# *Some basic reflections on the emittance measurement in the cooling channel*

**Helmut Haseroth**
**CERN**

*Some basic reflections on the emittance measuremen*
*in the cooling channel*

## Some people know what I am going to tell you.

## However, I realized that some (even intelligent) people do not know.

### 1) How to measure

Some basic thoughts on emittance measurements to check the performance of a (short) cooling channel

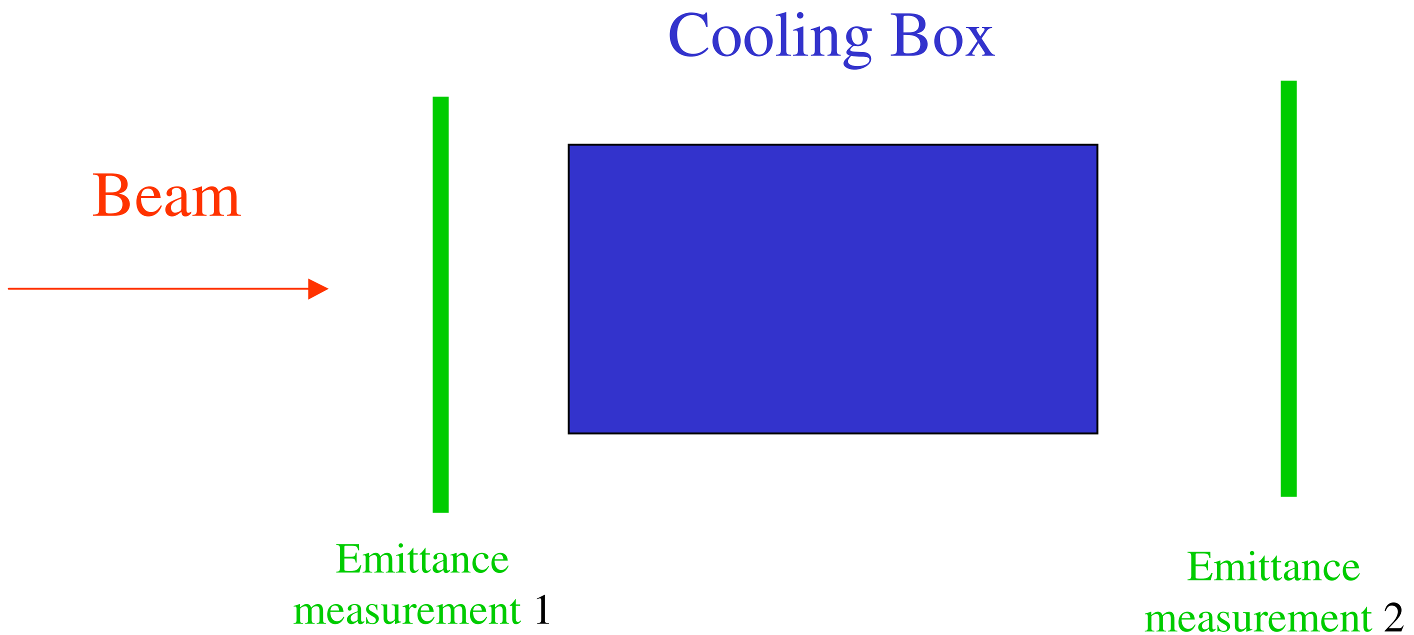
### 2) What to measure

x,x´ y,y´ x,y´ or…

Single particle, multi particle ???

