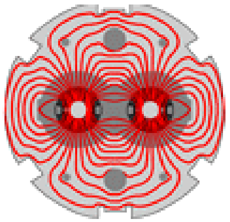

Collimation Day

The LHC Scraper System, 25th January 2002

ENERGY DEPOSITION BY LHC BEAMS IN TARGETS OF DIFFERENT MATERIALS

CERN/TIS–RP/IR/93–10

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Summary of the Presentation

- FLUKA simulations of the cascades induced in different materials by LHC beams have been made.
- Energy deposition was determined as a function of target size.
- These calculations provide a basis for determining the suitability of different materials for the construction of scrapers, *etc.*.
- The aim of was to provide basic data in an easily-available form while not intending to be a design-study for such devices.
- As a conclusion I will show some “incidents” I have known.

Introduction

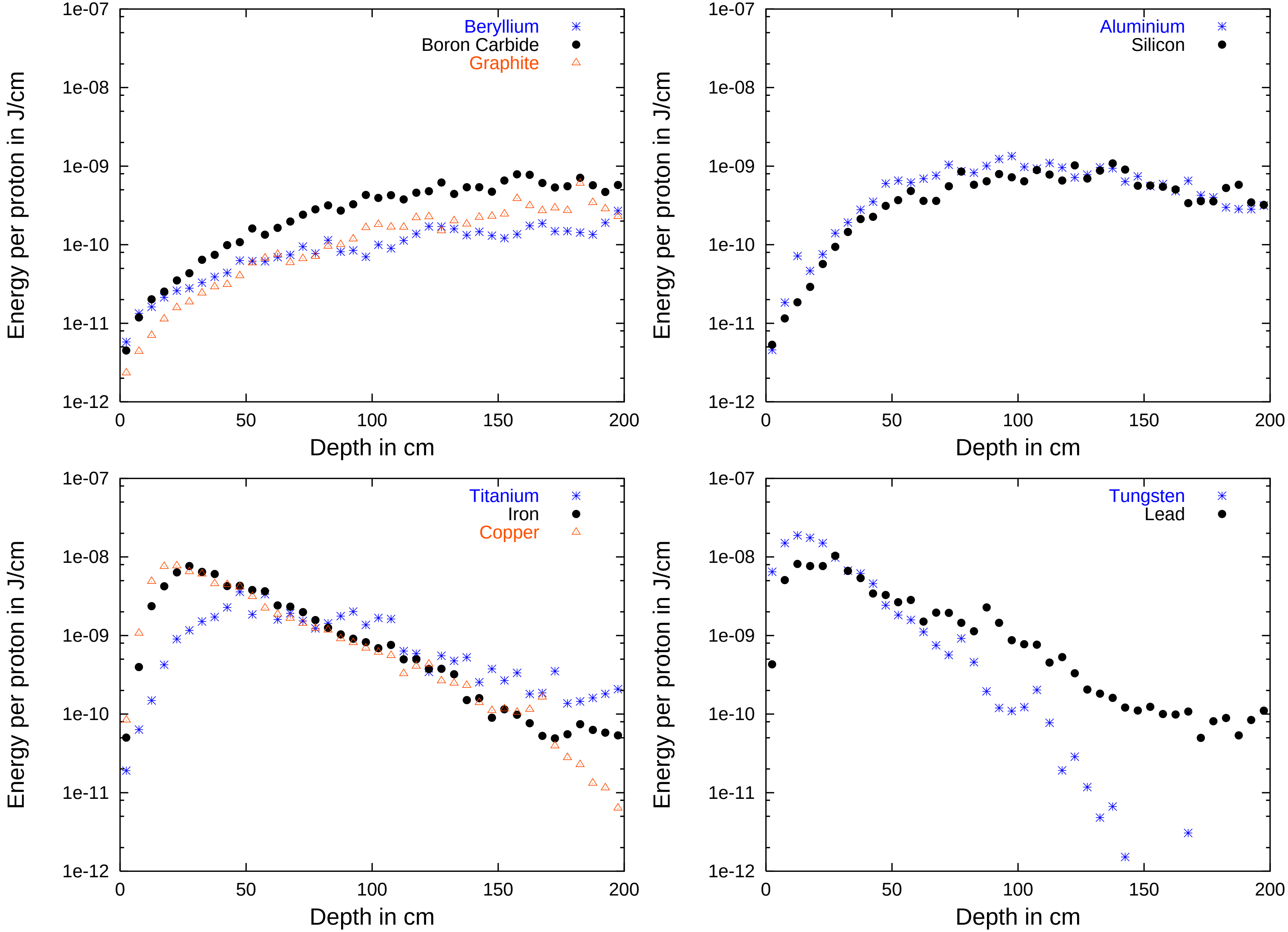
- The spatial development of a cascade depends essentially on three parameters:
  1. the high-energy hadron inelastic interaction length which controls the development of the purely hadronic part of the cascade,
  2. the radiation length which governs the development of the associated electromagnetic cascades originating from π^0 decay and
  3. the density which governs the physical extent of the cascade.
- The complex inter-relation between these three parameters means that there is no simple empirical expression which allows one to deduce the maximum energy deposition as a function of the atomic number of the irradiated material.
- Hence the need for studies such as the present one.

