Progress report

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Fast proton simulation

J. de Favereau + X. Rouby:

- Newest optics v6.5 implemented (uploading new and old optics files possible)
- Beam apertures included (what about the collimators?)
- Detector gaussian smearing introduced - first resolution/acceptance studies (@220m)
- Next steps:
  - Finalize acceptance studies
  - Integrate into ORCA

HECTOR – fast p simulation in the LHC

We perform a nominal (linear) simulation, by using transport matrices
We implemented :

- Beam-line elements : dipoles, quadrupoles and drifts;
  eg for a dipole:

$$\begin{pmatrix} x(s) \\ x'(s) \\ y(s) \\ y'(s) \\ \Delta p/p \end{pmatrix} = \begin{pmatrix} \cos\chi & R\sin\chi & 0 & 0 & R(1-\cos\chi) \\ -(1/R)\sin\chi & \cos\chi & 0 & 0 & \sin\chi \\ 0 & 0 & 1 & s & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ x'_0 \\ y_0 \\ y'_0 \\ \Delta p/p \end{pmatrix} \quad \text{where } \chi = s/l$$

s = element length
x, y = proton transverse coordinates
x', y' = proton transverse speeds
$R \approx 1/B$

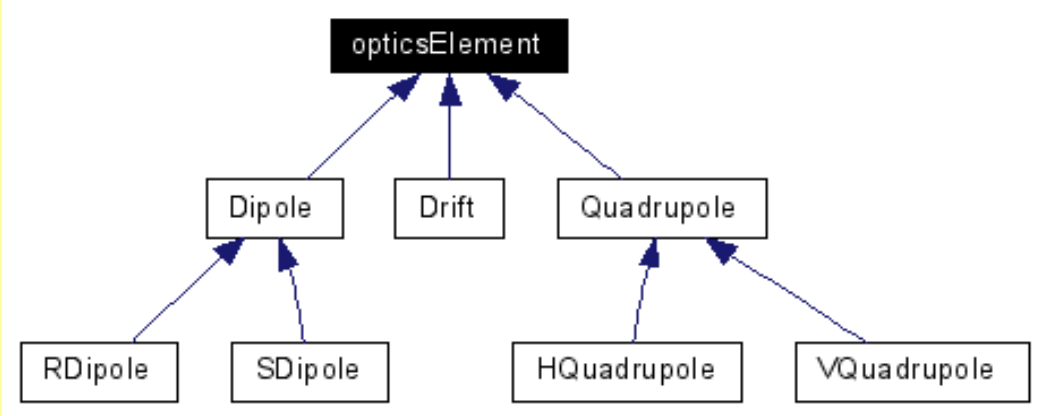
- The proton propagation through this beam-line, including the limited aperture effects

Program structure

The program code is based on C++ and ROOT 4.xx

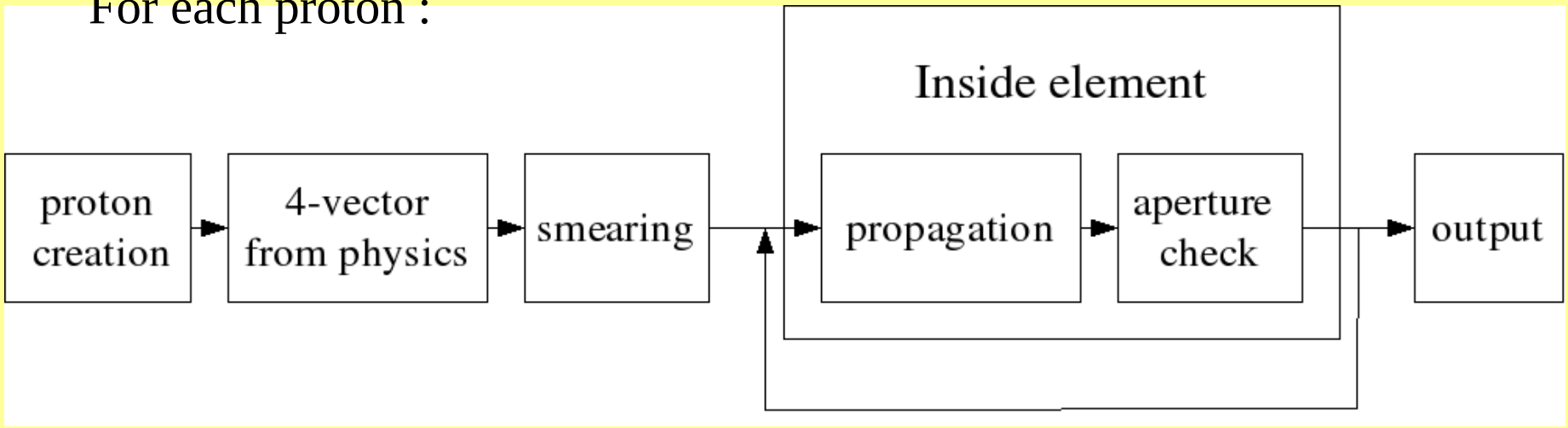
Hector allows :

- the simulation for thousands of protons really quickly (< 100 µs/evt)
- using special/personal beam-line settings
- easy importing of the official LHC beam-line tables
- drawing the beam profile/a single proton trajectory



How it works

For each proton :



The simplest example...

