Status of the LHC Project

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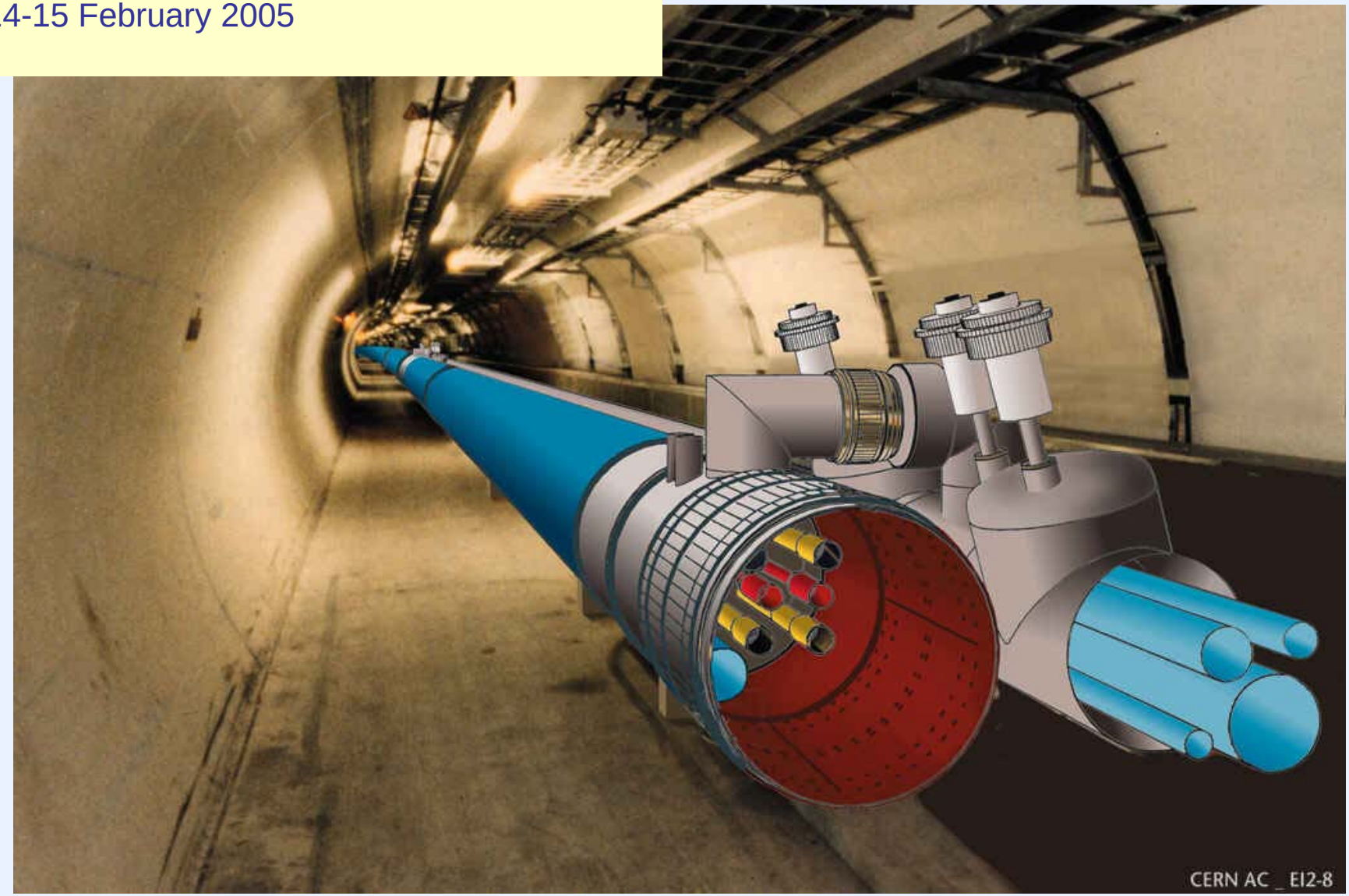
ASPEN Winter Session

14-15 February 2005



General Parameters (Protons)

Energy at collision	7	TeV
Energy at injection	450	GeV
Dipole field at 7 TeV	8.33	T
Coil inner diameter	56	mm
Distance between aperture axes (1.9 K)	194	mm
Luminosity	1	E34 $cm^{-2}s^{-1}$
Beam beam parameter	3.6	E-3
DC beam current	.56	A
Bunch spacing	7.48	m
Bunch separation	24.95	ns
Number of particles per bunch	1.1	E11
Normalized transverse emittance (r.m.s.)	3.75	µm
Total crossing angle	300	µrad
Luminosity lifetime	0	h
Energy loss per turn	7	keV
Critical photon energy	4.1	eV
Total radiated power per beam	3.8	kW
Stored energy per beam	350	MJ
Filling time per ring	4.3	min

