Project News

Cleaning Efficiency of the LHC Collimation System

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LARP Meeting April 6th, 2005

Port Jefferson

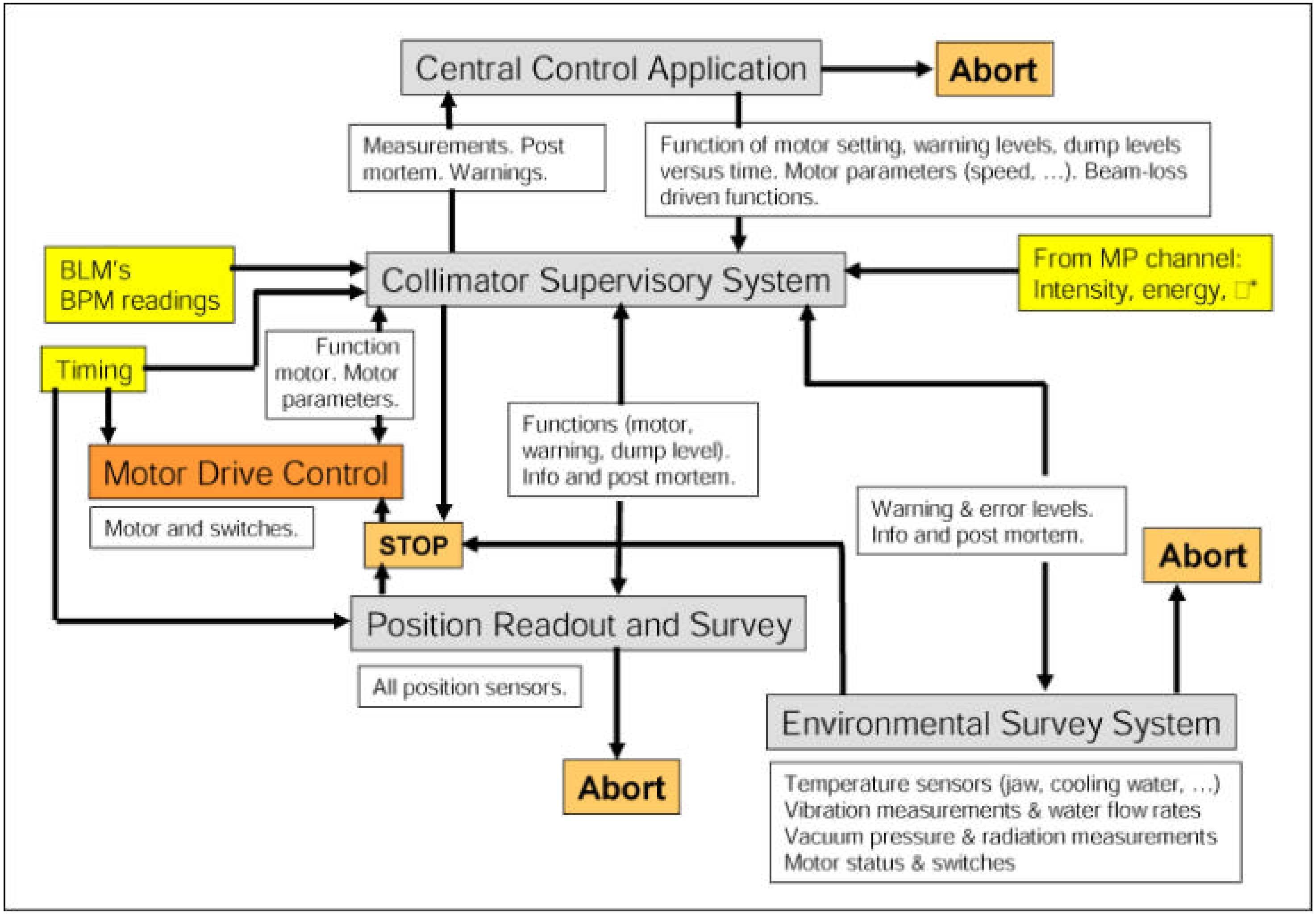
LHC Collimation Project News

- Layout has been finalized (placement of absorbers). Cleaning insertions will be frozen in the next weeks!
- Production of 125 collimators (all phase 1 and phase 3) has been approved by CERN Finance Committee.
- Production contract with industry being finalized.
- Budget has been consolidated, including new budget for infrastructure of phase 2 collimators and R&D for phase 2 collimators.
  - **Cables, water connections and base supports for phase 2 will be installed already before LHC start-up in 2007 (reduce radiation exposure of personnel to minimum for phase 2 installation).**
  - **Phase 2 R&D will be starting at CERN in 2005. Work package with CERN TS department to be defined.**
- Phase 2 of collimation is now an integral part of the LHC program and is seriously prepared (significant money is spent on it).

Basic Collimation Project Schedule

2003	Start of phase 1 R&D, project start. Definition of phased approach.
2004	Phase 1 hardware design verification with beam tests.
2005	Collimation layout and phase 1 major designs frozen. Other phase 1 designs. Start of phase 1 collimator production. Start of collimator infrastructure installation. Start of work on collimator control. Start of phase 2 R&D.
2006	All collimator infrastructure (phase 1, 2, 3) installed. Collimator controls test with beam in SPS. Construction of phase 2 prototypes.
2007	Most of phase 1 collimation system installed (some special designs delayed). **Beam commissioning of phase 1 collimation.**
2008	All phase 1 & phase 3 collimators installed. Completing production of collimator spares for phase 1. Installation of phase 2 prototypes. Beam tests of various phase 2 prototype collimators (different concepts: improve impedance and/or improve efficiency, crystals, …). **Decision on phase 2 concept, if required.**
2009	Production of phase 2 collimators.
2010	Installation of phase 2. Commissioning of phase 2 collimation.
2011	LHC ready for nominal intensities (earliest time)!?

Collimator Controls



Based on note by R. Assmann, M. Jonker, M. Lamont

Serious work starts now: Include experience from RHIC/TEVATRON on set-up procedures.

➔ Existing work package in LARP/Collimation (A. Drees).

➔ Specification by Summer 05.

Understanding LHC Cleaning Efficiency

Please note:

- Cleaning efficiency is outcome of an interplay between several processes. Quite complicated to calculate (numbers only with numerical Monte Carlo simulations.

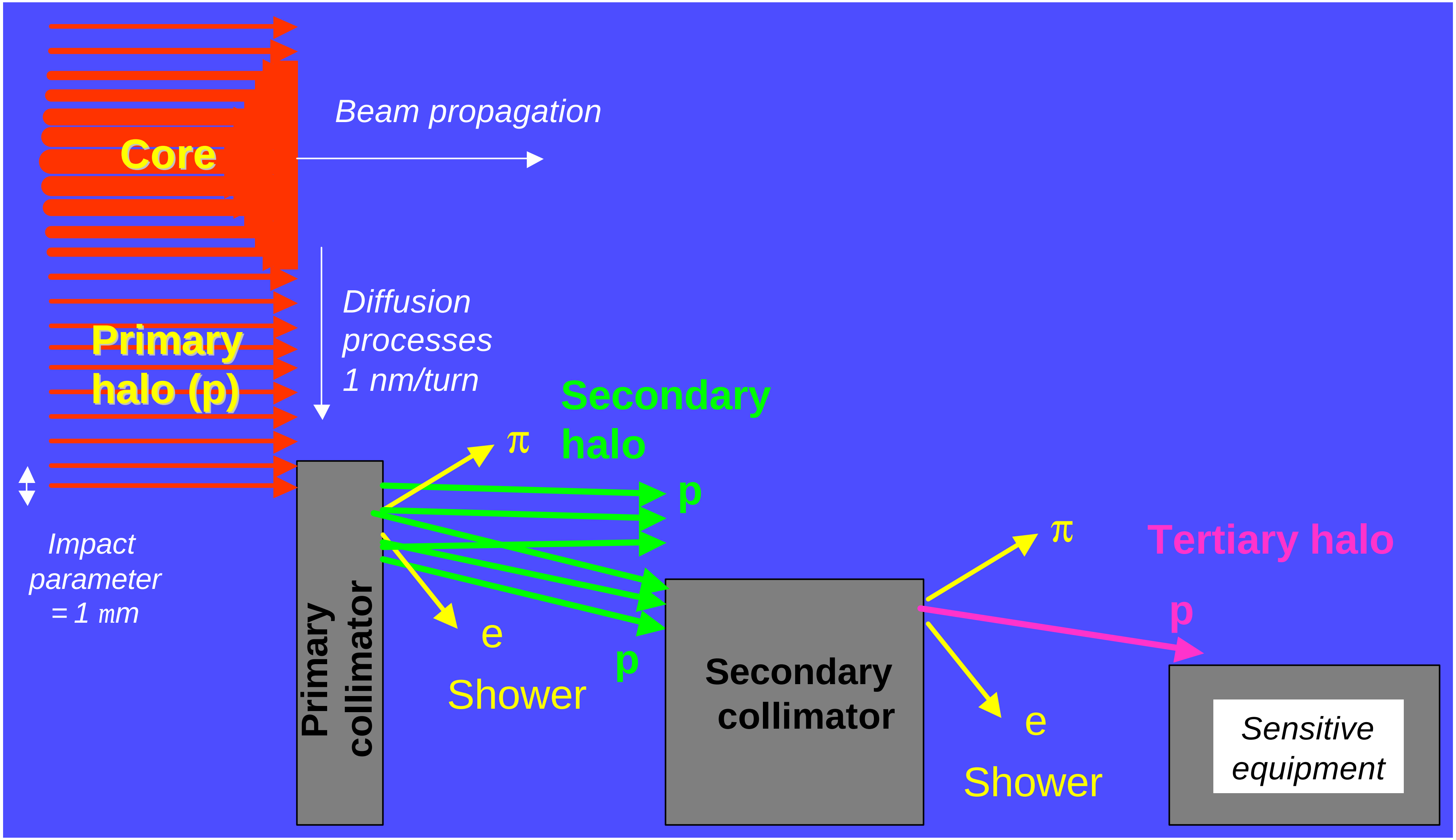
- Many studies done over the years for LHC collimation with different materials, lengths, impact parameters, …

- Here I give a general view of the interdependences! You will find results also for “obsolete” choices, e.g. Al primary collimators.

