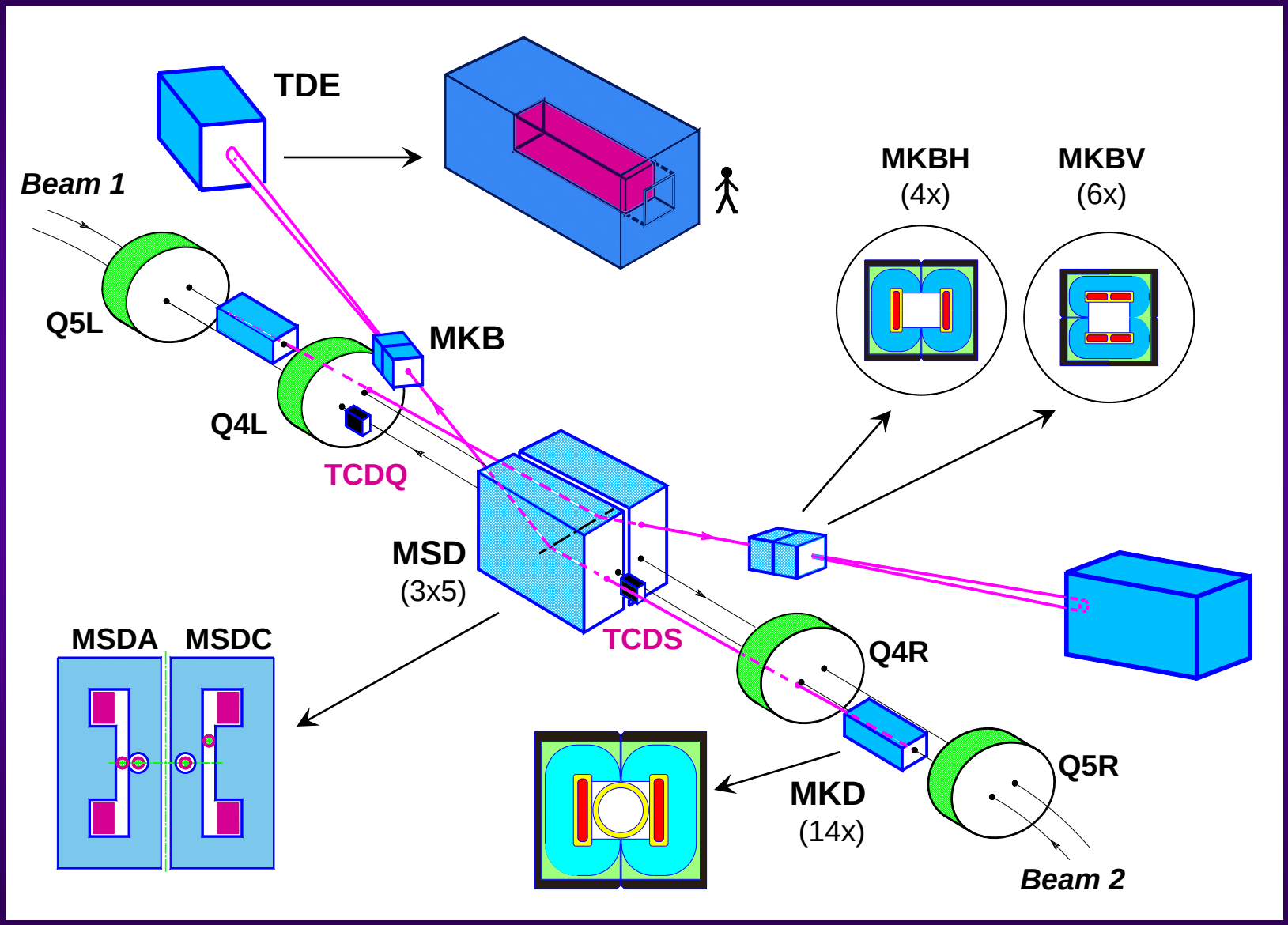
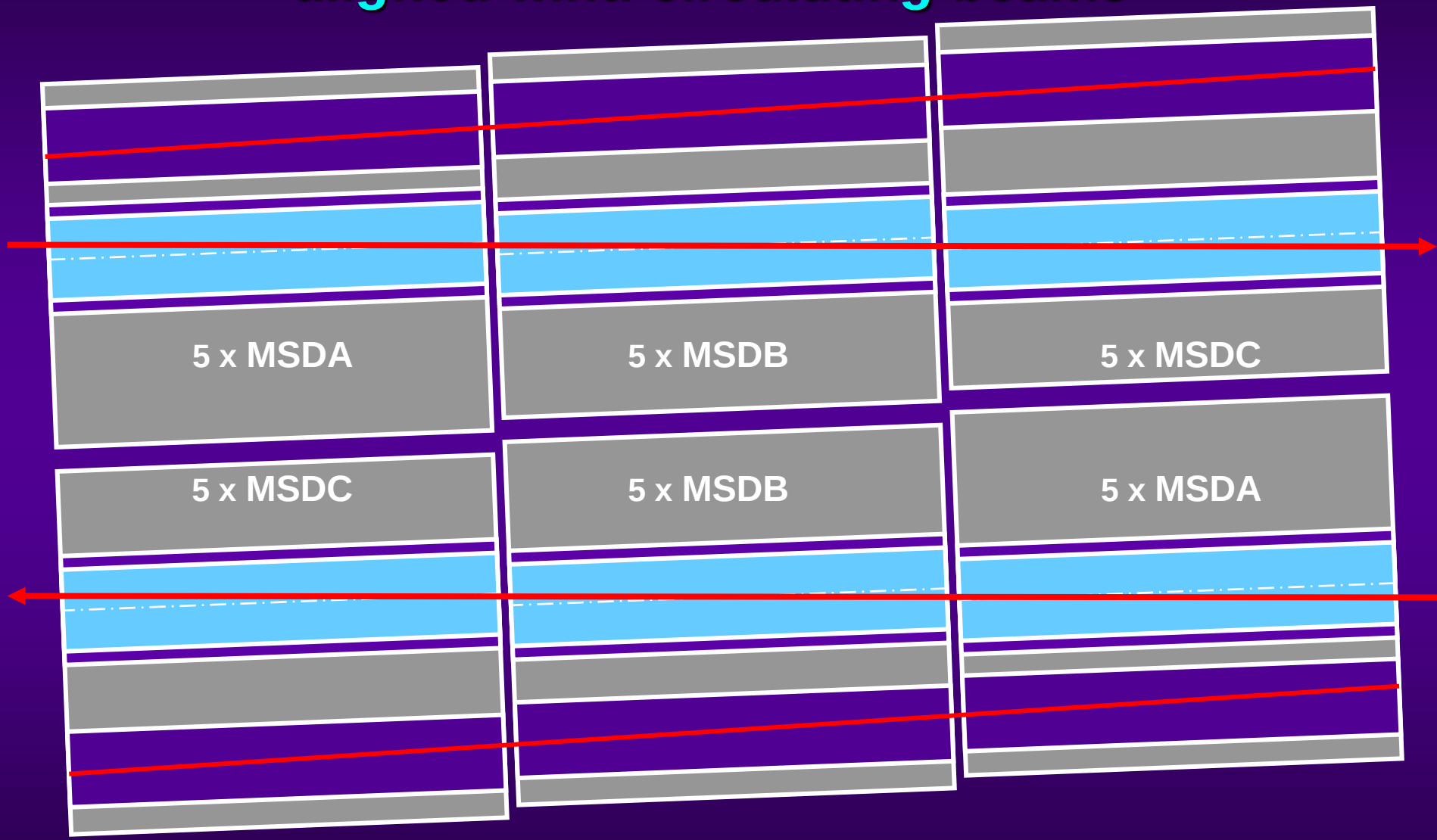
The LHC Beam Dump System

