Andrés Gómez Alonso

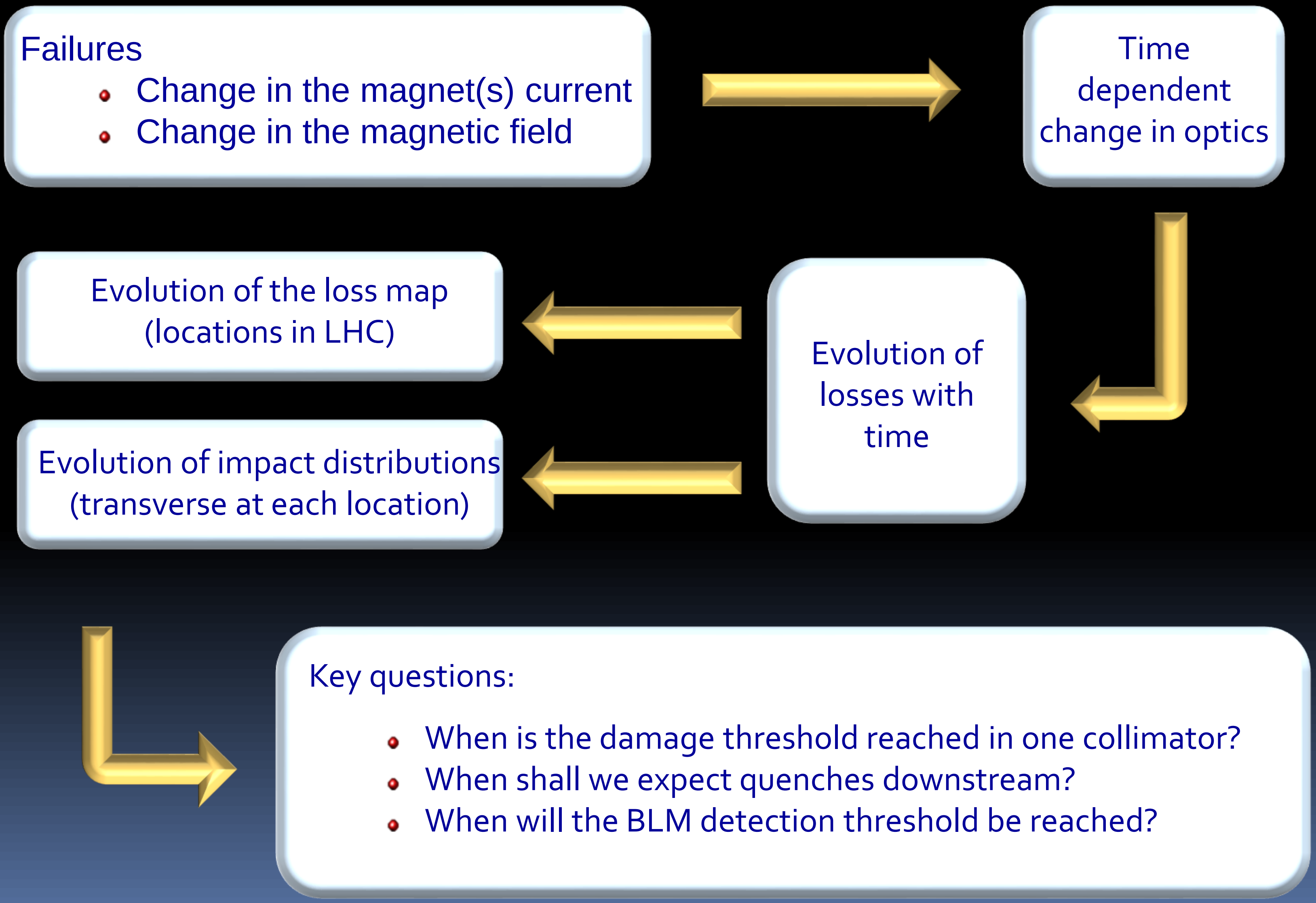
Many thanks to T. Weiler, C. Bracco

PARTICLE LOSSES AT COLLIMATORS DURING MAGNET POWERING FAILURES: DISTRIBUTION OF IMPACT PARAMETER

Outline

- Introduction: failure scenario with circualating beam
- Tracking with MADX
- Transverse impact distribution
- Post-impact tracking with sixtrack
- Estimation of time margin until quench
- Conclusions

Magnet failure with circulating beam: what happens?



Failures
- Change in the magnet(s) current
- Change in the magnetic field

Time dependent change in optics

Evolution of losses with time

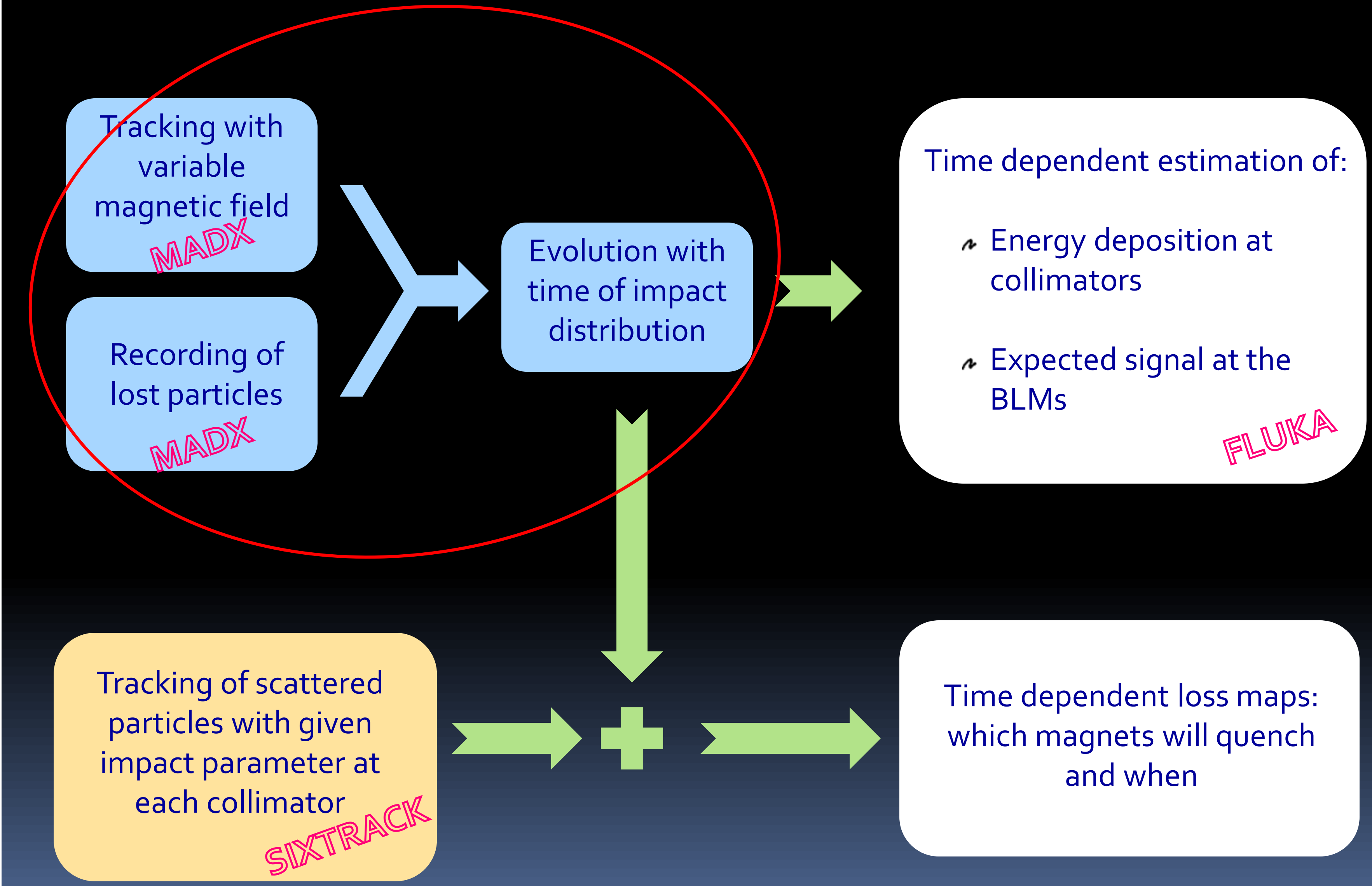
Evolution of the loss map (locations in LHC)

Evolution of impact distributions (transverse at each location)

Key questions:

- When is the damage threshold reached in one collimator?
- When shall we expect quenches downstream?
- When will the BLM detection threshold be reached?

