No frame!

Blue, green, red, no other COLORS!

No animals!

Reconstruction and Emittance calculation for MICE

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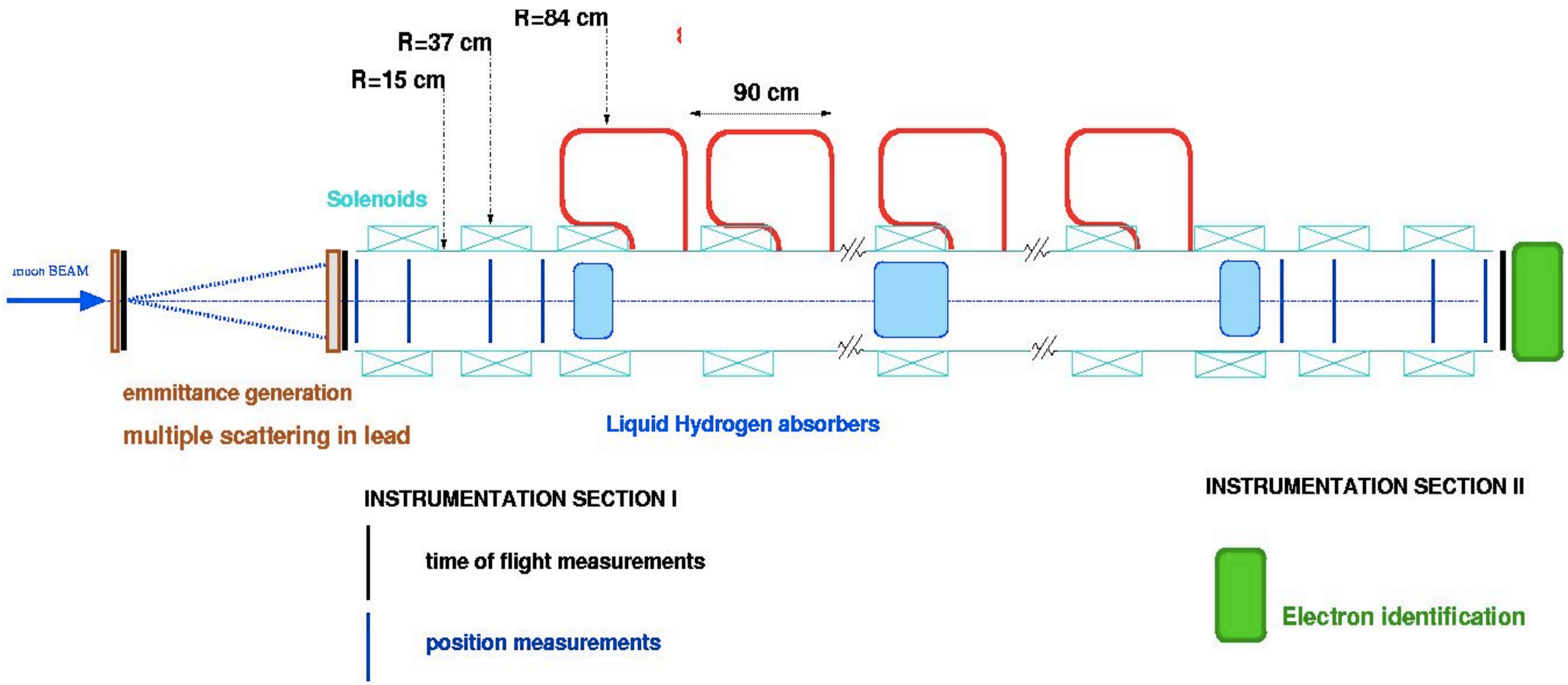
MICE



R=84 cm
R=37 cm
R=15 cm
90 cm
Solenoids
muon BEAM
emmittance generation
multiple scattering in lead
Liquid Hydrogen absorbers
INSTRUMENTATION SECTION I
time of flight measurements
position measurements
INSTRUMENTATION SECTION II
Electron identification

MICE
= Muon **I**onization **C**ooli

What is that?