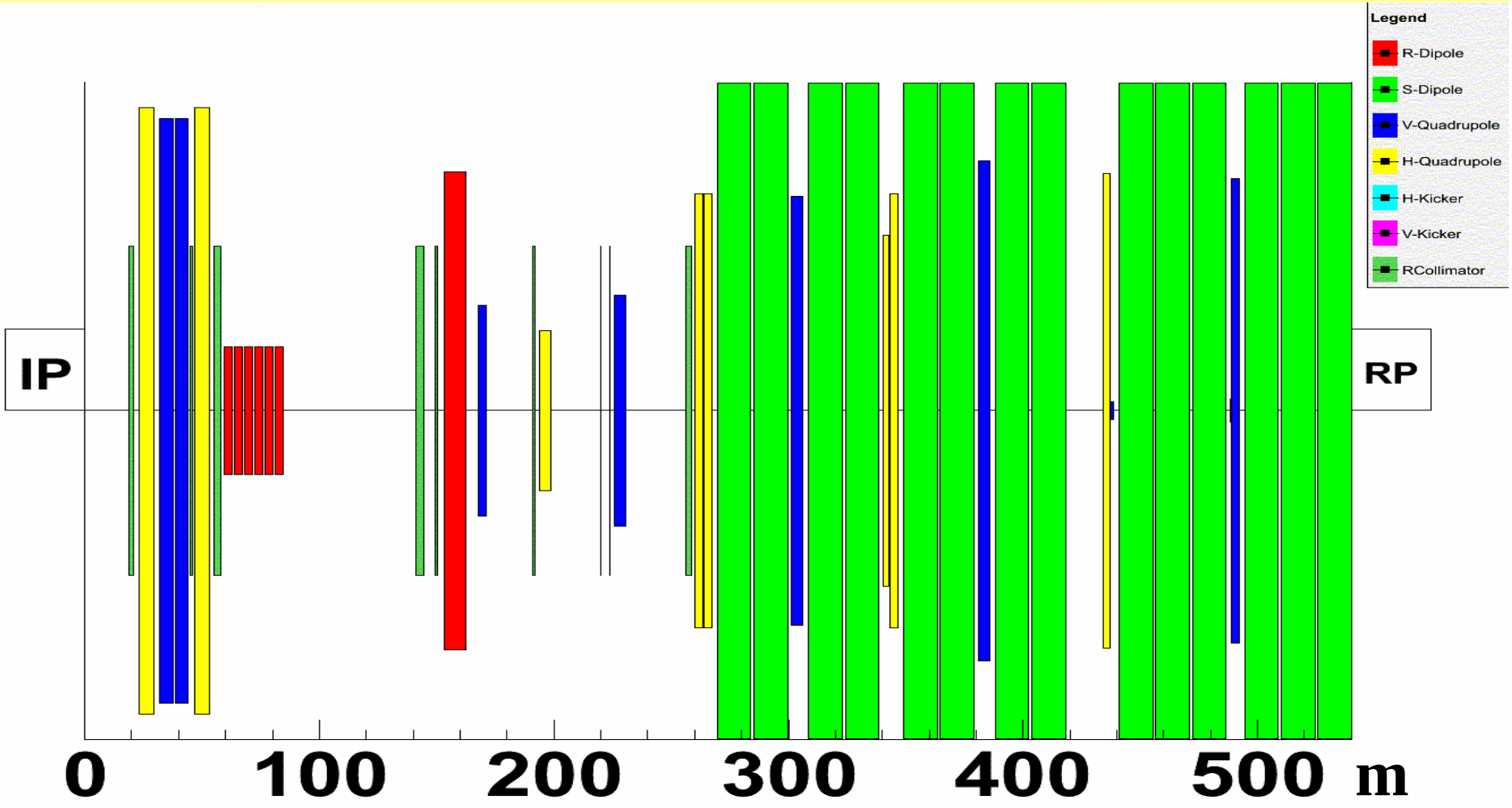
```
madtab* beam = new madtab(1,length);
beam->fill("ir5_1_65.txt");                    // reads the official LHC beam optics parameters V6.5
beam->showElements();                          // lists the elements
beam->calcMatrix();
beam->showMatrix();

TCanvas* bbb = new TCanvas("bbb","the proton beam canvas",1);
beam->draw();
TCanvas* ccc = new TCanvas("ccc","the proton test canvas",1);
ccc->Divide(1,2);
                                               // simulates 100 protons :
for(int i=0;i<100;i++) {
        proton p1;                             // creates a proton at IP
        p1.smearpos();                         // add smearing effects (position and angle)
        p1.smearang();
        if((i+1)<50) p1.emitgamma(100,-5);     // can simulate emission of a (100 GeV) virtual gamma

        p1.computePath(beam);                  // computes the whole path for the proton
        ccc->cd(1);
        int color =1;
        if((i+1)<50) color = 2;
        p1.drawPath(beam,0,!i,color);          // draws it
        ccc->cd(2);
        p1.drawPath(beam,1,!i,color);
}
```