General simulation procedure



Tracking with variable magnetic field

MADX

Recording of lost particles

MADX

Evolution with time of impact distribution

Time dependent estimation of:

- Energy deposition at collimators
- Expected signal at the BLMs

FLUKA

Tracking of scattered particles with given impact parameter at each collimator

SIXTRACK

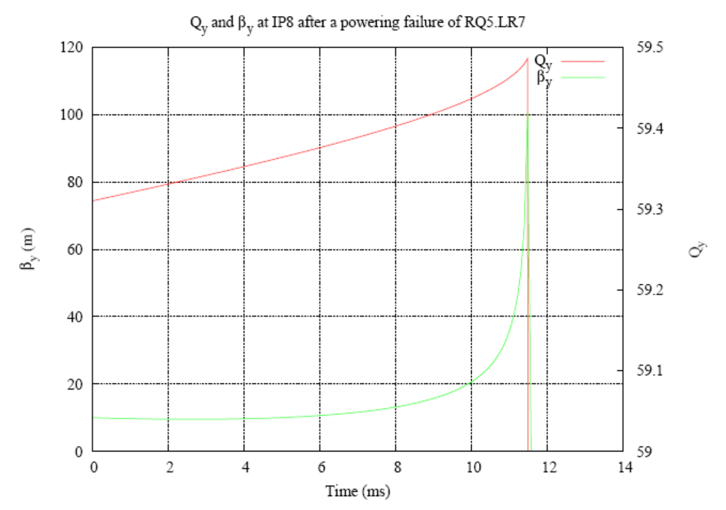
Time dependent loss maps: which magnets will quench and when

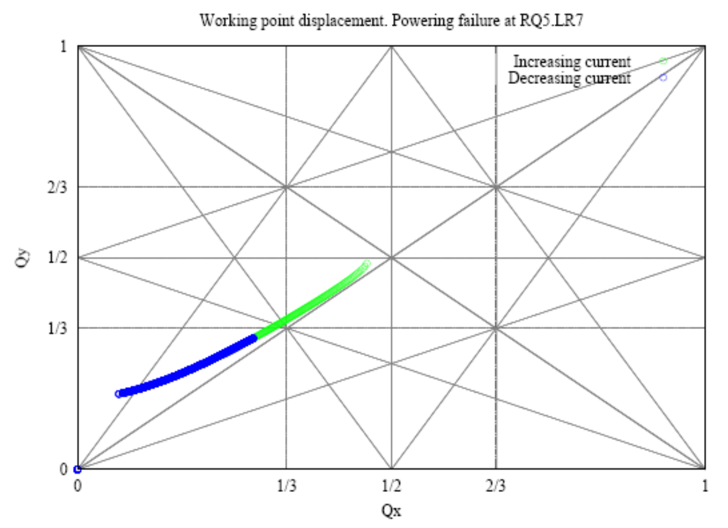
Magnet failure: evolution of the beam

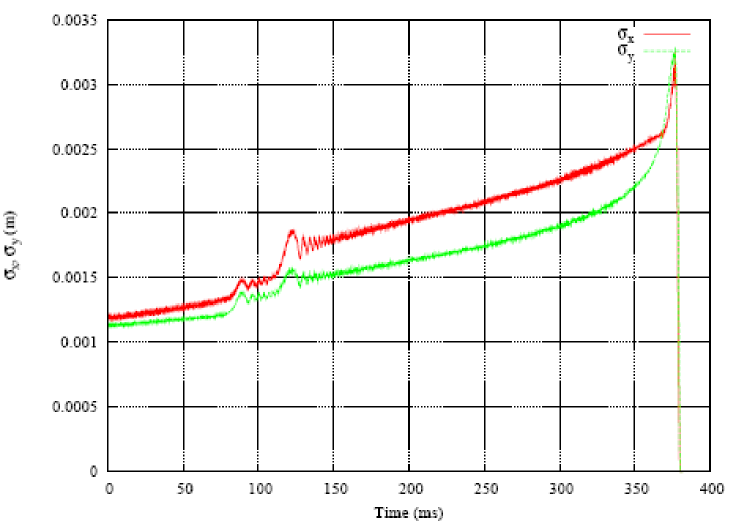
- The transverse evolution of the beam depends on:
  - Type of failing magnet
  - Type of failure
  - Speed of failure

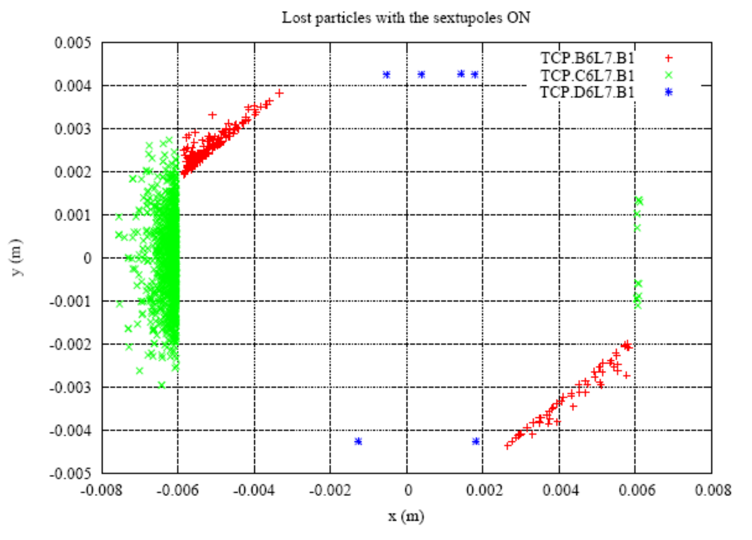
- Dipole failures: easily predictable
  - Change in closed orbit
  - Transverse displacement
- Quadrupole failures: difficult to estimate quantitatively
  - Change in twiss parameters (optics)
  - Defocusing & resonant effects

Quadrupole failures. Some observed effects


Q_y and β_y at IP8 after a powering failure of RQ5.LR7

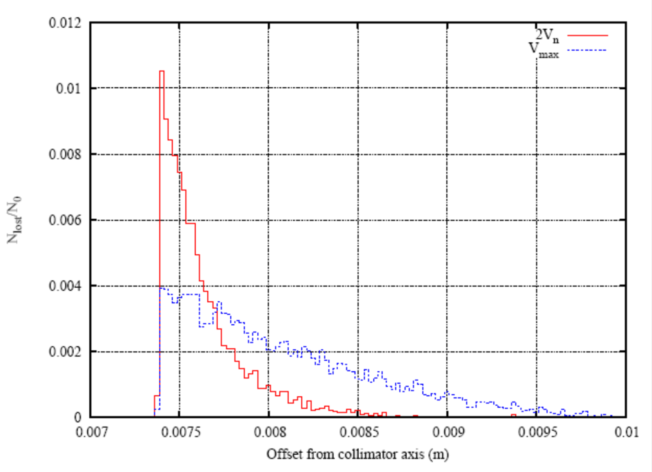

Working point displacement. Powering failure at RQ5.LR7




Lost particles with the sextupoles ON

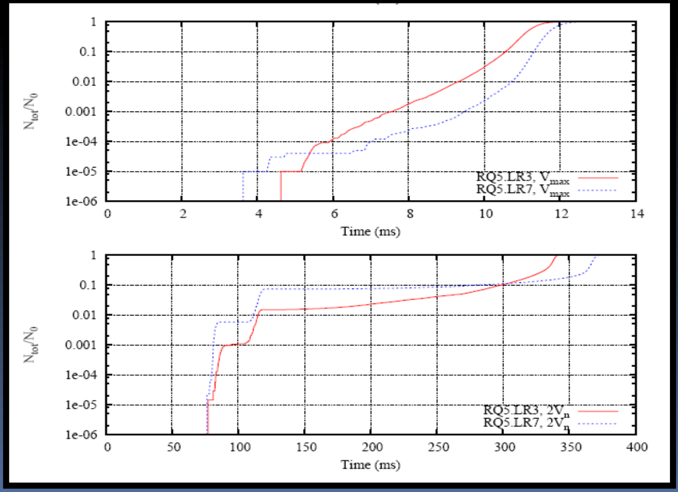
Influence of the speed of failures
Faster failures imply…