Simulation details

- The cascades were initiated by 7.3 TeV protons in targets of different materials.
- The radial beam size chosen for these studies was that of the LHC beam at the position of the scraper system proposed in IR3. The standard deviation of the projected beam distribution was expected to be 0.35 mm.
- The cascade was simulated in targets of 5 cm radius and 2 m in length.
- Energy deposition was determined as a function of radius and depth in both a coarse and fine radial bin structure. Both sets of bins were 5 cm in depth; the radial bin size of the coarse set was 1 mm whereas that of the fine set was smaller than the radial size of the incident beam, *viz.* 0.1 mm.
- Charged hadrons were followed down to an energy of 10 MeV; for electrons and positrons this limit was lowered to a kinetic energy of 1 MeV. Neutrons were also followed down to an energy of 1 MeV whereas the cut-off for photons was taken as 100 keV.

Longitudinal energy deposition

target radius 5 mm

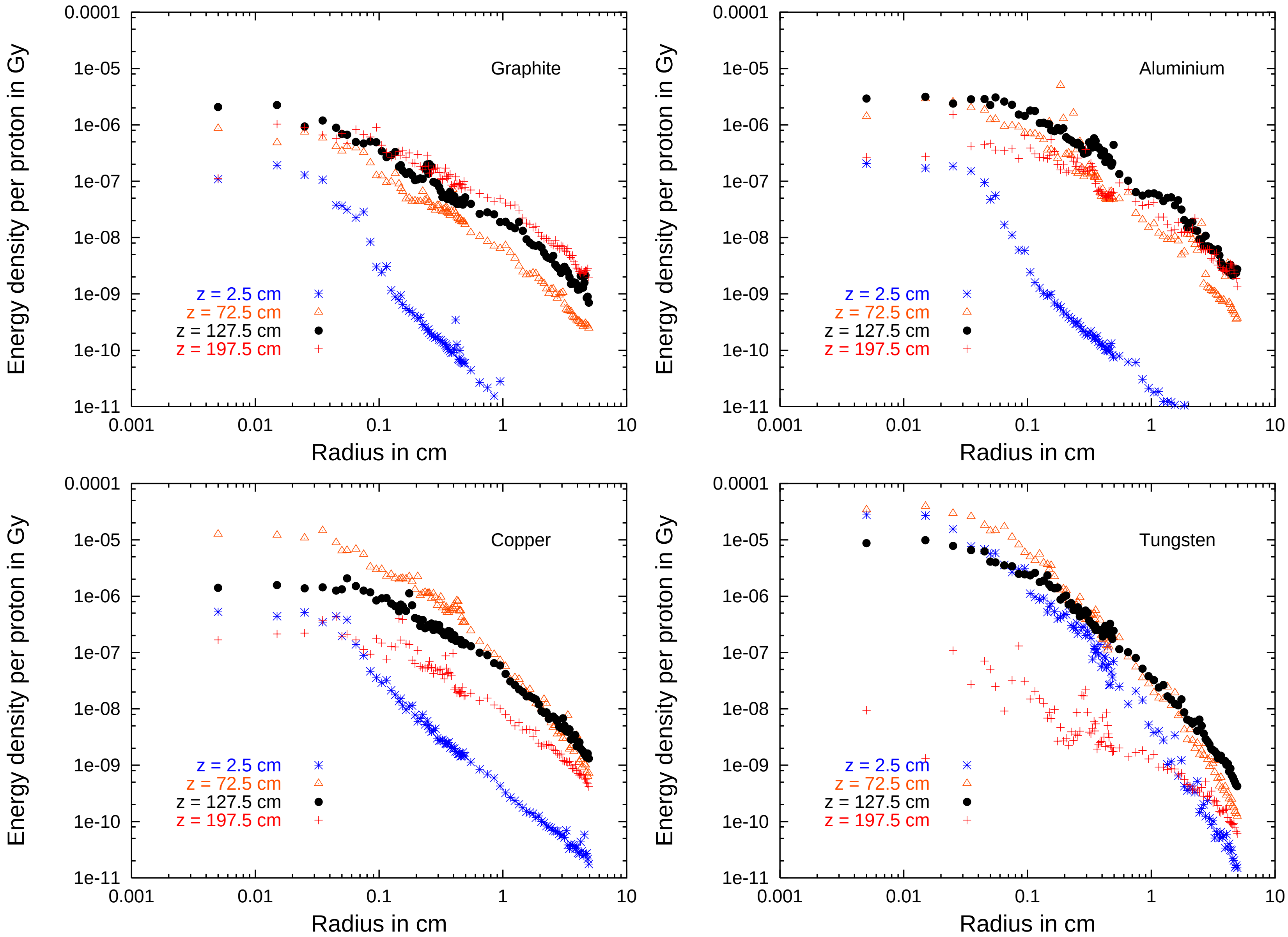


Longitudinal energy deposition – Summary

Maximum energy deposition in a target of 5 mm radius

Material		Density (g/cm^3)	Maximum energy deposition (J/cm)