- Aims:
  - Demonstration of Ionization Cooling of Muons
  - Demonstration of feasability to construct cooling channel items
  - Check simulations
  - Explore parameter space
- Single Particle Method
- Reconstruction of the emittance (just like in the theory!)
- Comparison measurement IN-OUT

Cooling

- "Cooling is emittance reduction" – *Van der Meer*

$$\Lambda_4 = \frac{\varepsilon_{\mathrm{x,in}}\varepsilon_{\mathrm{y,in}}}{\varepsilon_{\mathrm{x,out}}\varepsilon_{\mathrm{y,out}}} = (\Lambda_2)^2 \quad \varepsilon_{\mathrm{r}} = \sqrt{\varepsilon_{\mathrm{x}}\varepsilon_{\mathrm{y}}}.$$

Collimation?

$$\Xi_4 = \frac{\varepsilon_{\mathrm{x,in}}\varepsilon_{\mathrm{y,in}}}{\varepsilon_{\mathrm{x,out}}\varepsilon_{\mathrm{y,out}}}\frac{n_{\mathrm{out}}}{n_{\mathrm{in}}} = \Lambda_4 T \quad \Xi_2 = \Lambda_2\sqrt{T}$$

T = transmission

- "Cooling is phase space density increase" – *Liouville*

$$\Pi = \frac{n_{\mathrm{out}}\Big|_{\mathrm{particle\ in\ }\varepsilon_{\mathrm{acc}}}}{n_{\mathrm{in}}\Big|_{\mathrm{particle\ in\ }\varepsilon_{\mathrm{acc}}}}$$

- "Le couling, c'est moi" – *Blondel*

Why cooling?

- Stuff more particles in small accelerator.
  - Count particles
- Send more neutrinos to far detectors (⇔have low divergence in storage ring).
  - rms emittance

$$x' = \sqrt{\frac{\varepsilon}{\beta_\perp}}$$ (there are limits to the β-function)

- Increase luminosity of muon collider.
  - rms emittance

Emittance reduction

- Emittance? What emittance?
  - The 2/4D normalized transverse emittance, of cause.

$$\varepsilon_N = \beta\gamma\varepsilon \qquad \varepsilon^2 = \left\langle x^2 \right\rangle \left\langle x'^2 \right\rangle - \left\langle xx' \right\rangle^2$$

- Energy spread ± 50%, so what γ?
  - Standard solution: Average γ.
  - Low energy particles are penalized.
    (They have a smaller bending radius in the solenoid, so they *could* be transported, but they are ouside the allowed emittance).
  - Single particle momentum based rms emittance

