

Momentum Cleaning : Losses upstream of the Experiments

Collision Optics and Beam Cleaning

Nominal Collision Optics and
 Early Collision Optics - Version 6.5
 Beam 1 and Beam 2
 Chromaticity correction – ON
 Beam crossing schemes – ON

IP	Cross. plane	β^* [m] (separation [mm])	
		Nominal	Early
1	V	0.55 (H-1.0)	2.0 (H-1.0)
2	V	10.0 (H-4.0)	10.0 (H-1.0)
5	H	0.55 (V-1.0)	2.0 (V-1.0)
8	H	10.0 (V-4.0)	2.0 (V-1.0)

Collimators – baseline Phase 1
 Primary collimators - TCP
 Carbon-Carbon 60 cm
 Secondary collimators - TCSG
 Carbon-Carbon 100 cm
 Additional absorbers - TCLA
 Copper 100 cm

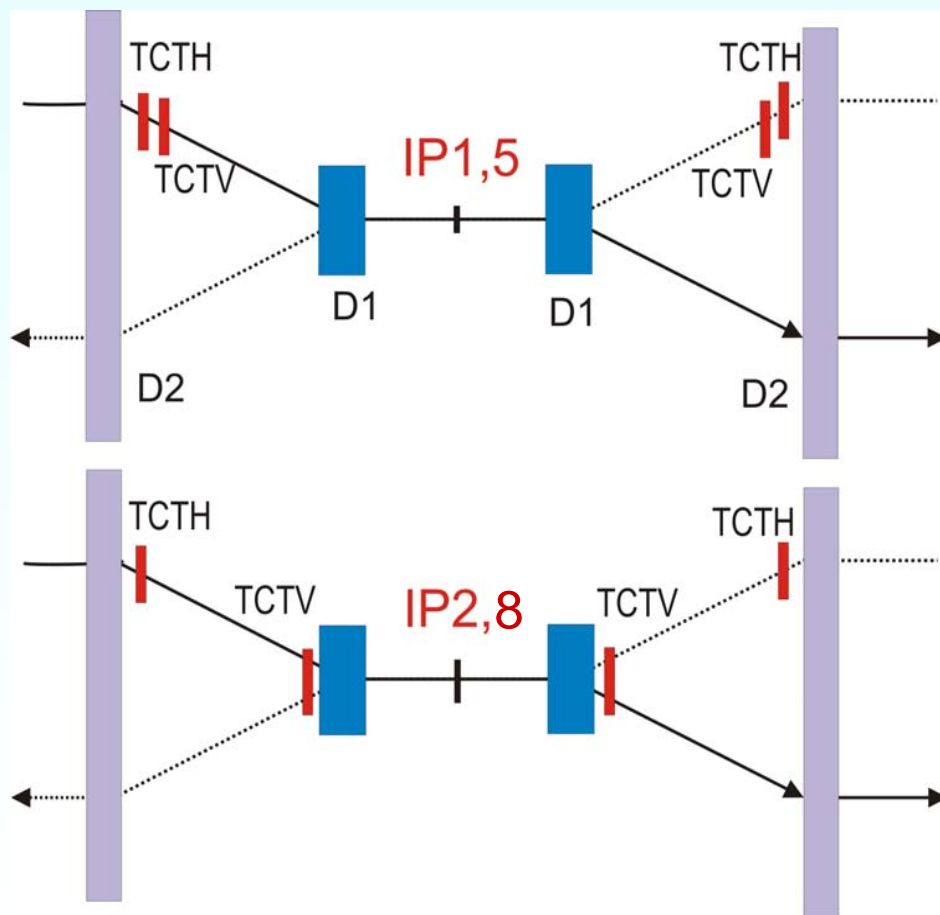
Momentum Collimation in IR3

$n1 = 15$, $n2 = 18$, $nA=10$ (V) , $nA=20$ (H)

Amplitude Collimation in IR7

$n1 = 6$, $n2 = 7$, $nA = 10$ (H,V)

Location of the tertiary collimators in the experimental insertions



- The “dogleg” horizontal beam separation at the location of the vertical tertiary collimators TCTV in IR2 and IR8 is small
- These collimators cannot be set around one beam
- Their gaps must include the vertical beam separation
- IP2 – vertical crossing and (no collisions) horizontal beam separation
- IP8 - horizontal crossing and (no collisions) vertical beam separation