Beryllium	Be	1.85	2×10^{-10}
Boron carbide	B_4C	2.6	7×10^{-10}
Graphite	C	1.75	3.5×10^{-10}
Aluminium	Al	2.7	1×10^{-9}
Silicon	Si	2.3	9×10^{-10}
Titanium	Ti	4.5	3×10^{-9}
Iron	Fe	7.88	8×10^{-9}
Copper	Cu	8.96	8×10^{-9}
Tungsten	W	19.3	2×10^{-8}
Lead	Pb	11.35	1×10^{-8}

Radial energy deposition



Max. energy deposition on the beam axis

Material	Specific Heat (J/°C.kg)	Maximum energy deposition (J/kg) per proton	Temperature rise for 10^{11} protons °C	Melting point °C
Be	1800	1.0×10^{-6}	55	1280
B_4C	1850	2.5×10^{-6}	130	2350
C	670	2.0×10^{-6}	300	3500
Al	880	3.0×10^{-6}	340	660
Si	750	2.5×10^{-6}	330	1410
Ti	460	8.0×10^{-6}	1750	1680
Fe	440	1.0×10^{-5}	2300	1540
Cu	380	1.5×10^{-5}	4000	1080
W	140	4.0×10^{-5}	29000	3380
Pb	125	1.5×10^{-5}	12000	330

- Care must be taken in interpreting the on-axis values deep in the cascade because of the statistical fluctuations inherent in these calculations.
- Values of the maximum adiabatic temperature rise for a single bunch of 10^{11} protons are given and are compared with the melting points of the different materials.
- The difficulties of materials heavier than the transition metals in supporting such an irradiation is evident.

