# Introduction to cooling experiment studies

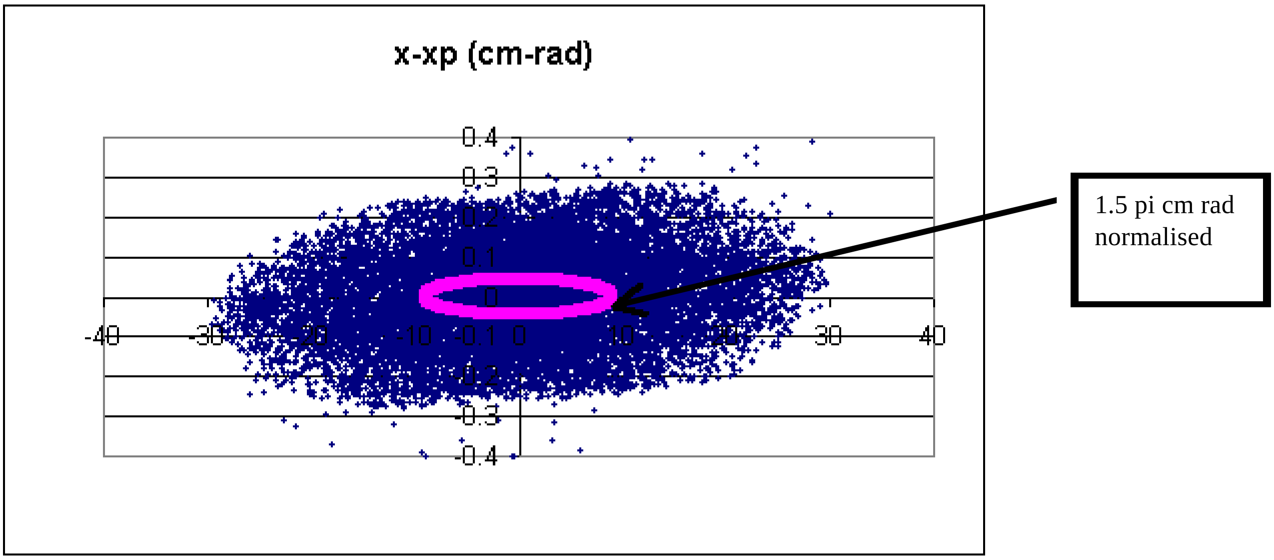
P. Gruber,G.Franchetti, K. Hanke,A. Lombardi,R. Scrivens

- How much cooling do we need for the neutrino factory
- CERN reference cooling channel
- What do we have to learn from a cooling experiment
- Cooling experiment tailored to the CERN reference scenario
- Open questions and feedback

how much cooling do we need ?

1. physics experiment : divergence less than $1/\gamma$
2. storage ring vacuum chamber of reasonable size
3. re-circulator energy acceptance

tra acceptance:1.5 pi cm rad ,
long acceptance : 15 pi cm rad
(50 GeV CERN ring)