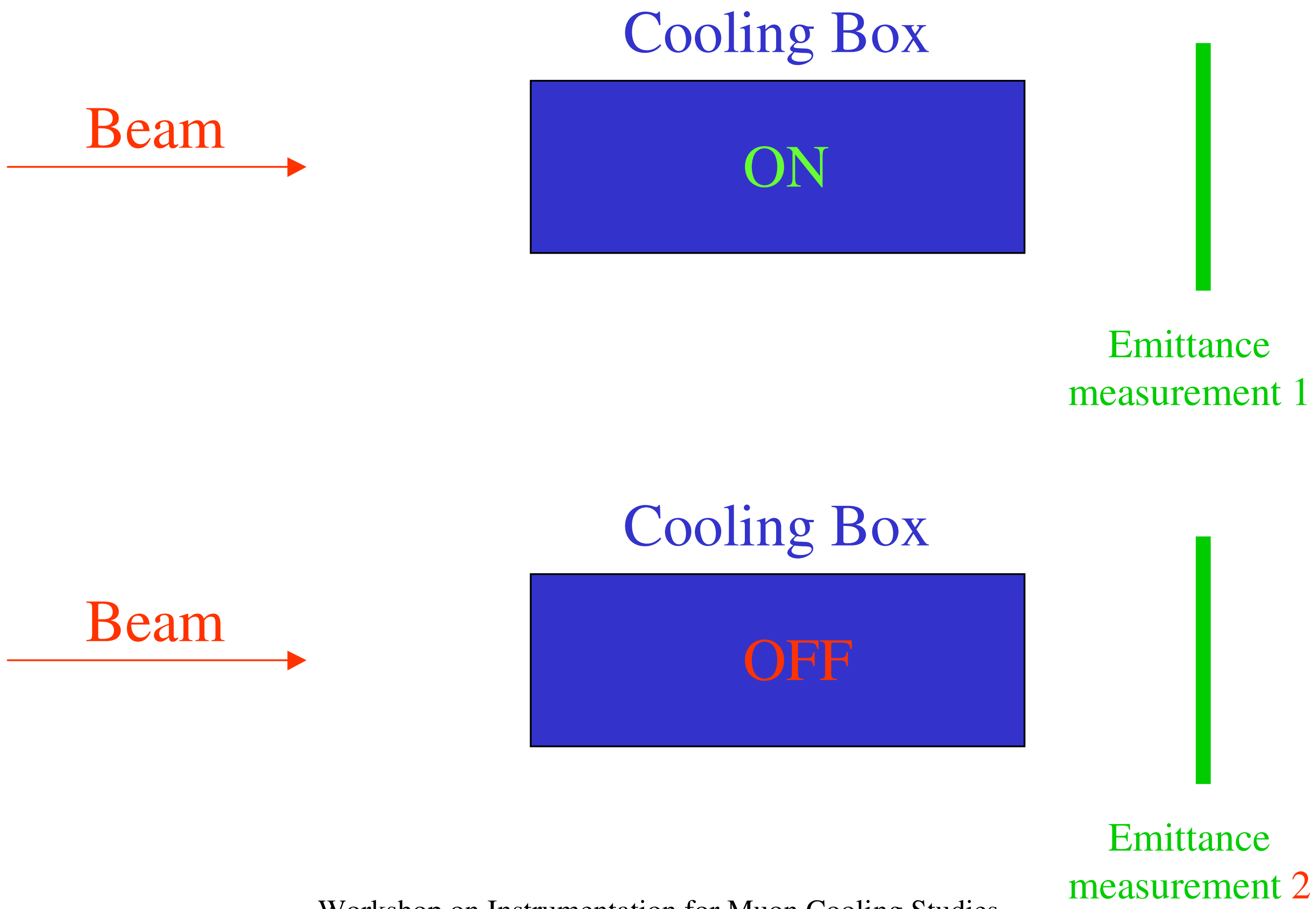
# Some basic thoughts on emittance measurements to check the performance of a (short) cooling channel

## Version 1



# Some basic thoughts on emittance measurements to check the performance of a (short) cooling channel

## Version 2



Version 1 calls for identical (absolute) measurements in positions 1 and 2. Version 2 calls for the possibility to switch off the "cooling box", i.e. to turn off the rf cavities and take out the $H_2$ absorbers (or to take out the whole line).

As the rf cavities are likely to influence the focussing, the solenoids need to be readjusted (ACCORDING TO WHICH CRITERION?).