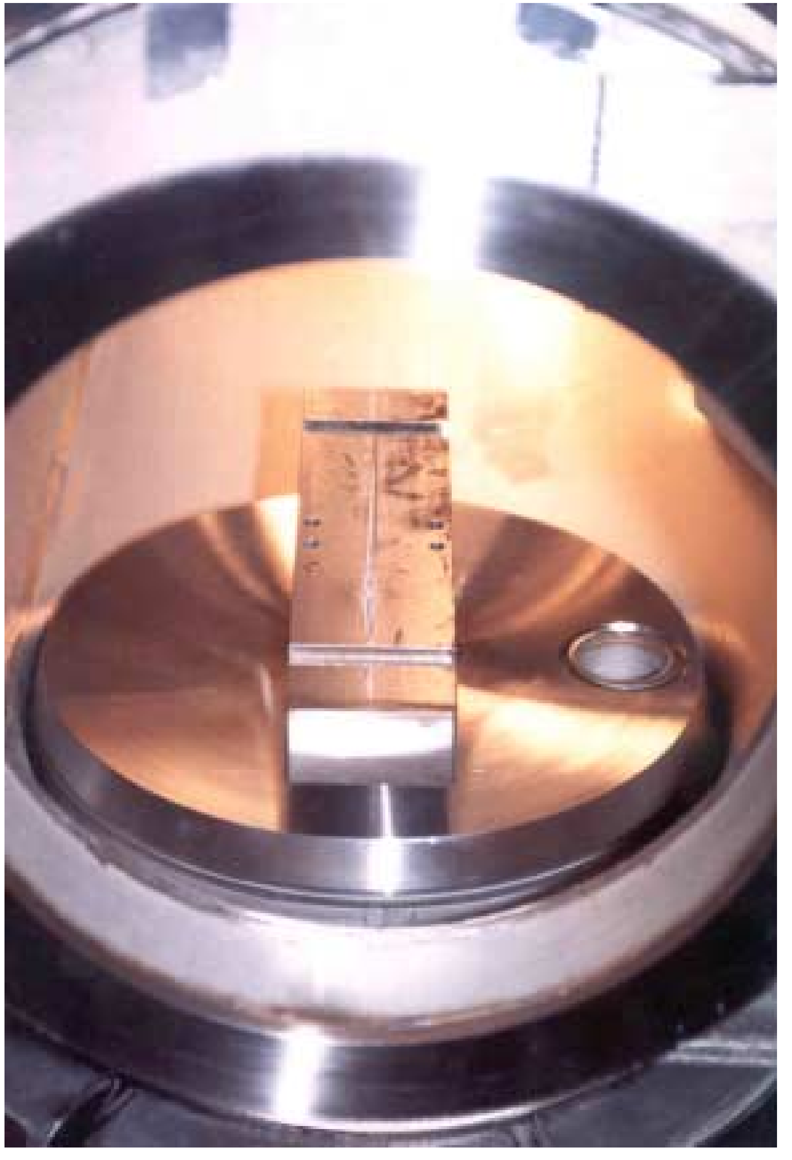
Deposited power

Power in watts deposited in targets of different materials and radii for 10^9 interacting protons per second

Material	5 mm radius Target length				5 cm radius Target length			
	5 cm	20 cm	50 cm	200 cm	5 cm	20 cm	50 cm	200 cm
Be	0.03	0.28	1.5	20	0.04	0.52	3.6	100
B_4C	0.02	0.31	2.4	70	0.03	0.57	6.2	280
C	0.012	0.13	0.9	31	0.014	0.19	2.0	130
Al	0.02	0.7	9	120	0.03	1.0	20	480
Si	0.03	0.32	5.5	97	0.04	0.57	12	400
Ti	0.10	3.3	5.1	200	0.15	5.9	134	680
Fe	0.25	35	210	330	0.40	57	430	860
Cu	0.42	70	240	330	0.70	110	500	870
W	33	290	510	550	38	390	820	960
Pb	2	110	290	400	3	170	550	890

SPS Tungsten Collimator

- A tungsten collimator was pushed too close to the circulating beam during a stored-beam machine development run at the SPS.