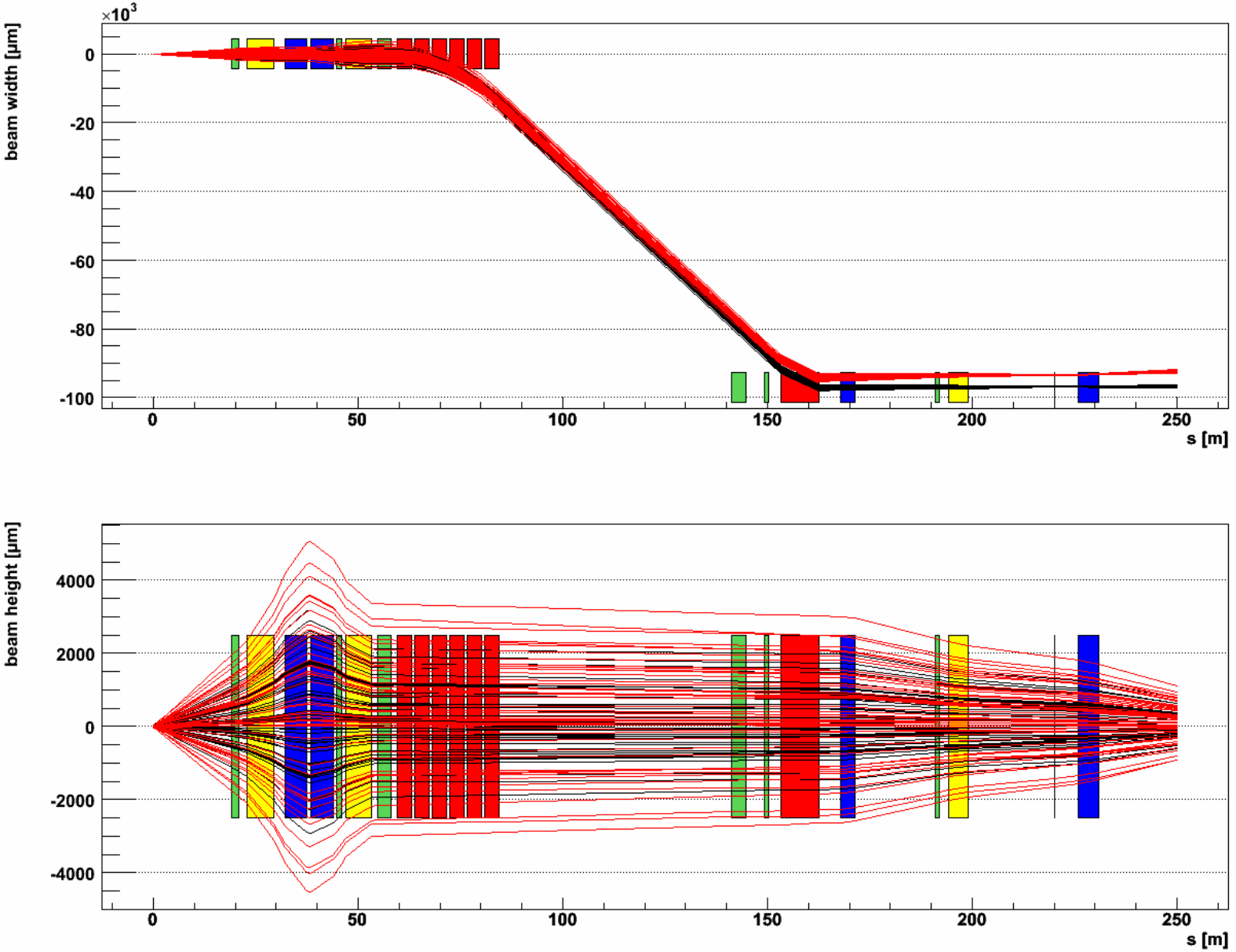
Example of graphical output

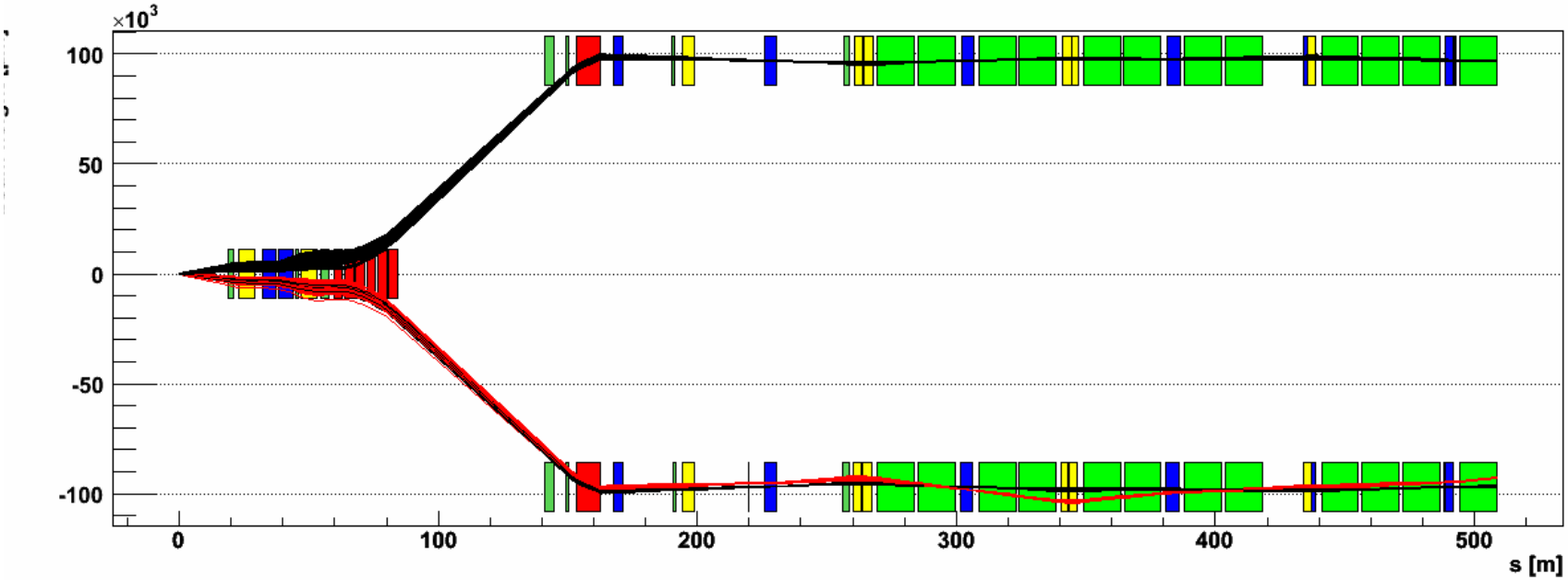
LHC beam optics elements from IR5, v6.5 (latest version)