Aperture limitations in the MSD septum magnet

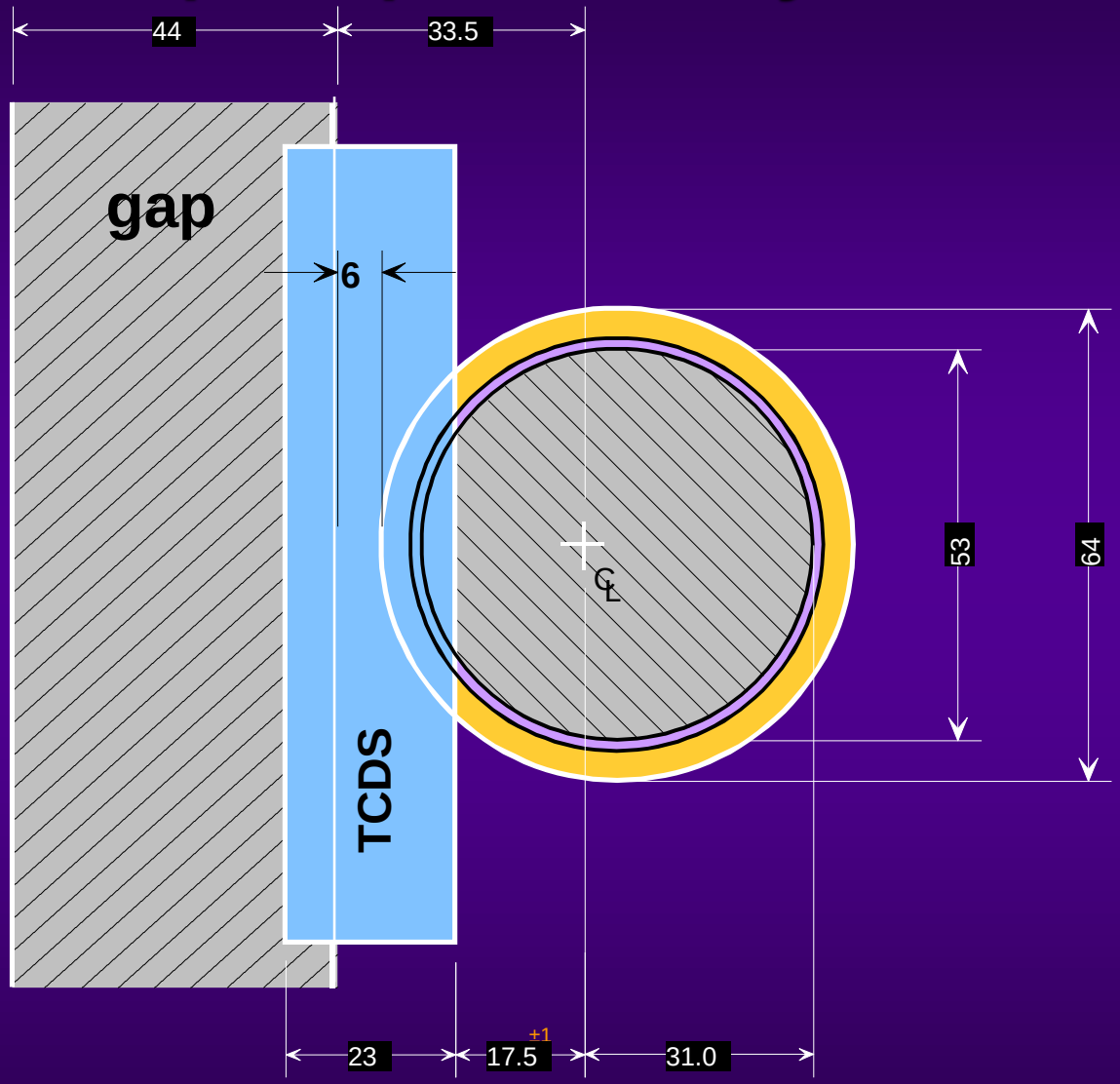
Schematic Layout



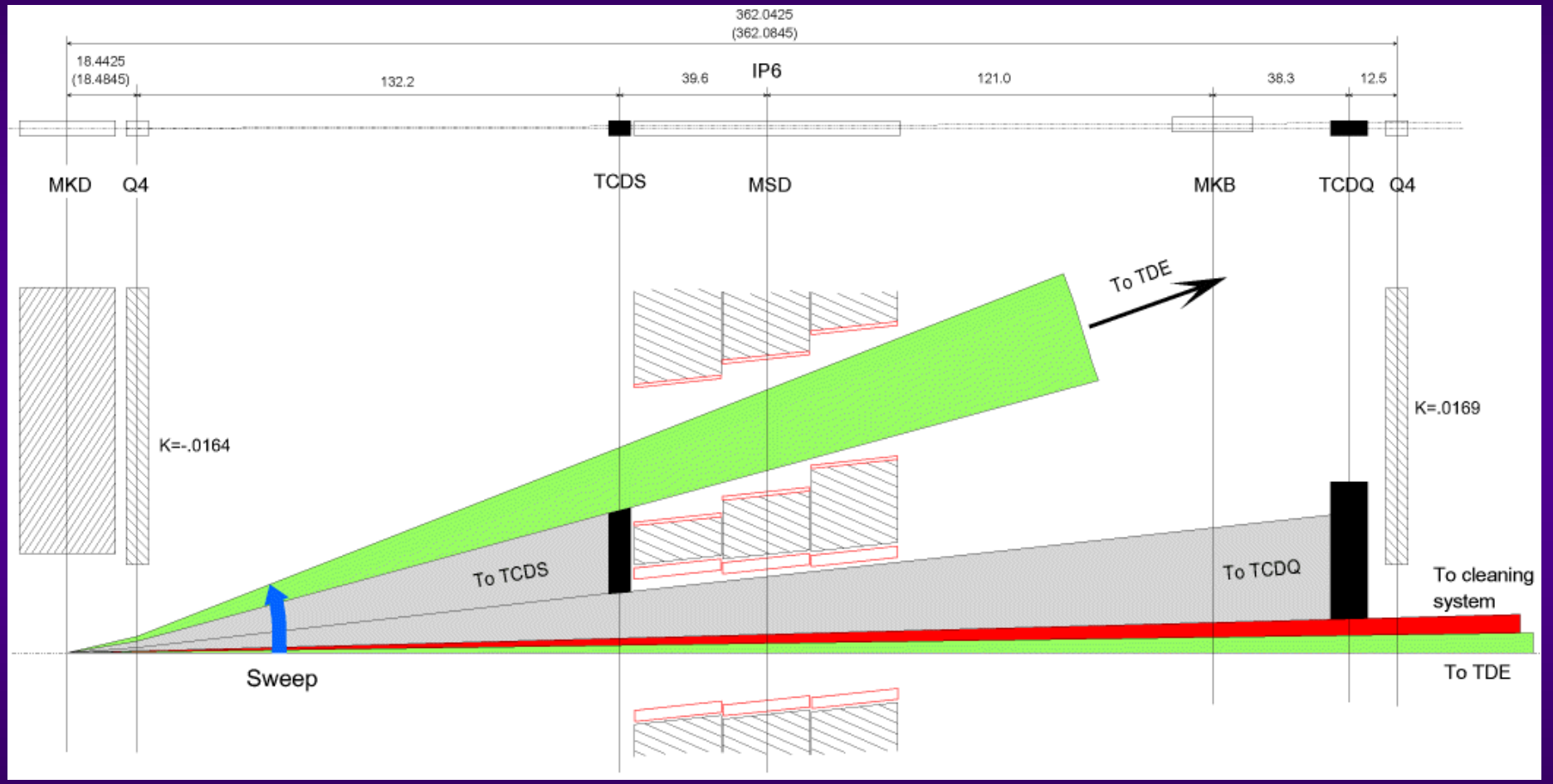
MSD for both rings – aligned w.r.t. circulating beams



