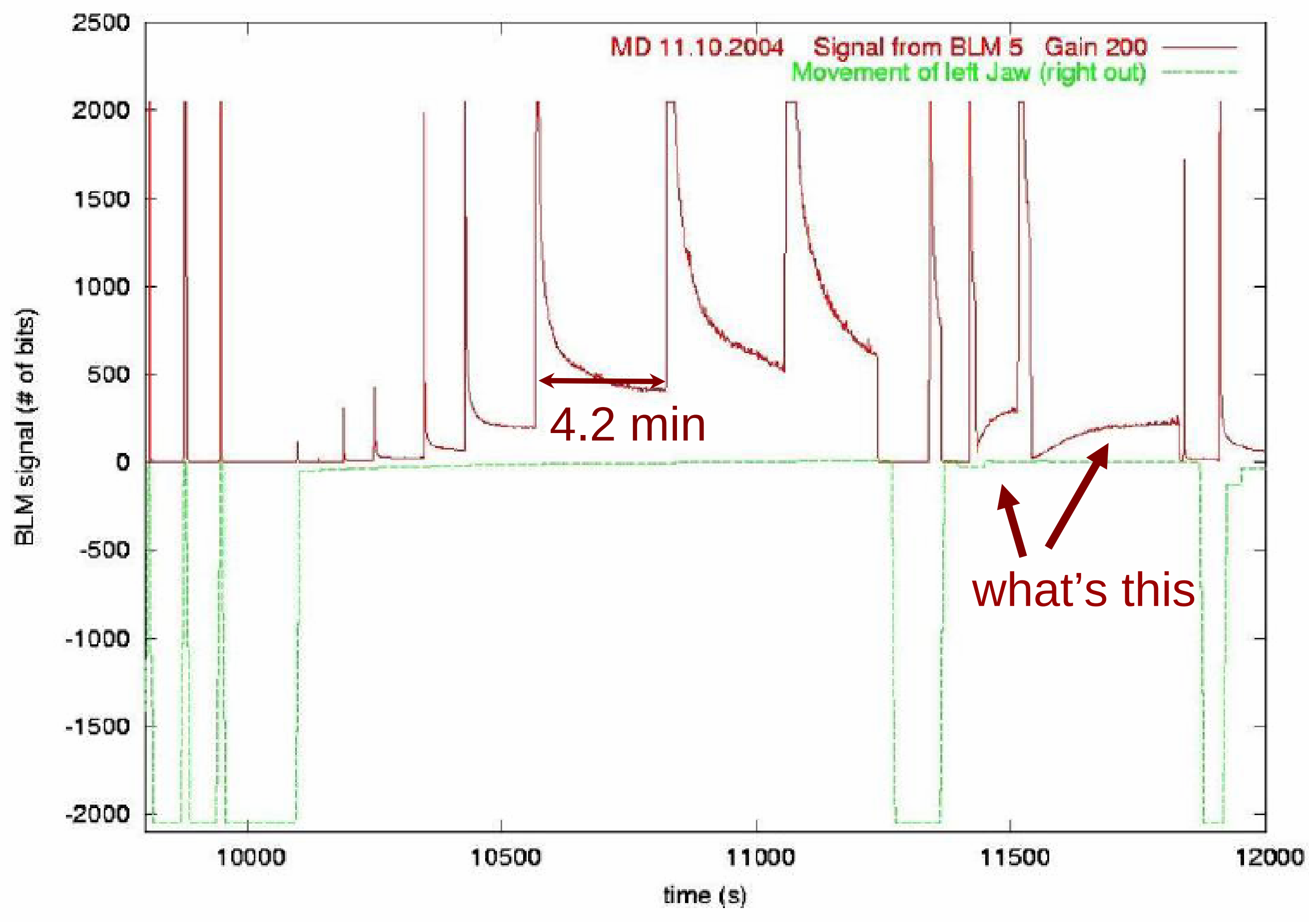
Analysis of BLM signal for the 2004 tests at the SPS