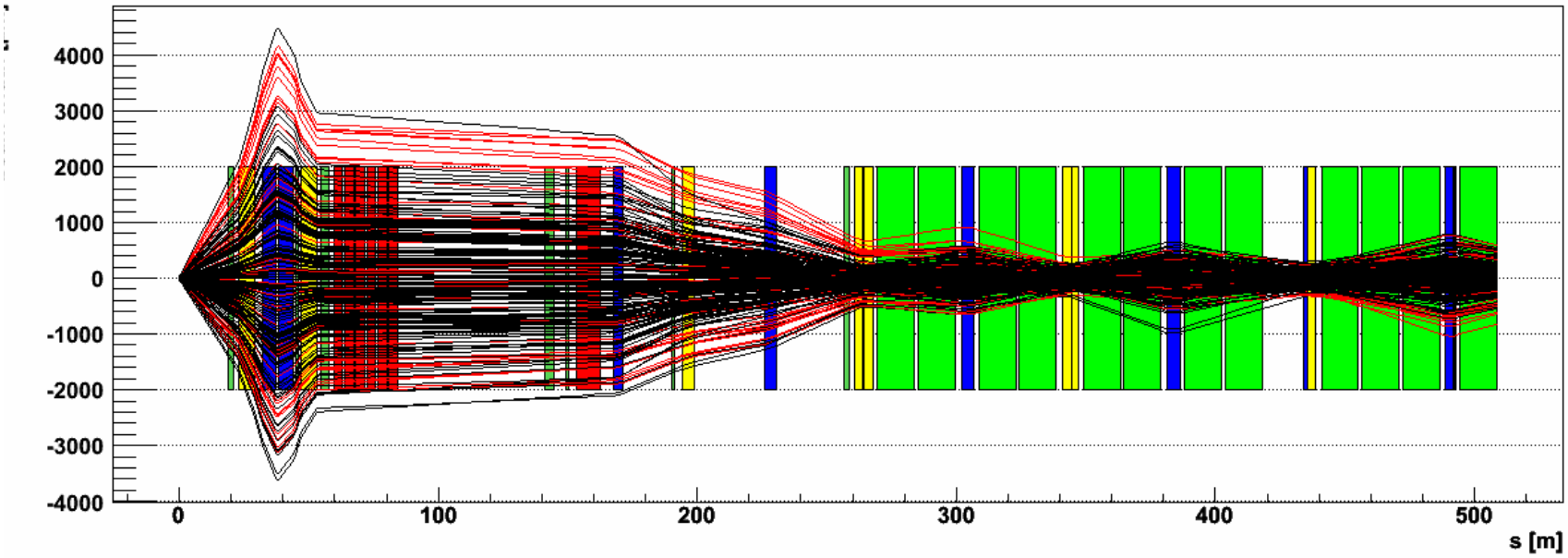


Here, the size of the elements reflects the field strength

Example of graphical output

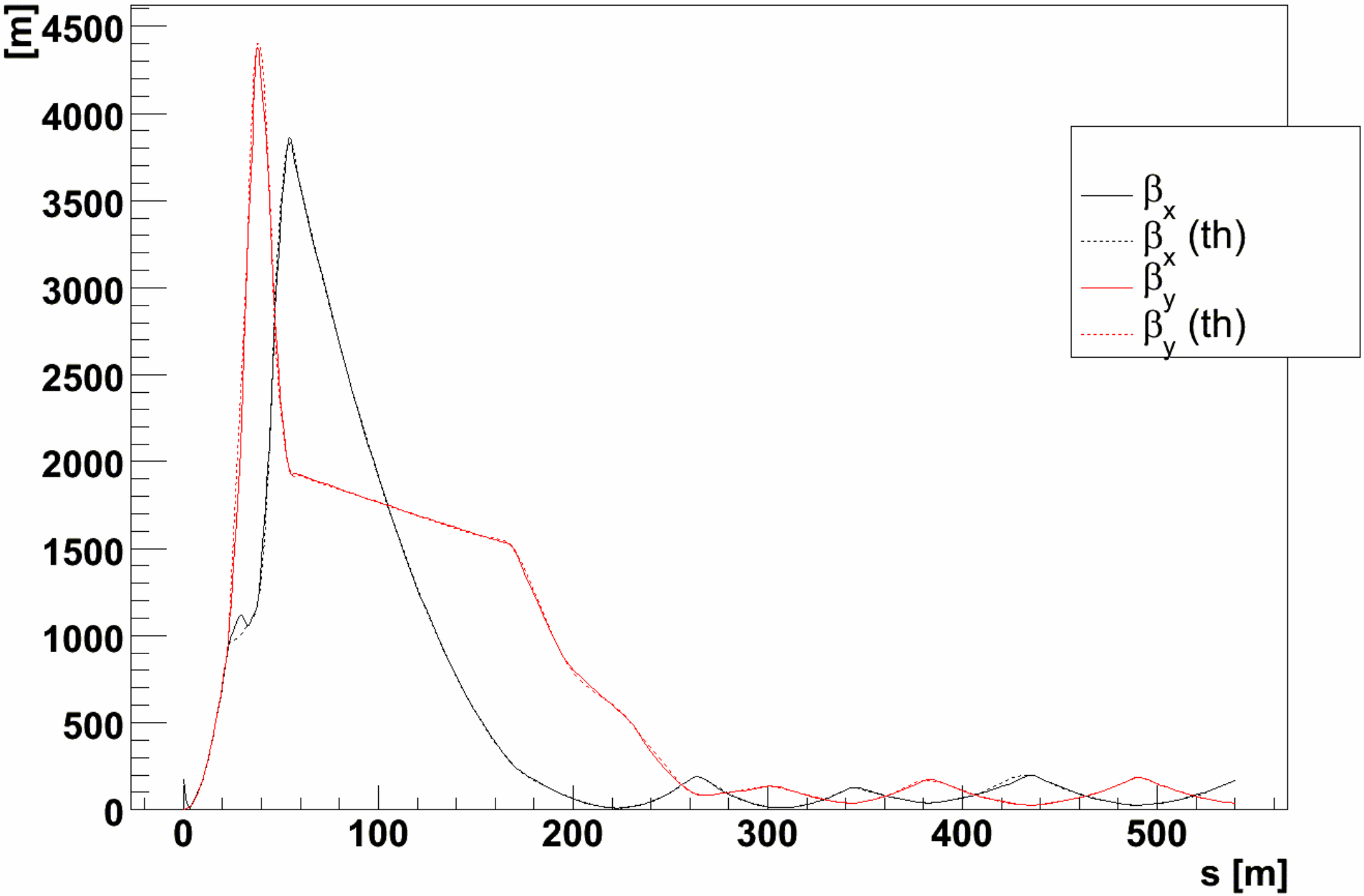



×10^3
100
50
0
-50
-100
0
100
200
300
400
500
s [m]


4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
0
100
200
300
400
500
s [m]