- Larger impact distribution



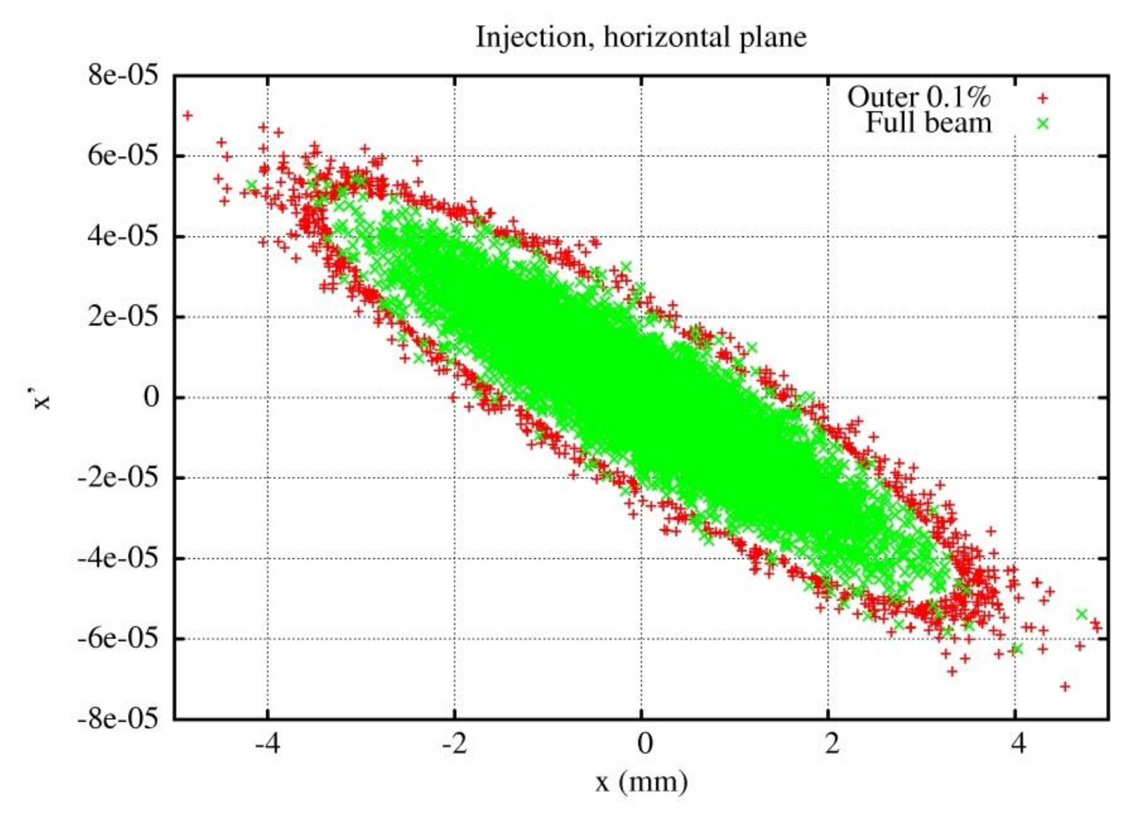
- Losses distributed in more collimators

- Smaller influence of non linear effects

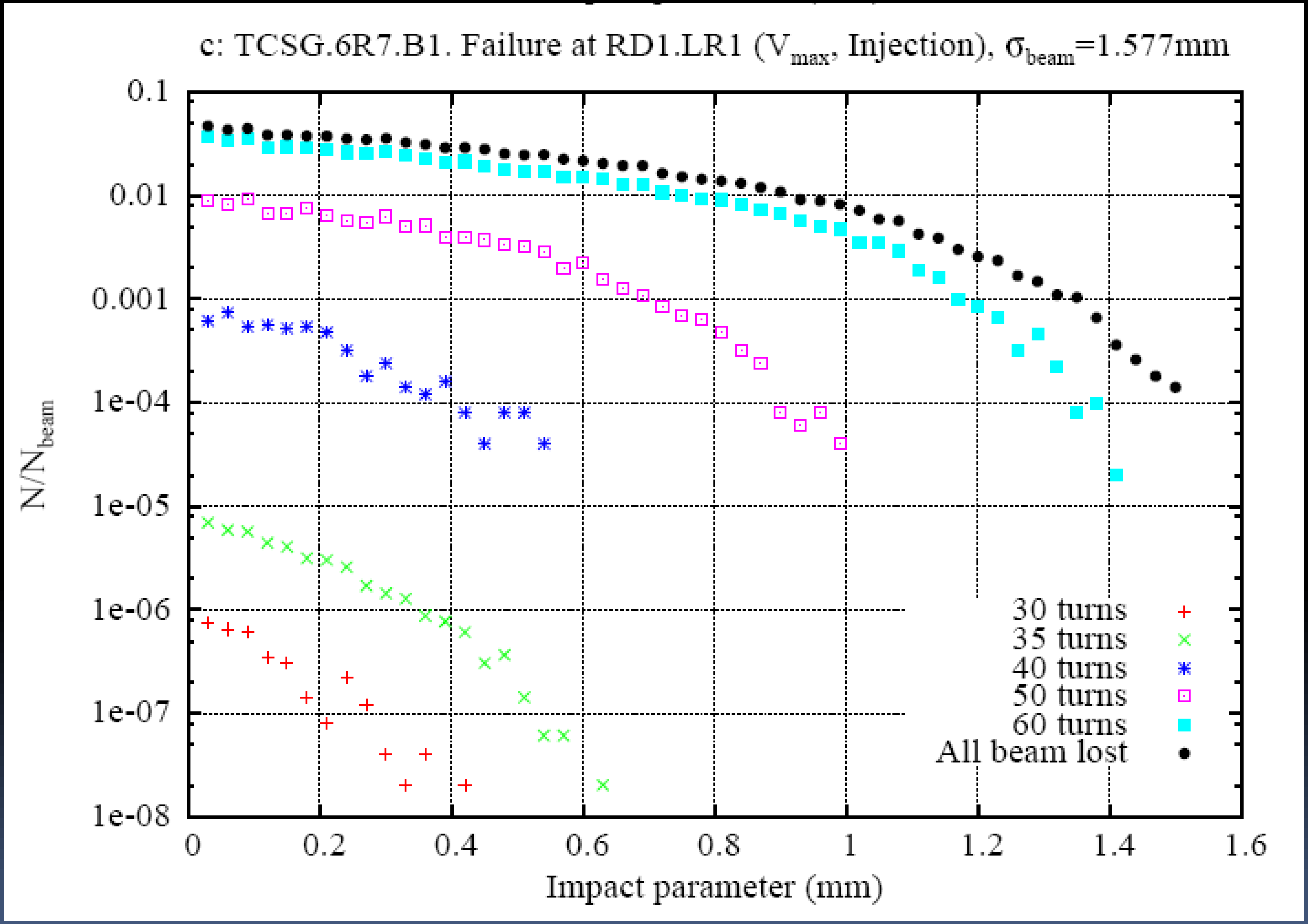


Tracking with variable magnetic field (MADX)