- I did not repeat a systematic study for a coherent set of parameters!

- Should be done in the future for reference!

Multi-stage & Multi-turn Cleaning!



Simplified View

Primary collimators: Primary function: Act as scatterer (spoiler).
Add small kick to protons (Multiple Coulomb Scattering).
Can induce inelastic interactions.

Important parameters:

Radiation length X_0 — MCS — θ_{rms} ~ vLength / (E vX_0)

Absorption length λ_a — Inelastic scattering on average after 1 λ_a

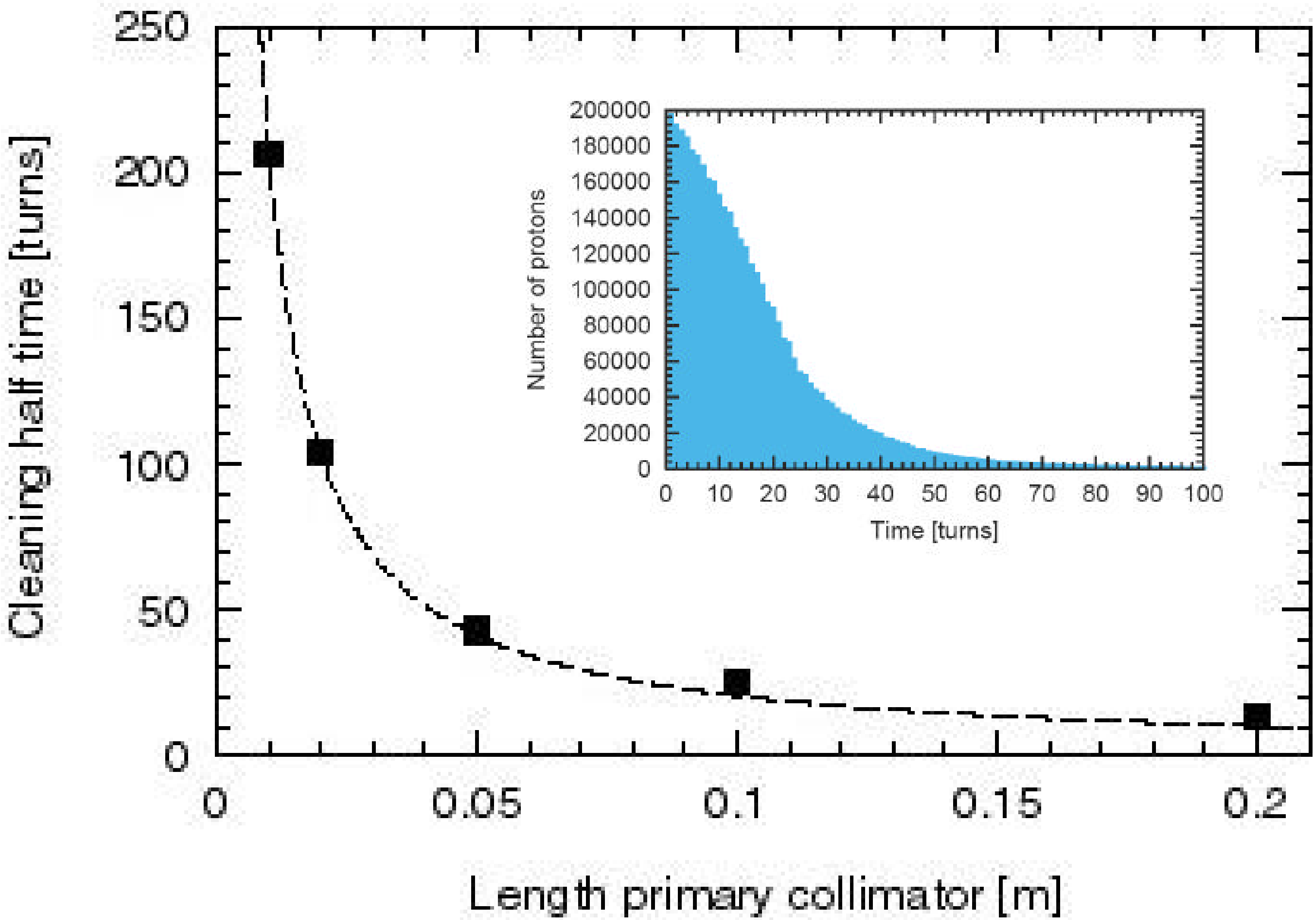
Material properties

	X_0	λ_a
Tungsten	0.35 cm	9.6 cm
Copper	1.4 cm	15 cm
Aluminium	8.9 cm	39 cm
Graphite	25 cm	38 cm

Replacing primary collimators: 20 cm Al ➔ 20 cm C
~ twice smaller MCS
~ same absorption

Protons come back to primary collimator and have higher chance to inelastically interact in primary collimator ➔ less load on downstream secondary collimators and less leakage of tertiary halo.