The reason of the mess

- Liouville: canonical variables …

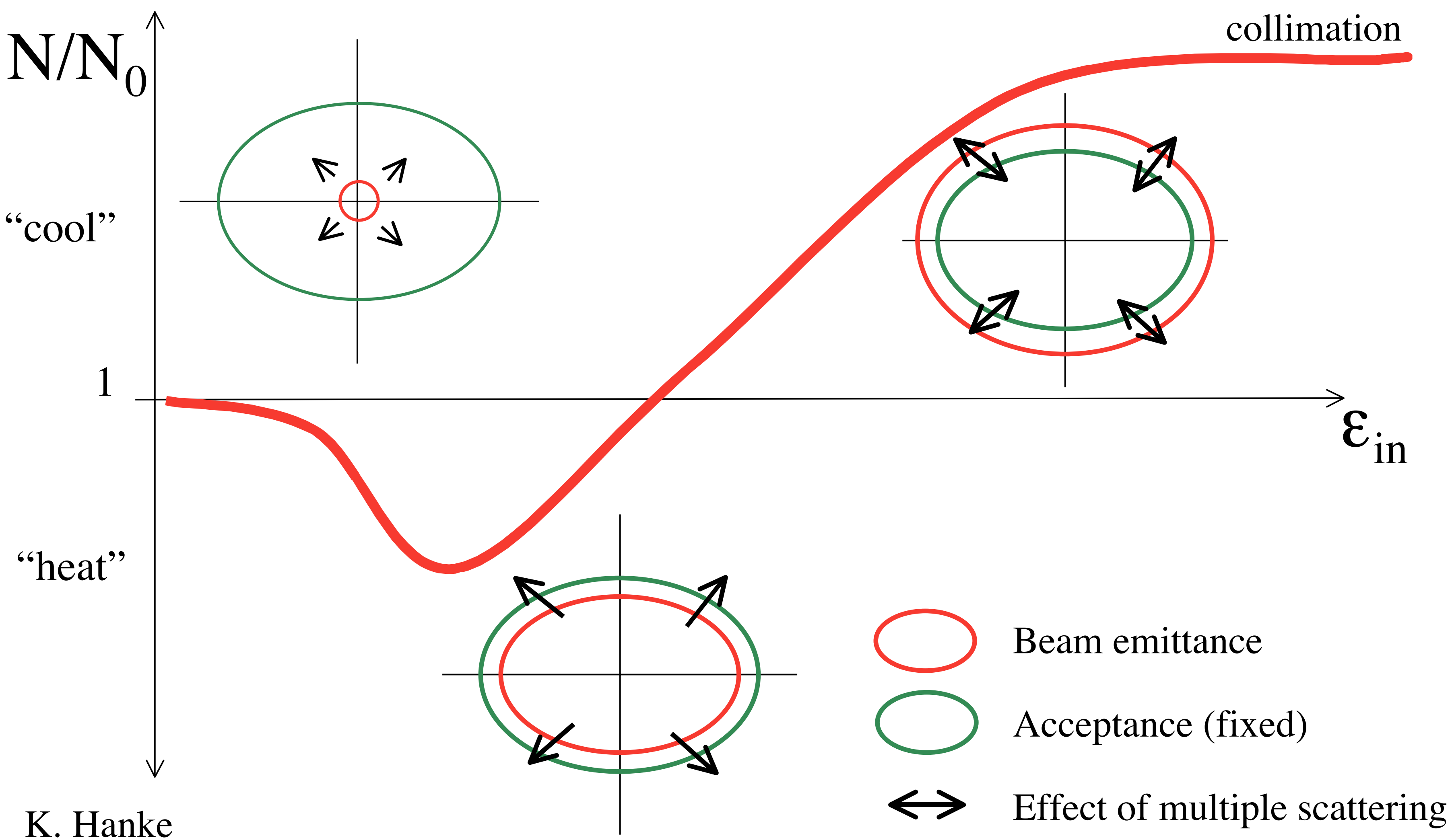
$$\varepsilon_N = \beta\gamma\varepsilon = \beta\gamma x x' = x\beta\gamma\frac{p_x}{p} = x\frac{p}{m_0 c}\frac{p_x}{p} = x p_x \frac{1}{m_0 c}$$

- We should canonicalize at the right place:

$$\varepsilon^2 = \langle x^2 \rangle \langle \beta_i \gamma_i x'^2 \rangle - \langle x x' \rangle^2$$