## 2) What to measure

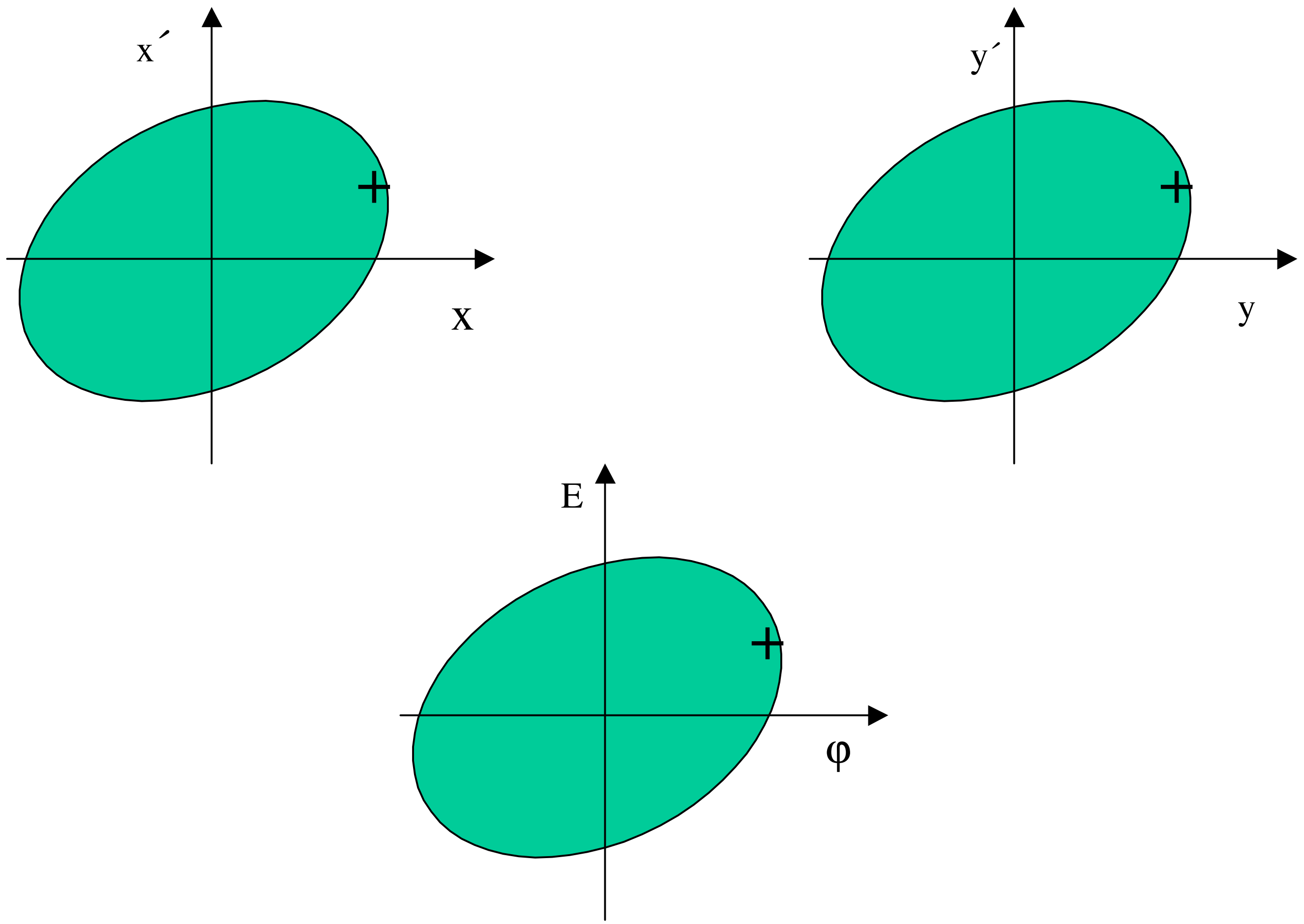
*Remembering Kirk McDonald's statement at our last meeting in Chicago:*

We need 21 parameters to define a 6D hyper ellipsoid

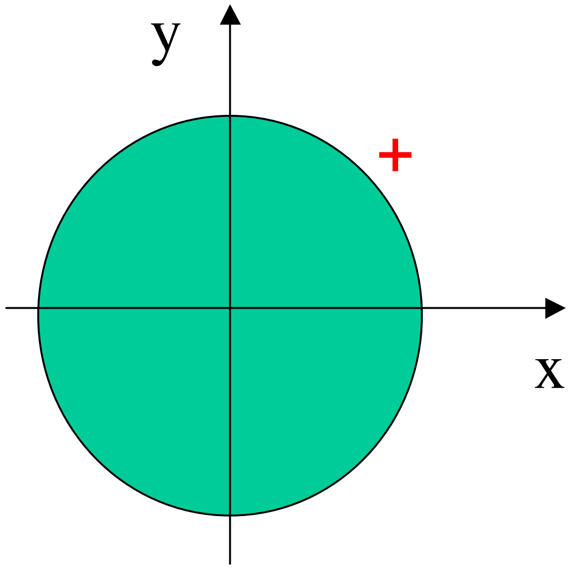
*How many do we need to characterize a non ellipsoidal shape?*