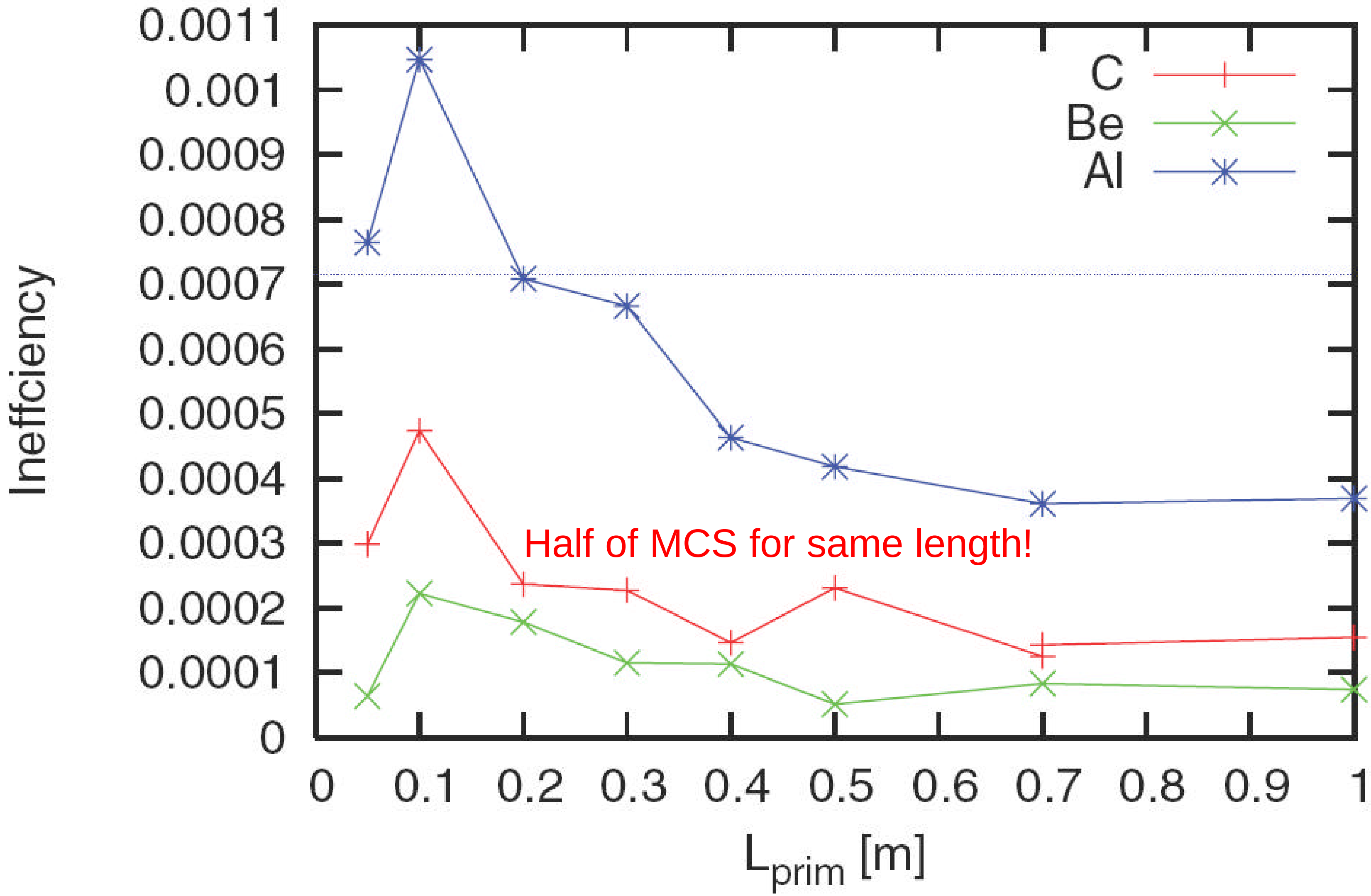
Cleaning Versus Time



Shorter primary collimator ➔ Smaller kicks ➔ Longer cleaning time

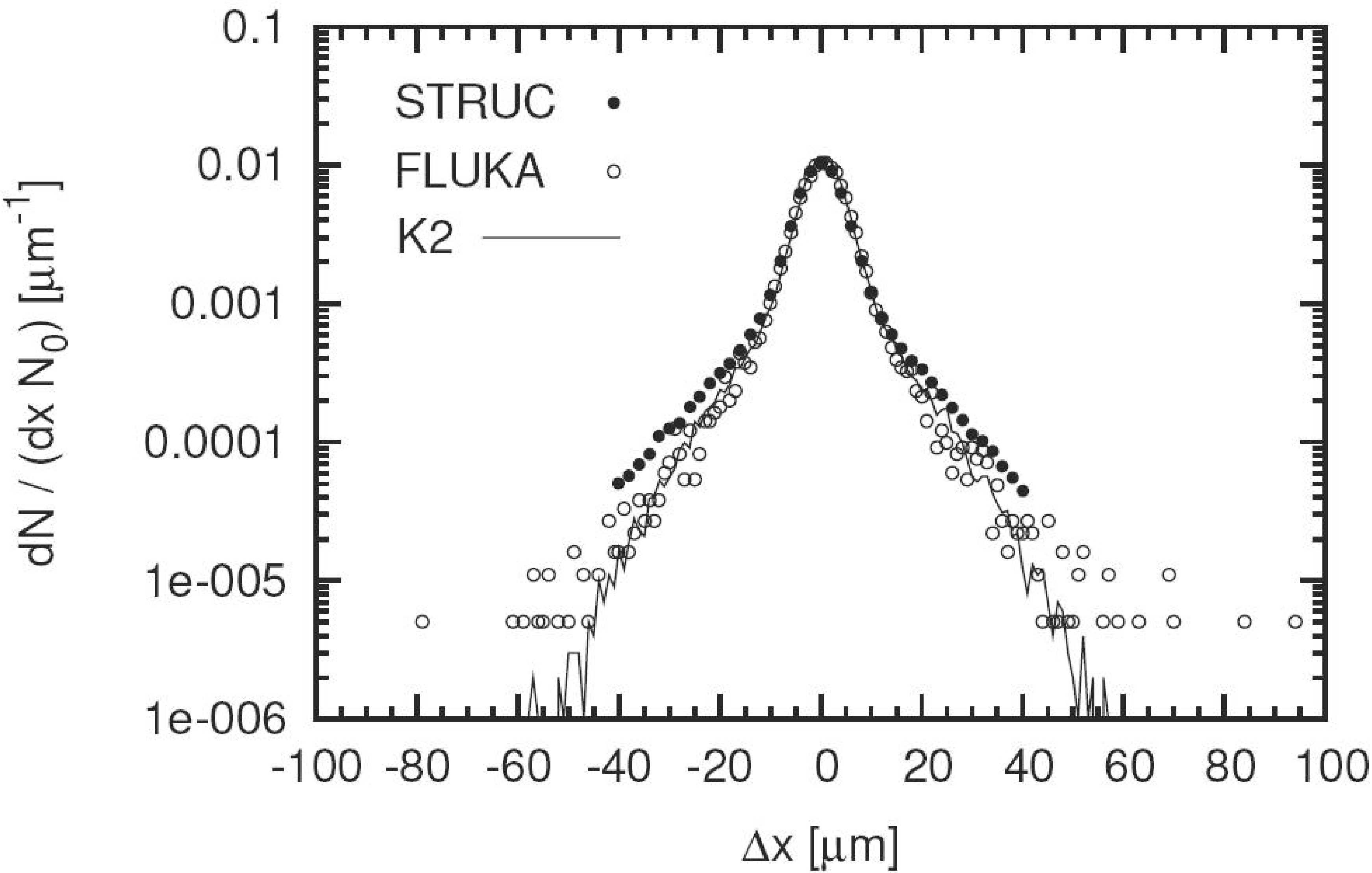
➔ More inelastic interactions at primary collimator

1. Change length of primary jaw:

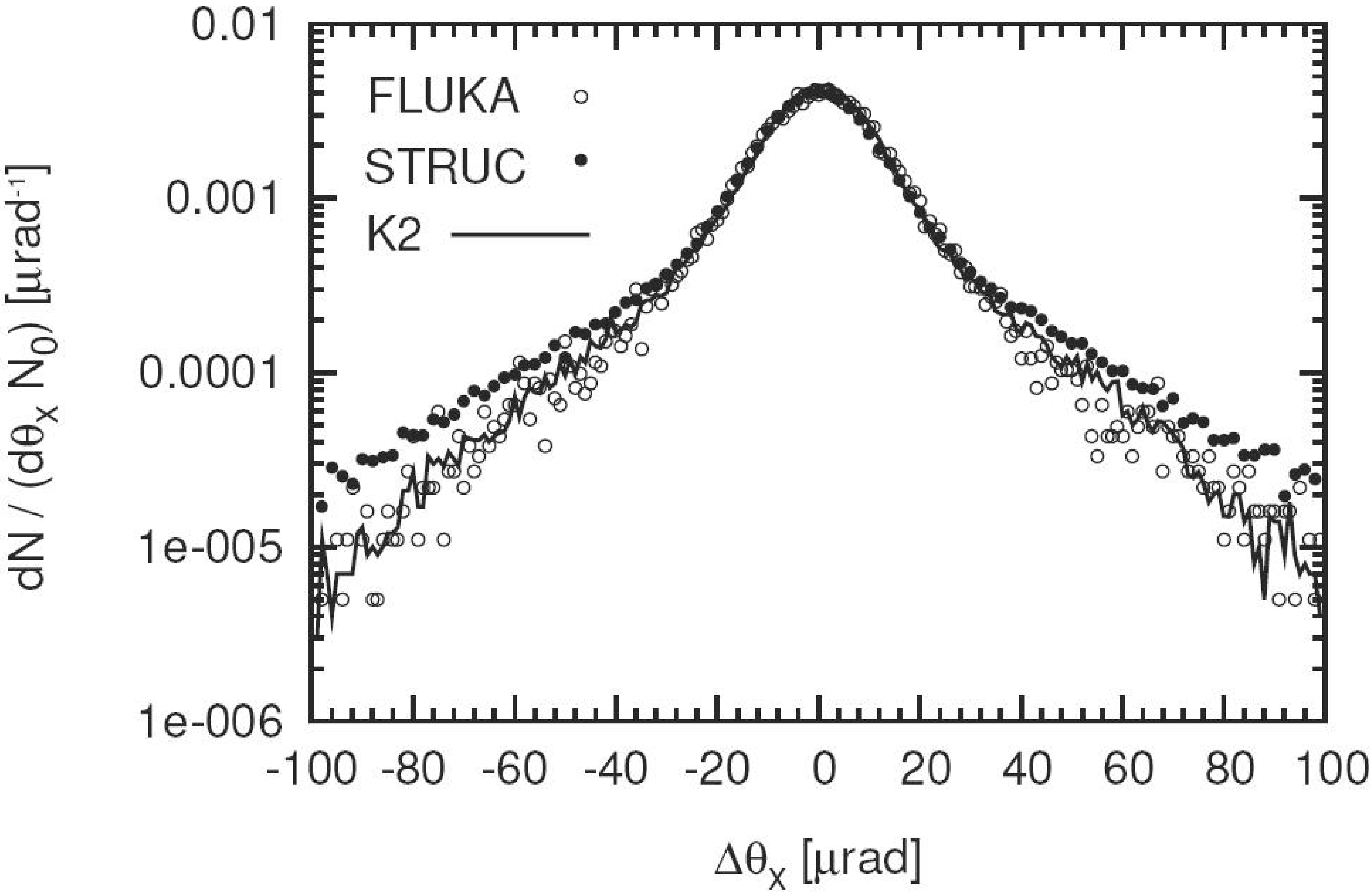


Observations: Win factor two for 0.2 m graphite (C)!
Stay with 0.2 m length for primary