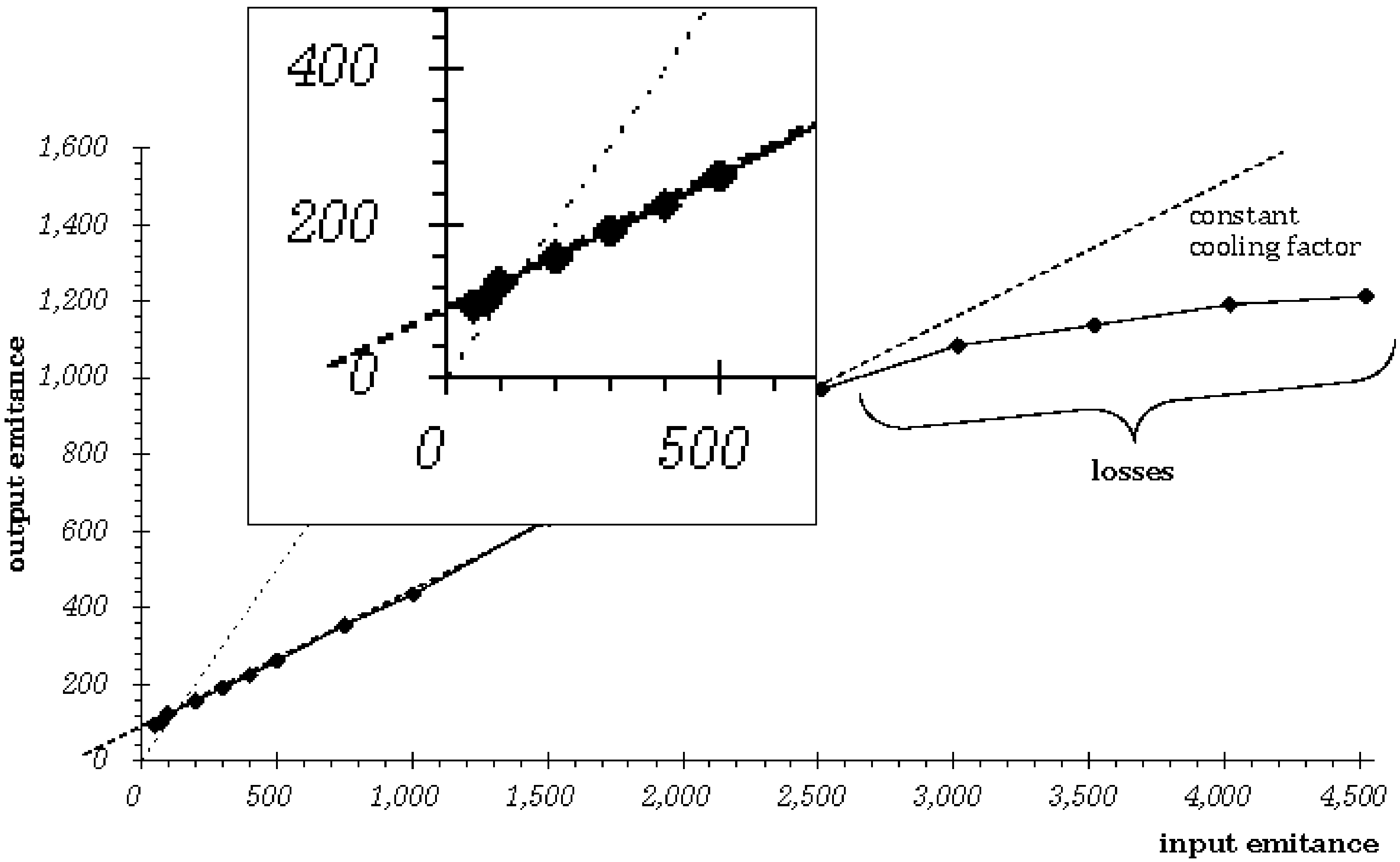
- It is just a second order effect … but still worth taking into account
- Already one customer!

Particle counting is difficult to interpret



K. Hanke

Emittance reduction



Measurement

5 or *n* Points
x, y, (t,z)