Nominal Lead Ions Parameters

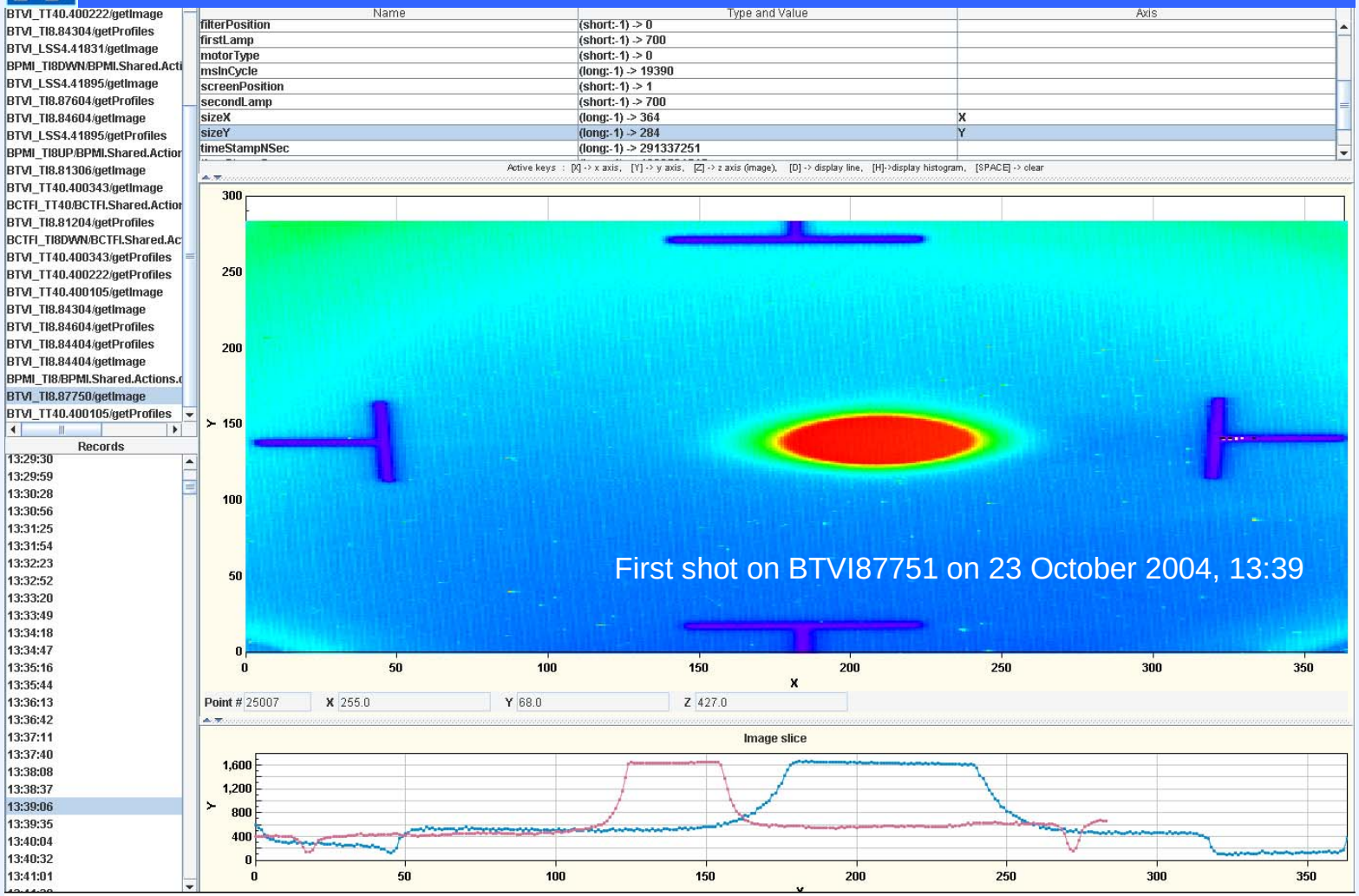
Parameters		*Units*	*Injection*	*Collision*
Energy per charge	E/Q	TeV/charge	0.45	7
Energy per nucleon	E/A	TeV/u	0.18	2.76
Centre-of-mass-energy	E_{cm}	TeV	73.8	1148
Dipole field	B_{max}	T	5.391	8.386
Transverse normalized emittance	ε^*	μm	1.5	1.5
β at IP	β^*	m	10	0.5
r.m.s. beam radius at IP	β^*	μm	280	16
Crossing angle		μrad	< 100	< 100
Longitudinal emittance	ε^*l	eVs/charge	1	2.5
r.m.s. bunch length	σ_s	cm	11.5	7.5
r.m.s. energy spread	σ_E/E	10^{-3}	0.468	0.114
Bunch spacing	l_b	ns	100	100
Bunch harmonic number	h_b		891	891
Number of bunches per ring	n_b		592	592
Filling time in the LHC		min	9.8	-
Number of ions per bunch	N_b	10^7	7.0	7.0
Number of ions per beam	N	10^{10}	4.1	4.1
Ion intensity per beam		mA	6.1	6.1
Initial luminosity per bunch		10^{24} cm^{-2} s^{-1}	-	1.7
Total initial luminosity	L_0	10^{27} cm^{-2} s^{-1}	-	1.0
IBS emittance growth		h	7.5	15
Luminosity half-life		h	-	4.2