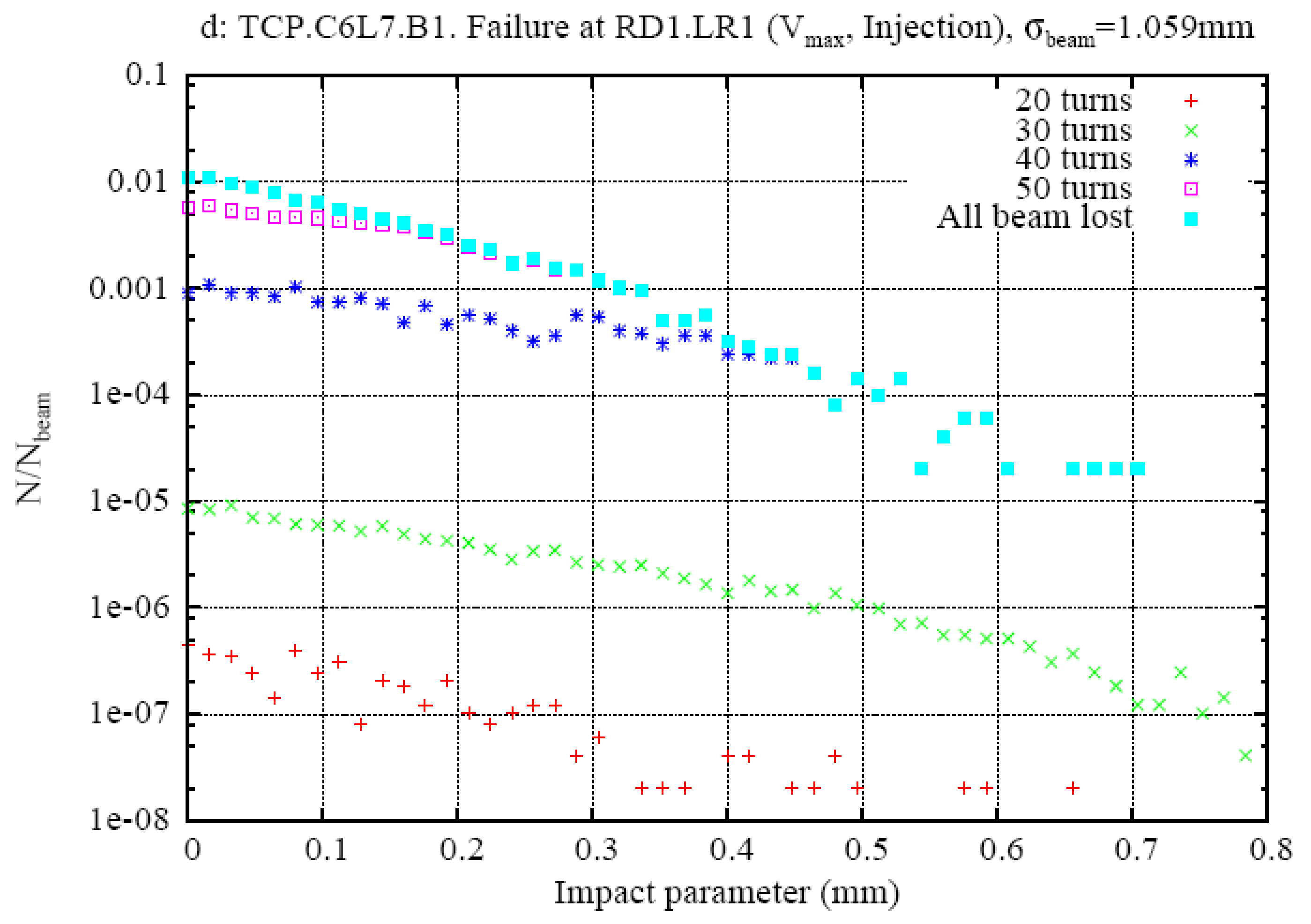
- Two different sets of particles: global view and good resolution
- 5 e4 particles in each case: “minimum” statistics for 1e-4 and 1e-7 of the beam



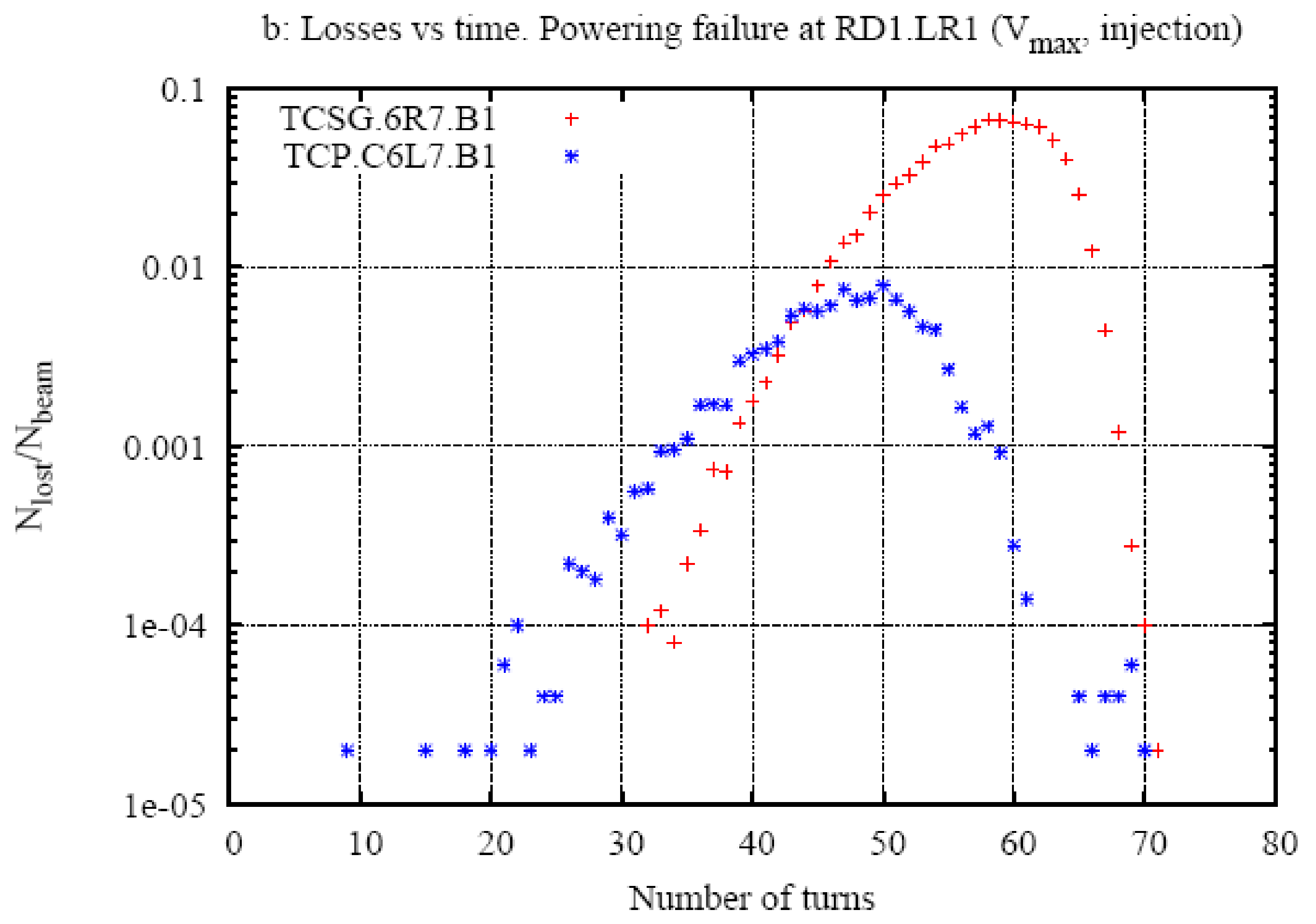
Evolution with time of the impact parameter (dipole)