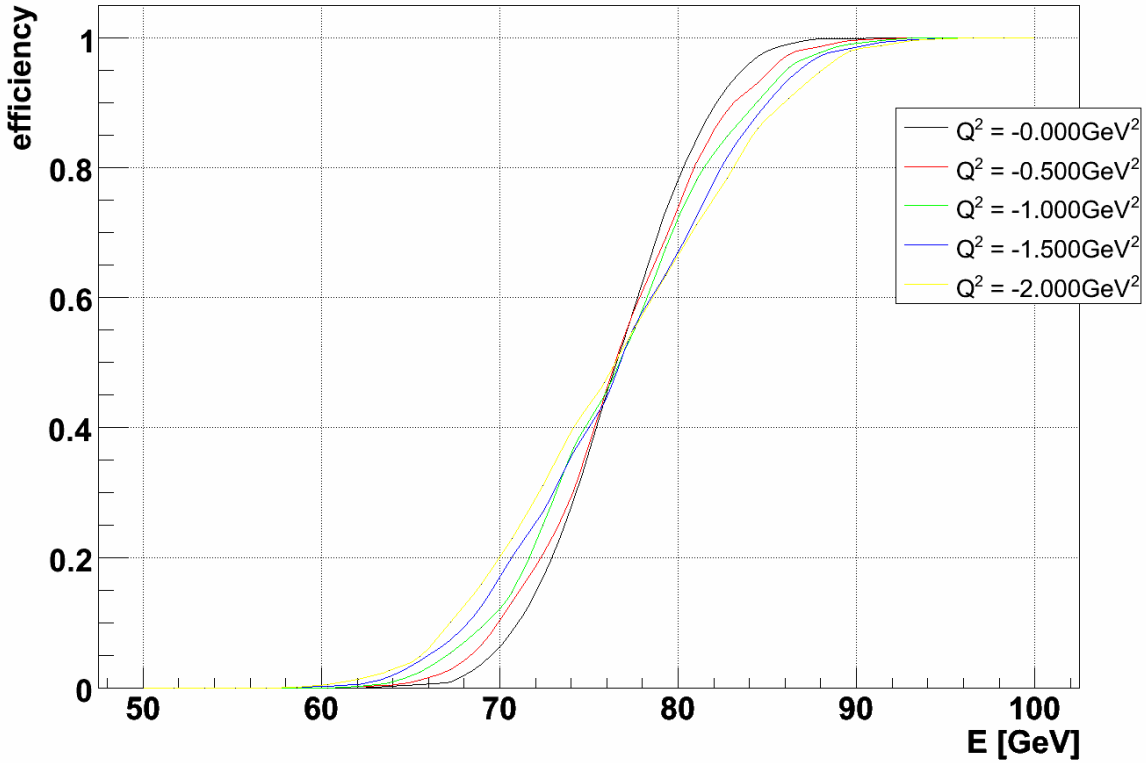
β functions

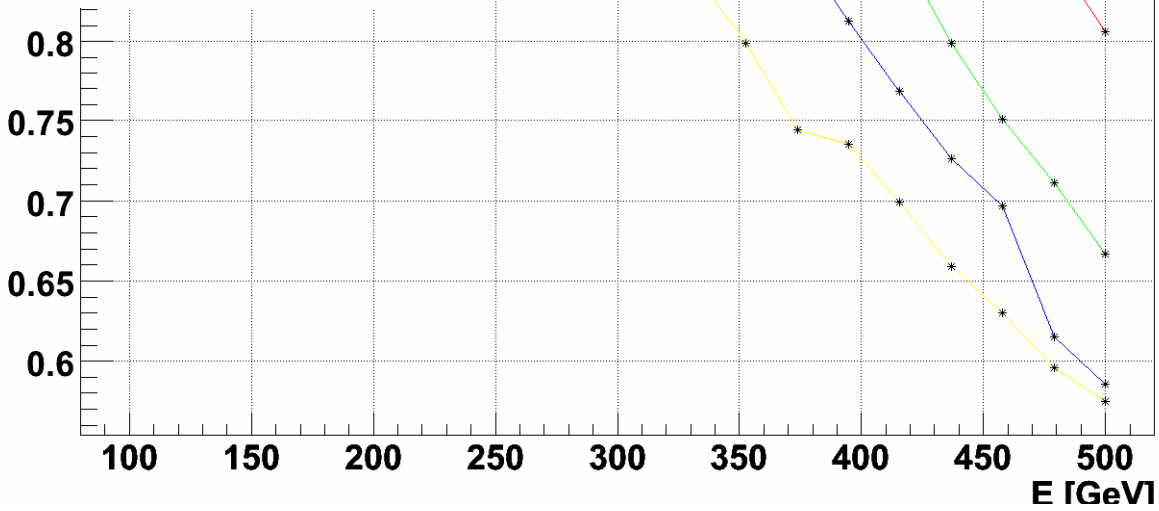