General situation

13:39 → beam at the end of TI 8, some 2.5 km away, at first attempt

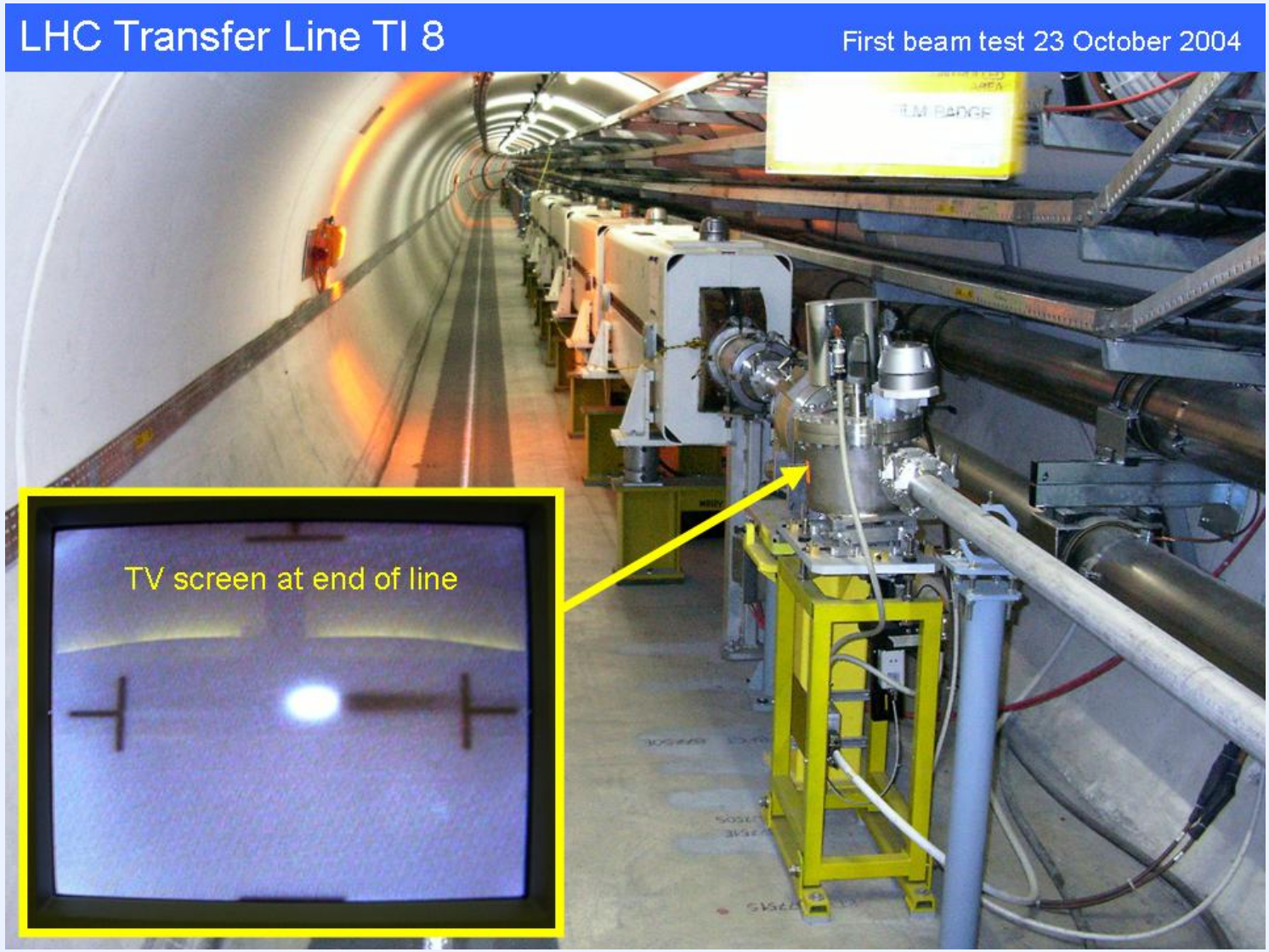
- **length of newly tested part ~ 2.5 km**
- **over 400 magnets**