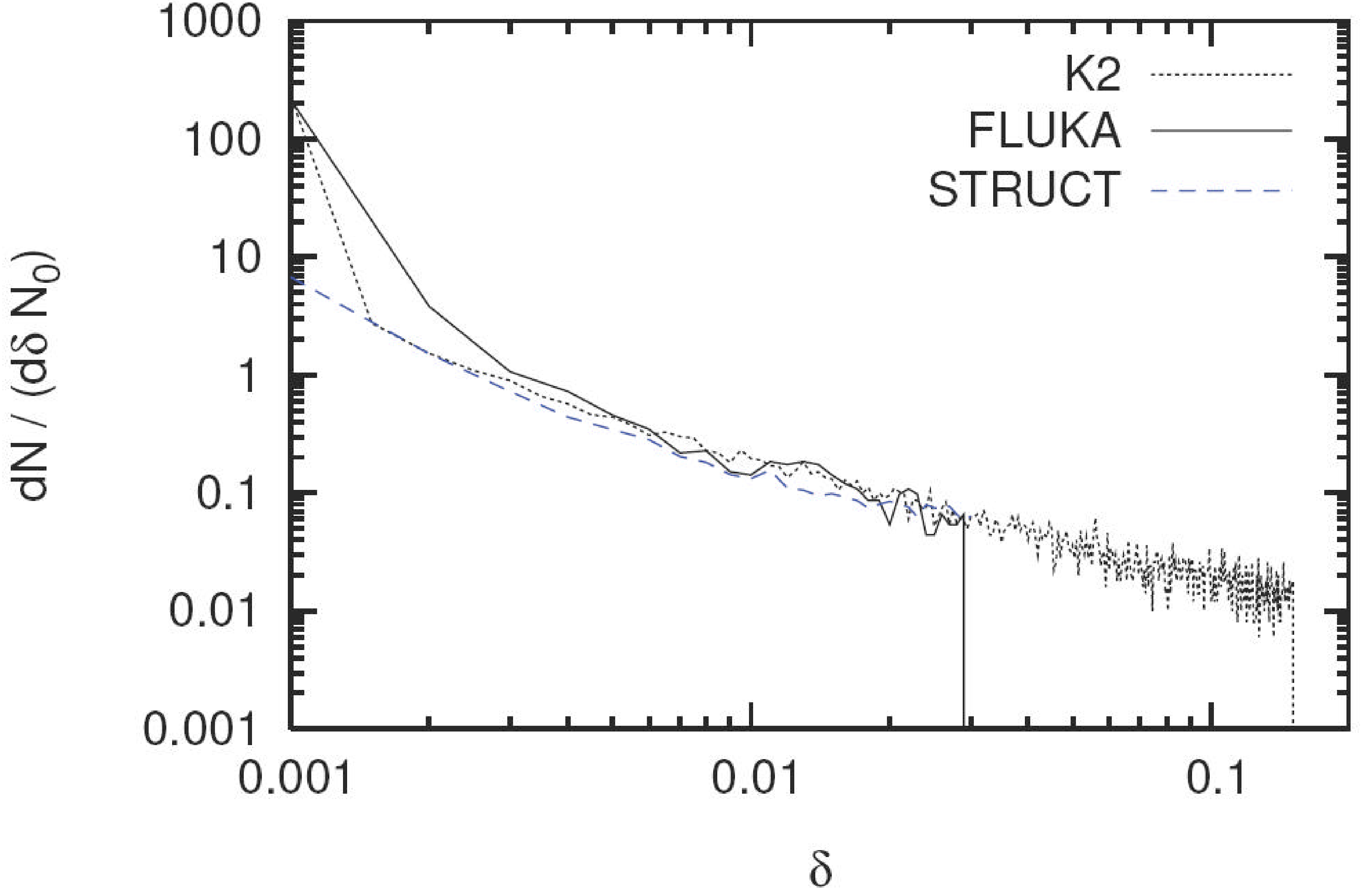
Displacement (50 cm Cu)



Kick (50 cm Cu)

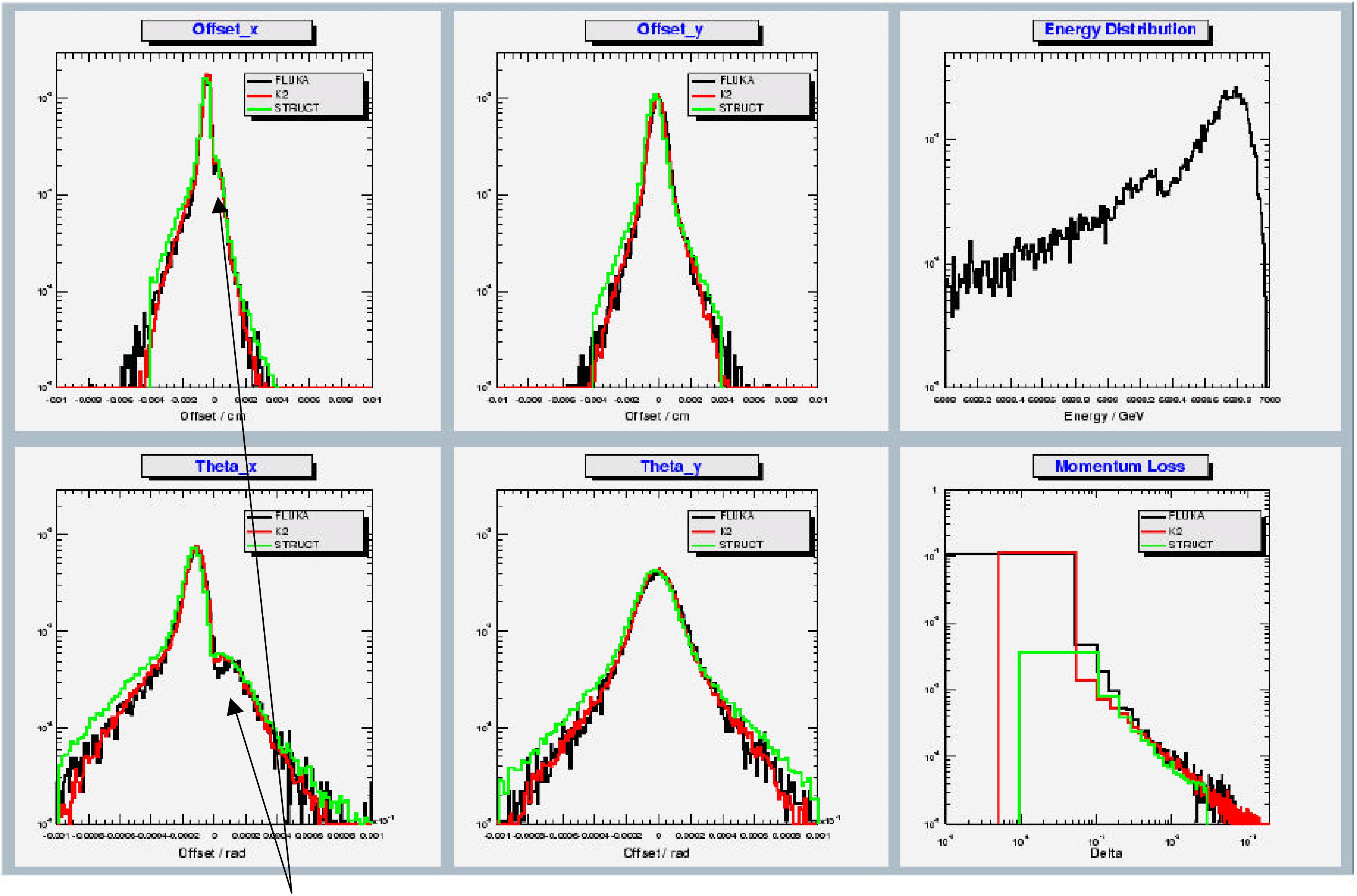

FLUKA
STRUC
K2
0.01
0.001
0.0001
1e-005
1e-006
dN / (dθx N0) [μrad-1]
-100
-80
-60
-40
-20
0
20
40
60
80
100
Δθx [μrad]

Energy Loss (50 cm Cu)



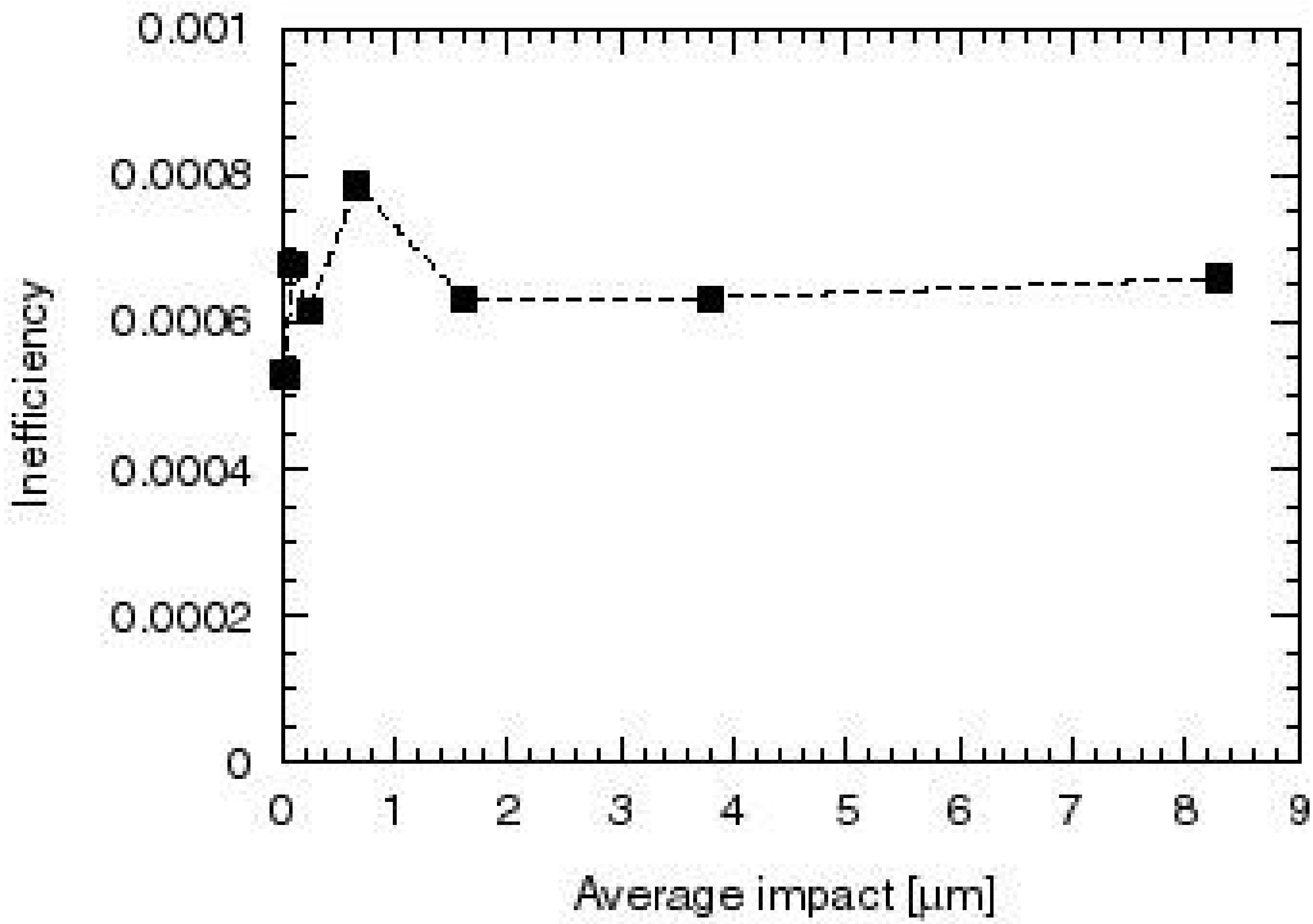
Importance of single-diffractive scattering!

