Agenda MPWG 14 January 2003

- Comments to minutes
- General Information

- Machine failures and triplet protection (R. Schmidt, R. Assmann)
- Chamonix workshop - session on “Operating with unprecedented beam energy”
- AOB

Unsynchronised beam dump

The Tevatron damaged twice the central detector of the physics experiment due to an unsynchronised beam dump

- in Spring 2002
- In Autumn 2002

the protection collimators were not correctly set (info from F.Zimmermann this week)

We must anticipate such failure

When operating with high beam intensity a similar failure would damage equipment (possibly the triplet magnets) - therefore it needs to be strictly avoided

Closed orbit errors in IR 6 and unsynchronised beam dump

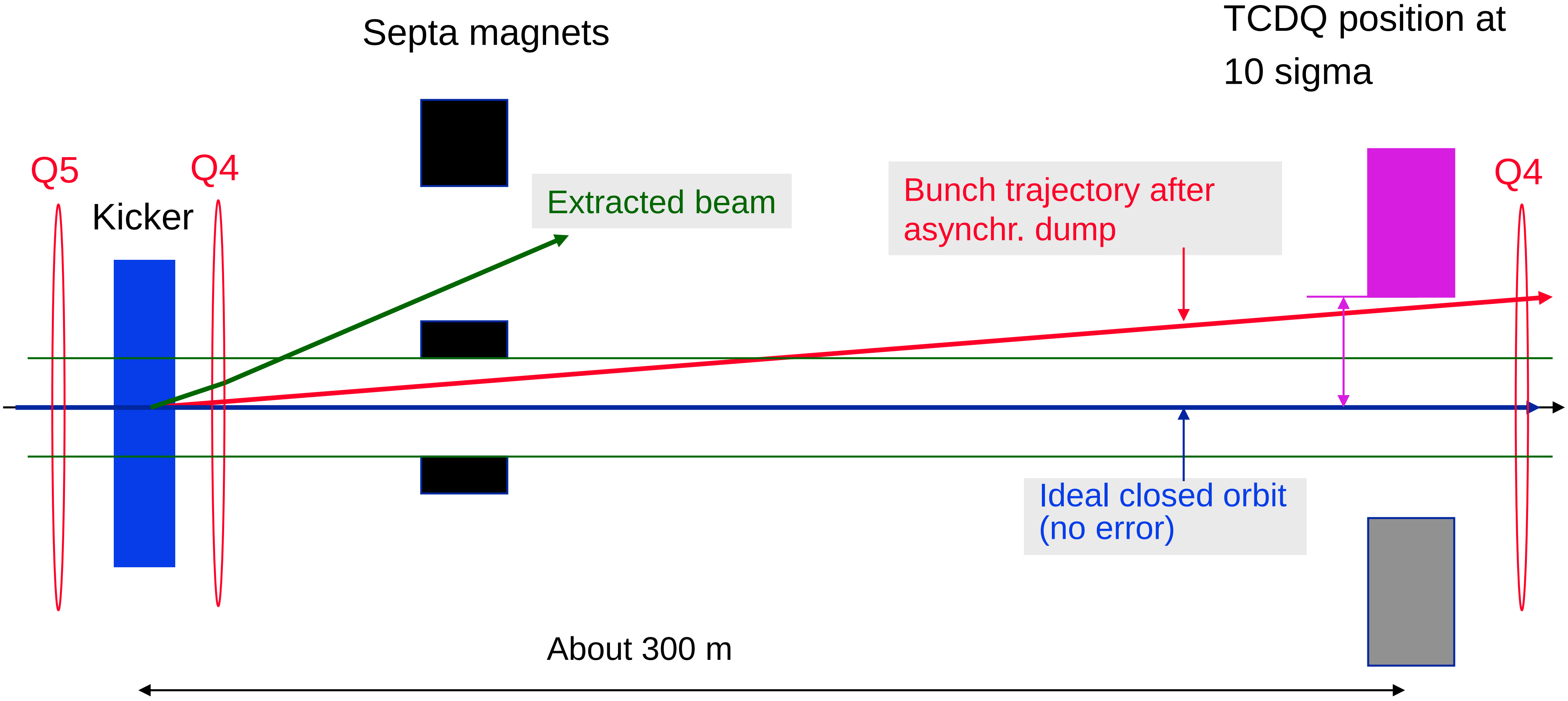
For beam dump aperture

- It is assumed that the static closed orbit is stabilised along IR6 to $\pm$ 1mm
- In this case the aperture for the CIRCULATING beam is about $n_1 = 7.1\ \sigma$
- The orbit is kept below this limit during injection, ramp, squeeze and physics
- The position of the TCDQ does not change to follow the orbit