Septum protected by TCDS



MSD Alignment



Constraints

Circulating beam:

- Vacuum chamber bakeable to 150 °C
- Should provide aperture of $n_1 = 7.0$

Normally extracted beam:

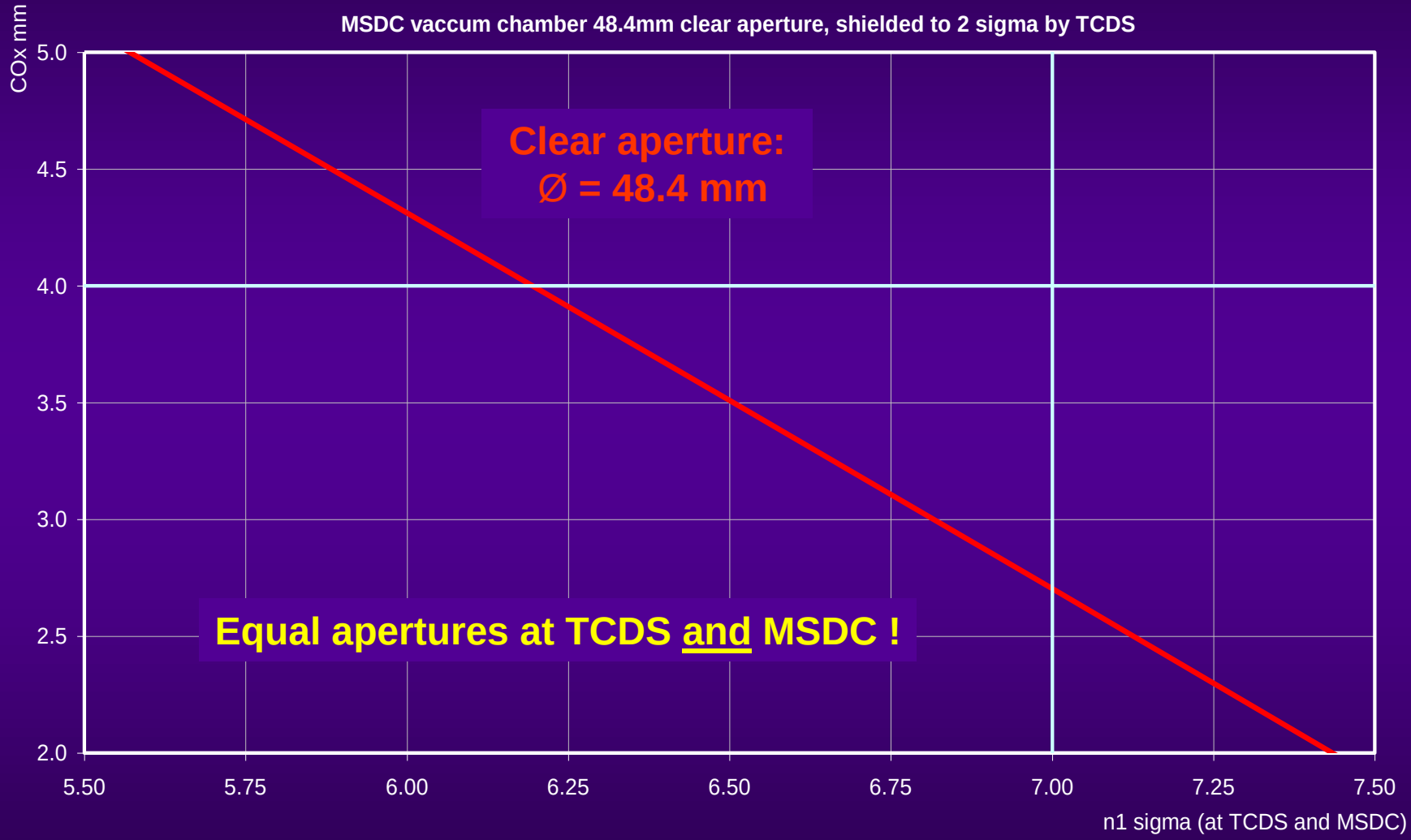
Should accept all beams with sufficient aperture

- 450 GeV and 7 TeV ($\geq$6.0 σ and $\geq$8.0 σ)
- 15 or 14 MKD modules firing
- MKD overshoot of maximum 10% (incl. tolerances)