Realistic Impact Parameters



Particles exit through surface of collimator for small impact parameters!

Role of Impact Parameter on Primary Collimator



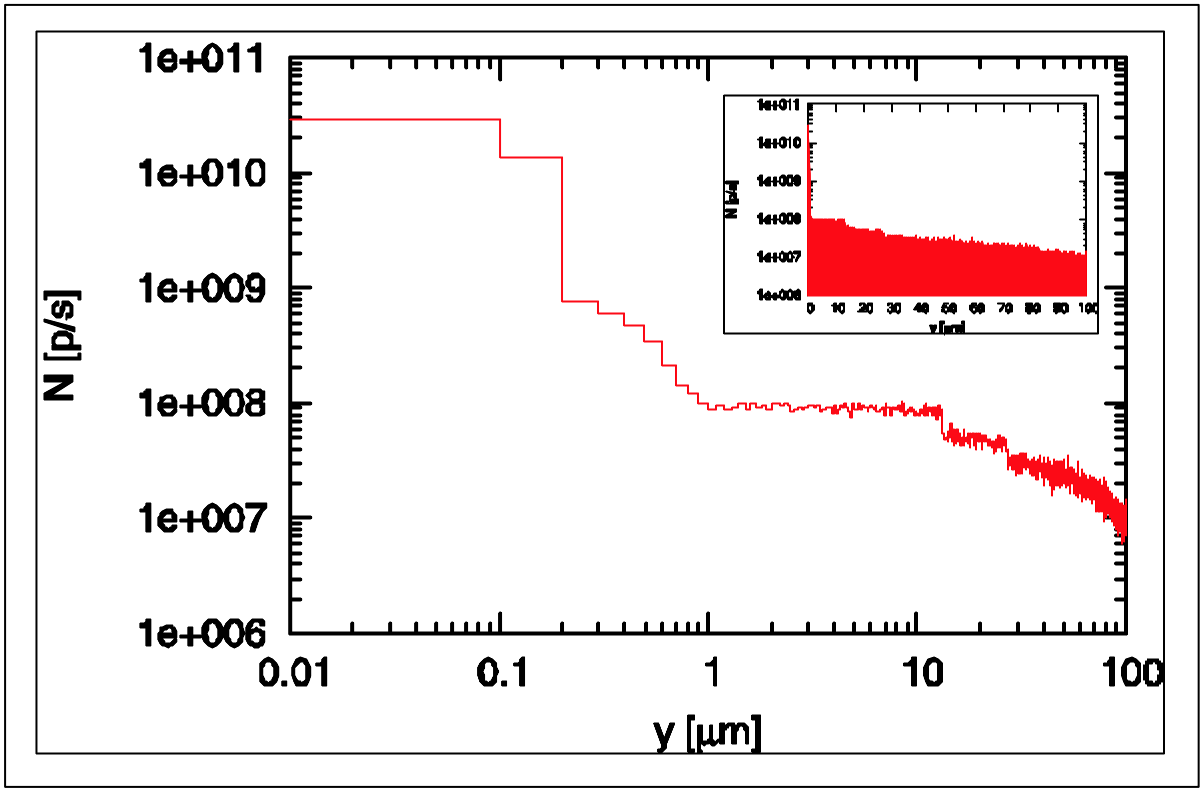
Impact Parameter with Slow Losses

Slow loss:

Uniform “emittance” blow-up

Beam lifetime: **0.2 h**	Loss rate:	4.1e11	p/s	
	Loss in 10 s:	4.1e12	p	(**1.4 %**)
		(~ 40 bunches)		

Assume drift:	0.3	sig/s	
	5.3	**nm/turn**	(sigma = 200 micron)



Mode	T [s]	τ [h]	R_{loss} [p/s]	P_{loss} [kW]
Injection	cont	1.0	0.8×10^{11}	6
	10	0.1	8.2×10^{11}	60
Top energy	cont	1.0	0.8×10^{11}	93
	10	0.2	4.1×10^{11}	465