5 Layers of SciFi or TPG

Resolution, inefficiencies, (dE/dx), multiple scattering

5-6 coordinates
x, y, (t), p_x, p_y, p_z

Riemann fit, Kalman filter

Phase space distorted by B-field

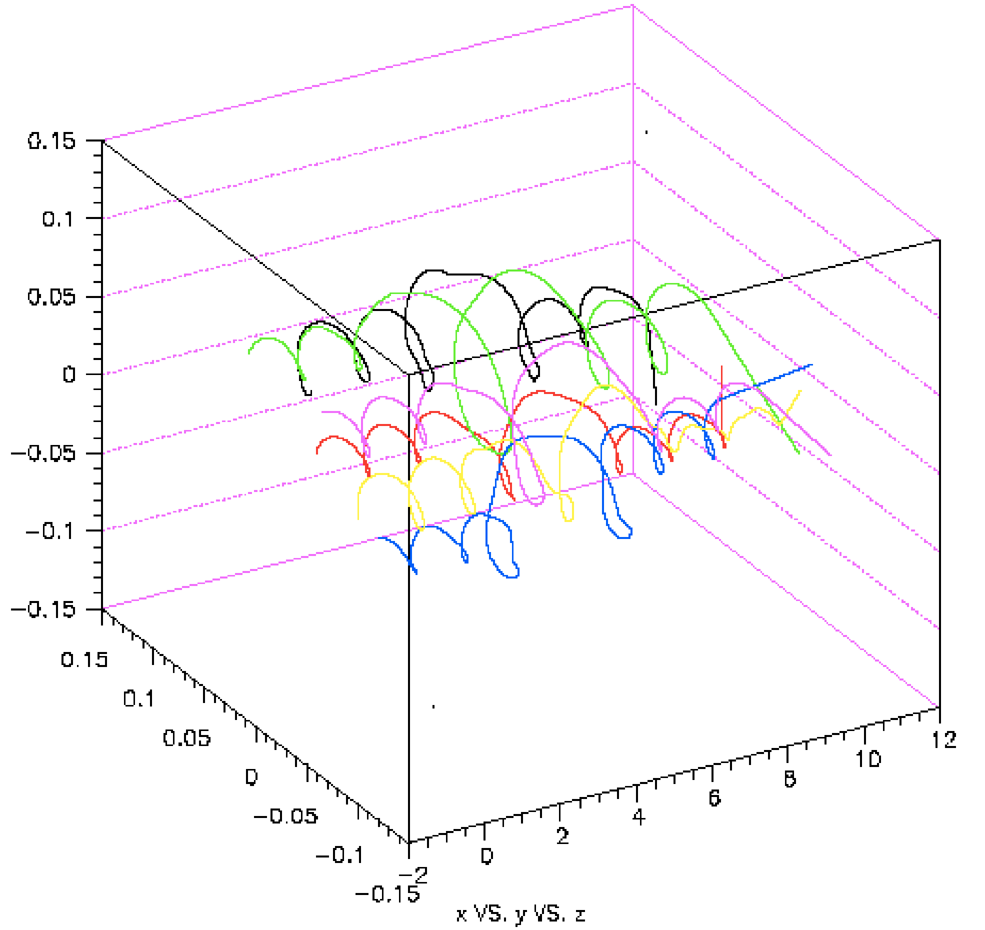
Emittance
x, x,, y, y,, E, φ

Headcount
N

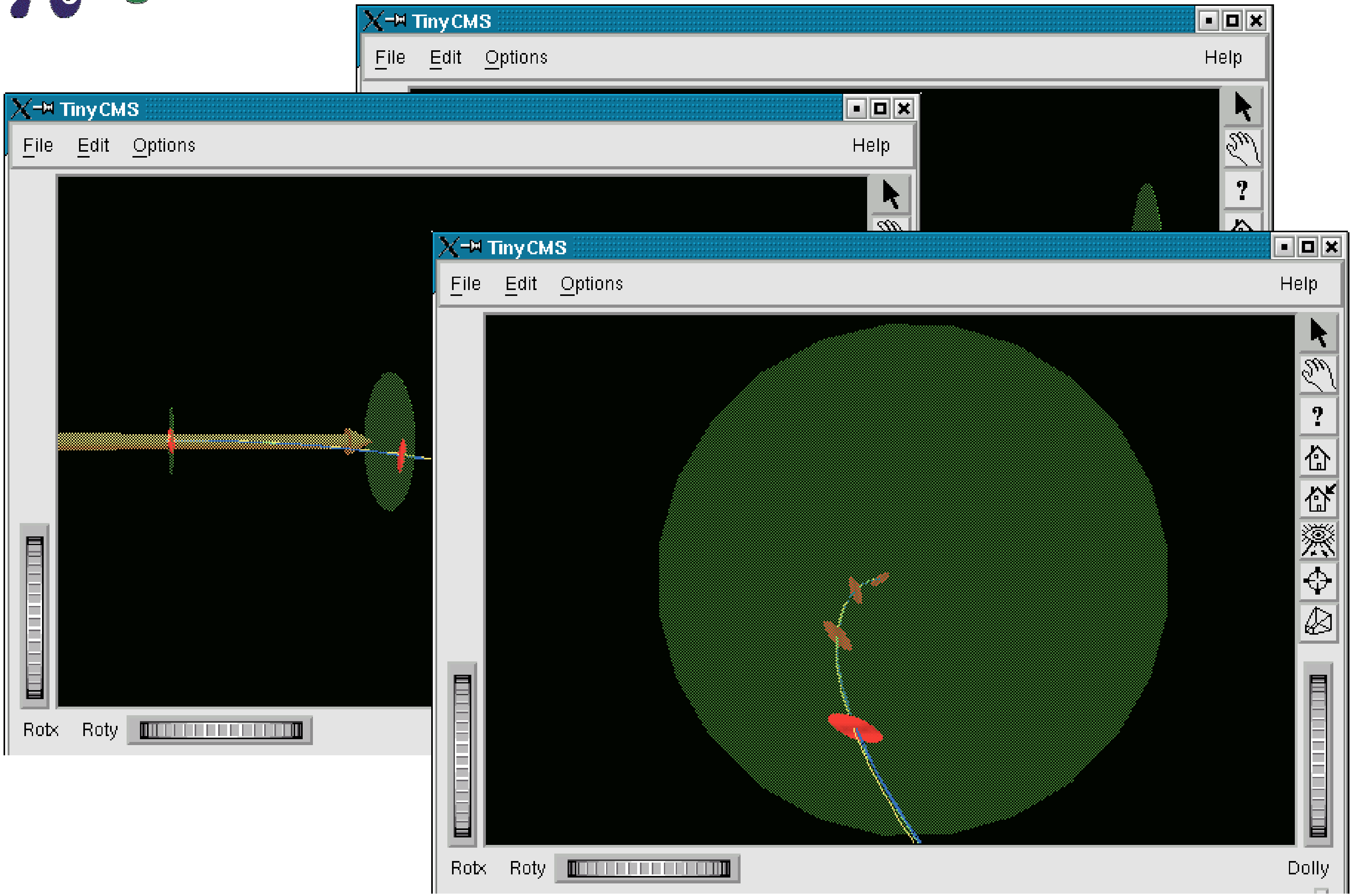
$\varepsilon_1, \varepsilon_2 \rightarrow \varepsilon_x, \varepsilon_y \rightarrow \varepsilon_r \,;\, (\varepsilon_l)$