MAD vs HECTOR



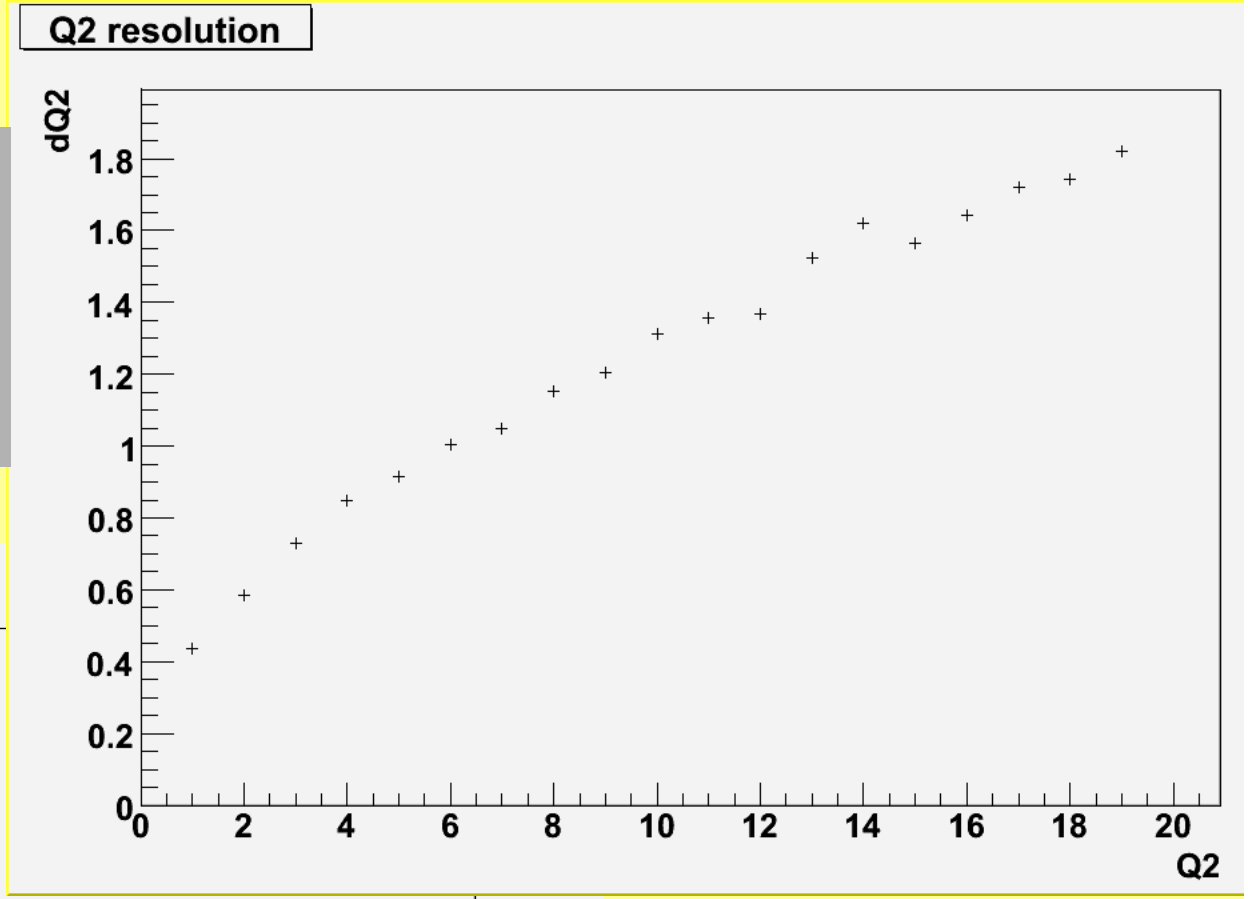
Efficiency studies @ 220m for 1.5 mm approach