Momentum Cleaning Rates

“M.Lamont - LHC Project Note 375 – *“Estimates of Annual Proton Losses in the LHC”*”

- Nominal Physics : 3.2×10^{14} protons/beam , $L = 10^{34} \text{ cm}^{-2}\text{s}^{-1}$,
beam losses in IR3 : total - 4.35×10^{15} /year , before physics - 1.22×10^{12} /fill
- First Year Physics : 1.1×10^{14} protons/beam , $L = 10^{33} \text{ cm}^{-2}\text{s}^{-1}$,
beam losses in IR3 : total - 8.0×10^{14} /year , before physics - $1.22 \times 10^{12} \times (1.1/3.2)$ /fill
- 140 days of physics per year , 1 fill per day, fill length - 12 hours
- Losses in physics = Total - Before physics
- The corresponding momentum cleaning rates “in physics”:

Nominal Physics	$4.3 \times 10^8 \text{ s}^{-1}$	($\tau_L = 207 \text{ h}$)
First Year Physics	$1.2 \times 10^8 \text{ s}^{-1}$	($\tau_L = 255 \text{ h}$)

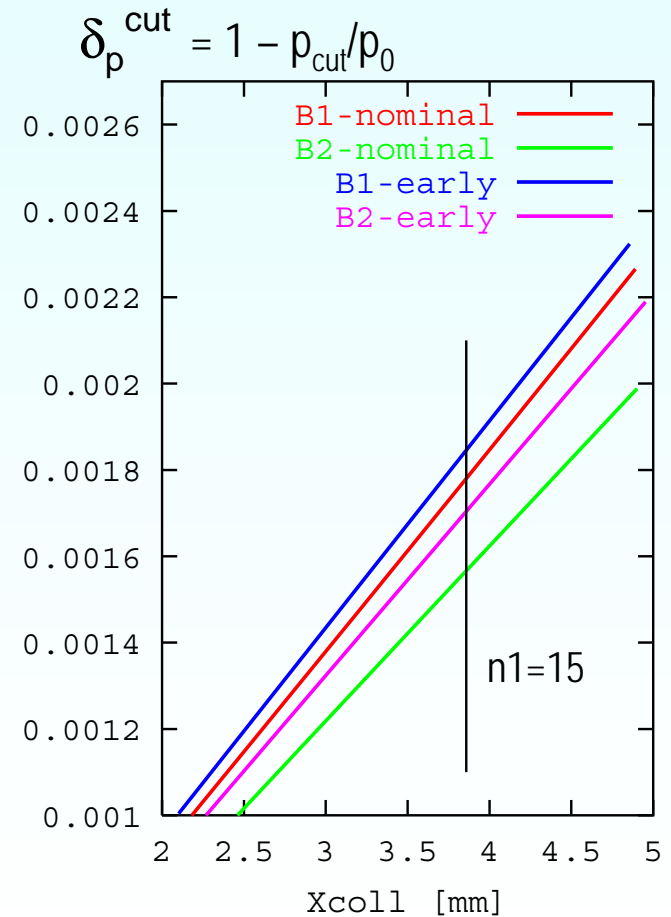
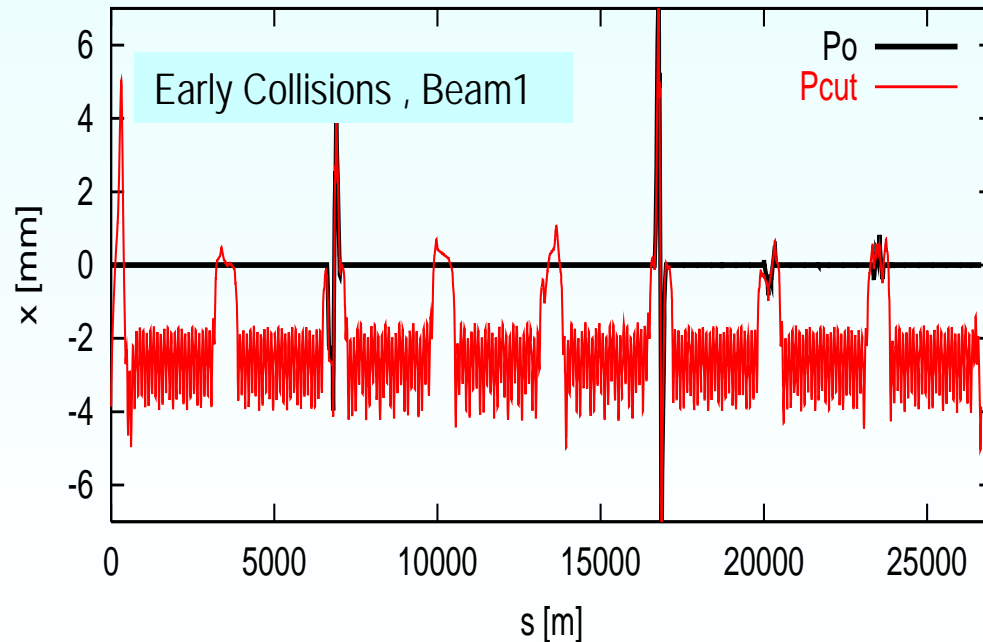
Simulation: the tool and some technical details