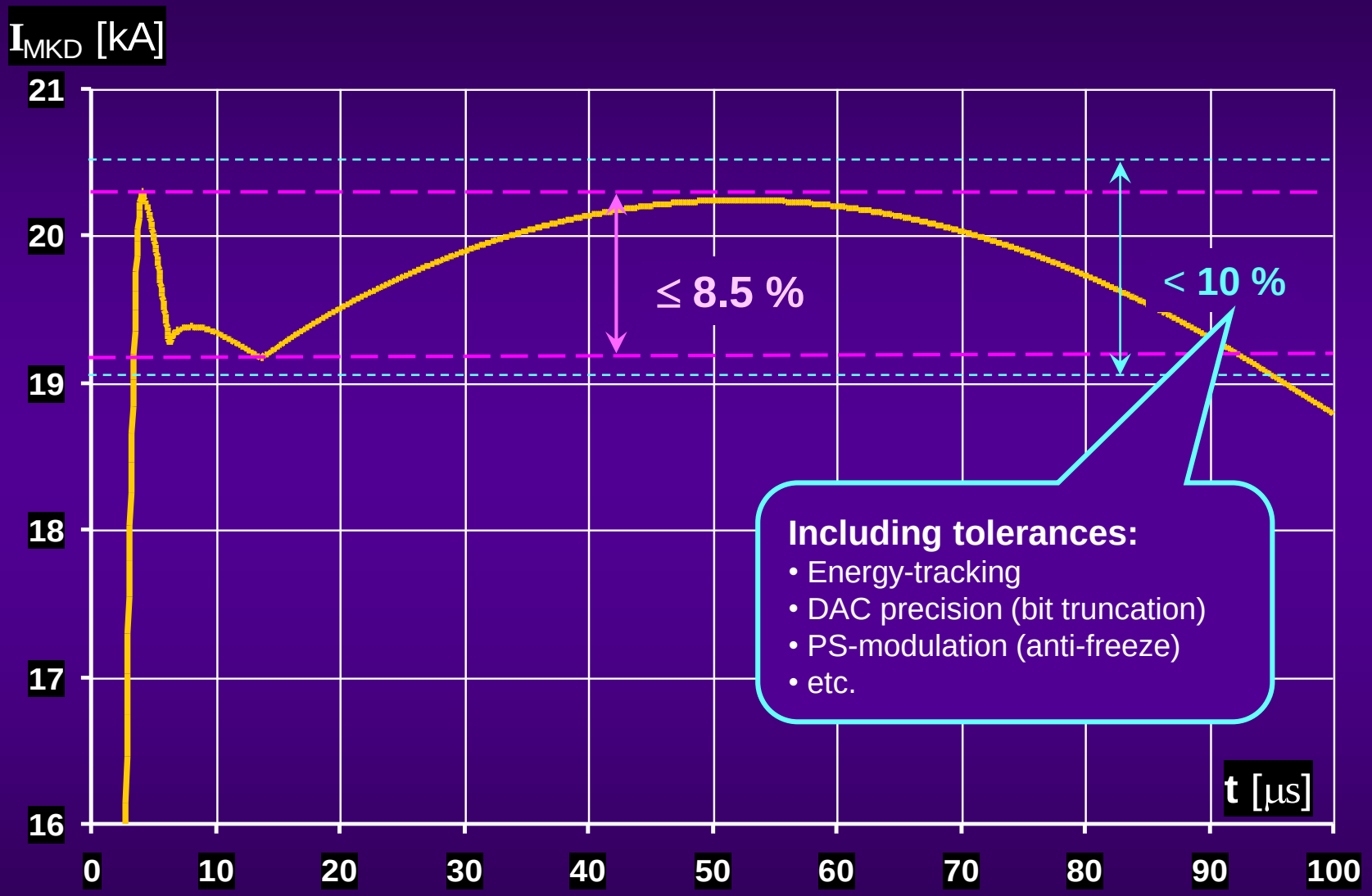
Asynchronous MKD firing :

- TCDS shadows MSD vacuum chamber up to 2 σ

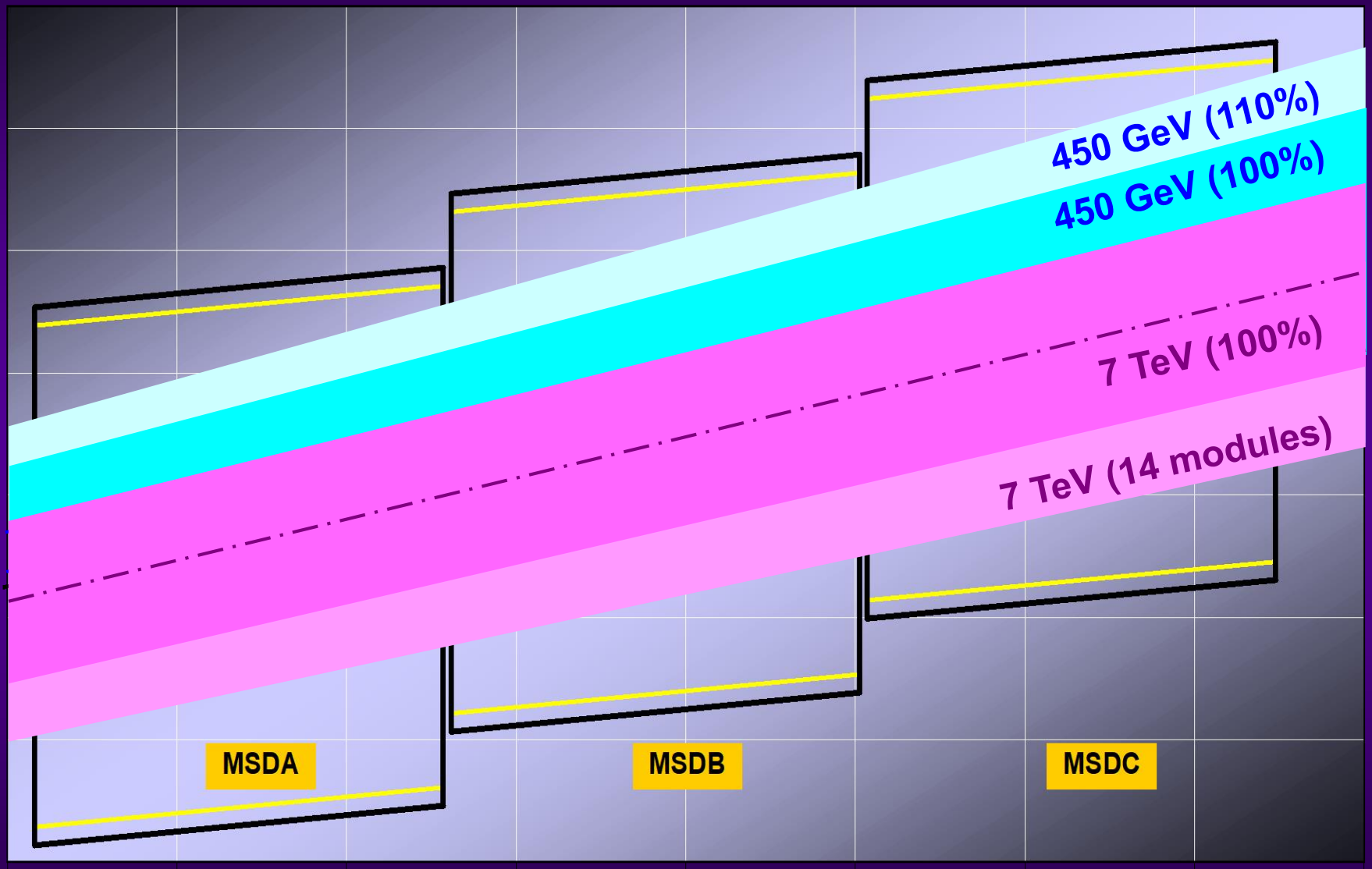
Circulating beam :
Derive maximum aperture with present vac. chamber…



MKD Flat-top Current Variation



“Nominal” Beams in Gap (horizontal)



Why do the constraints need to be changed?