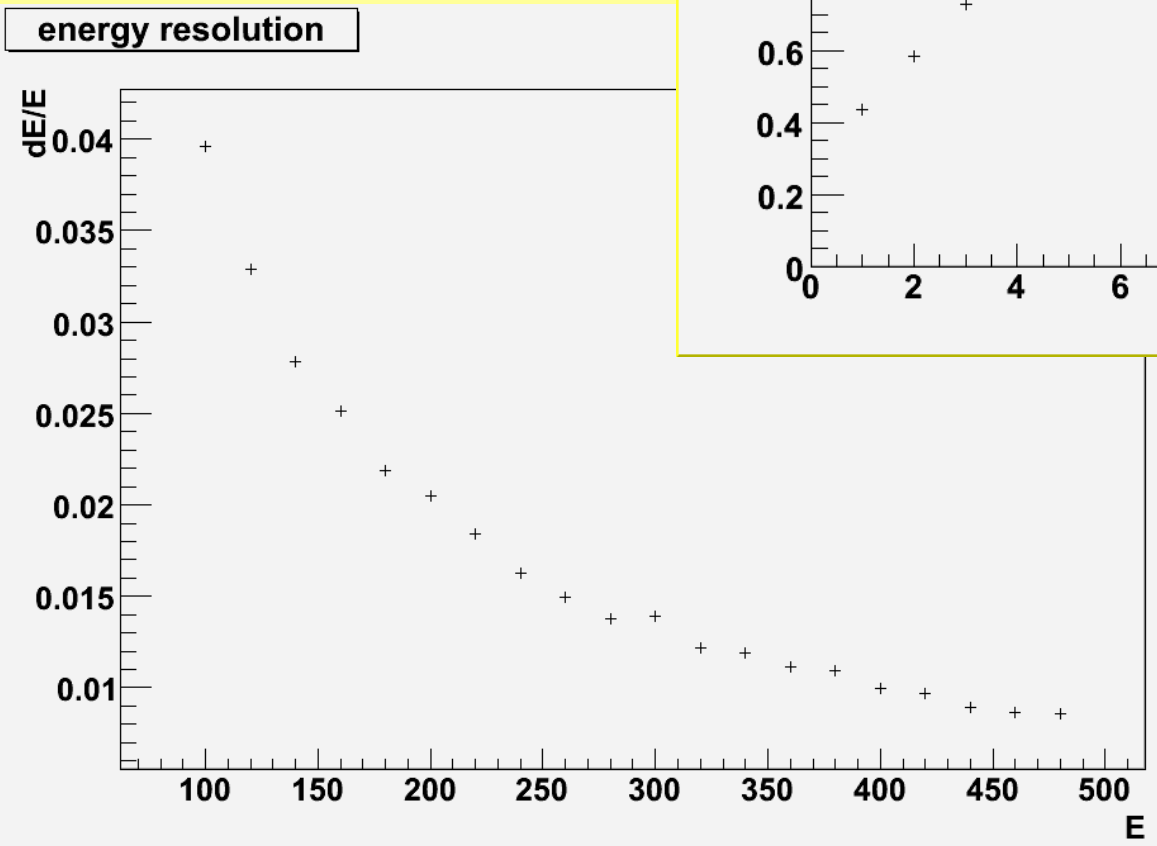
Detection efficiency wrt the energy



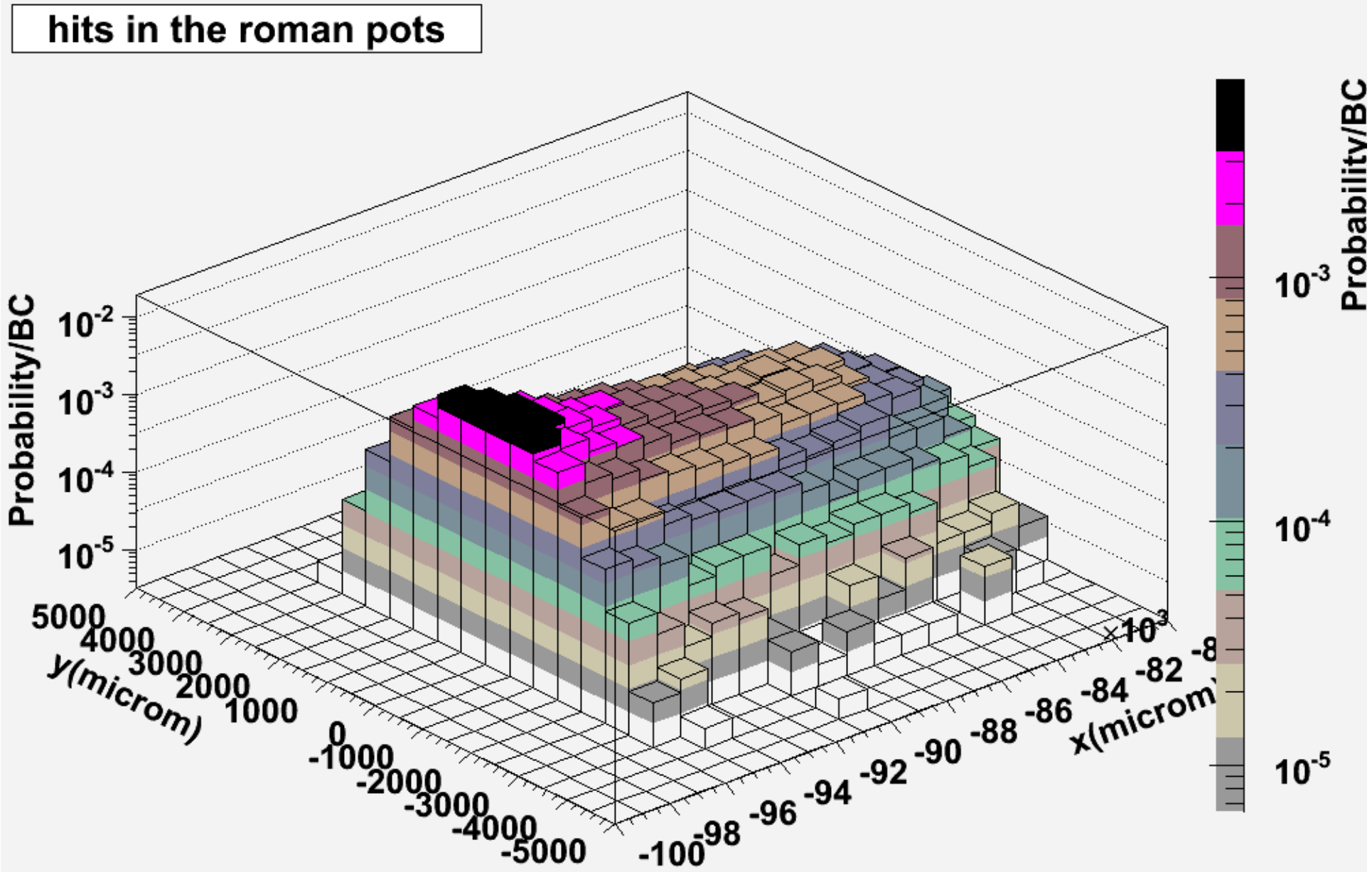


Kinematical resolutions assuming 10µm detector spatial resolution (and detector planes @5m)





PYTHIA+HECTOR:diffractive p flow at 220m (per BC and mm^2)



References

Klaus Wille, *The Physics of particle accelerators*, OXFORD, 1996

MAD homepage : *http://mad.home.cern.ch/mad/*

LHC optics : *https://edms.cern.ch*

Hector doxygenated : *http://www.fynu.ucl.ac.be/themes/he/ggamma/*