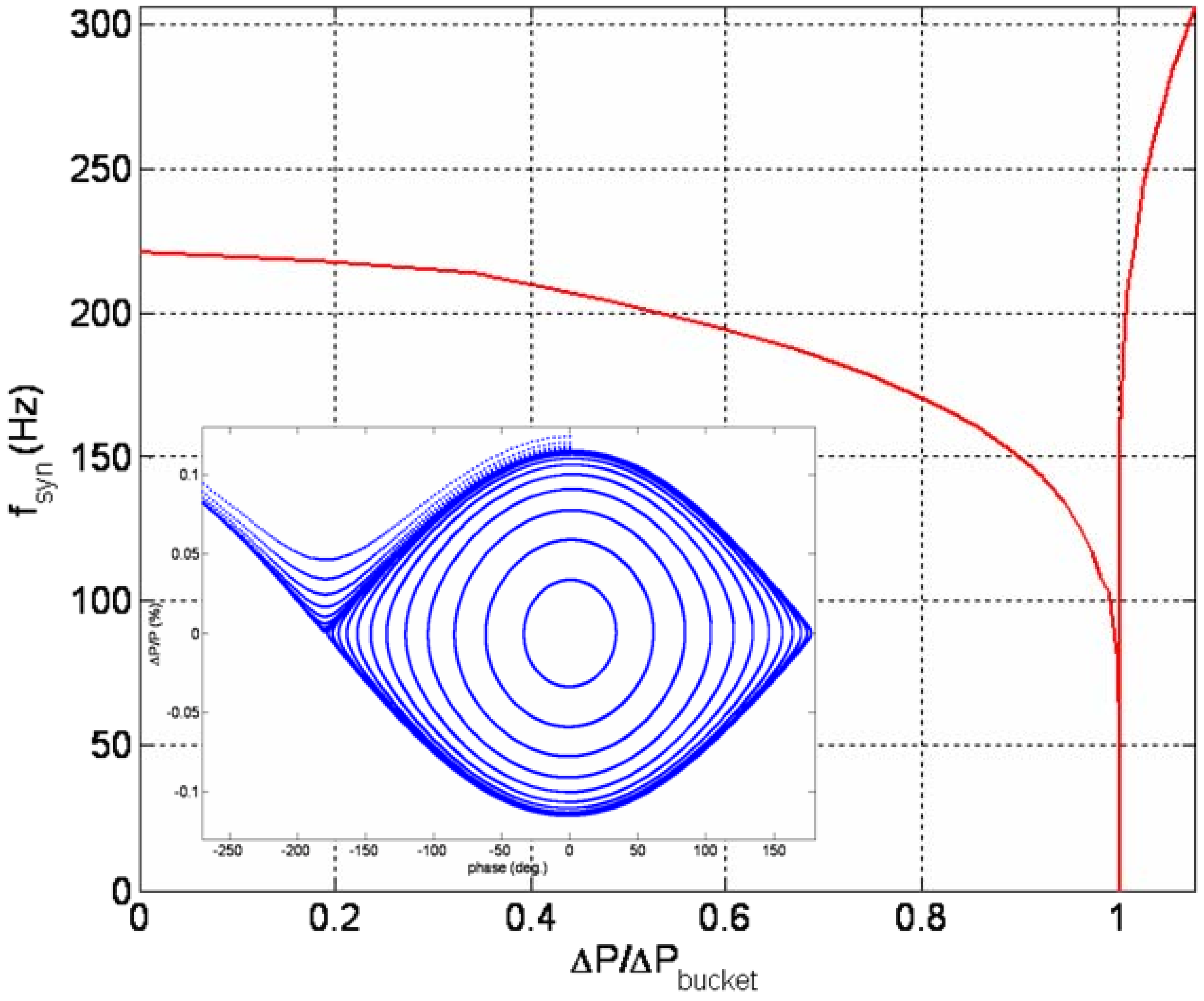
Hans-H. Braun, collimation working group meeting, 3.4.2006

- Motivation
- Time scale of synchrotron motion
- Single particle incoherent mirror image force
- Comparison of theoretical prediction with data
- Conclusions and predictions

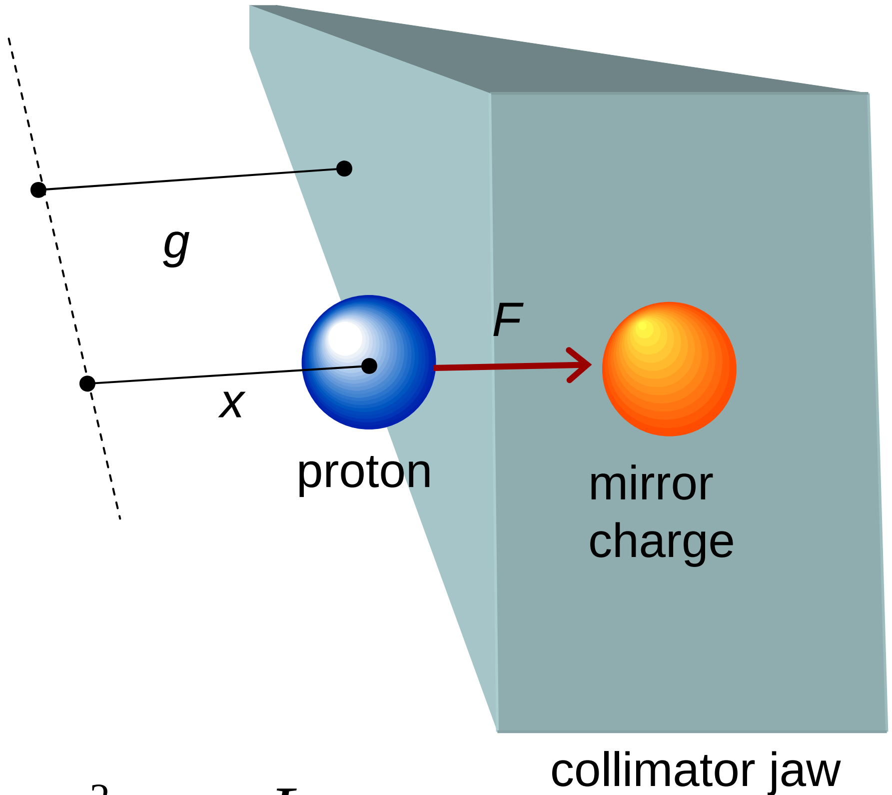
B. Holzer, Coll. Meeting, 26.11.2004



Slowest frequency in SPS synchrotron motion,
orders of magnitude to fast to explain timescale of minutes.