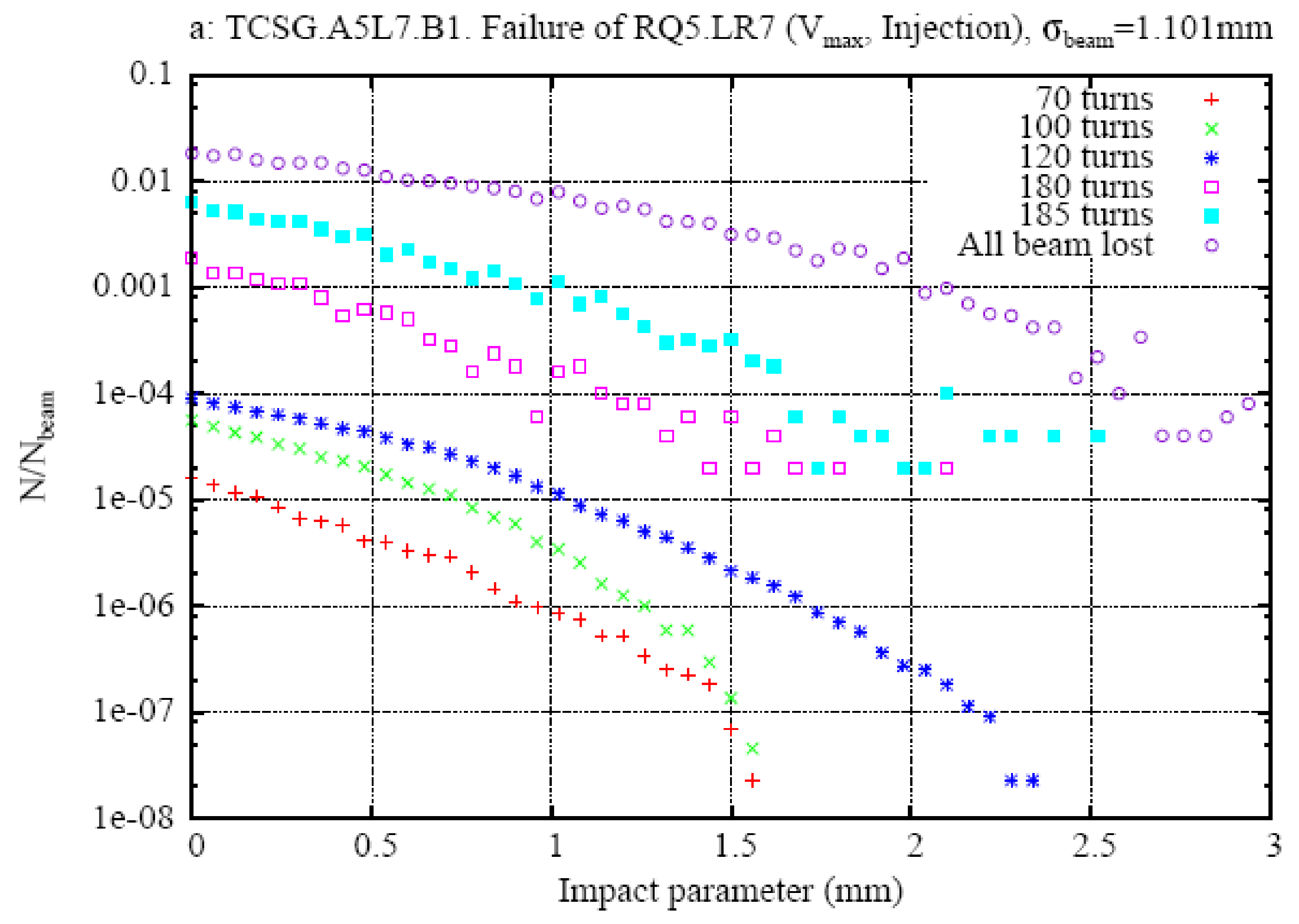
Evolution with time of the impact parameter (dipole)



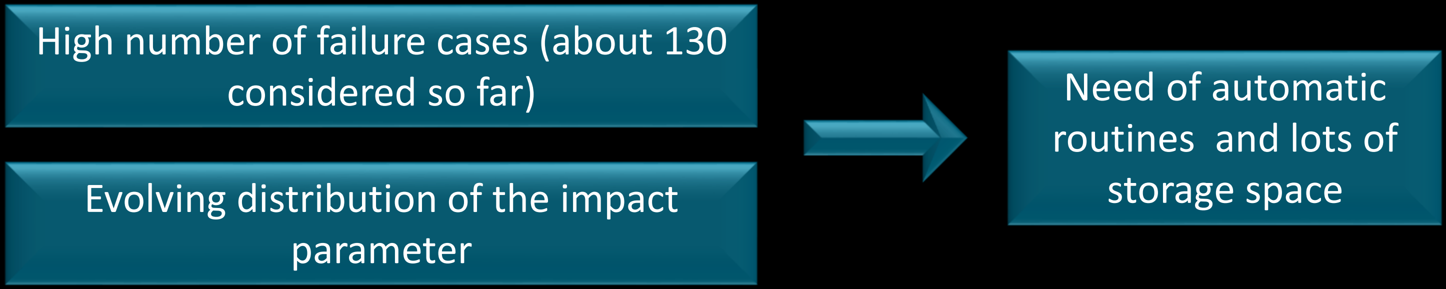
Lost particles per turn vs time



Evolution with time of the impact parameter (quadrupole)



Fit of the impact distribution



High number of failure cases (about 130 considered so far)

Evolving distribution of the impact parameter

Need of automatic routines and lots of storage space

More elegant and efficient:

1. Find a PDF that fits the distribution of the impact parameter
2. Obtain the parameters of the PDF from the impact parameter of each particle
3. Store these (few) parameters for each failure and turn
4. Reconstruct the distribution when needed

Advantages:

1. Less information is stored
2. The change in the parameters can be interpreted directly
3. Normalized function: independent of number of particles, resolution of the binning, etc.

Disadvantage:

1. The fit is not 100% accurate, but acceptable

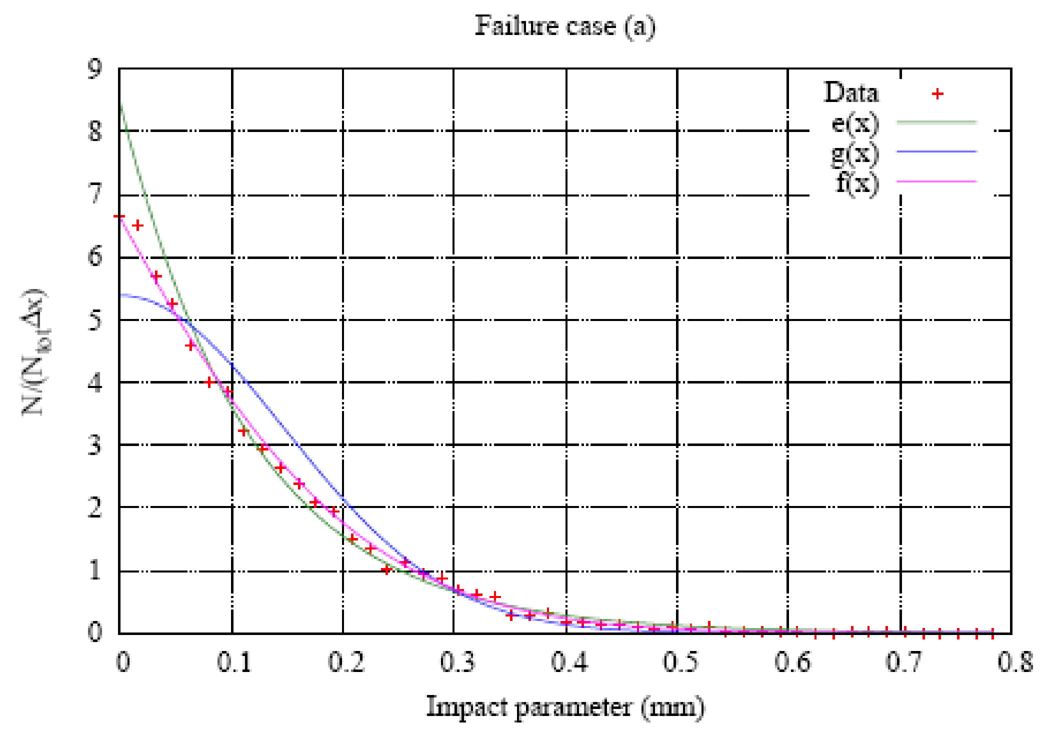
Fit details

Appropriate Probability Density Function:

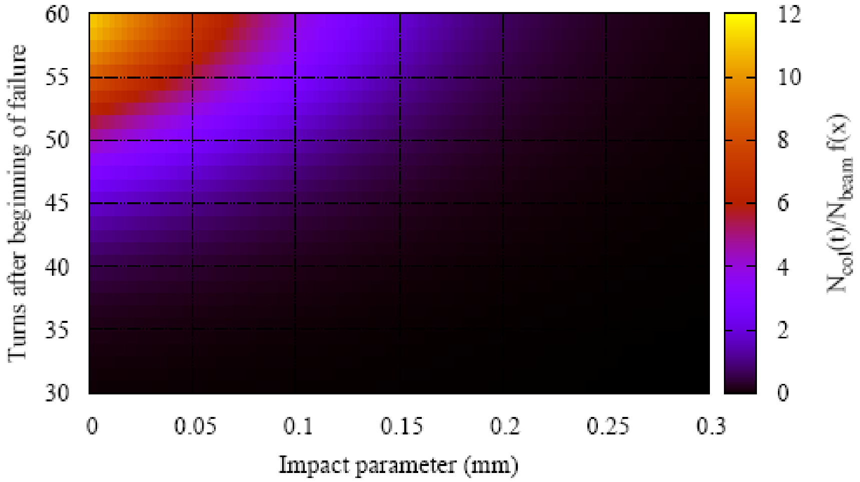
$$f(x) = A_f e^{-\frac{x^2}{2\sigma^2} - \frac{x}{\tau}}$$