- STRUCT code - beam losses in the proton synchrotrons
- Electromagnetic and nuclear scattering of high energy protons in “targets” (collimators etc.)
- Inelastic scattering - diffractive and non-diffractive production of protons with $p < 0.7p_0$
- Multi-turn tracking of the scattered protons through the accelerator lattice until their absorption in the collimators or their loss at the apertures of other elements.
- The MAD output (elements sequence, lengths and k -values for “thick lense”, not the lattice functions) is used as the input lattice/optics. The lattice functions are reproduced very well.
- 10 million protons were tracked in each run to get more or less acceptable statistics for the losses outside the two collimation systems (both momentum and amplitude).
- The losses below are given per 1 initial proton. They are multiplied by the cleaning rates from the previous slide to obtain the “absolute” loss rates.
- For example $2 \times 10^{-4} \times 1.2 \times 10^8 \text{ s}^{-1} = 2.4 \times 10^4 \text{ p/s}$

Features of simulation

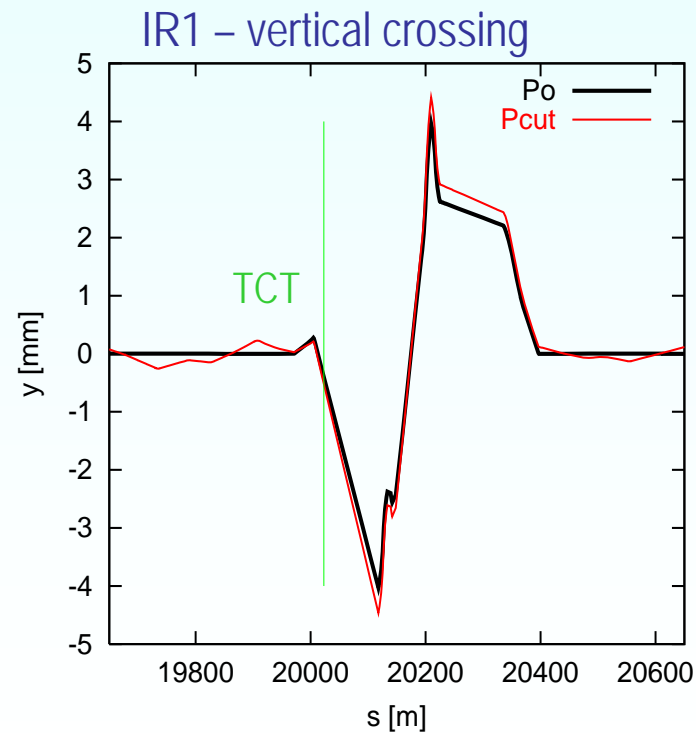
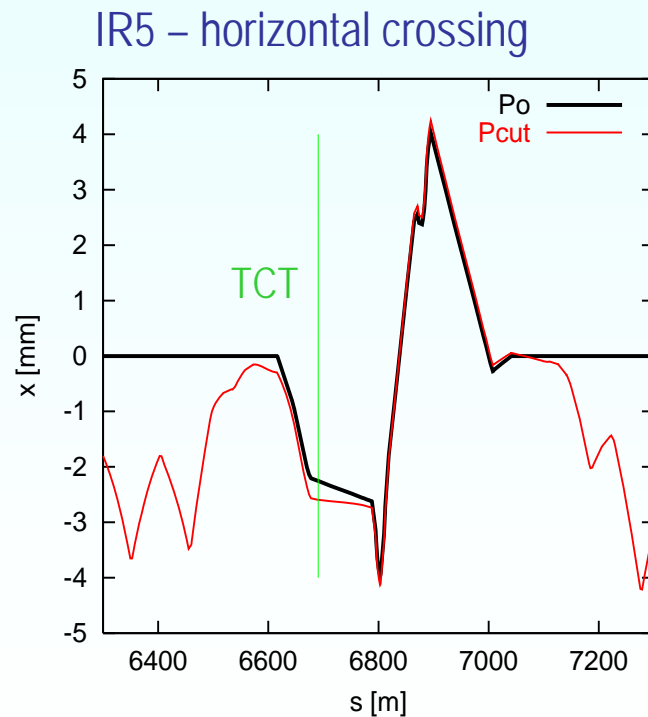
The **off-momentum orbit** ($p = p_{\text{cut}} < p_0$) touching the edge of the primary collimator ($x = x_{\text{TCP}}$) must be found first.