N/N_0

Tracks

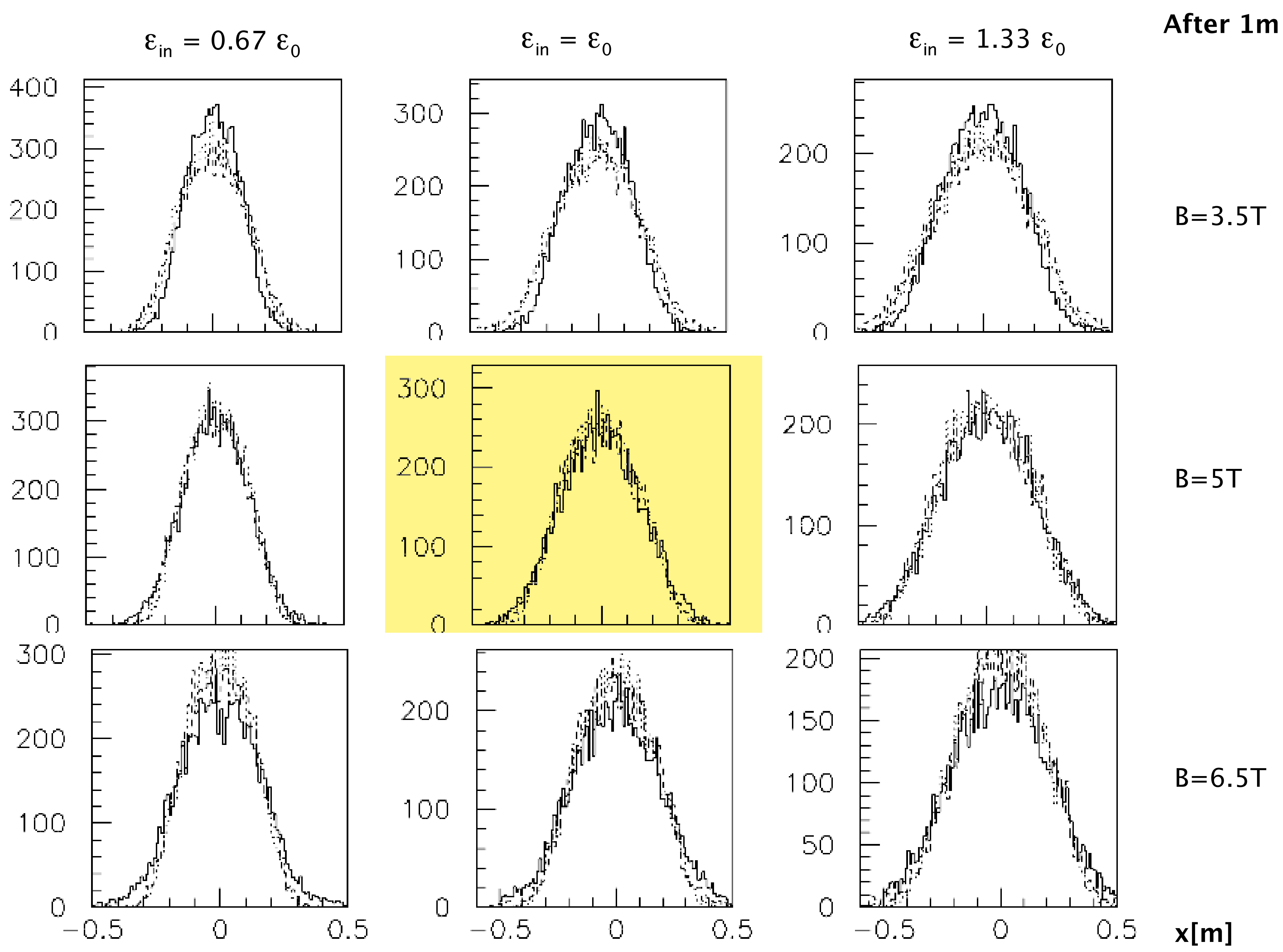

0.15
0.1
0.05
0
−0.05
−0.1
−0.15
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−2
0
2
4
6
8
10
12
x VS. y VS. z

Kalman Filter



Simulation Strategy

- P. Janot's program
- Experiment simulation in PATH
  - 6D coordinates read out at detector positions
- Experiment simulation in G4
- Feed into reconstruction program