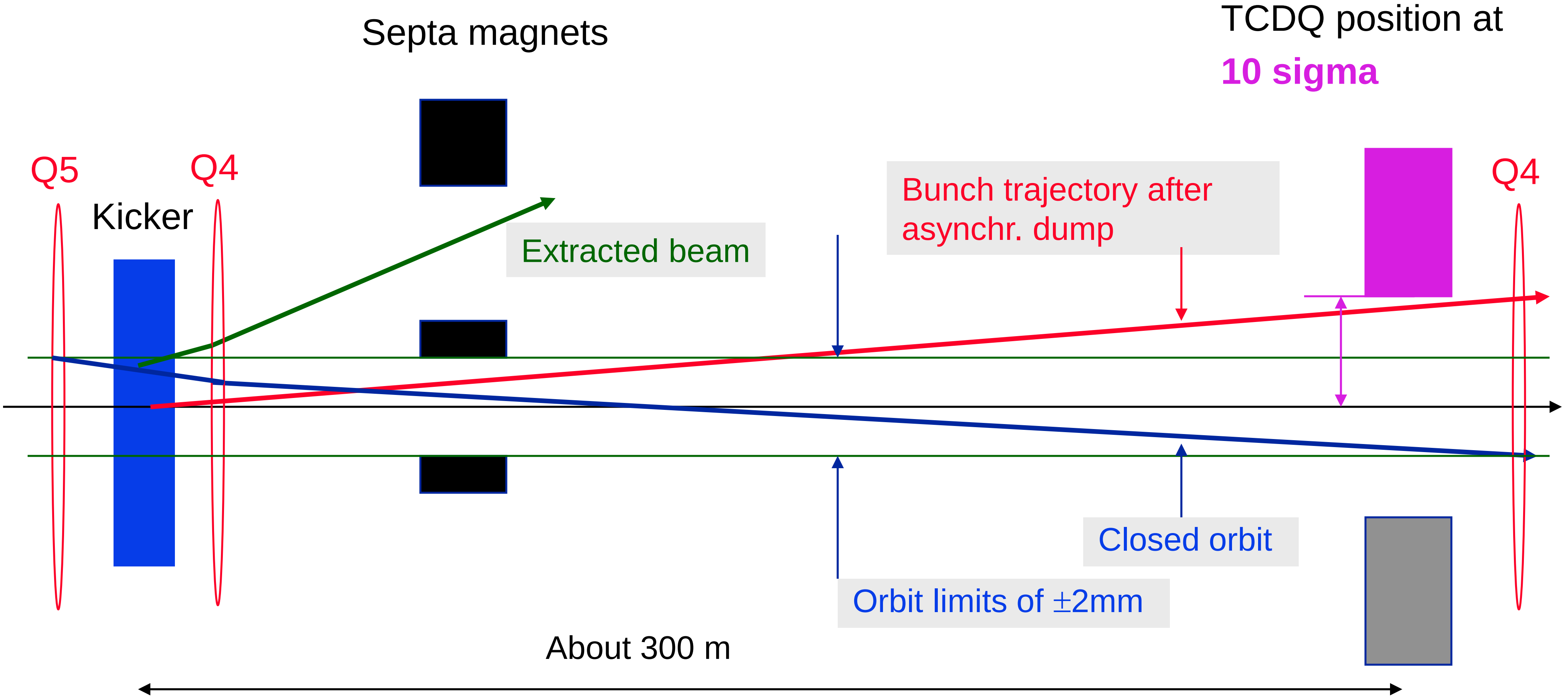
Failure scenario

- An asynchronous beam dump is assumed. Such failure is not correlated to other failures that would change the orbit significantly in a very short time.
- A safety margin for the closed-orbit of 1mm is assumed - an orbit along IR6 that is between $\pm$ 2mm (stabilisation $\pm$1mm)
- The worst case of such orbit is assumed: the orbit is outside at Q5L, and inside (away from the TCDQ) at Q4R by 2mm