The protons scattered in the TCP will do the betatronic oscillations around this orbit, not around the beam orbit.



Off-momentum orbits in the experimental insertions

The dispersion function in the insertions is small and the off-momentum orbits are much closer to the beam orbit than in the arcs. In the most cases this difference between the orbits at the TCT location does not exceed 1σ



Losses upstream of the experiments without tertiary collimators

	Location	Loss (per 1)	Loss rate [p/s]
<u>Nominal Collisions</u>			
Beam 1	D2 - IP5	7.7×10^{-4}	3.3×10^5
	D2 - IP1	$\sim 5 \times 10^{-7}$	~ 200
Beam 2	D2 - IP1	3.9×10^{-4}	1.7×10^5
	D2 - IP5	$\sim 10^{-6}$	~ 400
<u>Early Collisions</u>			
Beam 1	D2 - IP5	$\sim 10^{-6}$	~ 100
Beam 2	D2 - IP1	4.8×10^{-5}	5.8×10^3
	D2 - IP8	1.3×10^{-4}	1.6×10^4

Losses at the tertiary collimators in IR1

Nominal Collisions

Half gap [σ]	IR1 Left - Beam 1		IR1 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	2.16×10^{-5}	3.44×10^{-5}	7.60×10^{-4}	1.742×10^{-3}
10	8.4×10^{-6}	4.5×10^{-6}	4.27×10^{-4}	1.127×10^{-3}
15	1.1×10^{-6}	$< 10^{-7}$	1.35×10^{-4}	3.28×10^{-4}

Early Collisions

Half gap [σ]	IR1 Left - Beam 1		IR1 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	7.7×10^{-6}	5.47×10^{-5}	5.74×10^{-4}	7.06×10^{-4}
10	2.6×10^{-6}	1.08×10^{-5}	4.95×10^{-4}	5.55×10^{-5}
15	3×10^{-7}	$< 10^{-7}$	3.63×10^{-4}	$< 10^{-7}$

Losses at the tertiary collimators in IR2

Nominal Collisions

"Half gap"* [σ]	IR2 Left - Beam 1		IR2 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	4.86×10^{-5}	1.031×10^{-3}	1.743×10^{-3}	6.61×10^{-4}
10	4.22×10^{-5}	1.34×10^{-4}	6.62×10^{-4}	2.42×10^{-4}
15	2.51×10^{-5}	1.81×10^{-5}	3.25×10^{-4}	1.25×10^{-5}

Early Collisions

"Half gap"* [σ]	IR2 Left - Beam 1		IR2 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	4.05×10^{-4}	4.43×10^{-4}	1.524×10^{-3}	5.60×10^{-4}
10	6.97×10^{-5}	5.68×10^{-5}	6.71×10^{-4}	1.74×10^{-4}
15	4×10^{-7}	2×10^{-7}	2.41×10^{-4}	6.5×10^{-6}

* - the real half gap of the TCTVs in IR2 must include the half of the vertical beam separation

Losses at the tertiary collimators in IR5

Nominal Collisions

Half gap [σ]	IR5 Left - Beam 1		IR5 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	1.429×10^{-3}	5.78×10^{-4}	3.14×10^{-5}	2.9×10^{-6}
10	1.104×10^{-3}	4.76×10^{-4}	2.05×10^{-5}	2×10^{-7}
15	5.96×10^{-4}	2.72×10^{-4}	8×10^{-7}	$< 10^{-7}$

Early Collisions

Half gap [σ]	IR5 Left - Beam 1		IR5 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	1.256×10^{-3}	1.316×10^{-2}	1.3×10^{-6}	2.2×10^{-6}
10	9.29×10^{-4}	2.070×10^{-3}	$< 10^{-7}$	1×10^{-7}
15	4.81×10^{-4}	3.8×10^{-6}	$< 10^{-7}$	$< 10^{-7}$