- **Circulating beam:**

  Not possible to respect aperture of n_1=7.0 for 4mm CO_x

- **Extracted beam:**

  Aperture problems for extracted beam if 4.0mm Cox

  (at 7 TeV limitation is due to available kick strength)

	450 GeV	7 TeV
15/15 MKD	4.0 σ	2.1 σ
14/15 MKD	0.6 σ	~0 σ

Additional 'new' factors

'Dynamic orbit' (RA):

In the event of specific machine faults, beam position may move substantially in point 6 before the dump can be fired.

Worst case values given (assume dump at 3 sigma intercept)

	450 GeV	7 TeV	7 TeV squeezed
Nominal ($\beta^* = 0.5$ m)	8.7 mm	11 mm	2 mm
Initial ($\beta^* = 1.0$ m)	8.7 mm	11 mm	4 mm

Asynchronous 'leftovers':

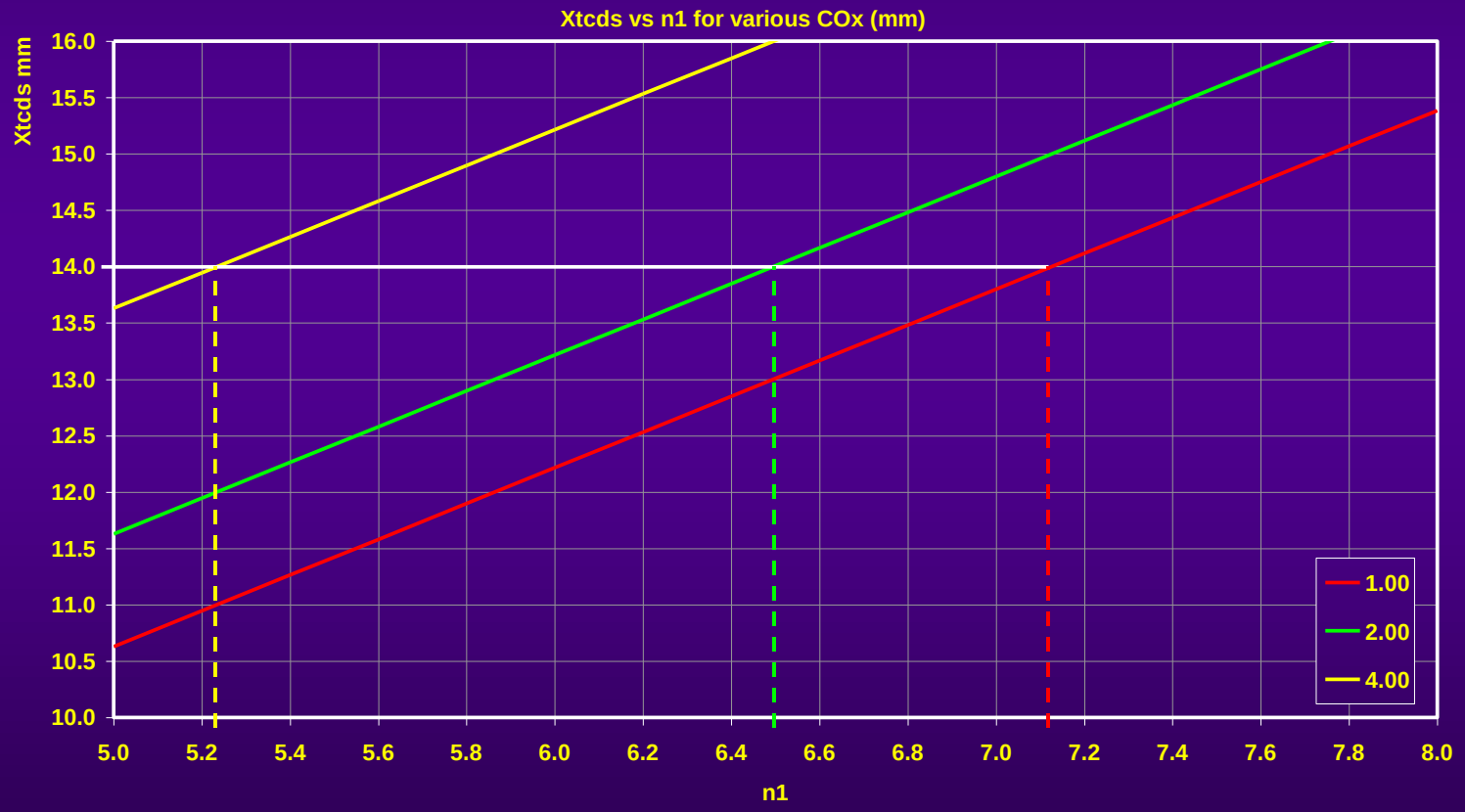
In the event of a prefire, beam below ~7-8 σ makes 1 turn and arrives back with a large offset — must still be extracted

What can be done…

- **Investigated possible solutions :**
  - **Assume various faults are decoupled**
  - **Increase aperture of vacuum chamber – limited effect**
    - ***second-to-last resort (last resort is new MSD…)***
  - **Reduce MKD overshoot**
    - ***still fighting to keep total below 10% – already modifications to generator for this - cannot go much further (also adversely affects rise time and dilution…)***
  - **Orbit feedback to reduce CO_x – very important effect**
    - ***From MPWG & JW, assume ±1.0mm at extraction elements…***
  - **For 14/15 case, allow part of beam to strike TCDS**
  - **For asynchronous case, make TCDS 2-sided… ?**