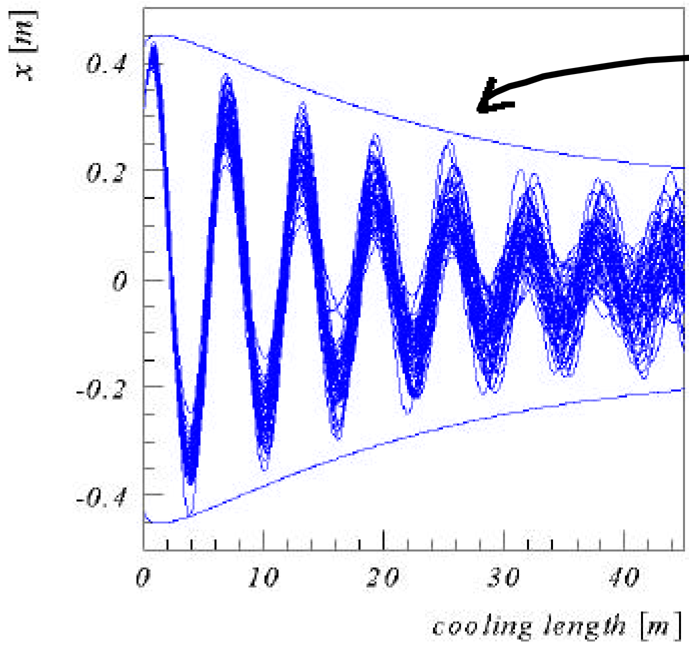



at production

2 GeV proton beam instantaneously impinging on the target
FLUKA calculations of 2.6 cm long Hg target + 20T solenoid

we need a 6D cooling of a factor 20 to produce $10^{21}$ muons with a 4 MW proton beam cooling channel

- emittance decrease is few percent / stage (limit is the rf gradient)




coefficient of dumping is proportional to the electric field gradient

- we need several stages (typically 100)
- we need a focusing system
- we need an overall optimisation of the channel

## choice of frequency

- the beam must be (and stay) bunched :

    acceptable energy spread is function of the frequency

- gradient prop frequency, cavity size inversely proportional

    trade-off cooling rate / acceptance

low frequency
high gradient
big bore
uniform field

solutions/compromises

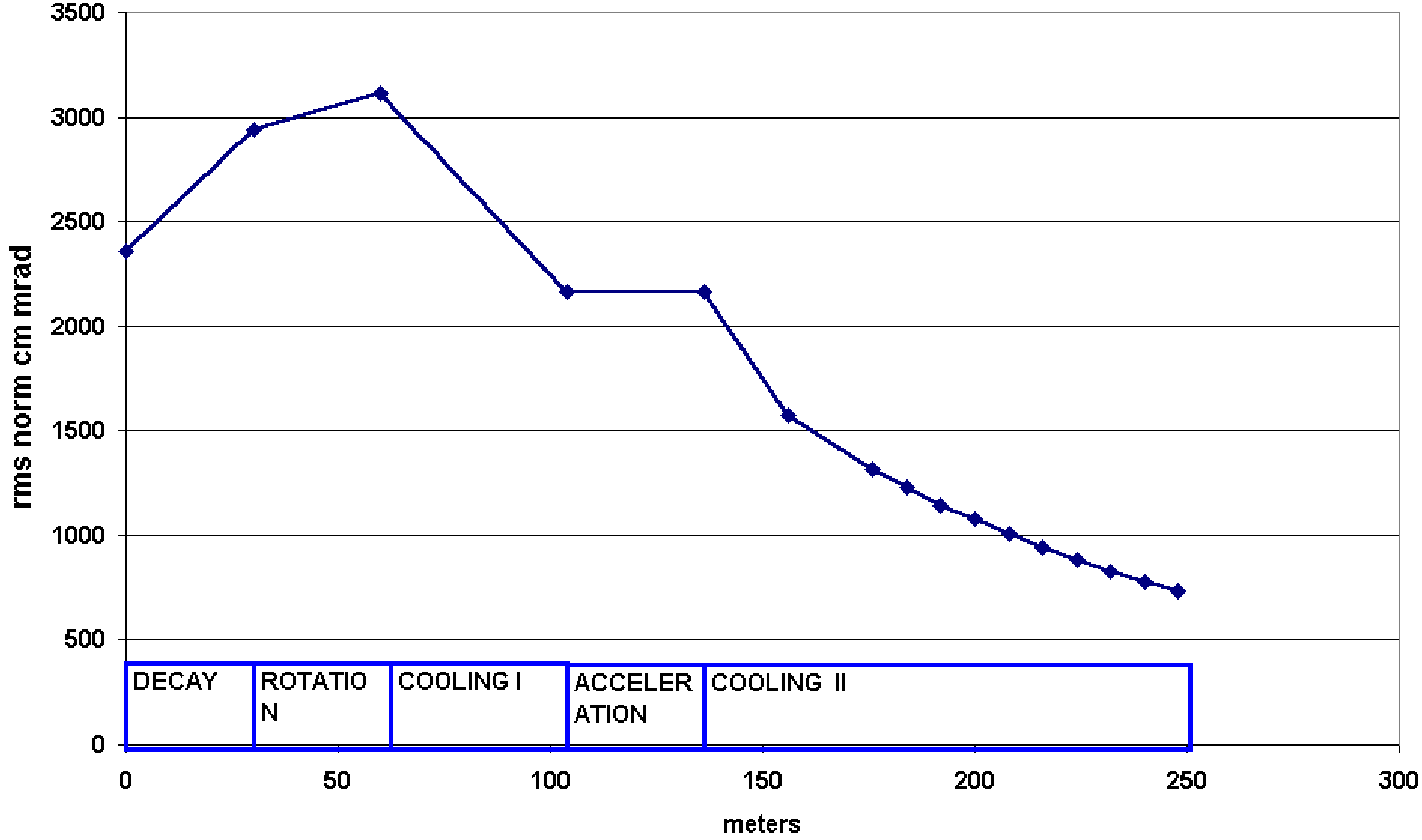
- use low frequency cavities (below 100 MHz) and accept higher energy spread (limit is the slope of Bethe –Bloch)