Losses at the tertiary collimators in IR8

Nominal Collisions

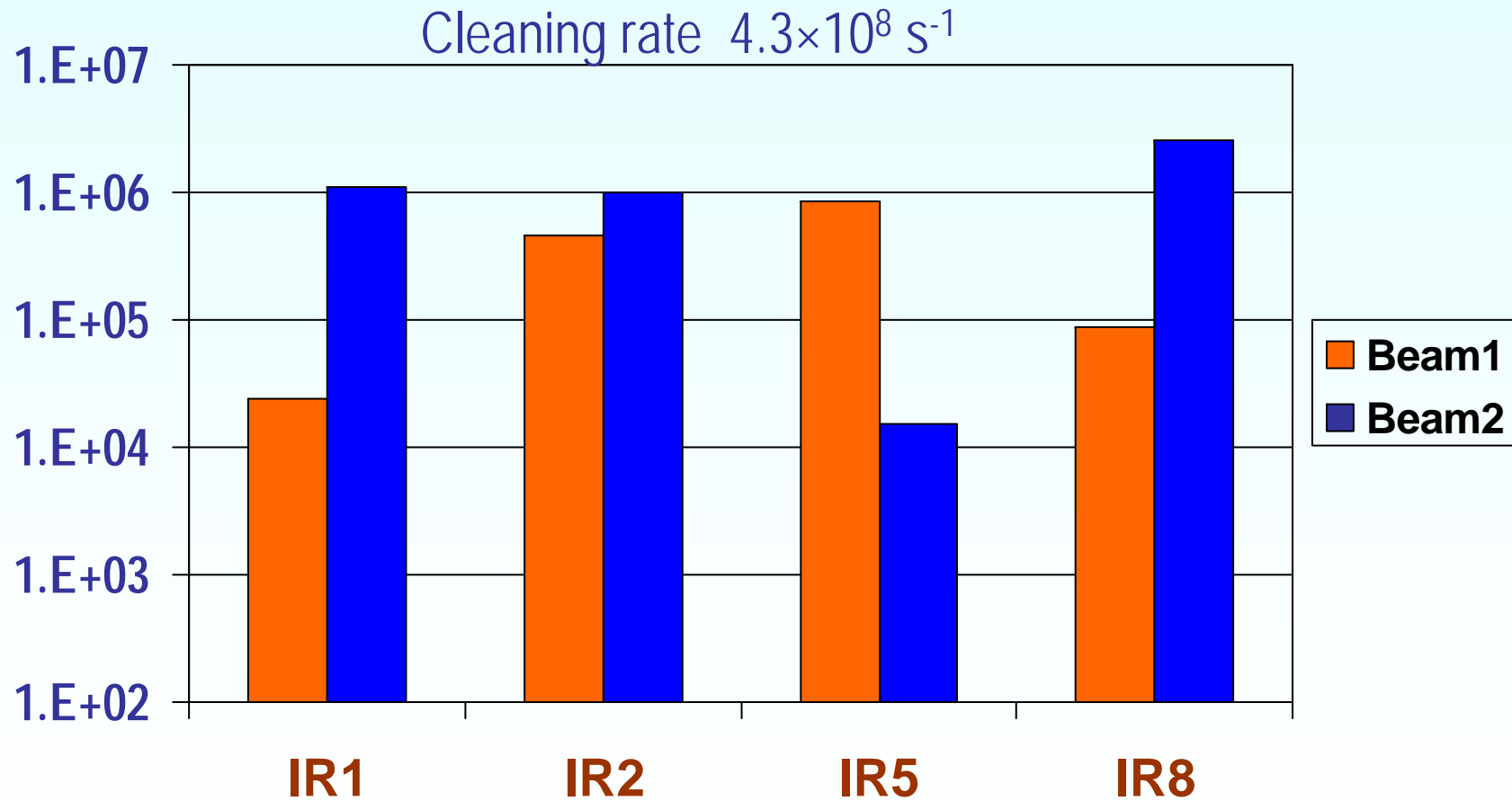
"Half gap"* [σ]	IR8 Left - Beam 1		IR8 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	8.80×10^{-5}	1.15×10^{-4}	5.814×10^{-3}	2.30×10^{-4}
10	4.56×10^{-5}	2.0×10^{-6}	3.110×10^{-3}	2.22×10^{-4}
15	2.3×10^{-6}	$< 10^{-7}$	1.76×10^{-4}	1.79×10^{-4}