*What shape?*

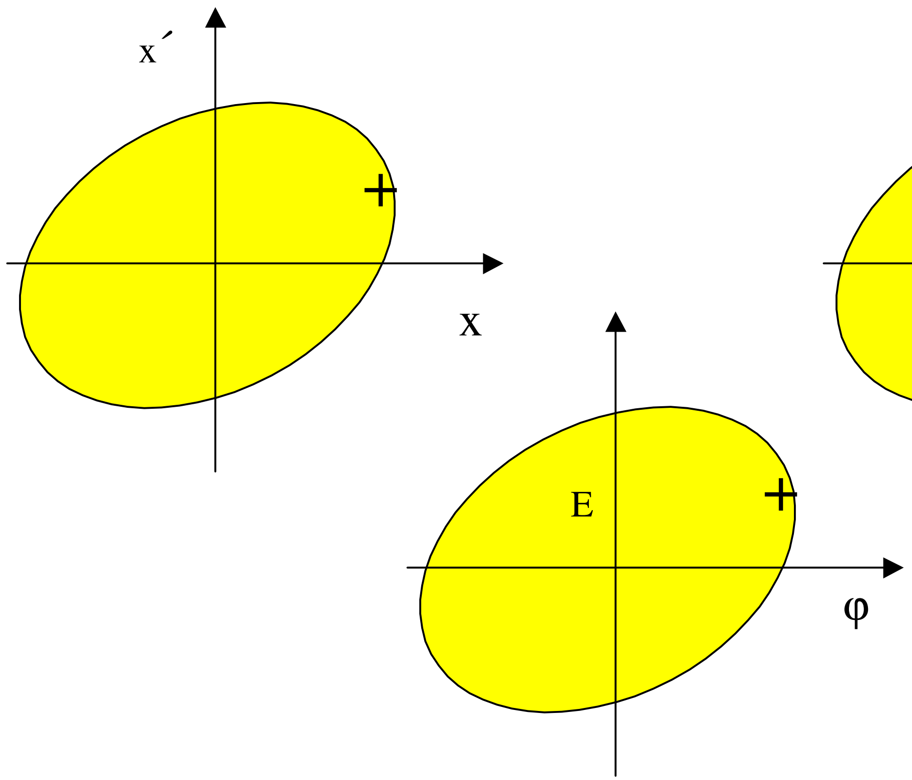
# Take one particle at the edge of the distribution...



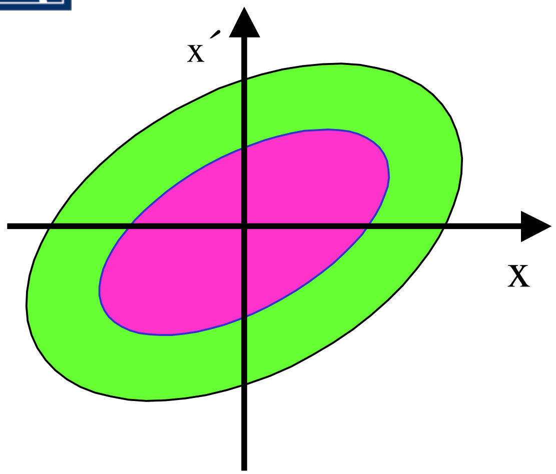
# …it is obviously NOT in the acceptance of a round vacuum chamber