- Integrated simulation


After 1m
ε_in = 0.67 ε_0
ε_in = ε_0
ε_in = 1.33 ε_0
B=3.5T
B=5T
B=6.5T
x[m]
400
300
200
100
0
−0.5
0
0.5
150
50

Computing platforms

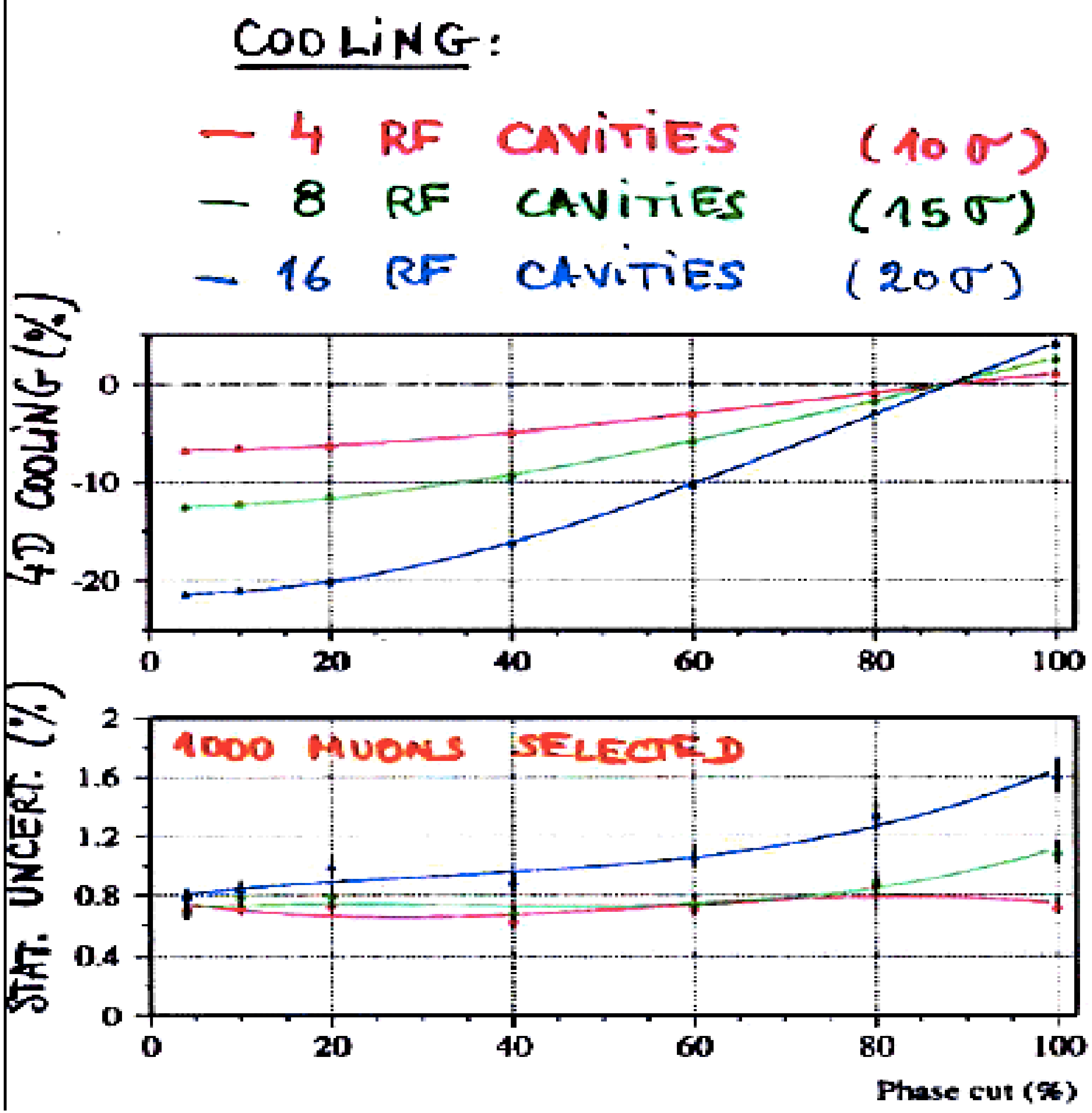
- As much recycling as possibe, but based on what?
- First need to know what to reconstruct
- Tiny CMS (Vienna)
- HARP reconstruction SW (Kalman Filter etc. will become available “soon”)
- Other ideas …