Early Collisions

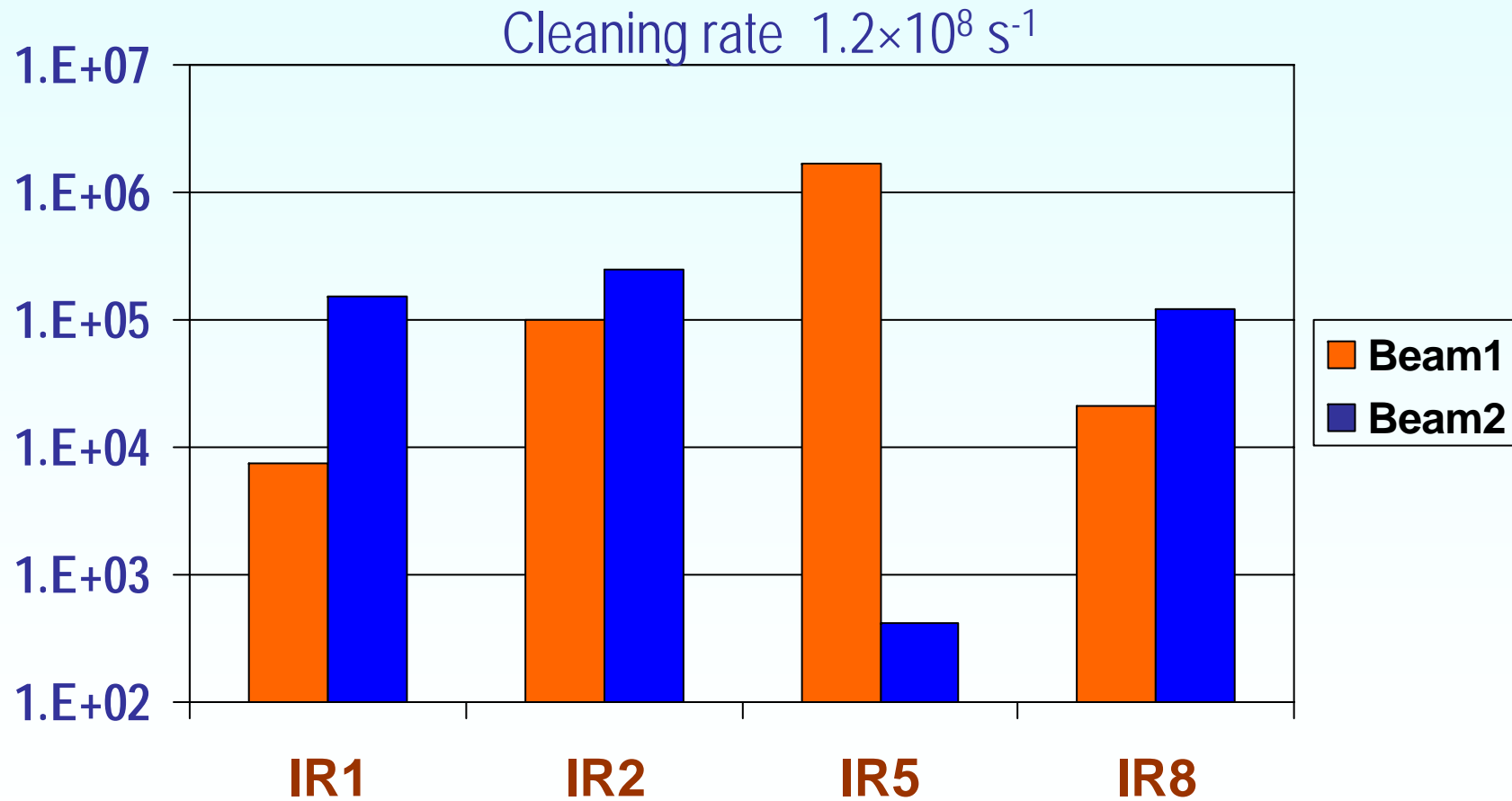
"Half gap"* [σ]	IR8 Left - Beam 1		IR8 Right - Beam 2	
	TCTH	TCTV	TCTH	TCTV
8.3	1.67×10^{-4}	8.0×10^{-6}	3.07×10^{-4}	6.85×10^{-4}
10	8.43×10^{-5}	1.1×10^{-6}	2.24×10^{-4}	6.89×10^{-4}
15	1.13×10^{-5}	$< 10^{-7}$	9.30×10^{-5}	2.86×10^{-4}