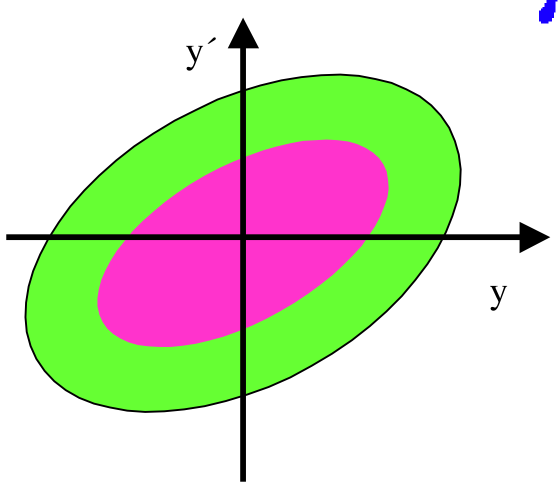


# Take one particle at the edge of the distribution...

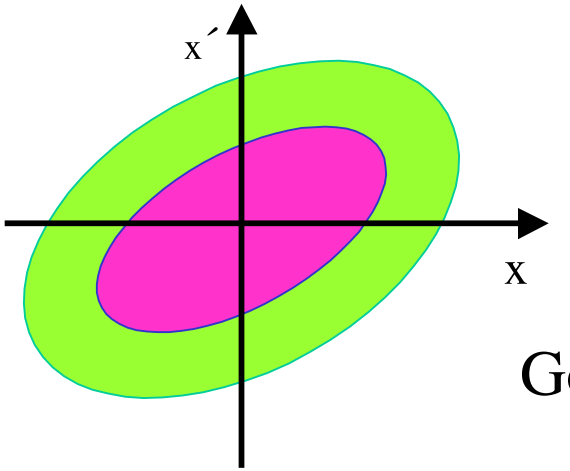


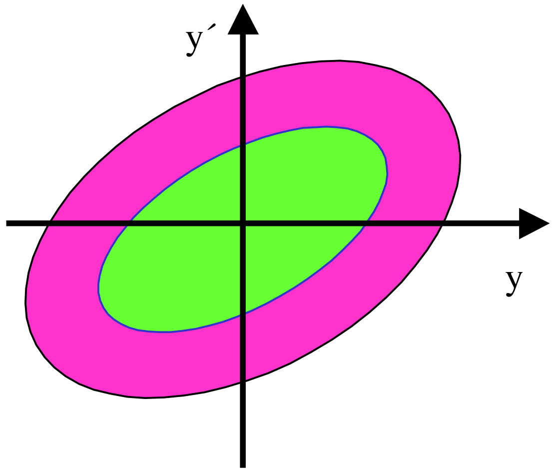

If a particle is in the “acceptance” ellipse (i.e. the projection of the 6D hyper ellipsoid onto a specific plane), this is not a sufficient condition to be inside the 6D hyper ellipsoid.