Single particle incoherent mirror image force



$$\delta x' = \frac{e^2}{16\pi\varepsilon_0 m_U c^2}\frac{Z^2}{A}\frac{L_{jaw}}{(\beta\gamma)^2(g-x)^2}$$

$$\frac{1}{(g-x)^2} = \frac{1}{4g^2}\sum_{i=1}^{\infty} i\left(\frac{x}{g}\right)^{i-1}$$

$\Rightarrow$ No matter what's $\boldsymbol{Q_X}$, motion is unstable very simple tracking code (repeatedly one turn matrix, single particle mirror kick) gives

$$\text{single jaw} \quad : \quad t = 3.38 \cdot 10^{-8} \frac{\mathrm{s}}{\mathrm{m^2 eV^2}} \cdot \frac{C_{Ring}\, T_{Kin}{}^{2}\, g}{\beta_X\, L_{Coll}} \cdot \left(g - x_0\right)^2$$

$$\text{pair of jaws} : \quad t = 1.69 \cdot 10^{-8} \frac{\mathrm{s}}{\mathrm{m^2 eV^2}} \cdot \frac{C_{Ring}\, T_{Kin}{}^{2}\, g}{\beta_X\, L_{Coll}} \cdot \left(g - x_0\right)^2$$

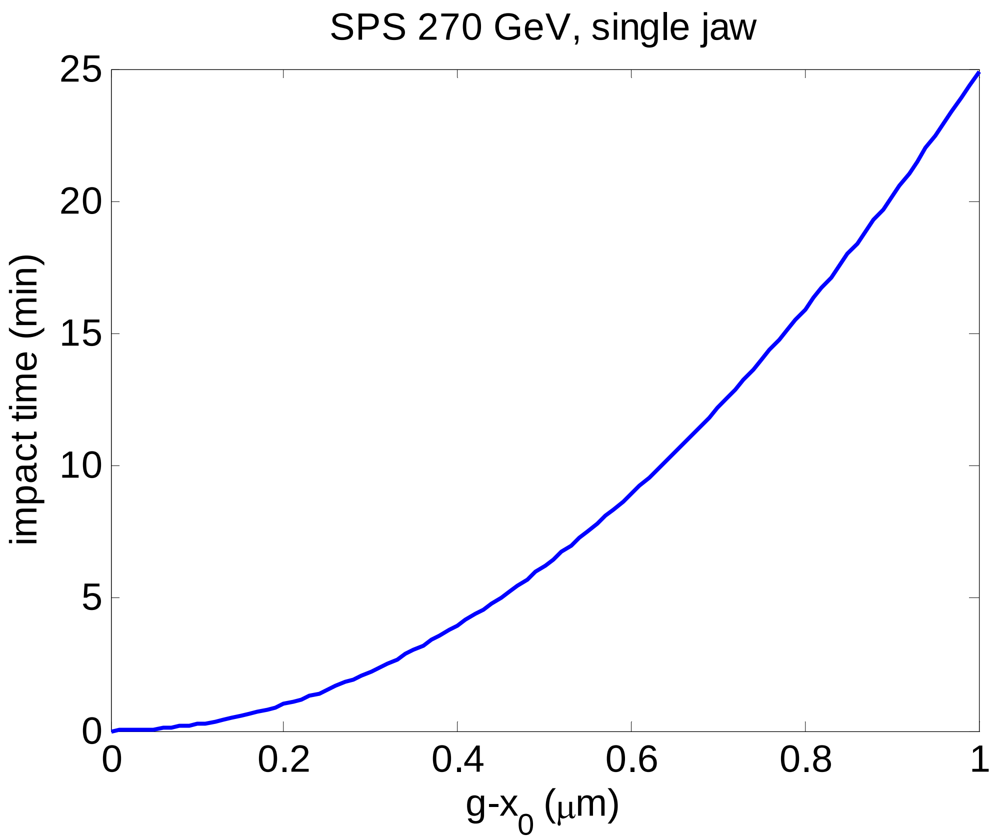
x_0 = starting coordinate

t = time interval from start to impact on jaw

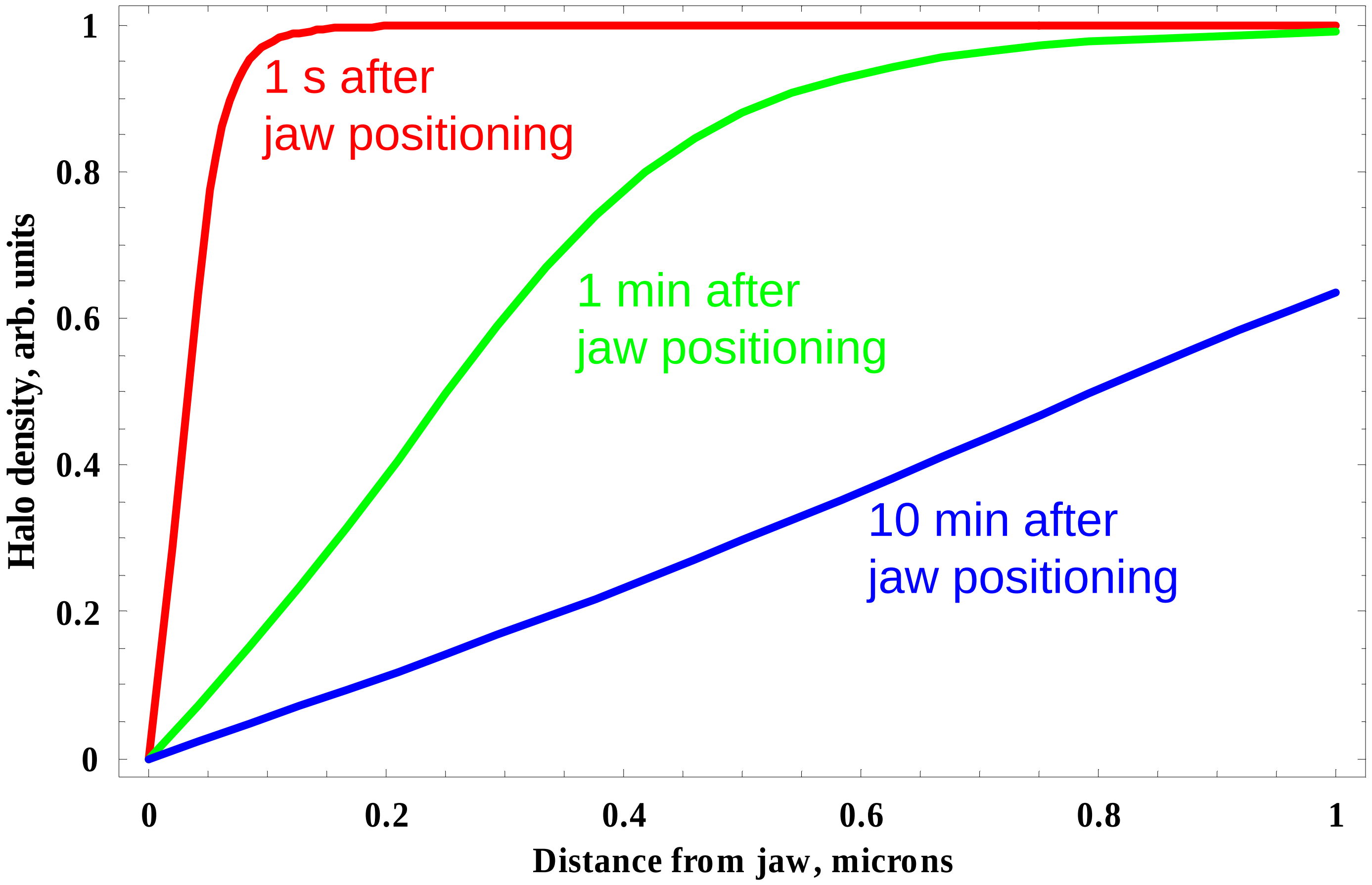
g = distance beam axis - jaw surface

Valid if $t >> \textit{revolution time}$

Independent of Q_X except for low order resonances values

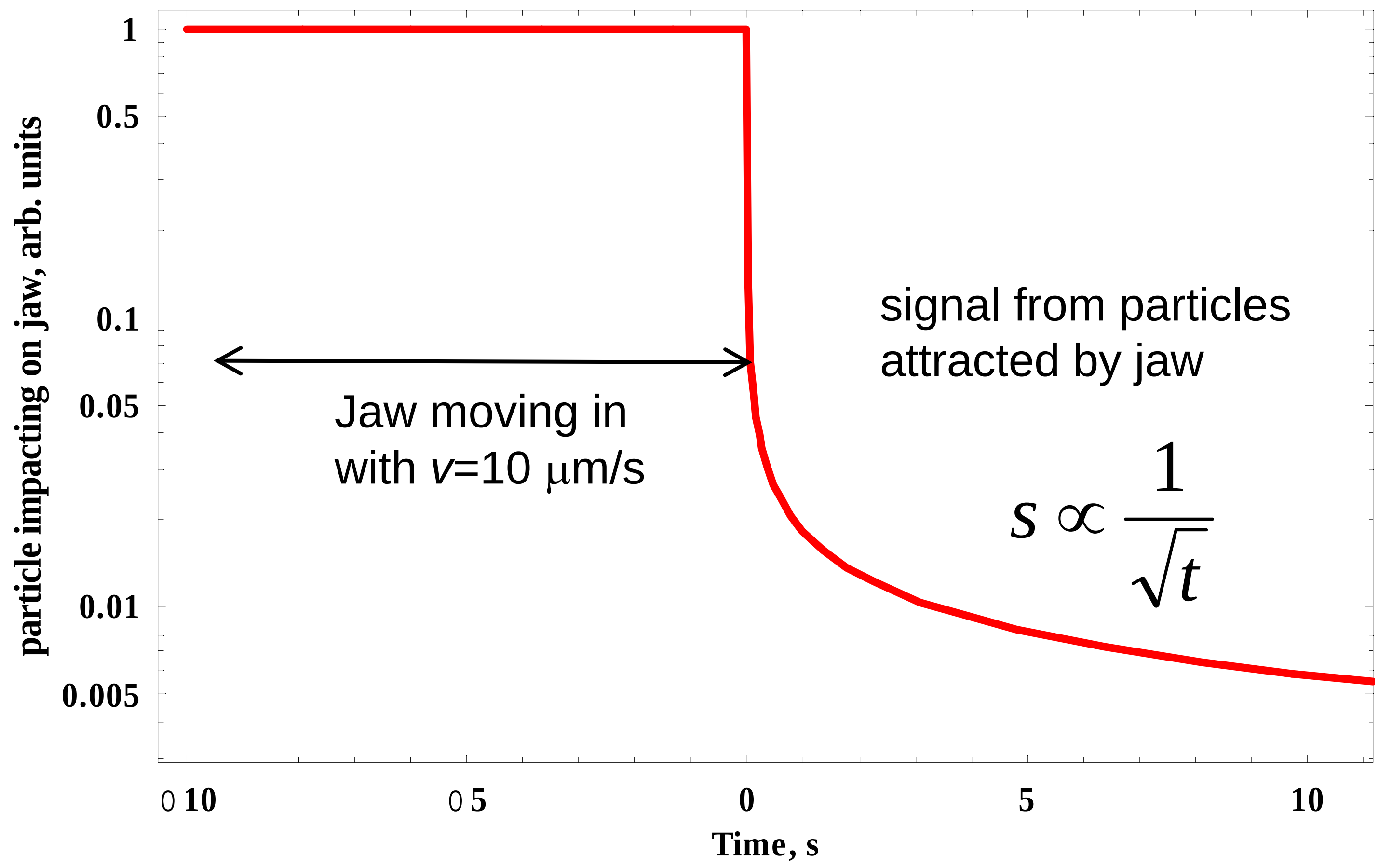

SPS 270 GeV, single jaw
impact time (min)
g-x0 (μm)
0
5
10
15
20
25
0
0.2
0.4
0.6
0.8
1

Time/distance dependence + continuity equation
allows to compute halo density dynamics in neighborhood of jaw



Assumption: - jaw moves in fast and from far away,
- initial halo density constant over μm scale
- no other sources of halo re-population

Time/distance dependence of single particle space charge allows to compute time dependence of losses on jaw