- use high frequency cavities (above 100 MHz) closed with Berillium windows (extra scattering in the windows + technical problems during breakdowns ….

40-80 MHz solution
(CERN-NFWG-note 34)

| | Decay | Rotation | Cooling I | Acceleration | "Cooling II" | Acceleration |
|---|---|---|---|---|---|---|
| Length [m] | 30 | 30 | 46 | 32 | 112 | ≈450 |
| Diameter [cm] | 60 | 60 | 60 | 60 | 30 | 20 |
| Focalisation [T] | 1.8 | 1.8 | 2.0 | 2.0 | 2.6 | 2.6 |
| Frequency [MHz] | | 40 | 40 | 40 | 80 | 80-200 |
| Gradient [MV/m] | | 2 | 2 | 2 | 4 | 4-10 |
| Kin Energy [MeV] | | 200 | | 280 | 300 | 2000 |

emittance evolution in the front end of the neutrino factory




**Cooling increases the phase space density of a factor of 16**

- RF cavities test

  gradient achievable
  gradient in presence of high magnetic field
  gradient with a big bore radius

- Energy loss

  Bethe-Bloch confirmed

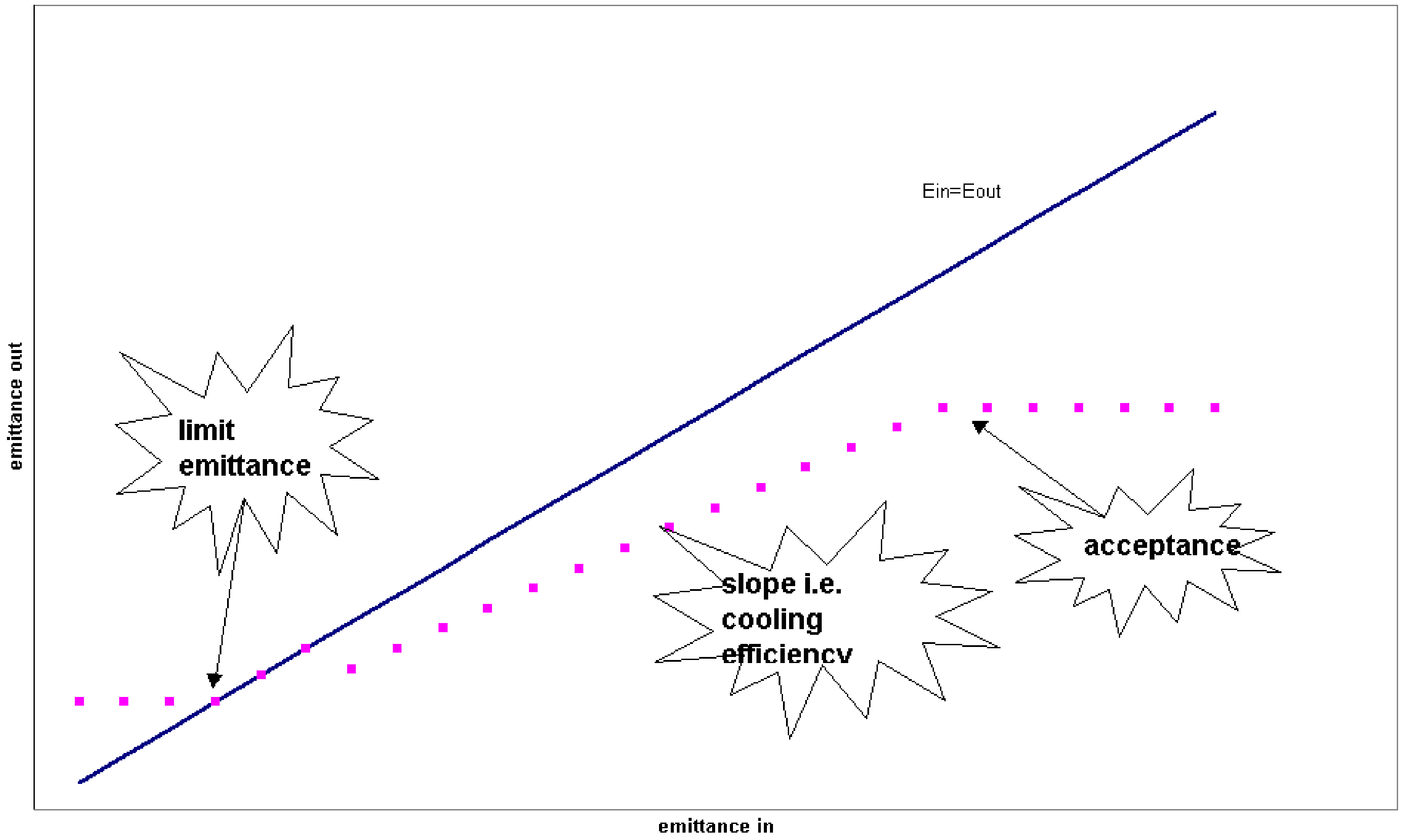
- Multiple scattering

  MUSCAT results cover some parts

## what we miss

- Putting it all together
- Measure cooling/heating and what factors influence the transition between the two regimes
- Check theoretical/computer prediction for the system

example of a cooling experiment output



defining a cooling experiment

| input selector<br><br>defines and changes properties of the input beam | cooling engine | output diagnostics |
| --- | --- | --- |

- sensitivity of the overall cooling efficiency to

  input conditions
  parameter settings
  matching
  computing tools (programs, number of particles…)

CERN reference scenario sensitivity study (P. Gruber)
comparing codes (R. Scrivens)
solenoidal channel dynamics (G. Franchetti)

- simulate the experiment set-up (part of the cooling channel itself)

  provide input for defining the measurement gear
  ideal vs. obtainable fields (RF fields and solenoidal field)
  define quality factors for cavities and solenoids

(K. Hanke)

a cooling channel tailored to the CERN reference scenario

- frequency :
  40 and 80 MHz in the channel.
  choice is to test 80MHz because of foreseen RF test

- start with two cooling stages (16 rf cavities and 1 m hydrogen)

- ideal fields vs. fields from a field solver (minimum design work for solenoid)

add ideal field vs SFH plot

## open questions

what precision do we need to be able to extrapolate from few cooling stages to the whole channel

what can be re-scaled to other cases (frequency)

……..