Determine Dynamic Range requirements.

Drive Beam 2.4 GeV



1 bunch train

Main Beam 9 GeV



1 bunch train

Thank you for your attention

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