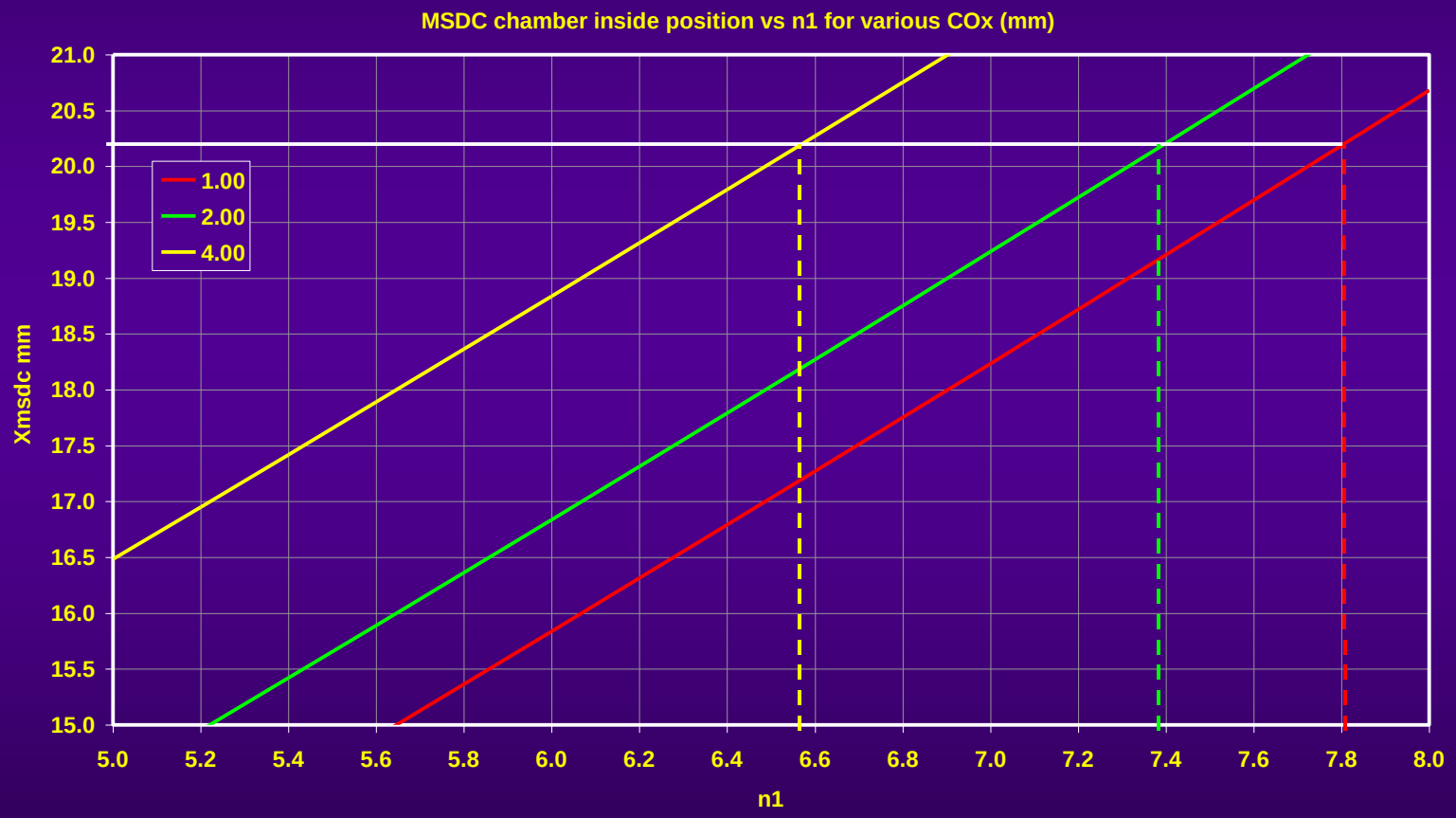
Methodology

- **Circulating beam aperture :**
  - **Place TCDS at 14.0 $^{\pm 1.0}$ mm**



Methodology

- **Position MSDC in shadow of TCDS (2σ) :**
- **MSDC exit at –20.2** mm



Assume orbit well controlled for asynchronous dump (i.e. faults decoupled)

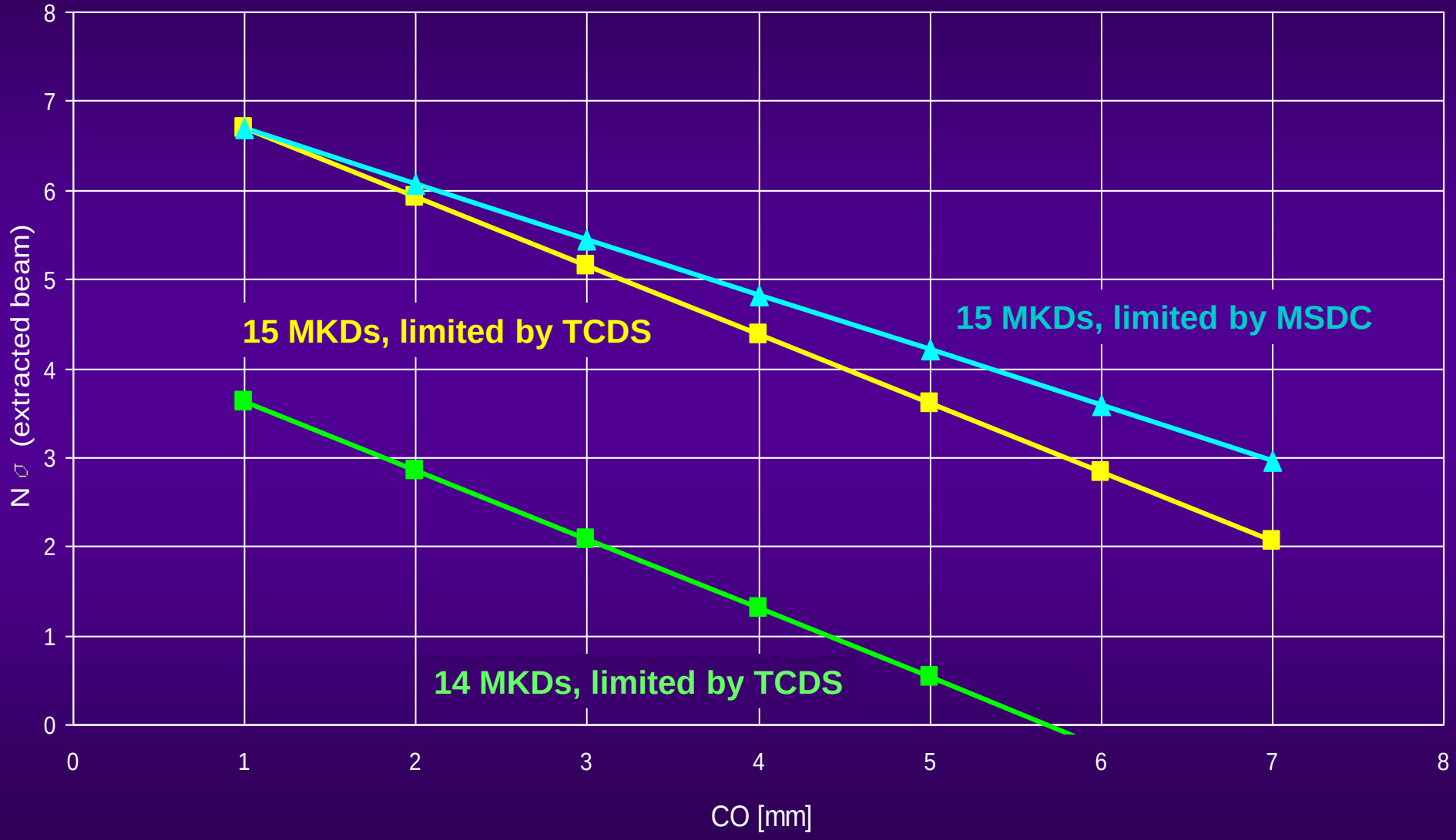
Methodology

- **Optimise clearances for extracted beam :**
  - **Assume normalised emittance ε = 3.75 x 1.17 x 1.21 μm**
  - **Assume nominal orbit $\pm$1.0 mm**
  - **Allow 14/15 MKD case to approach TCDS**
  - **Fix same MKD kick from 450 GeV to 7 TeV**