- The maximum amplitude of a bunch at the TCDQ after an unsynchronised kick is given by the sum of the position of the TCDQ and the closed orbit

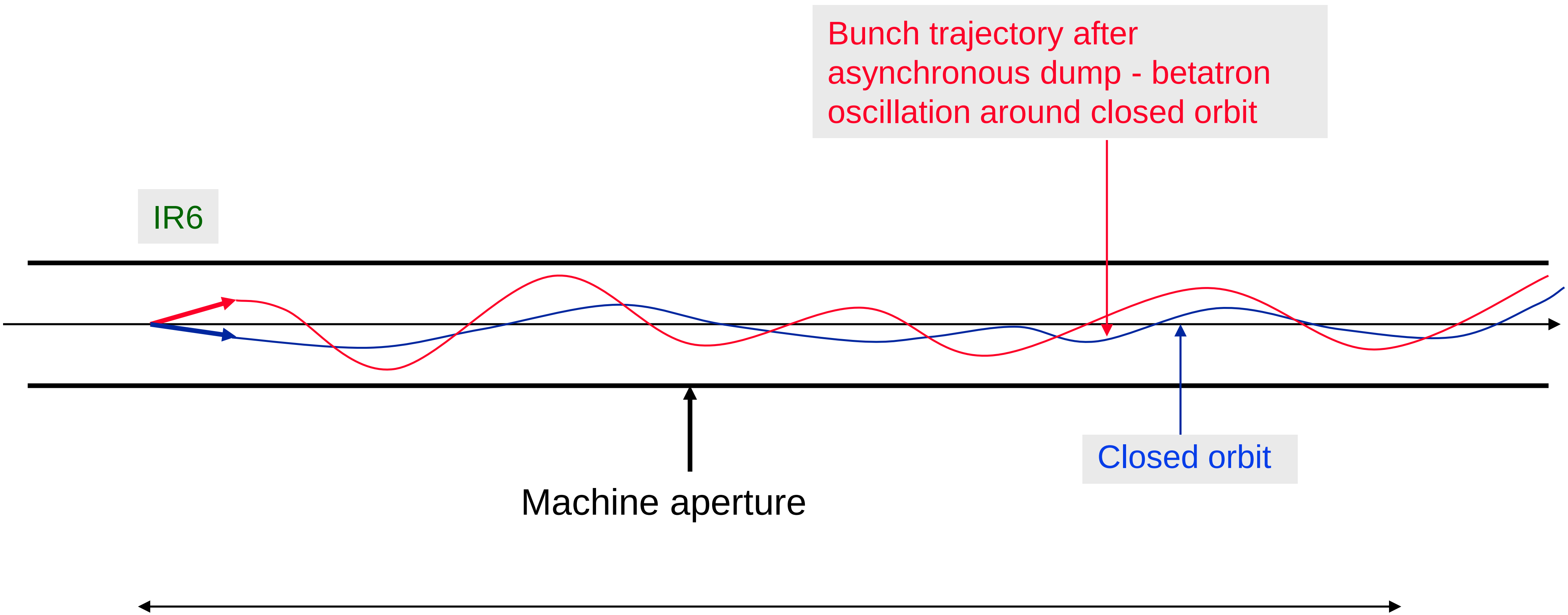
Schematic drawing of extraction trajectory in case of failure - no closed orbit errors



Schematic drawing of extraction trajectory in case of failure - closed orbit errors limited to 2 mm