Three parameters to store as a function of time: A_f, σ, τ

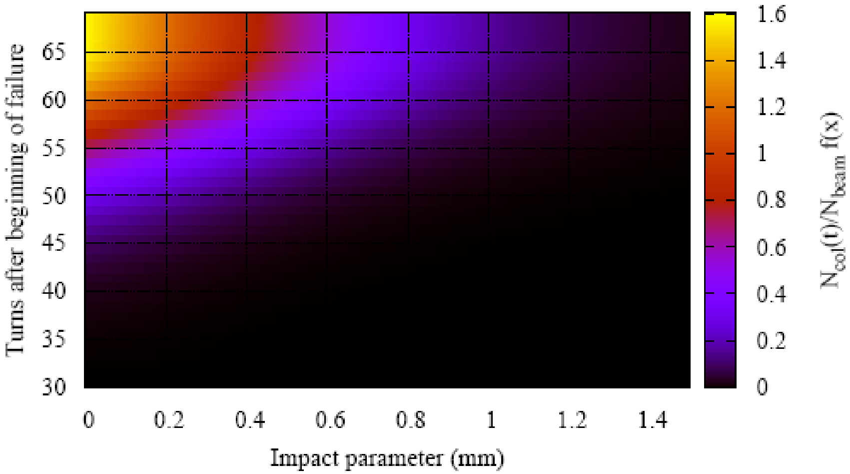
Calculated at each turn using the method of the moments



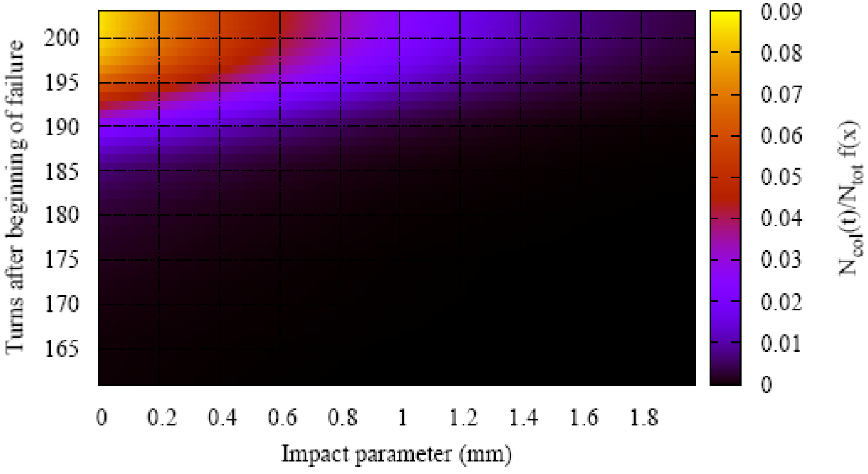
Examples



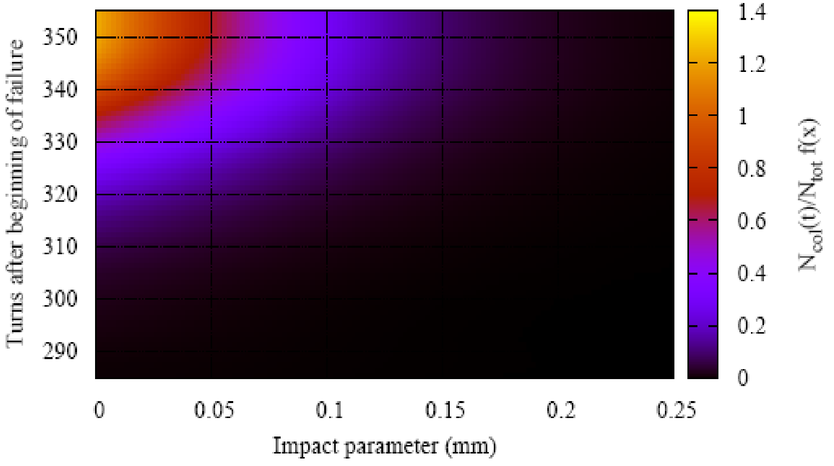
a: TCP.C6L7.B1. Failure at RD1.LR1 (0V, Collision) σ_{beam}=0.278mm



b: TCSG.6R7.B1. Failure at RD1.LR1 (V_{max}, Injection) σ_{beam}=1.577mm



c: TCSG.A5L7. Failure of RQ5.LR7 (V_{max}, Injection), σ_{beam}=1.101mm



d: TCSG.A4R7. Quench at RQX.R1 (Collision), σ_{beam}=0.262mm

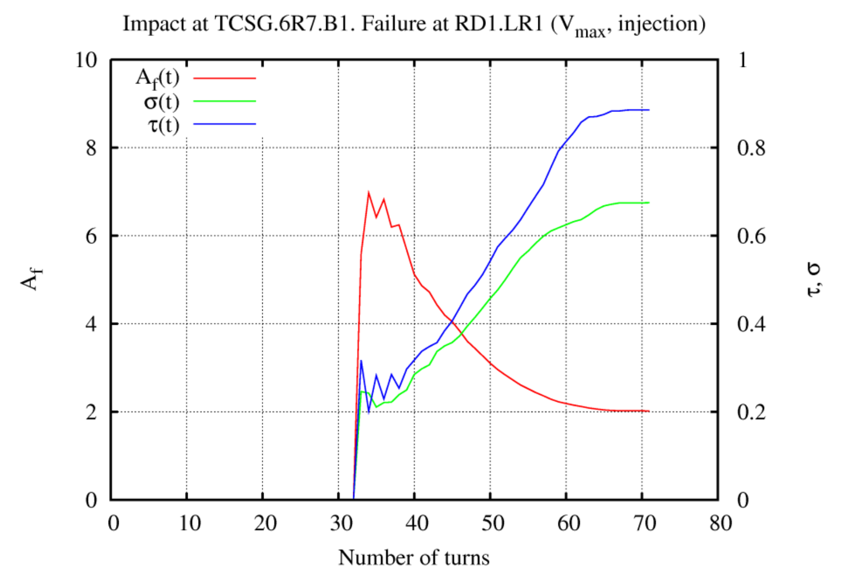
Click me

Direct interpretation

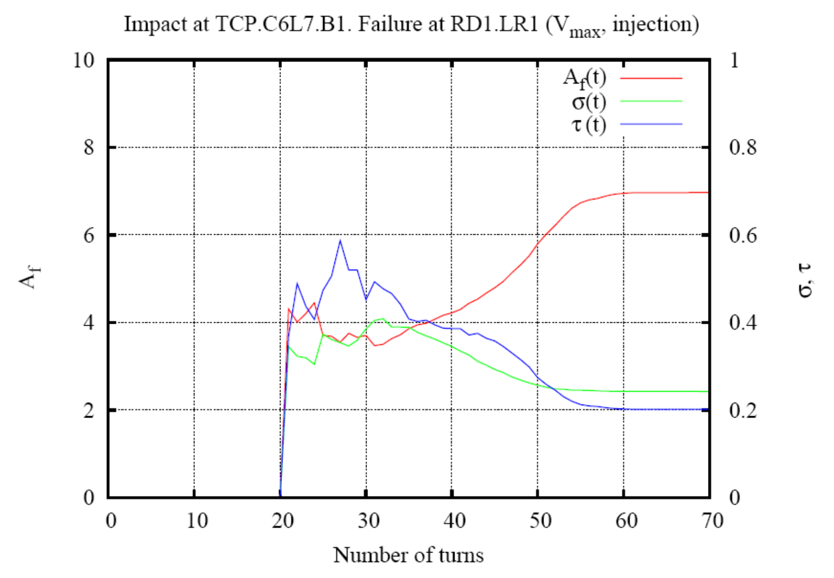
A_f, σ, τ plotted vs time contain all the information about the shape of the distribution