Transverse impact parameter

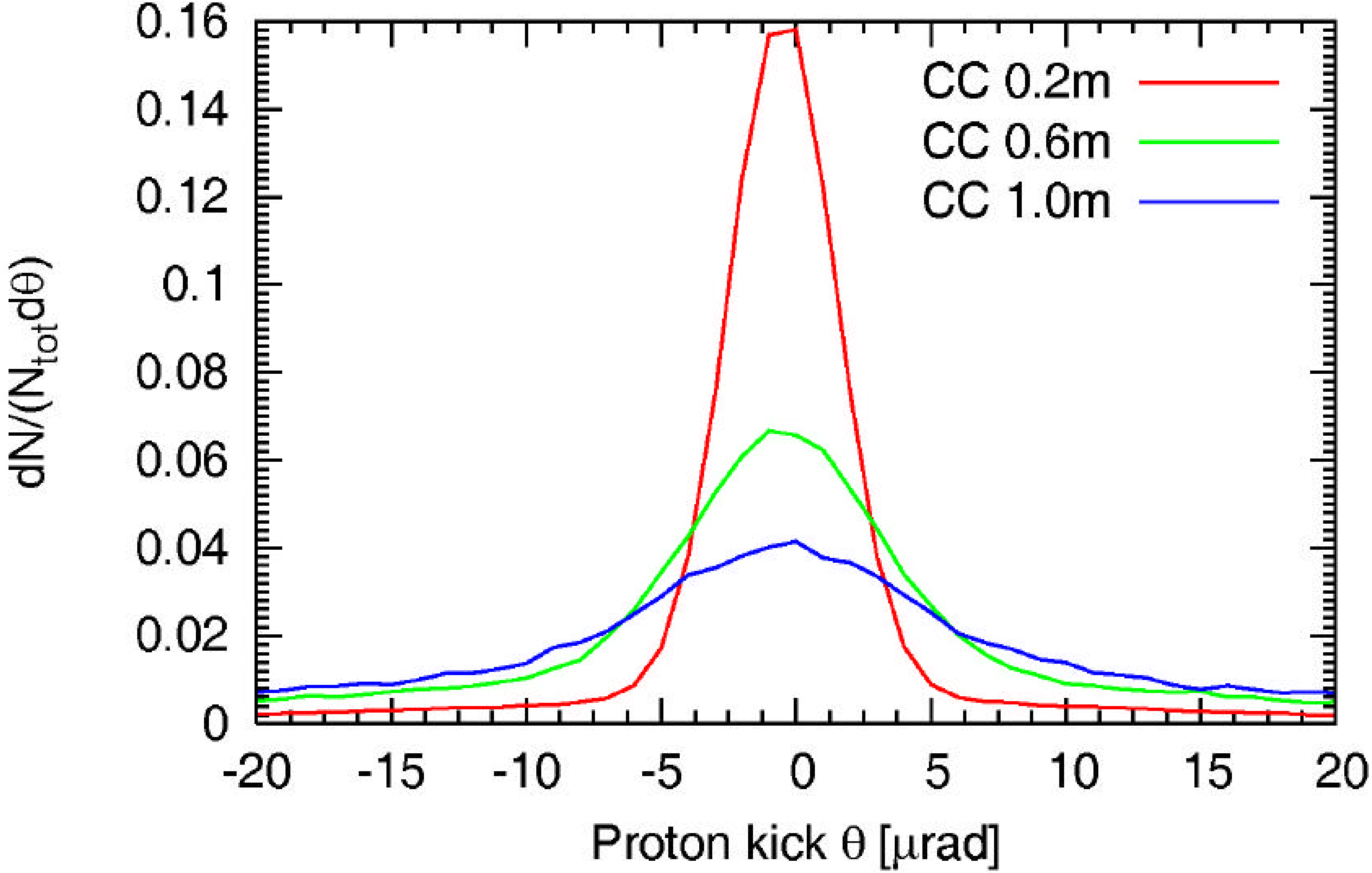
Almost all particles impact with

y = 0.2 μm

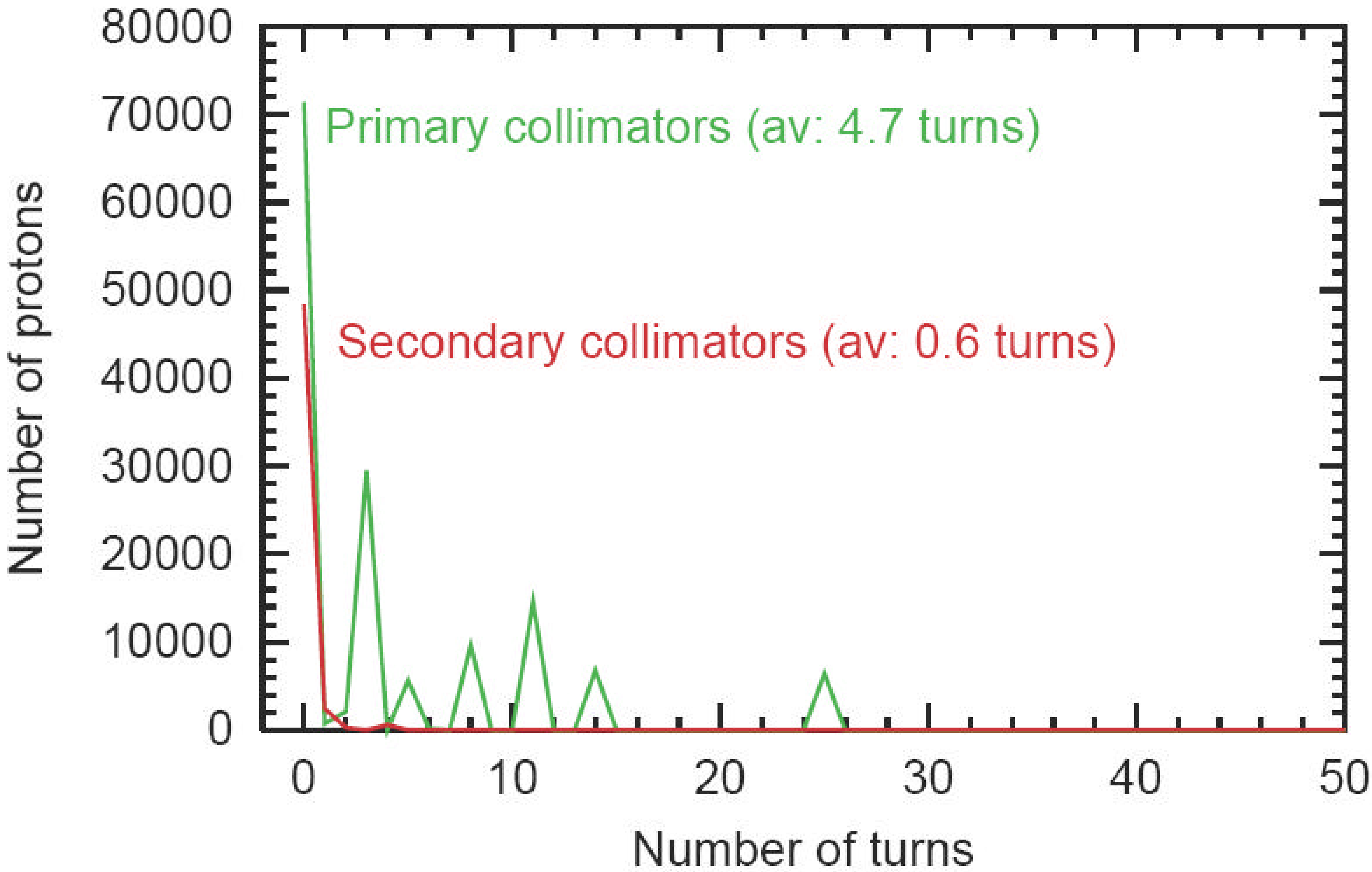
Surface phenomenon!

R. Assmann

Scattering Angles at 7 TeV



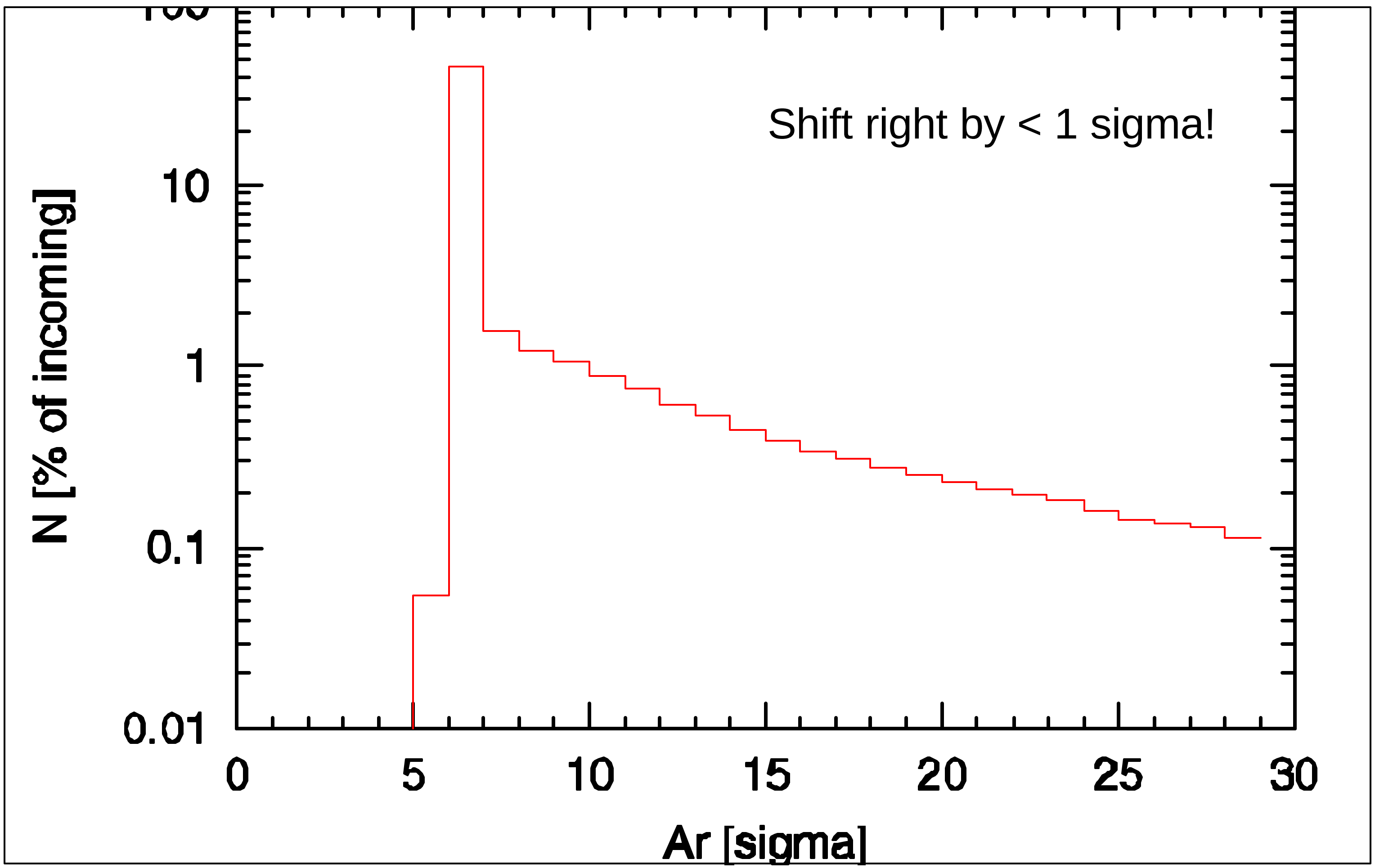
Survival after Collimator Hit (Old Example)



Long survival after hit of primary collimator ➔ Multi-turn process!