Schematic drawing of trajectory through the machine - in case of such failure



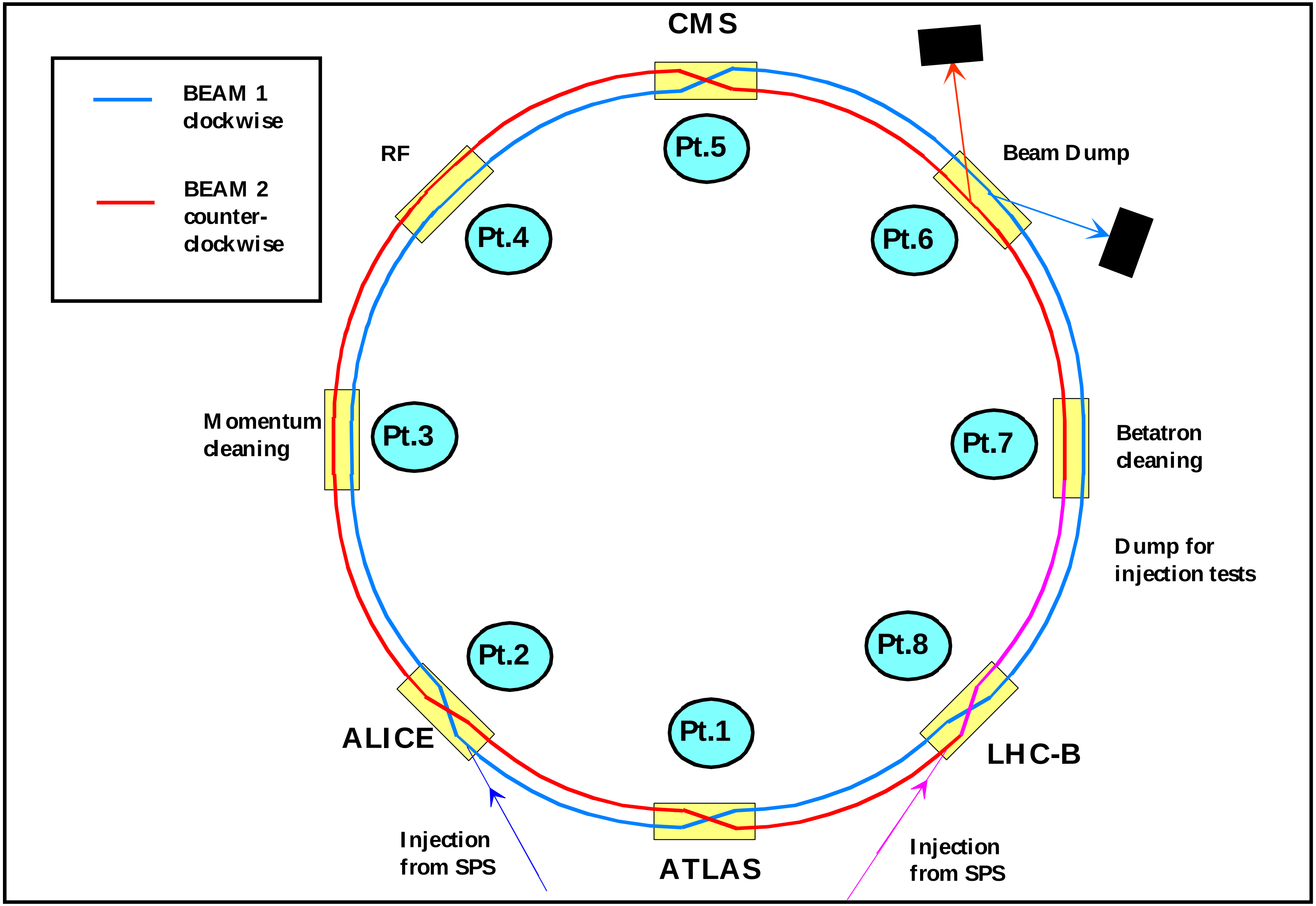
Trajectory of partially deflected beam (for 7 TeV)

no orbit errors in IR6

- TCDQ at 10 σ, corresponds to a distance between orbit and TCDQ of 5.23mm
- Kick by the kicker with 0.0123mrad
- Bunch position at TCDQ is about 5.3mm (just passing through)
- Maximum oscillation amplitude in the arc 3.05mm (10 σ amplitude)

orbit errors in IR6 of 2mm

- TCDQ at 10 σ with respect to ideal orbit, corresponds to 5.23mm
- Orbit at TCDQ at -2mm
- Bunch position at TCDQ is about 5.3mm (just passing through)
- Angle of the kick 0.0161mrad
- Maximum oscillation amplitude around the closed orbit of 4.3mm (corresponds to 14 σ amplitude)