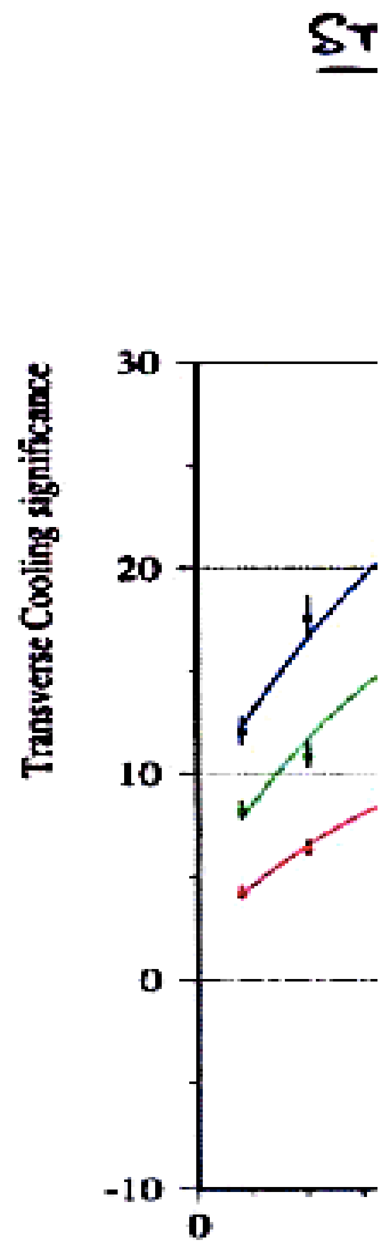
Can we do it?

- Cooling in the 4Cav-200MHz scenario is

3%	**2D-Emittance reduction**
6%	**4D-Emittance reduction**
10%	**6D-density increase**

- Pretty small effect
- Preliminary answer: yes! (P. Janot)
- Has to be seen when all effects are included
- Scanning through parameter range improbable


COOLING:
— 4 RF CAVITIES (10σ)
— 8 RF CAVITIES (15σ)
— 16 RF CAVITIES (20σ)
4D COOLING (%)
STAT. UNCERT. (%)
1000 MUONS SELECTED
Phase cut (%)


ST
Transverse Cooling significance

Conclusions

- We can do it.
- Need first agreement on
  (a) figure of merit and
  (b) emittance definition for high ΔE
- Some parts of simulation+reconstruction are here
- Avoid work on intermediate solutions
- Decide on computing platform
- Integrate simulation + reconstruction
- Timescale: before end of the year (MICE proposal)

Thanks to: S. Gilardoni, H. Haseroth