The impact evolution with time is fully defined by this plot and the number of particles lost in the collimator as a function of time

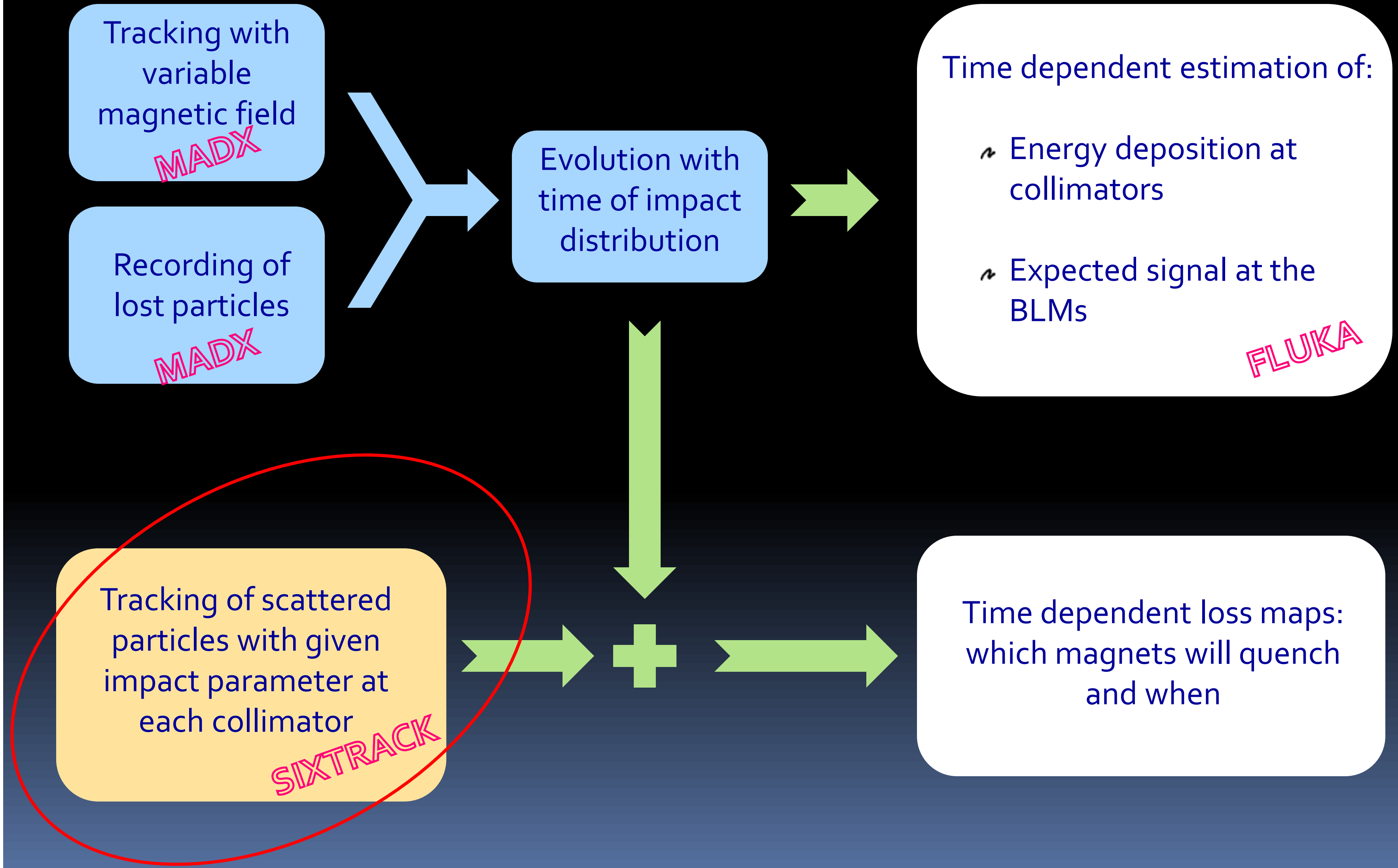
Distribution that gets larger with time



Distribution that gets narrower with time



General simulation procedure



Tracking with variable magnetic field

MADX

Recording of lost particles

MADX

Evolution with time of impact distribution

Time dependent estimation of:

- Energy deposition at collimators
- Expected signal at the BLMs

FLUKA

Tracking of scattered particles with given impact parameter at each collimator

SIXTRACK

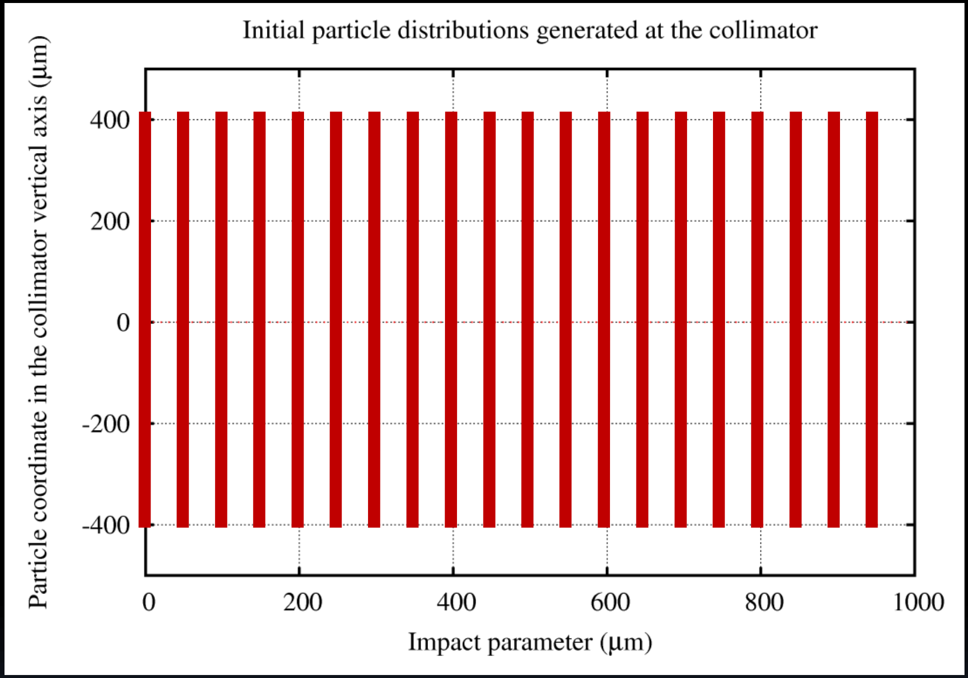
Time dependent loss maps: which magnets will quench and when

Evolution of scattered particles

- In case of failure, the average impact parameter of collimated particles can reach up to 620 μm (max of ~5 μm during normal operation)
- The probability that a particle is scattered after an impact on a collimator depends on its impact parameter.
- Tracking with sixtrack (colltrack) to study this dependence