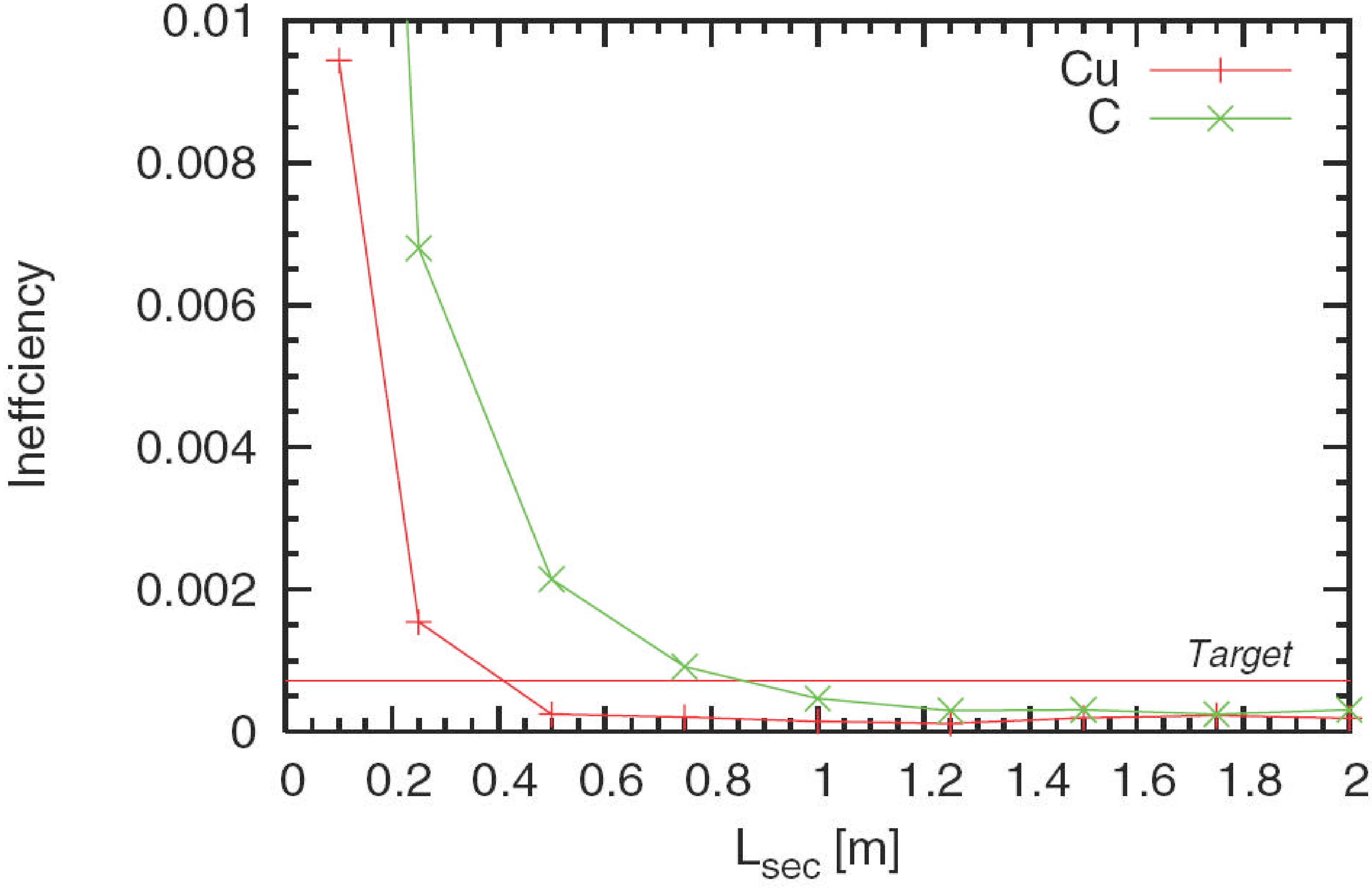
Short survival after hit of secondary collimator ➔ Single-turn process!

Radial Amplitude after Passage of 20cm C



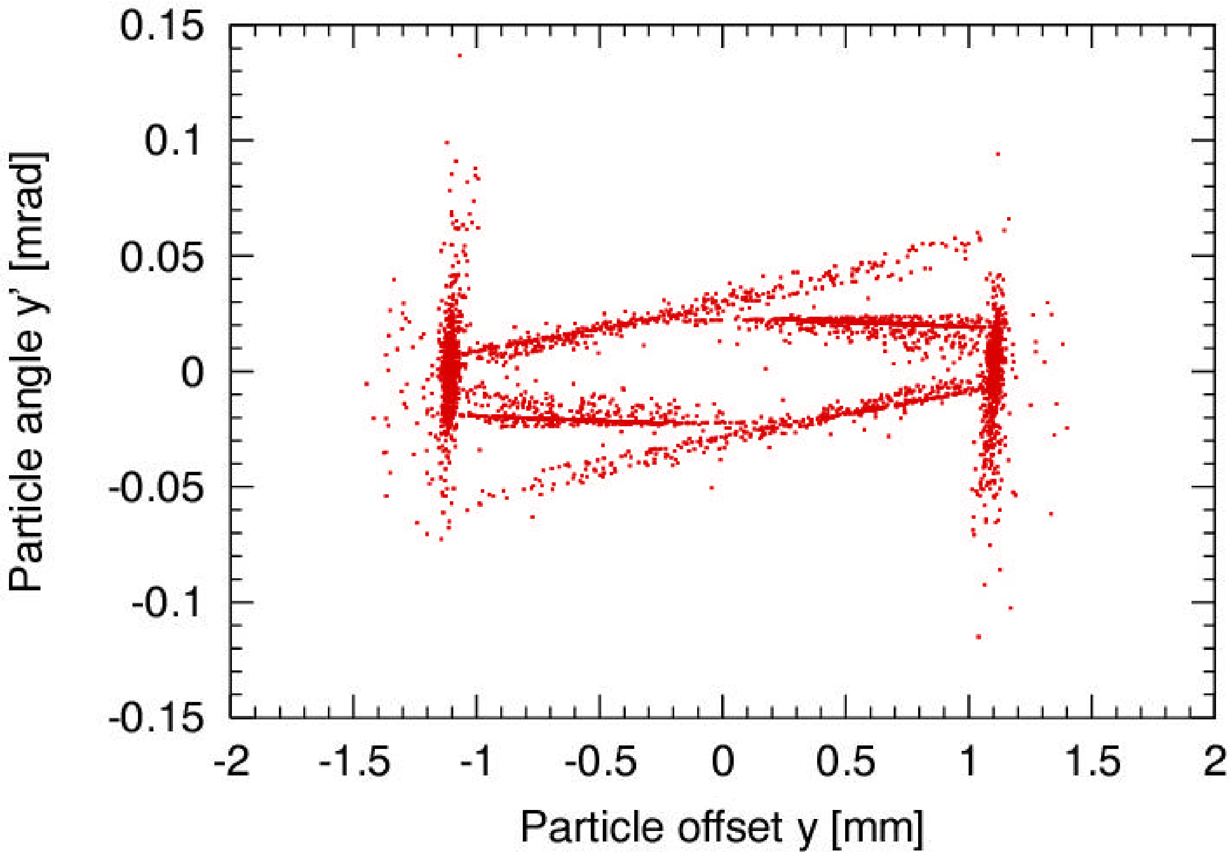
With unrealistic impact parameter! Realistically many particles will have less than 20 cm of path length in C (exit before)!

2. Vary length of secondary jaw with 0.2 m C as primary:



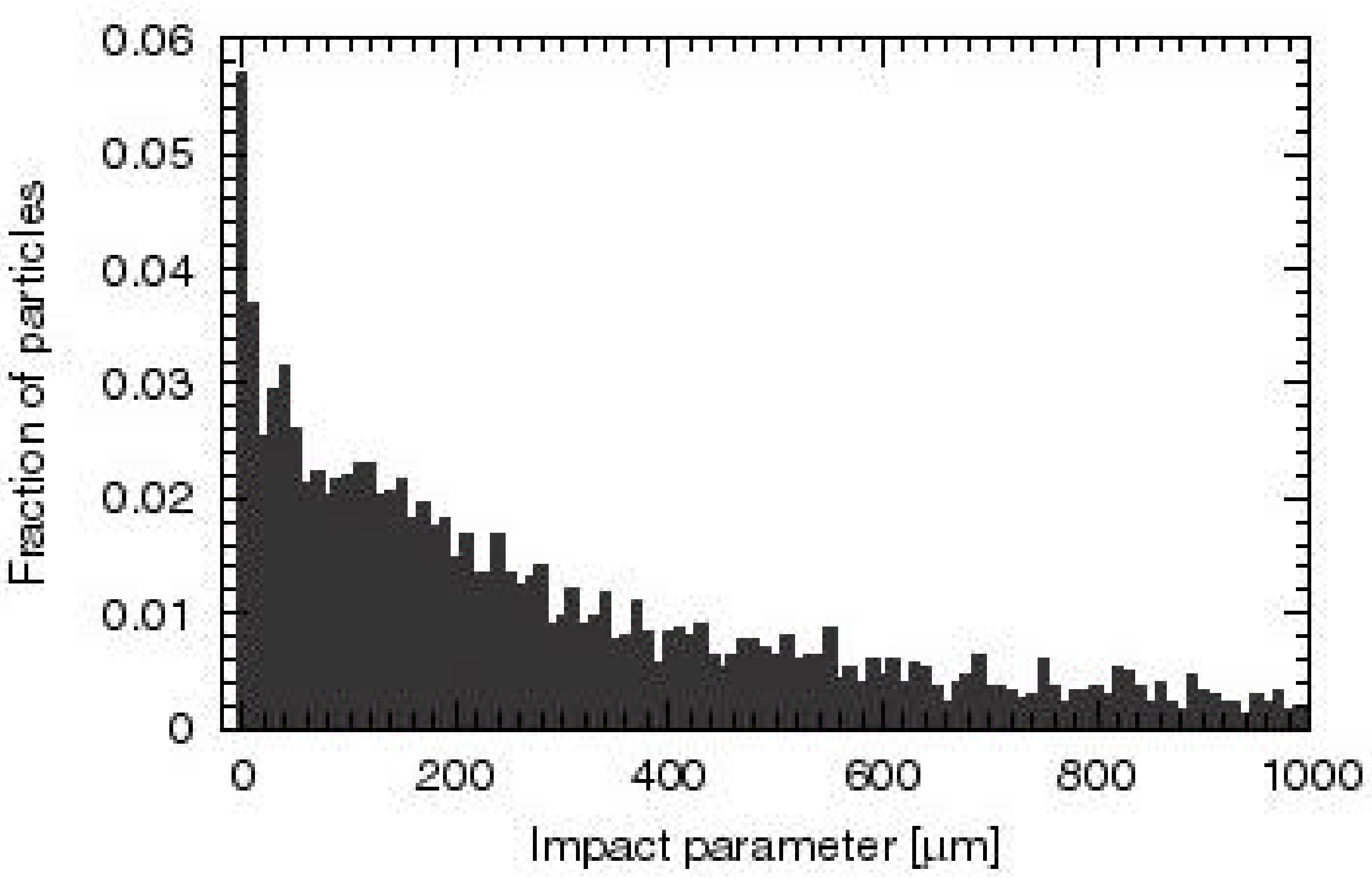
Observations: Keep cleaning efficiency with 1 m secondary jaw made out of C.