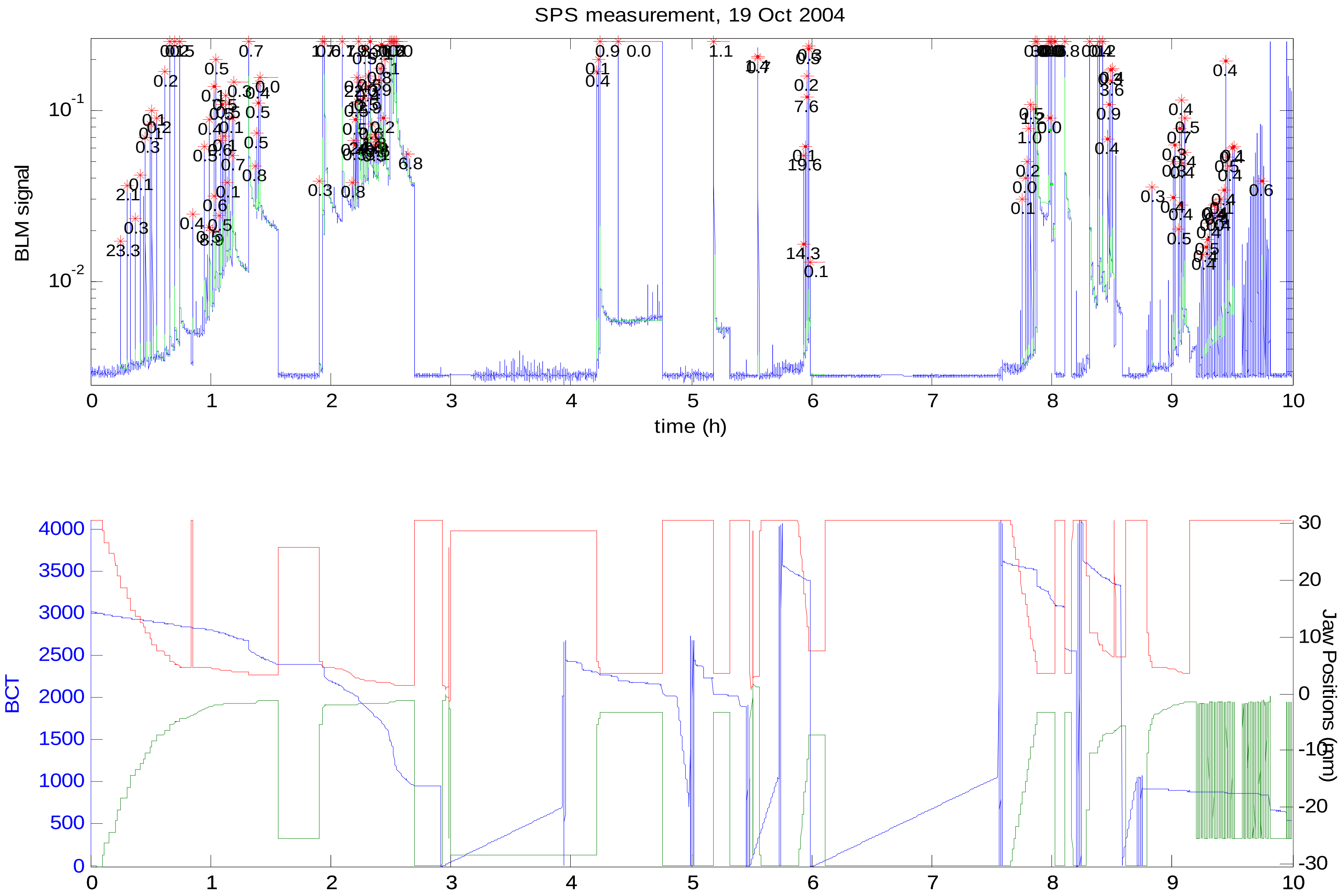


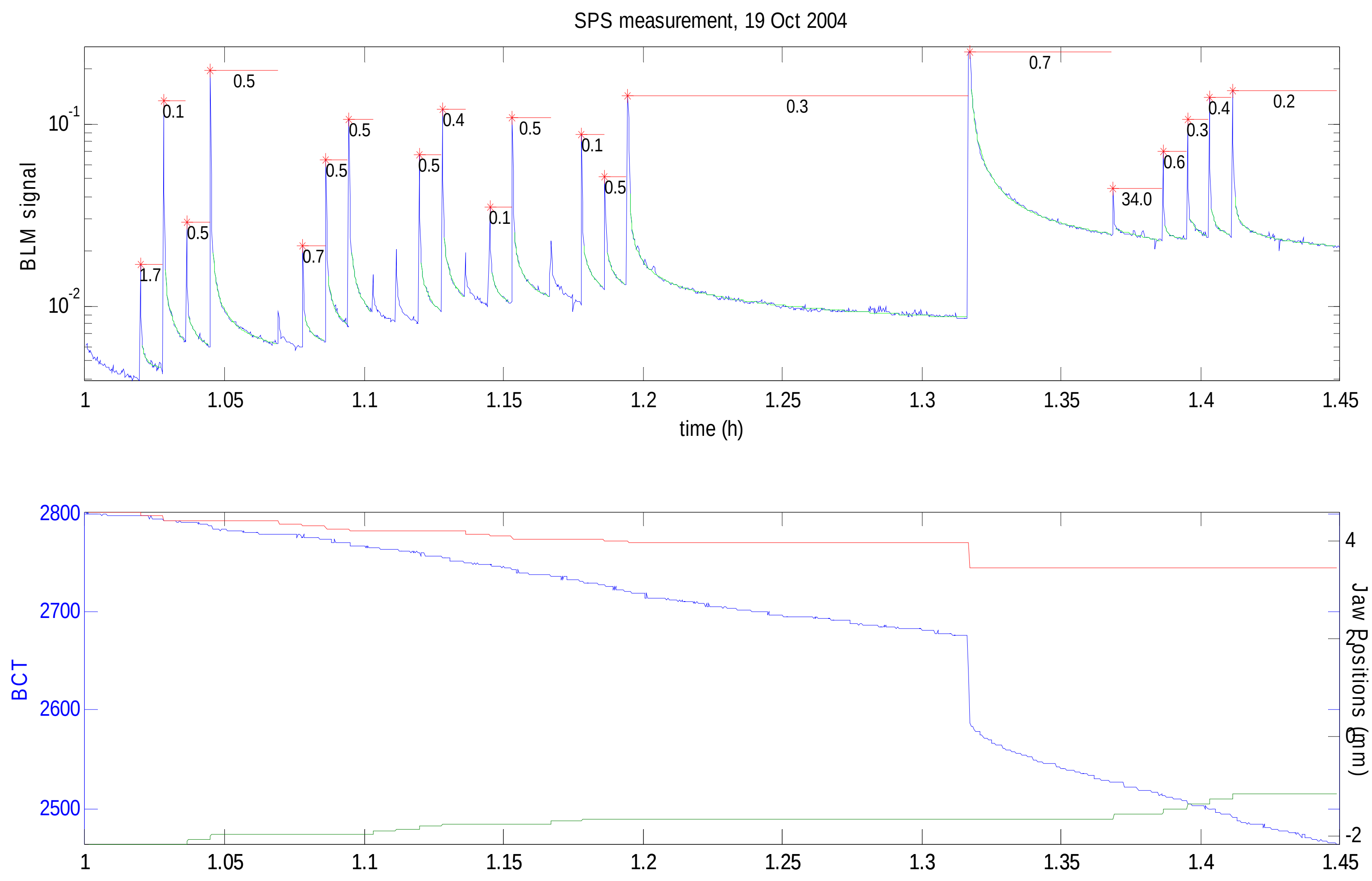
Assumption: - jaw moves in from far away,

- initial halo density constant over μm scale
- no other sources of halo re-population