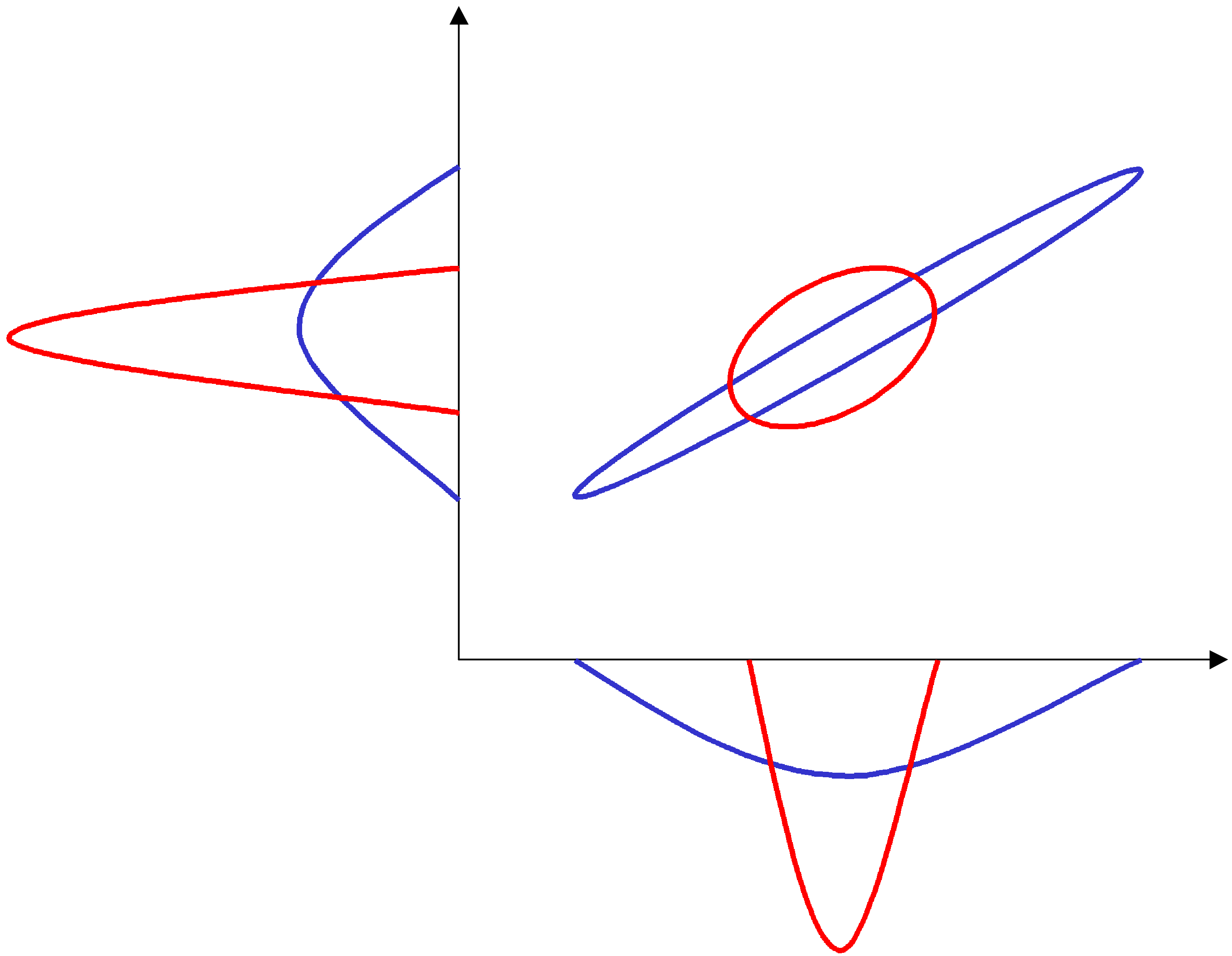

Bad distribution



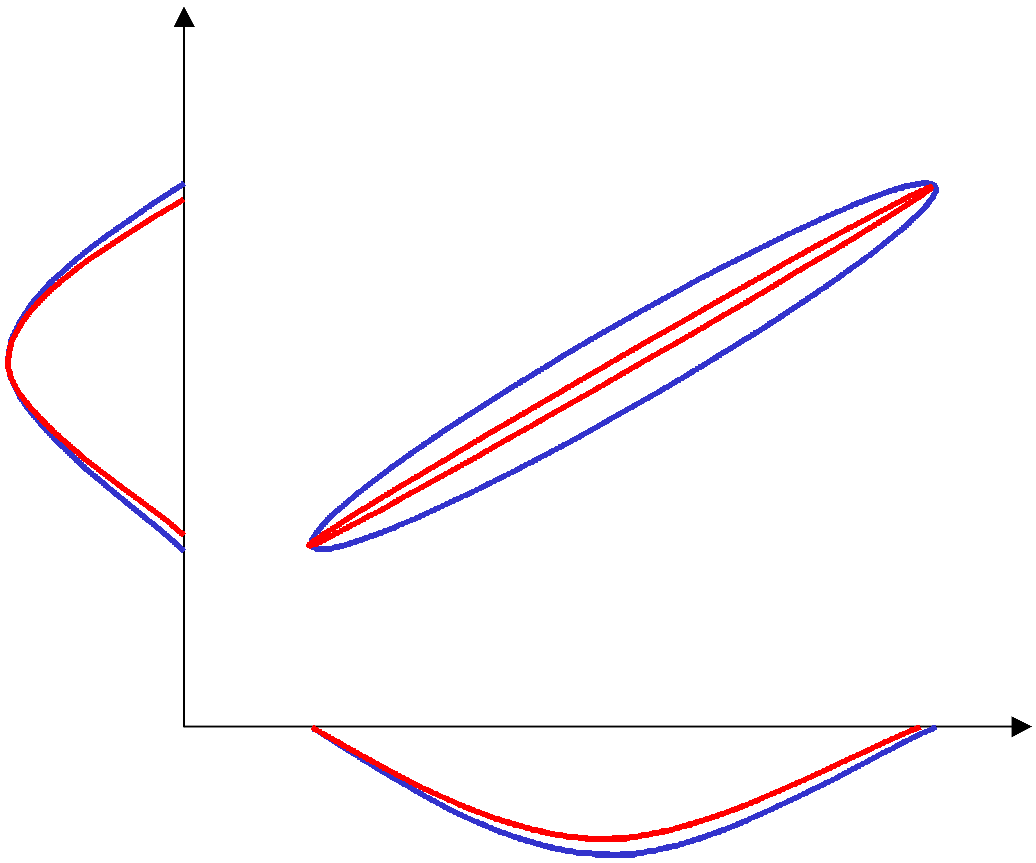




Good distribution

# Example in a 2D case:
# Do not claim the red ellipse is "cooled"!



# Example in a 2D case:
# Red ellipse IS "cooled"!



## *Therefore global measurements NOT adequate, even if rms emittance shrinks*

*Need to measure the position of each particle in 6D phase space:*

In case of hypersphere we need:

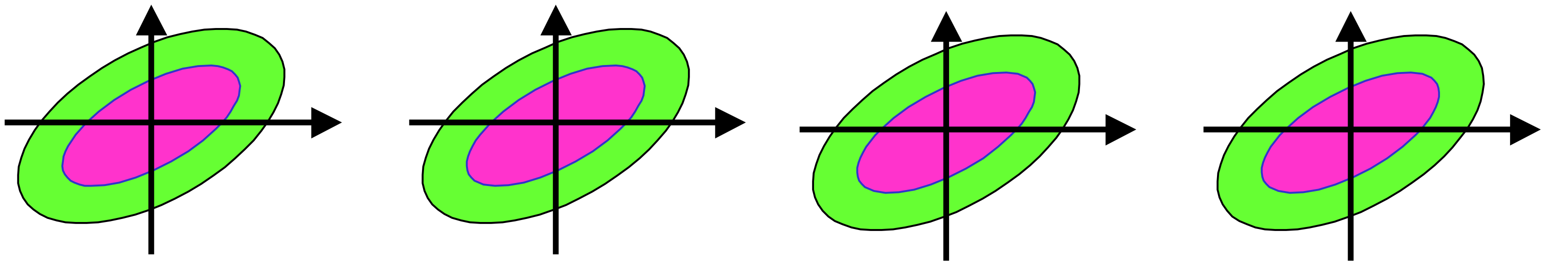
$$\mathbf{x^2 + x'^2 + y^2 + y'^2 + \Delta p^2 + \varphi^2 \leq const \times r^6}$$

if r = radius of hypersphere and if the particle is to be inside the hypersphere.