Tertiary halo in phase space



Halo generated at specific phase space locations!

Typical Impact Parameter on Secondary Coll.



Exponential distribution:	Many p with < 10 µm impact parameter!
E.g. 20 µrad angular misalignment:	20 µm offset after 1 m jaw length!
	p see reduced collimator length (~25 cm)!

Scaling for Secondary Collimators

Replacing secondary collimators: 100 cm C ➔ 100 cm W
10 times higher MCS
4 times higher absorption

Protons at secondary collimators do not see full collimator length. Assume 10 cm interaction length:

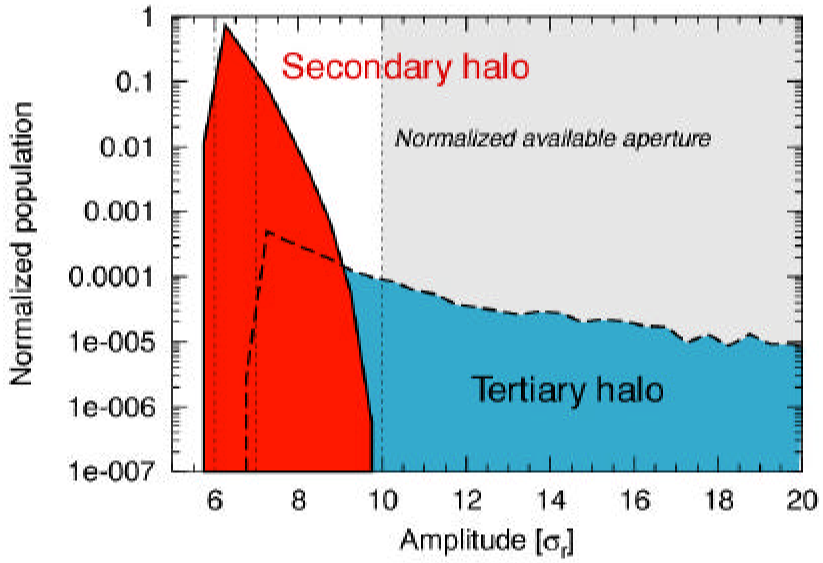
C: 0.6 absorption lengths.
W: 2.5 absorption lengths with 10 times higher MCS angles than C.

Though for same length tungsten 6 times less particles enter the tertiary halo, those that still escape do so with higher amplitudes (shift halos to higher amplitudes)…

➔ Two competing processes…
Explanation for non evident scaling!?

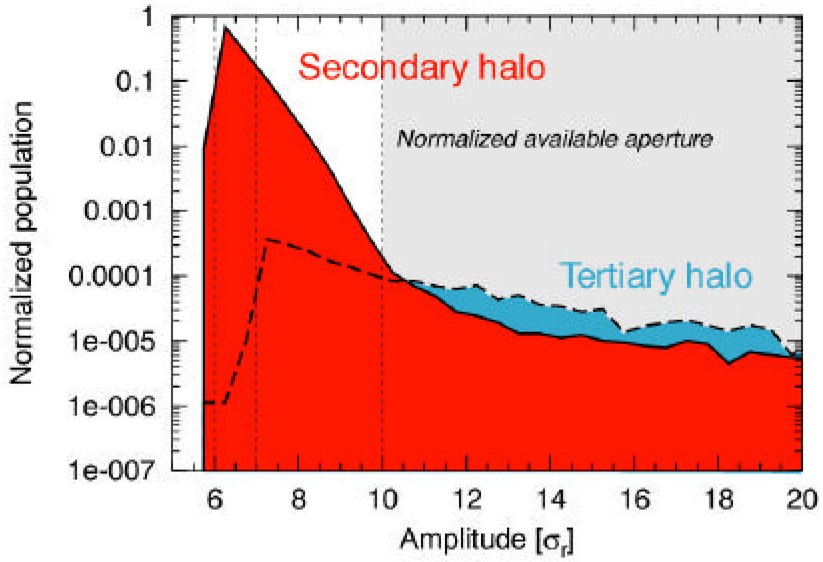
Detailed scaling only with full tracking (all processes included).

Beam Halos



At zero dispersion point
(inefficiency curve produced here)

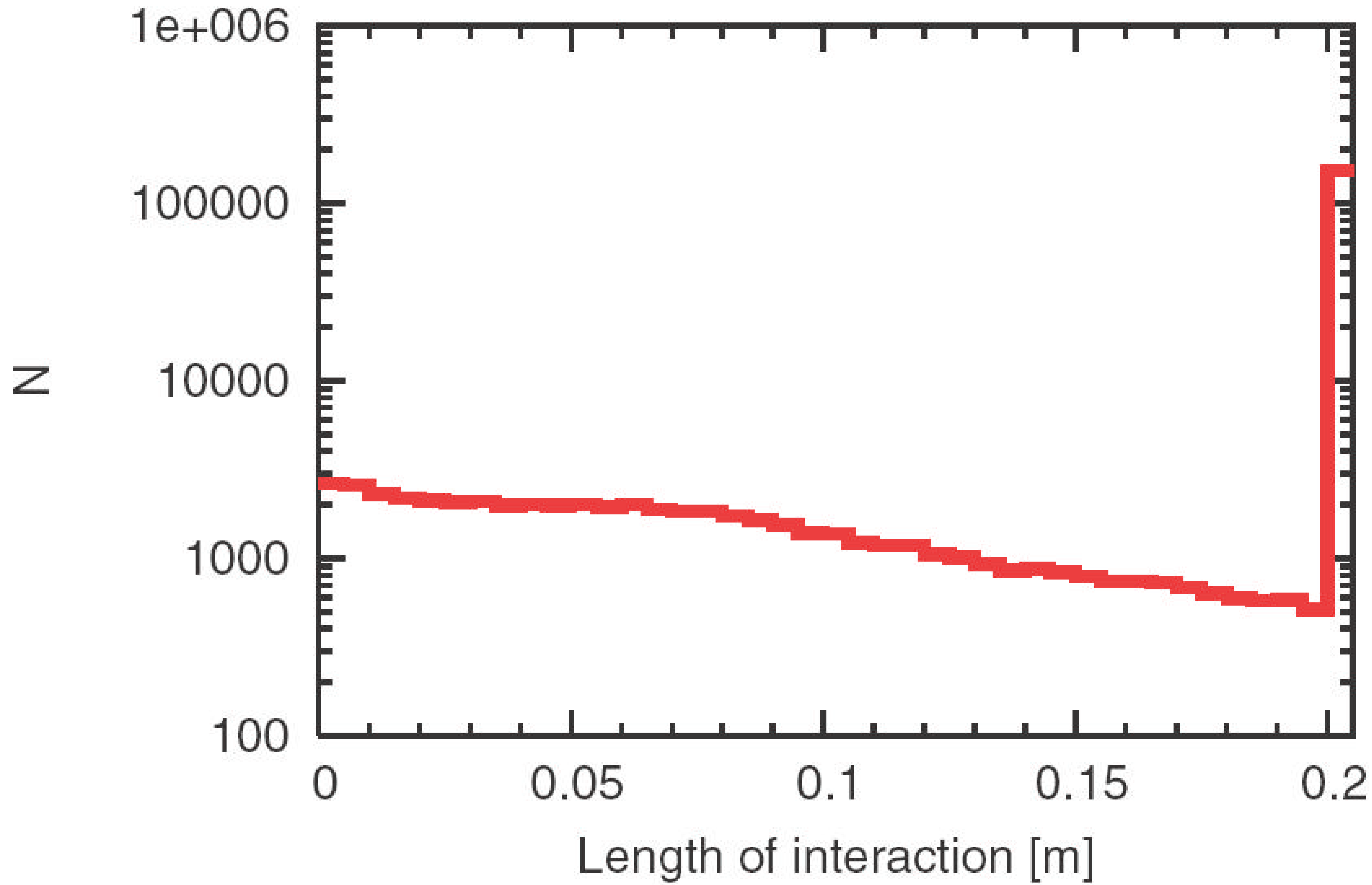
➔ Any shift right will decrease efficiency!



At arc dispersion point

➔ Important role of energy loss and dispersion!

Thanks for your attention…



Most particles traverse the full 0.2 m length of the Al jaw!

Element	Z	A	λ_{abs}	L_R
H	1	1	720	865
Be	4	9	40	35
Al	13	27	39	8.9
Cu	29	63.5	15	1.4
W	74	207	9.6	0.35