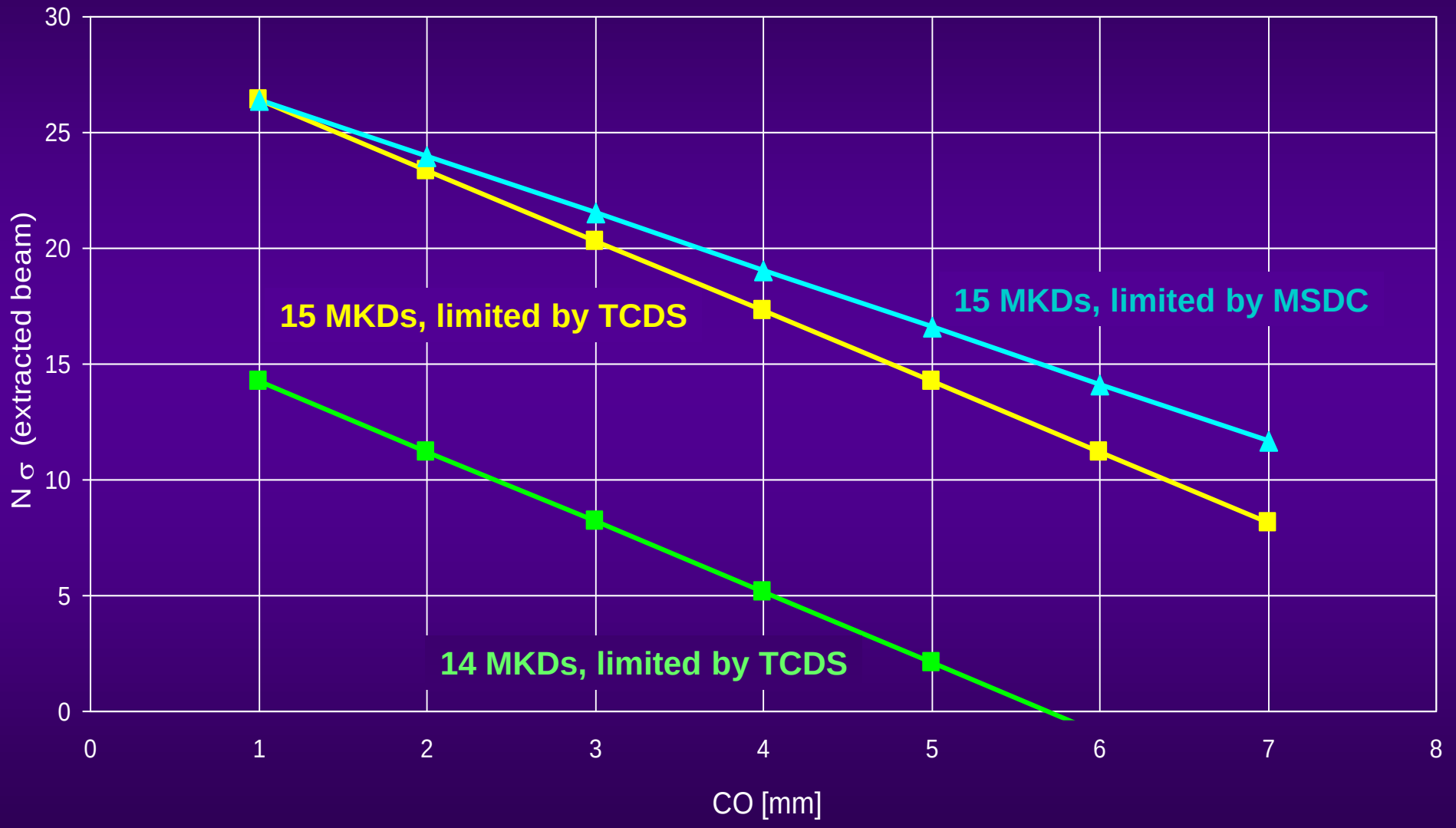
Aperture for extracted beam if 1.0 mm CO_x

	450 GeV	7 TeV
15/15 MKD	6.6 σ	27 σ
14/15 MKD	3.7 σ	14 σ

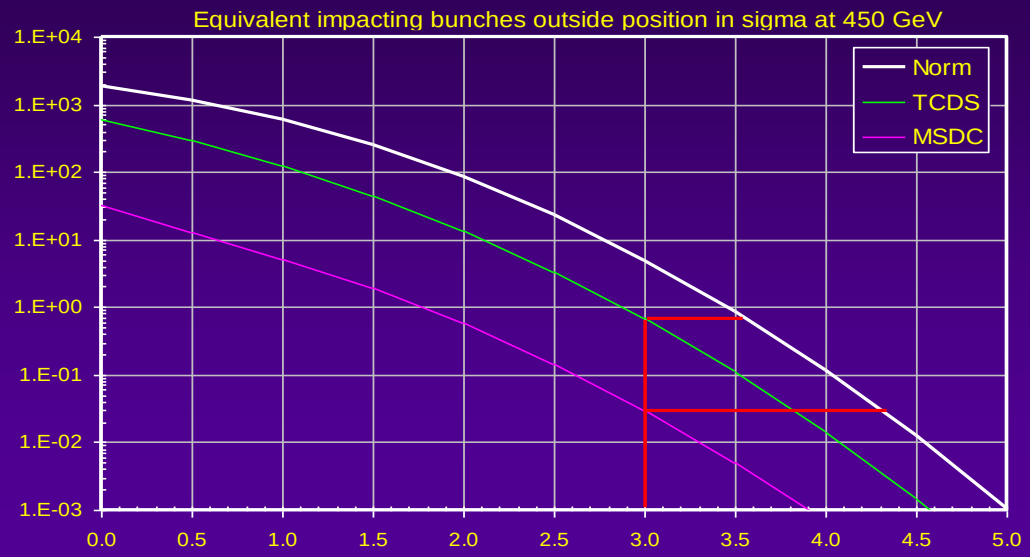
Admittance (Nσ) at 450 GeV as function of CO_x