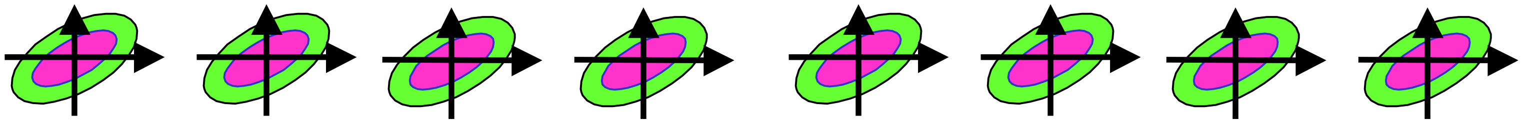
***You may measure "cooling" of a single particle when r becomes smaller***

*Of course the situation is different if the cooling factor is large and the projections of the 6D phase space occupied by all the particles is shrinking by a large factor…*

If before before cooling we have this:

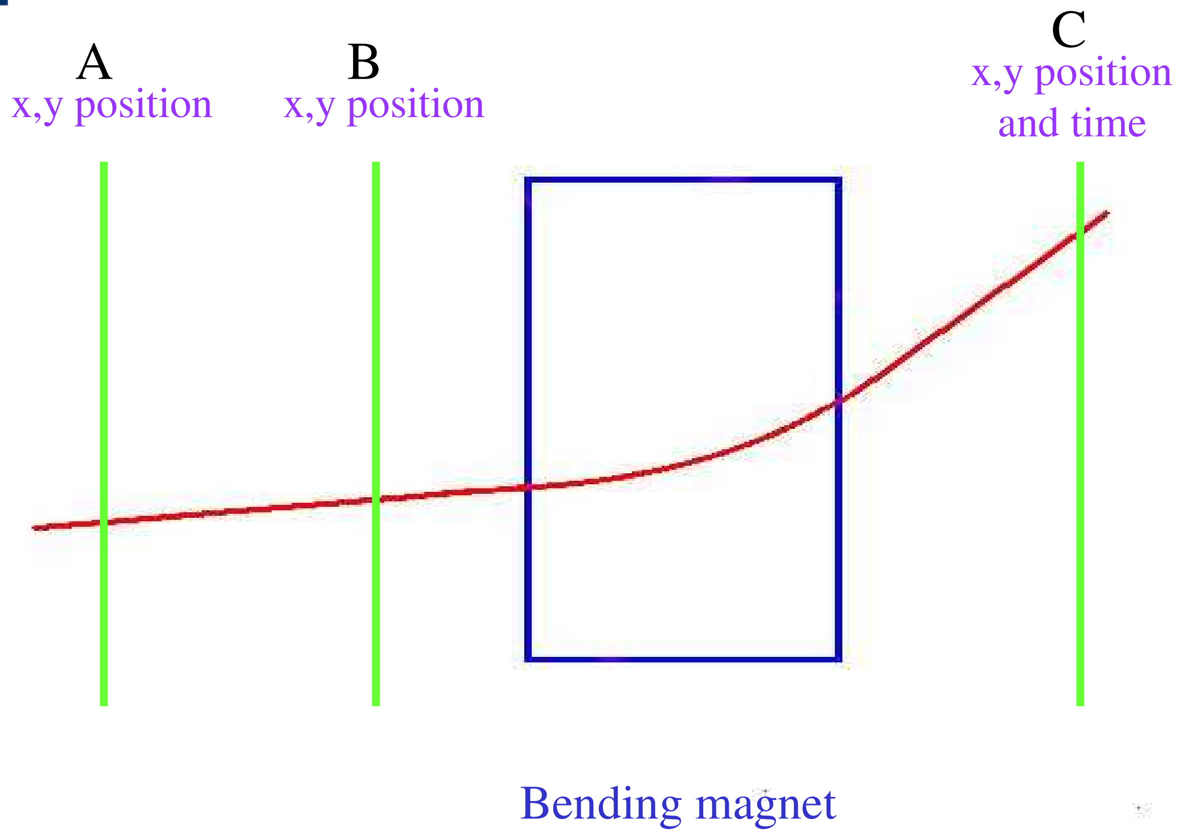


And after cooling we are here:



***Then there is obviously no big discussion about shape and/or detailed distributions...***

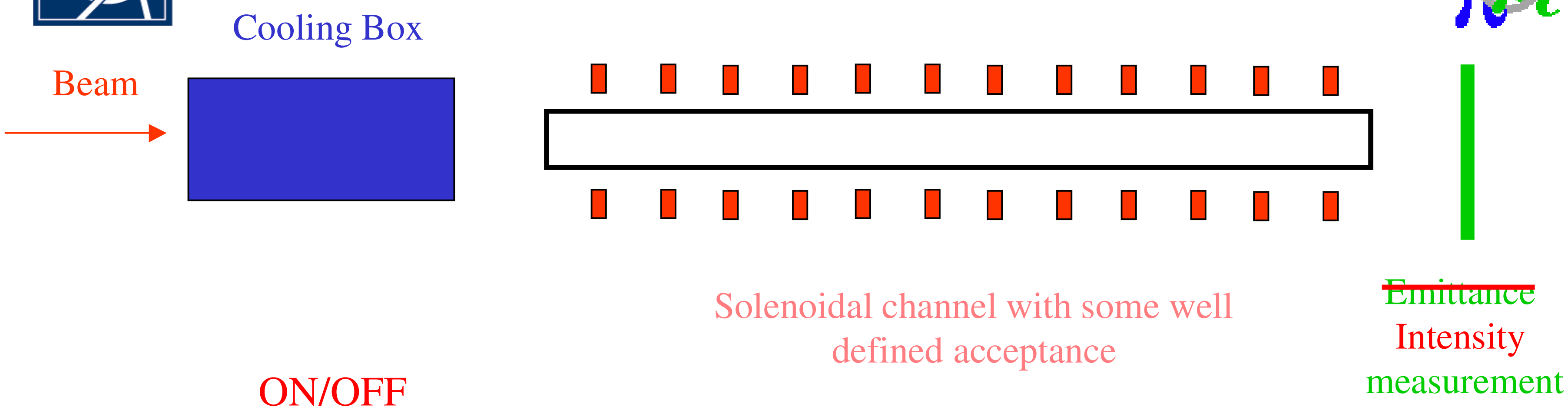
# How to measure the 6D coordinates of a single particle?




***A and B gives transverse coordinates, C (together with the fieldmap of the bending magnet) the longitudinal coordinates. Needs measurements which work in the specific environment and are "transparent"…***
***Note: They are not in rf or solenoidal fields!***

## *Let us forget for the moment about measurements in 6D*

There might be an alternative way to measure the effect of a (small) cooling factor for many particles in 4D:




*If cooling - at least of the core of the beam - is achieved: transmission will be increased if cooling box is ON.*

***To measure intensity to 1% should be fairly easy!***

This arrangement measures the 4D volume and not projections!

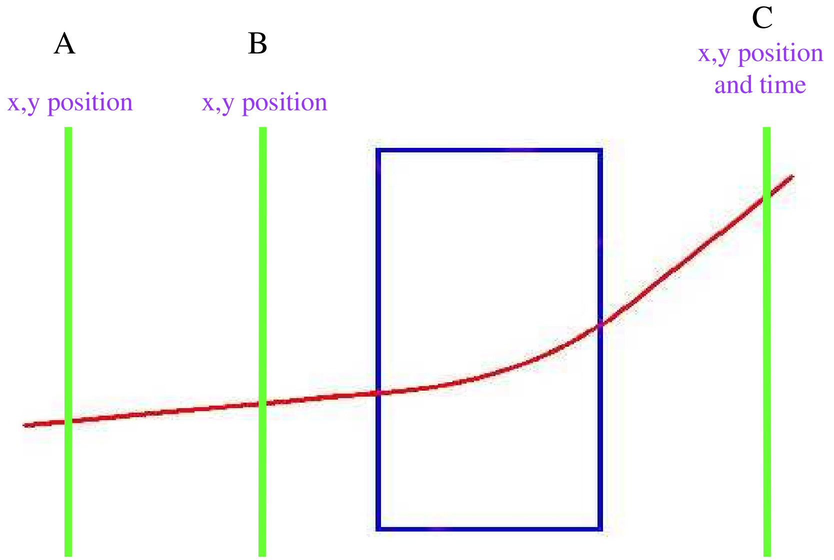
***This layout has clearly no well defined acceptance in longitudinal phase space. R. Garoby suggested to add rf cavities to the solenoidal transport line to define also the longitudinal acceptance. Unfortunately longitudinally not accepted particles may not be lost. In this case some kind of a spectrometer line might be necessary in addition (plus some phase/timing measurement). The cost in any case would be considerably higher.***

*Conclusion:*

*1) Abandon the idea of  multiparticle measurements*

*2) Concentrate on what can work for single particles in the neighborhood  of rf, solenoidal fields and some other radiation…*

*Make it sufficiently transparent!*




***It is fairly simple.***

***(If you disagree make a simpler proposition!)***