* - the real half gap of the TCTVs in IR8 must include the half of the vertical beam separation (if any)

Rates (p/s) at the tertiary collimators (H+V @ 8.3σ) Nominal Collisions

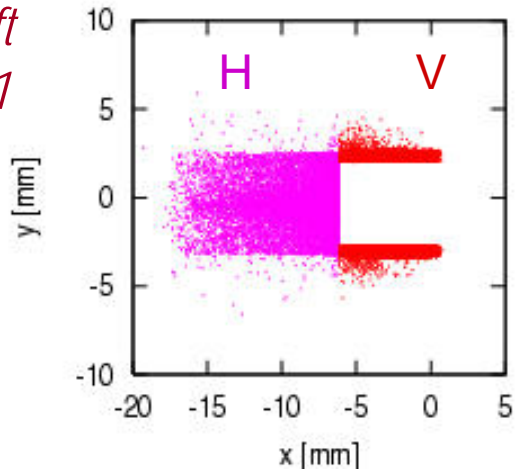


Rates (p/s) at the tertiary collimators (H+V @ 8.3σ) Early Collisions

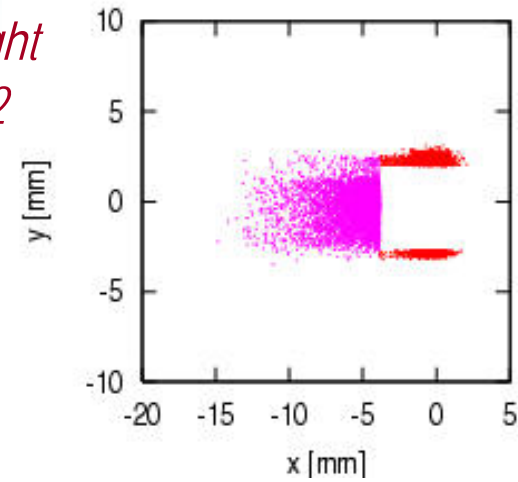


Impact maps at the TCT - an example

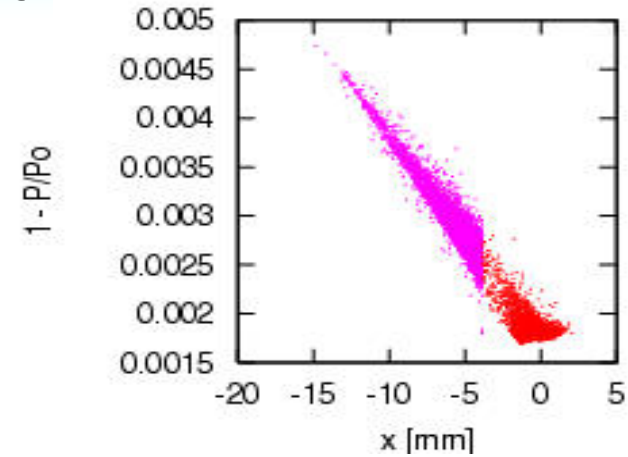
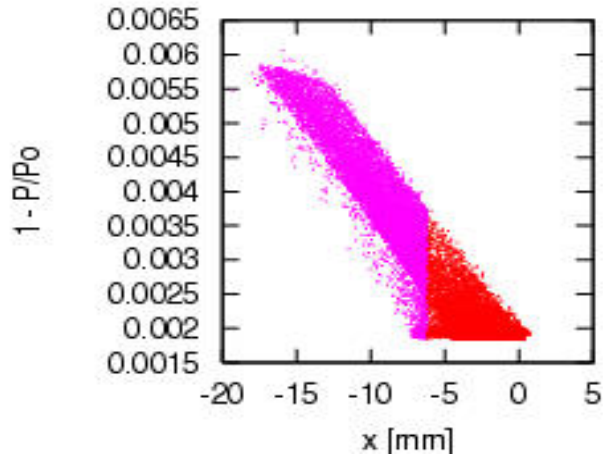
*IR5 Left
Beam 1*



*IR1 Right
Beam 2*



Early
Collisions



Rates (p/s) at the tertiary collimators (H+V @ 10σ) Early Collisions