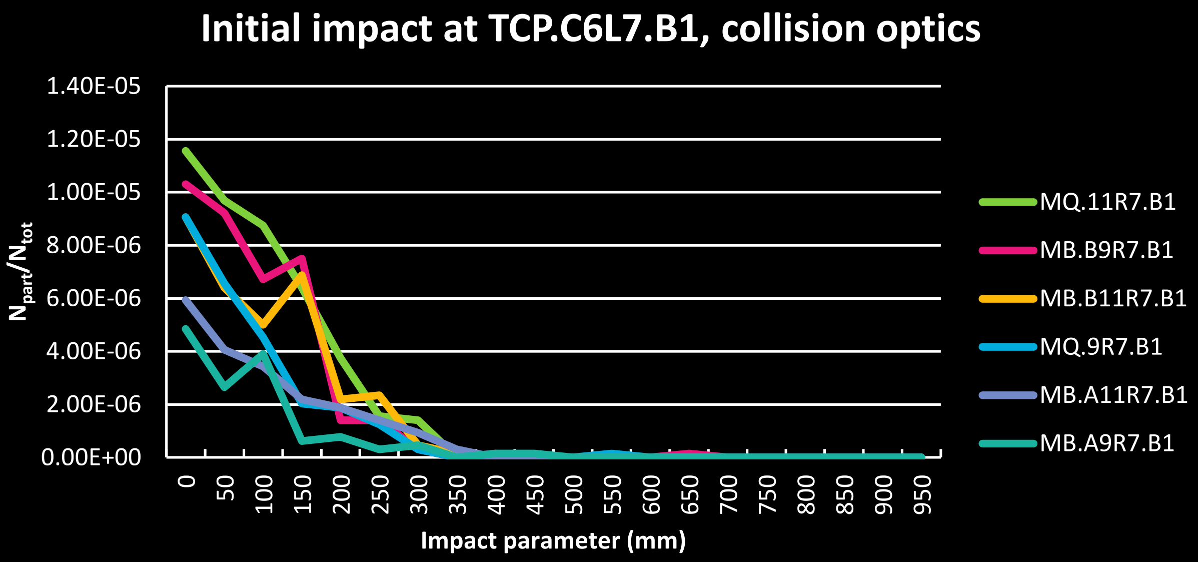
Procedure

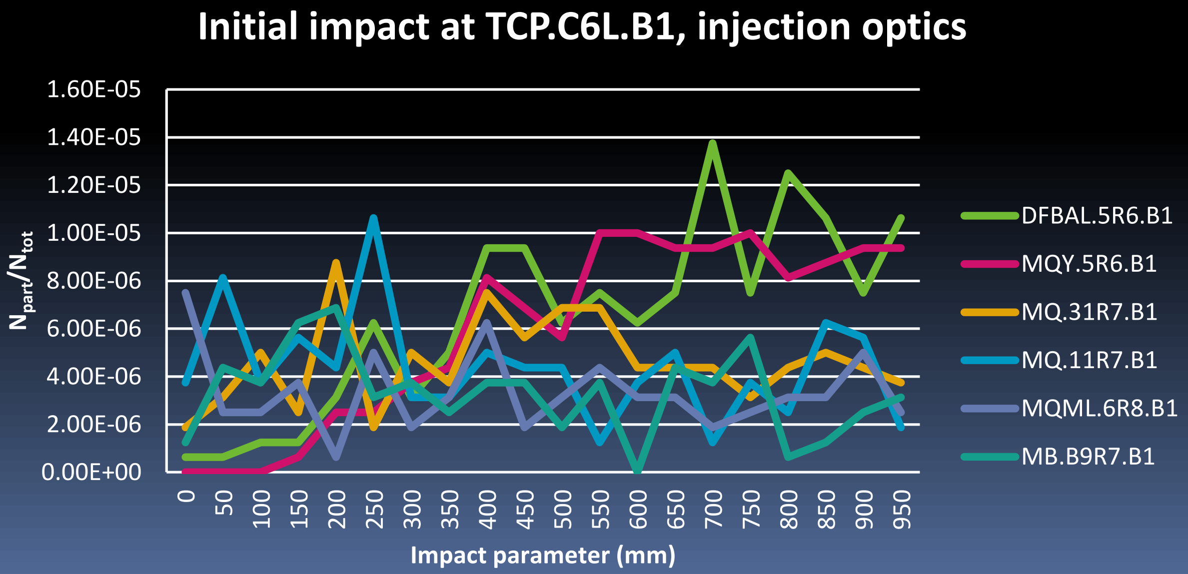
- Sheet beams at different impact parameters are generated (collimator reference frame)



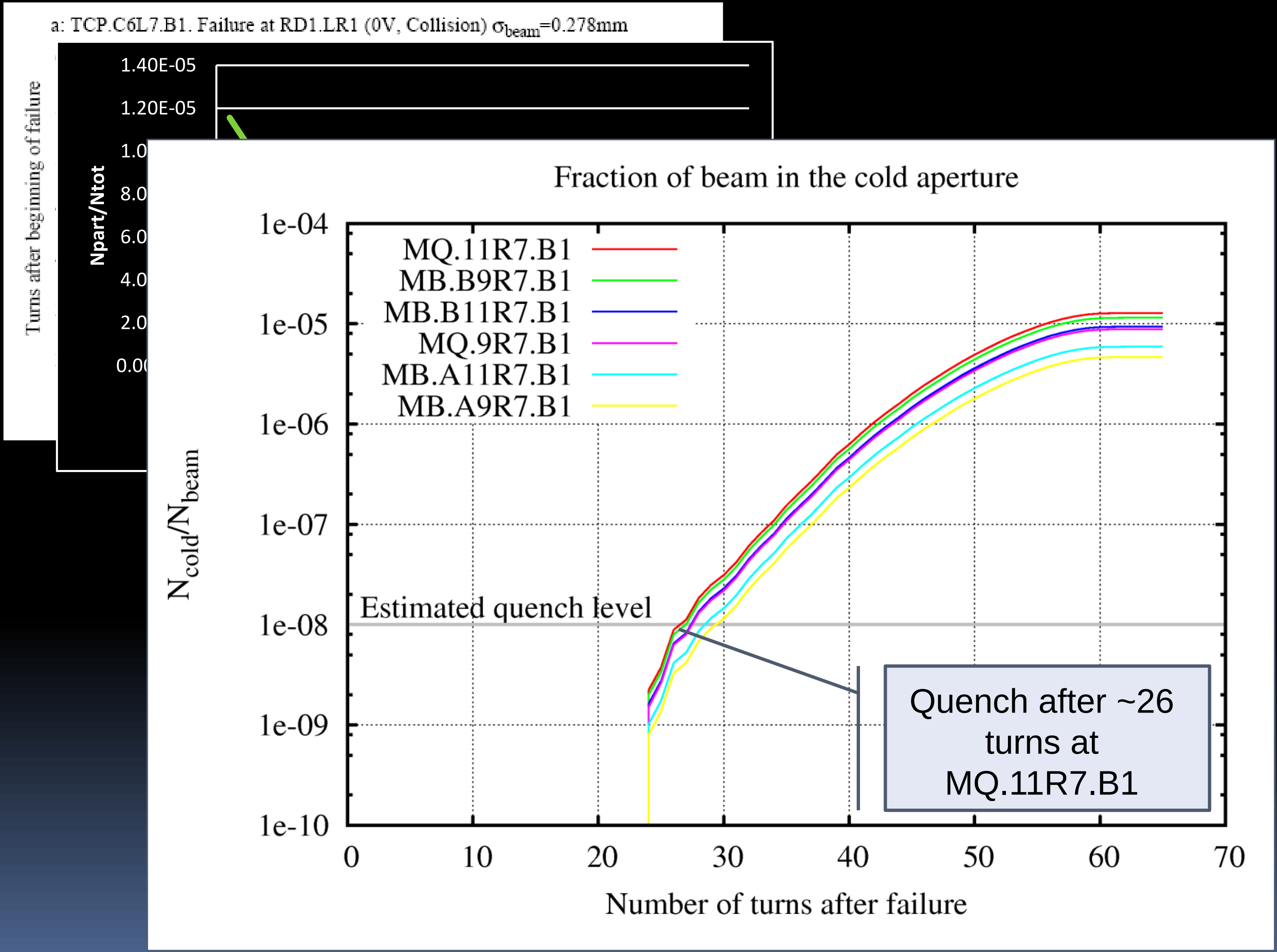
- Each sheet beam carries 1.6 10^6 particles, they are spaced by 50 μm
- The scattered particles are tracked and losses are recorded for each initial impact parameter

Scattered protons hitting the cold aperture





Combination of the results



Quench after ~26 turns at MQ.11R7.B1

Summary, conclusions & outlook

- The **evolution of the impact distribution** has been successfully estimated for a number of relevant failures
- An exponential PDF allows an **analytical reconstruction** of the distribution with little stored data (**3 parameters only)**
- A sampled simulation using sixtrack has been done to estimate the **influence of the impact parameter** at the collimator **on the losses downstream**
- Combination of the time-dependent impact distribution and the data from the sixtrack simulations allows estimating the **quench time constant** for each failure scenario

- Challenge: **automatic treatment** of output data for all the failure scenarios
- **Time constants** for **damage** at collimators and **BLM detection** to be obtained from the impact distributions using FLUKA

Thank you for your attention
(and questions)