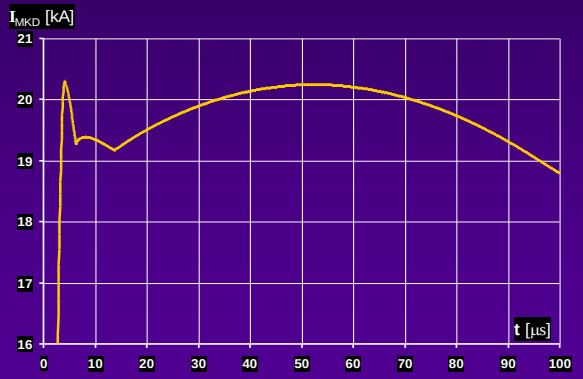


Admittance (Nσ) at 7 TeV as function of CO_x



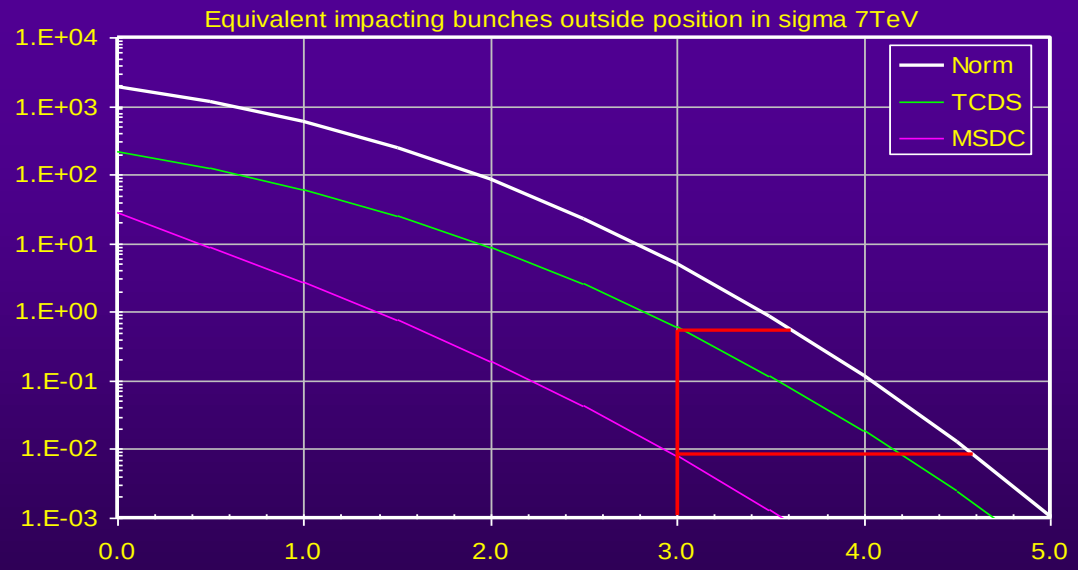
Protons on the TCDS & MSDC – MKE waveform effect



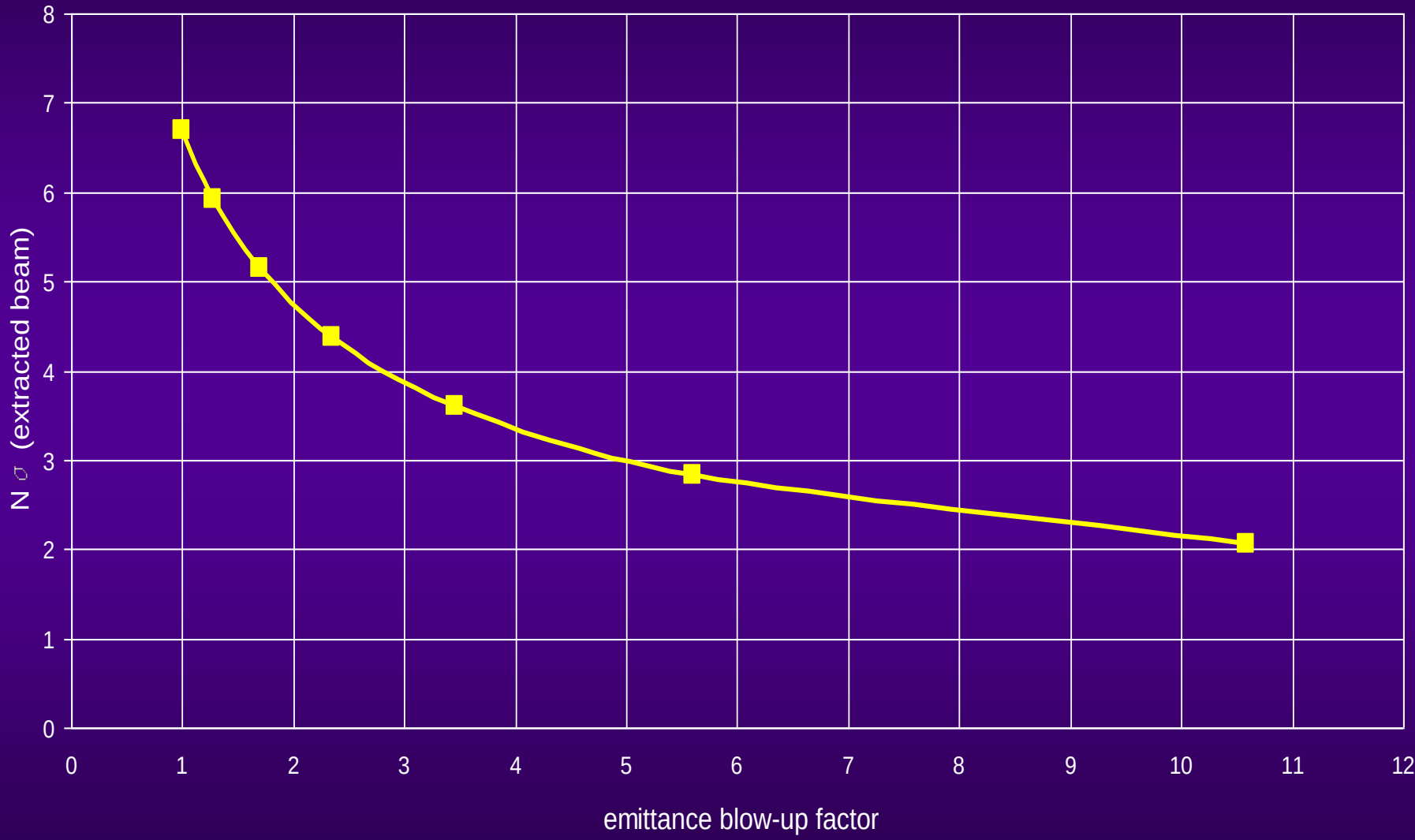


Gain ~0.5 σ for TCDS
~1.3 σ for MSDC

Adds some safety margin



Acceptance vs ε at 450 GeV



Conclusions

- **The MSD do not have enough aperture to extract the LHC beam under the old set of constraints**

- **All aperture requirements can be met with the present optics, MKD kickers, MSD magnets and vacuum chambers, if :**
  - **The horizontal closed orbit is controlled to about ±1.0mm in point 6 using feedback (which is not connected to machine protection system)**
    - For circulating beam aperture at TCDS, this means accepting ±2mm and n_1 = 6.5
  - **MKD and LHC machine fault cases are not correlated**
  - **The total MKD overshoot (including all tolerances) is within 10%**
  - **The beam approaches the TCDS for 14/15 MKD firing**
  - **Fast beam position changes due to machine faults are detected by local BPMs – which trigger beam dump when the position exceeds ~4mm**
  - **Fast emittance growth (at 450GeV) is detected at 2 - 3 x nominal, and the beam dumped**
  - **The few bunches making a full turn after an asynchronous dump are captured by a second TCDS jaw (to be verified)**