CMS
BEAM 1
clockwise
BEAM 2
counter-
clockwise
RF
Pt.5
Beam Dump
Pt.4
Pt.6
Momentum
cleaning
Pt.3
Pt.7
Betatron
cleaning
Dump for
injection tests
Pt.2
Pt.8
ALICE
Pt.1
LHC-B
Injection
from SPS
ATLAS
Injection
from SPS

What happens further - in the machine and the low-beta triplets

In case of asynchronous beam dump, assuming an orbit error at the TCDQ of 2mm

at top energy there is lot of aperture in the arcs

the typical beam size in the arc is about 0.4 mm

6 sigma	**+**	**14 sigma**	**+**	**4 mm**	**=**	**12 mm, well within aperture**
beam size		**betatron oscillations**		**orbit error**		

the clockwise beam will pass through the collimation section and bunches with large amplitude will be stopped (to be confirmed)

the anti-clockwise beam will travel with large oscillation to IR 5 and could touch the aperture in the triplet magnets

IR5 - in collision, assuming horizontal separation

At QUADRUPOLE MQXB.B2L5

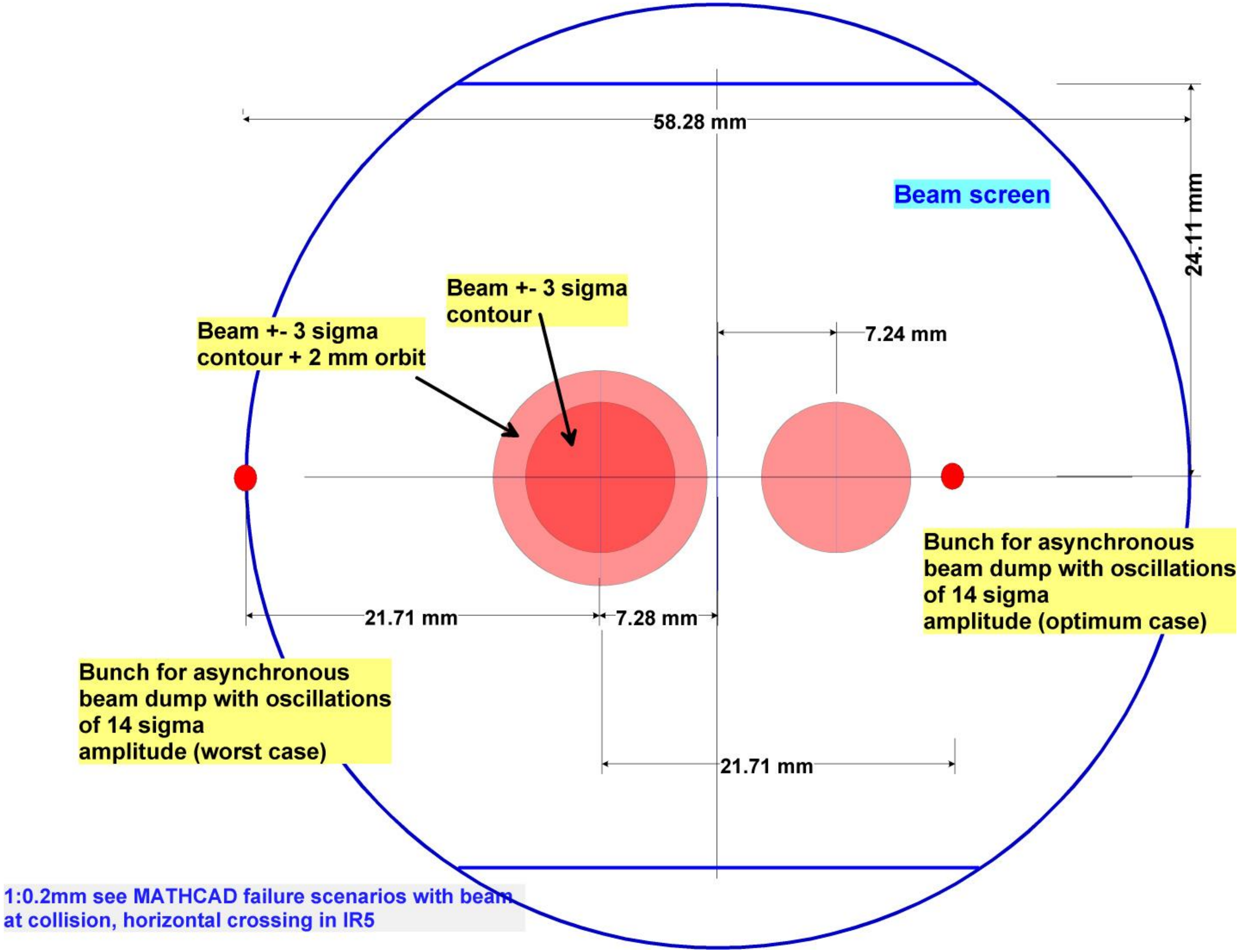
βx = 4810.43 m

orbit displacement due to crossing angle= -7.22 mm

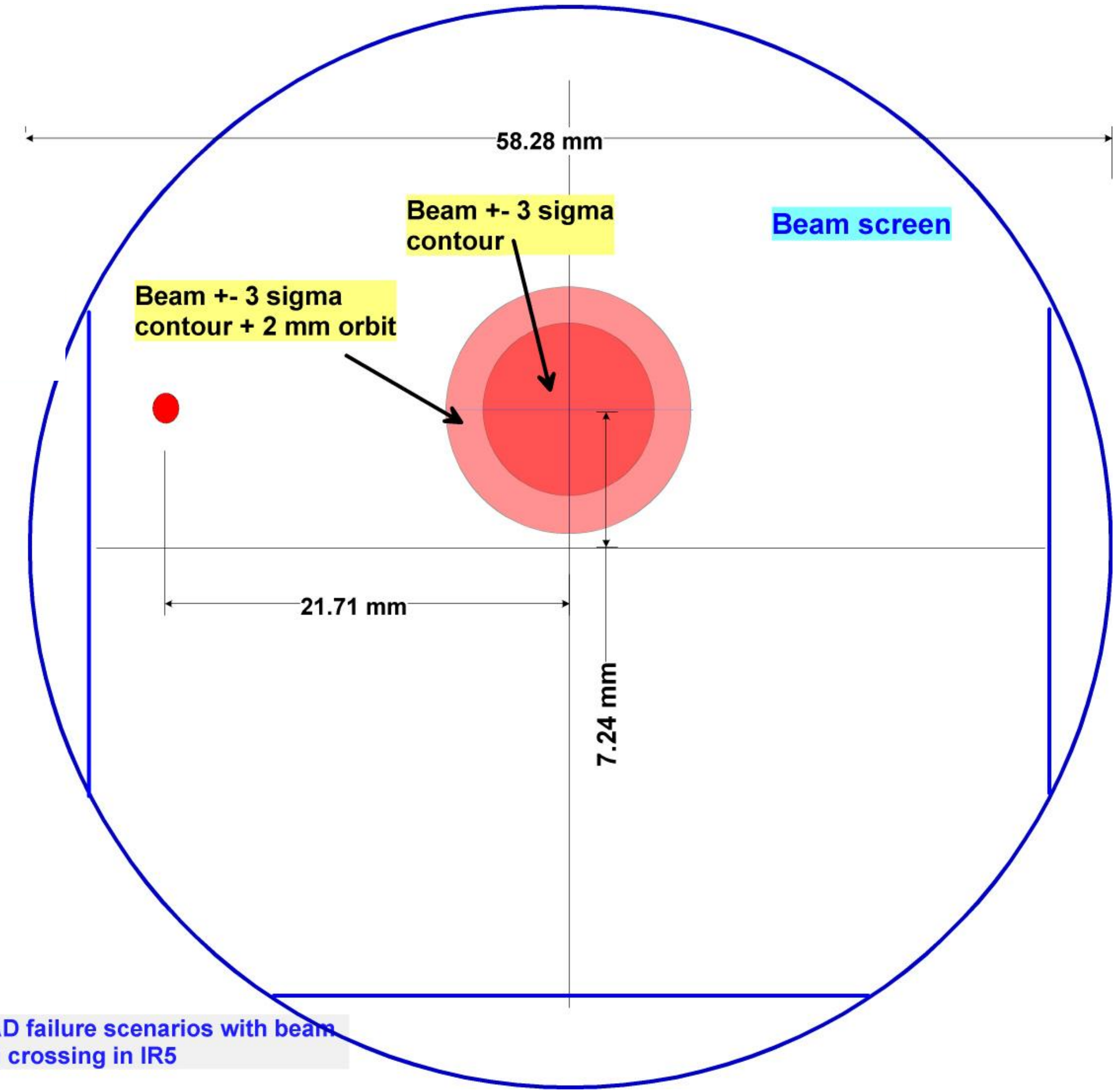
beam size with nominal emittance = 1.56 mm