Check prediction by fitting all BLM peaks in SPS measurements with

$$s = a\,(t - t_0)^{-b}$$

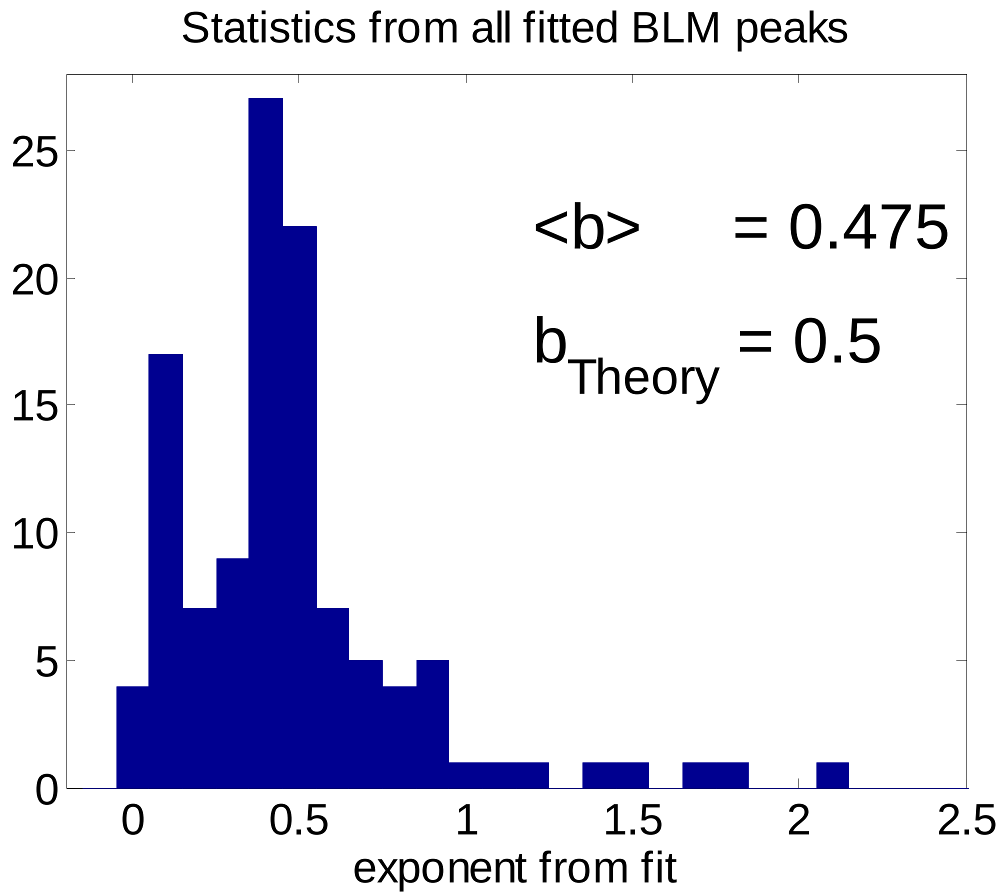




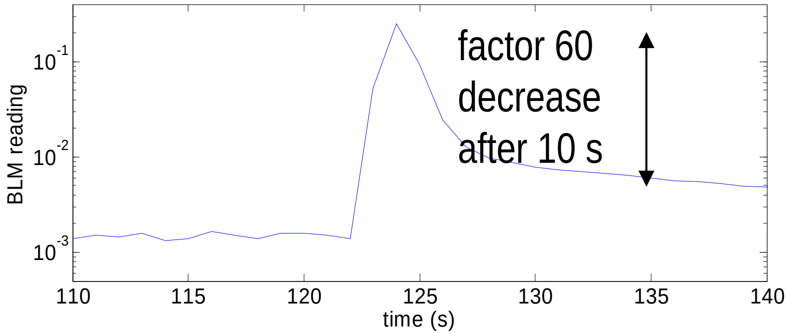
SPS measurement, 19 Oct 2004
BLM signal
time (h)
BCT
Jaw Positions (mm)
1.7
0.1
0.5
0.5
0.7
0.5
0.5
0.5
0.4
0.1
0.5
0.1
0.5
0.3
0.7
34.0
0.6
0.3
0.4
0.2

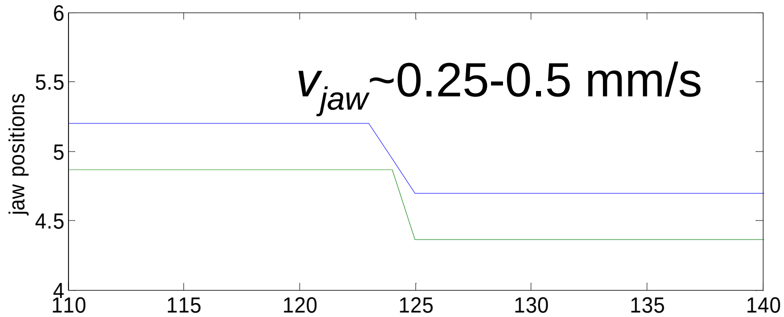
Fit function

$$s=a\ (t-t_0)^{-b}$$

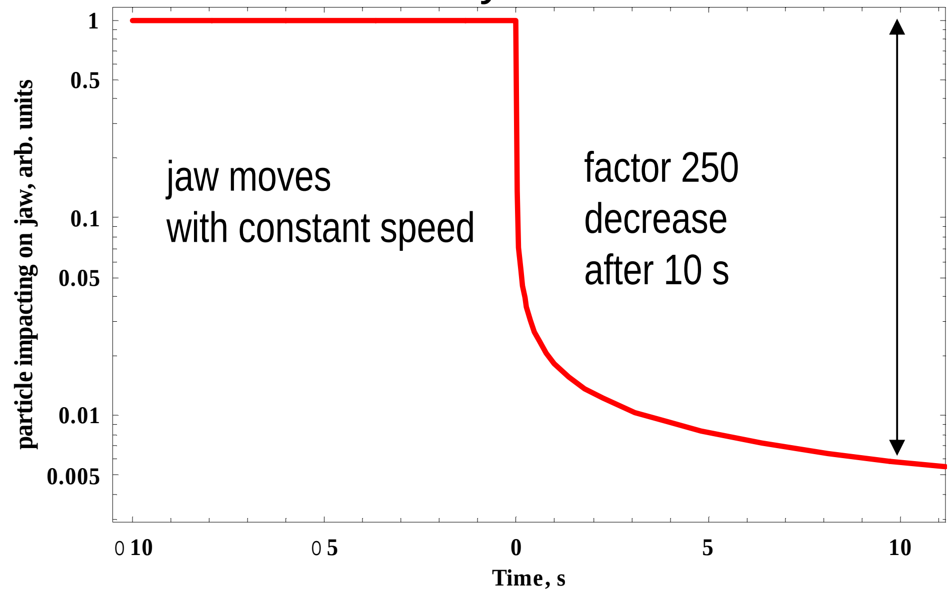


Zoom on peak





Theory



Ratio *signal during jaw positioning / signal after jaw positioning* seems to be lower than predicted.