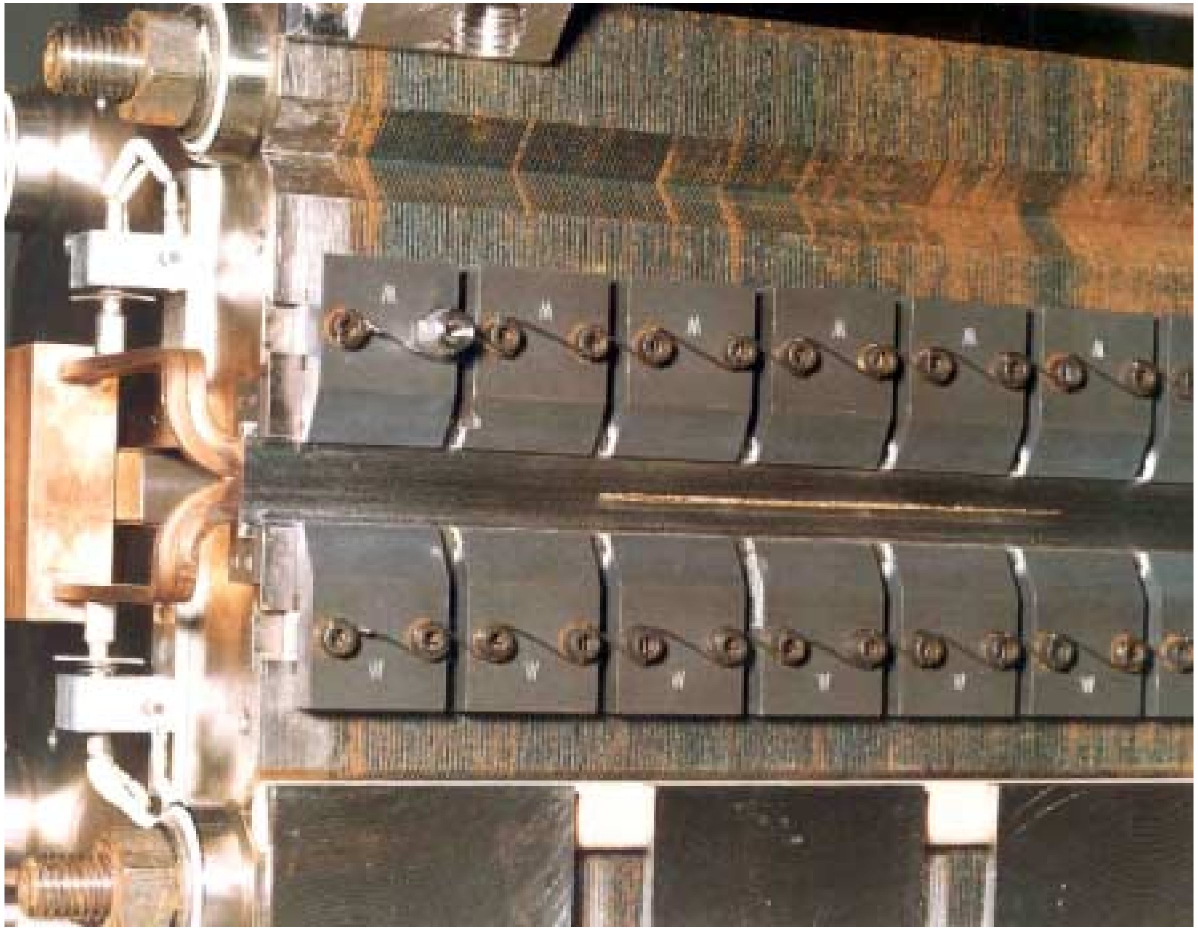


One-shot fast extraction

- A bending magnet was not powered during a fast-slow extraction to the WANF target.
- The beam entered the coil through the flange to the left of the vacuum chamber.
- The cascade melted the vacuum chamber at the maximum of the cascade.
- All magnet currents are now part of an interlock system!

SPS Thin Magnetic Septum

- The thin magnetic septum is downstream of the initial electrostatic septum.
- A spark occurred in the electrostatic septum just during extraction.
- The beam struck the water-cooled coils, ripping them apart at the maximum of the cascade.



Pirate Neutrino Experiment

- A lead block was used to counterbalance a heavy metal target placed in the secondary pions downstream of the WANF target.
- Unfortunately the block was placed directly in the beam of protons passing through the neutrino target.
- A manipulator was needed to cut apart the experiment and clean up the mess.