The partially kicked beam can tough the aperture, this depends on:

- aperture in the triplet
- phase advance between beam dump kicker and triplet
- direction of kick in IR6
- horizontal or vertical crossing
- closed orbit errors in triplet and in IR6
- position of TCDQ with respect to closed orbit in IR6
- bump for separating the beams in the other plane (non x-ing angle plane)



58.28 mm
Beam screen
24.11 mm
Beam +- 3 sigma
contour
Beam +- 3 sigma
contour + 2 mm orbit
7.24 mm
Bunch for asynchronous
beam dump with oscillations
of 14 sigma
amplitude (optimum case)
21.71 mm
7.28 mm
Bunch for asynchronous
beam dump with oscillations
of 14 sigma
amplitude (worst case)
21.71 mm
1:0.2mm see MATHCAD failure scenarios with beam
at collision, horizontal crossing in IR5



1:0.2mm see MATHCAD failure scenarios with beam
at collision, horizontal crossing in IR5

Conclusions and future studies - for discussion

- With non-squeezed optics - there should be no problem in the triplets
- For the considered failure case (fully squeezed), there might not be enough aperture for some sets of parameters
  - calculate the trajectories with some standard parameters - to be done
  - what could be the variations of these parameters?
  - impact on TOTEM?
- The TCDQ position is a very critical element during operation - in particular during squeezing
  - Must be tight to the beam, when squeezed - failure not permitted
  - A TCDQ from both sides would help - **OR** - a standard collimator behind the TCDQ that limits the aperture, TCDQ becomes less critical

- Beam density in triplet not very high (the beam spot is 20 times larger than at the collimators) - can it destroy the beam screen?

How can we lose the beam?

Beam loss scenarios and strategies for machine protection

Also considered as introduction to following two sessions, references will be given

Challenge of the LHC - Beam energy and Beam energy density

(Protection of magnets is not discussed in detail)

Beam dump blocks are the only elements that can stand full beam without damage

Approach to the design the Machine Protection Systems

- Classification of Beam Losses (4 classes)
- Discussing mechanisms leading to such losses
- Protection against these losses - per class

Classification - examples for each class, and overview of possible failures

Ultrafast beam loss (less than one turn) – Injection kickers – Beam dump kickers – Aperture kickers	Passive protection by operational procedures, collimators at correct settings, prepration from beam in SPS and TLs, orbit control and interlocks to prevent wrong operation
Very fast beam loss (several turns) – D1 normal conducting magnet – others - will be discussed	+ Beam loss monitors and few beam position monitors
Fast beam loss (several 10 ms) – Magnets, other systems	+ Equipment interlocks
Slow Beam loss (several seconds) – Magnets, other systems	+ Software interlocks - operator - beam lifetime …..