Reasons:

- Time resolution BLM signal to coarse ?
- Do particles hitting deep in the jaw produce less BLM signal ?
- Mirror kick is stronger because of resistive wake, surface roughness… ?
- … ?.

Conclusions

- BLM signals after jaw positioning follow reasonably well a $t^{-1/2}$ law as predicted by single particle mirror kick model.
- Ratio *signal during jaw positioning* / *signal after jaw positioning* seems to be lower than predicted, but better time resolution for BLM and jaw position needed for detailed analysis. FLUKA simulation of BLM signal as function of impact parameter in jaw would be extremely useful !
- Ratio *signal during jaw positioning* / *signal after jaw positioning* is predicted to vary linear with beam energy.
- Ratio *signal during jaw positioning* / *signal after jaw positioning* is predicted to vary with the square root of the atomic number, i.e. **14 times more tails for ^{208}Pb**.
- Energy and atomic number dependence should be measured during next SPS collimator MD and during SPS ion commisioning !

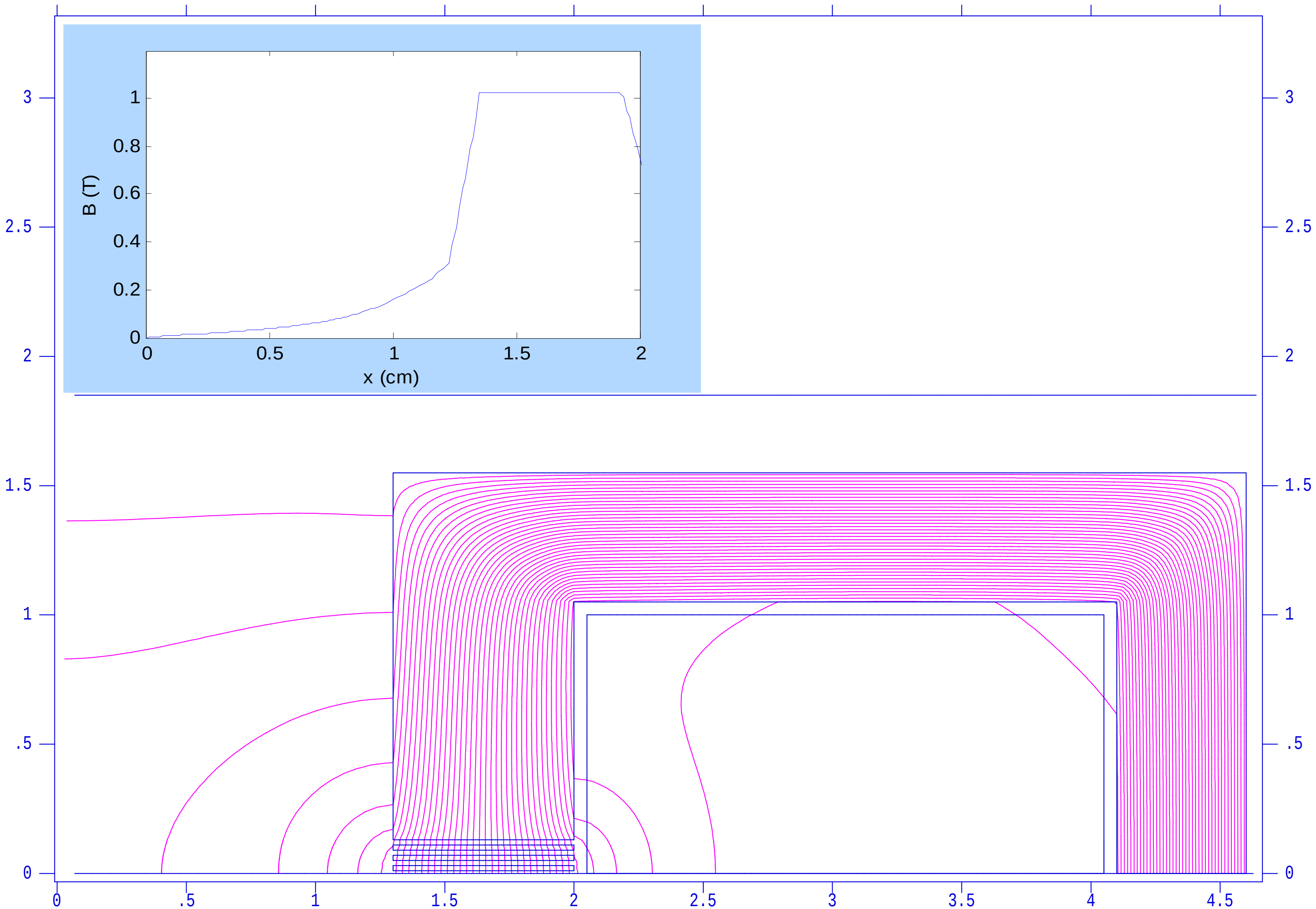
Can mirror kick effect be used to improve ion collimation efficiency
by kicking particles from surface of primary collimator on secondary collimator ?

$\Rightarrow$ No, required kick corresponds to **~ 0.5 Tm** bending strength,
mirror kick with LHC parameters falls ~ 3 orders of magnitude short

Coffee discussion with Fritz Casper and Frank Zimmermann on the subject

$\Rightarrow$ Why not use a collimator which generates a
deflecting field with similar characteristic ?

&reg kprob=0,   ; Declares a POISSON problem



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Many thanks to Stefano for providing and explaining the 2004 MD data,

and

to Gianluigi for providing the SPS parameters and optics data