TI 8 commissioning

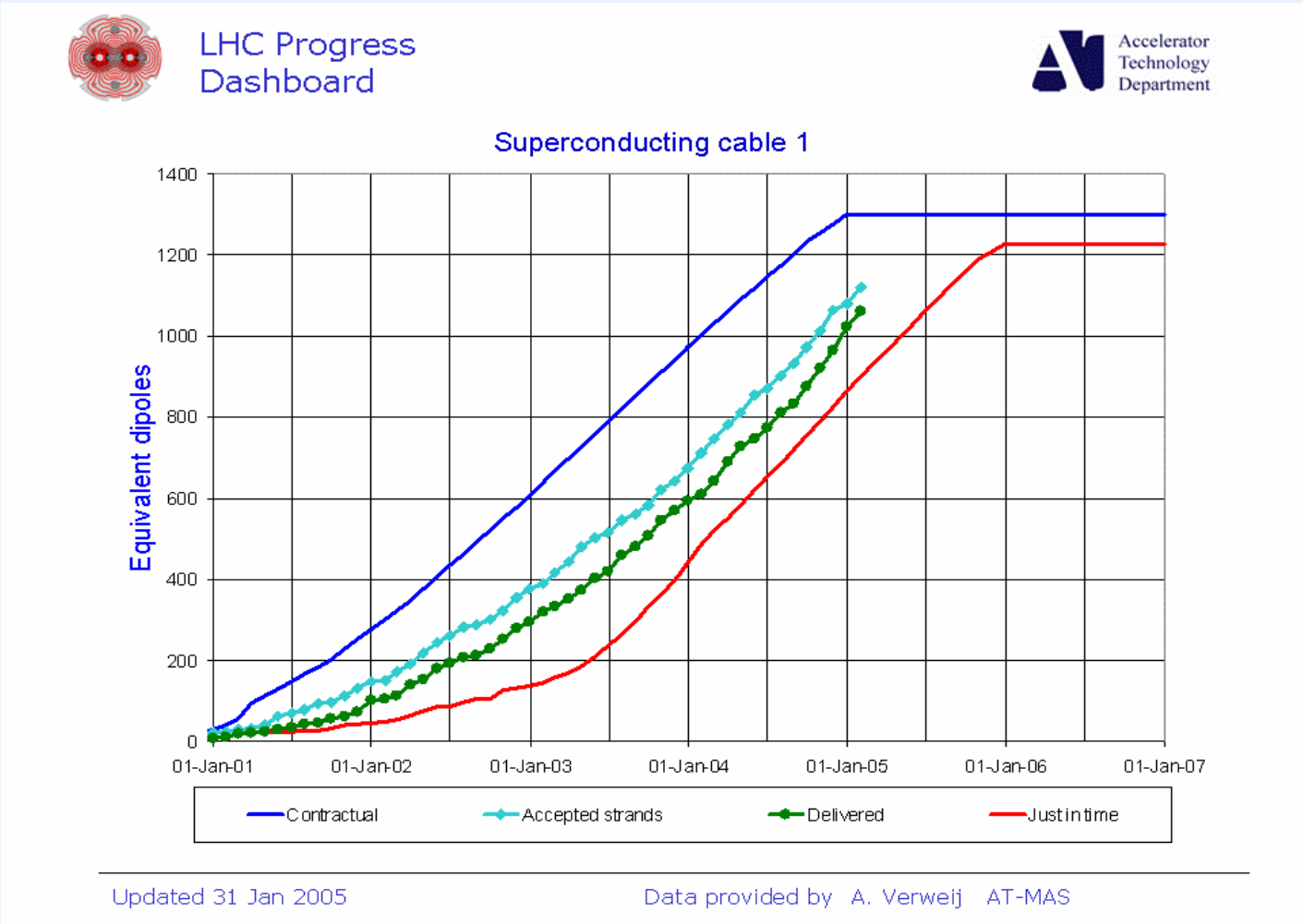


TI 8 commissioning / V.Mertens / TCC, 29.10.2004

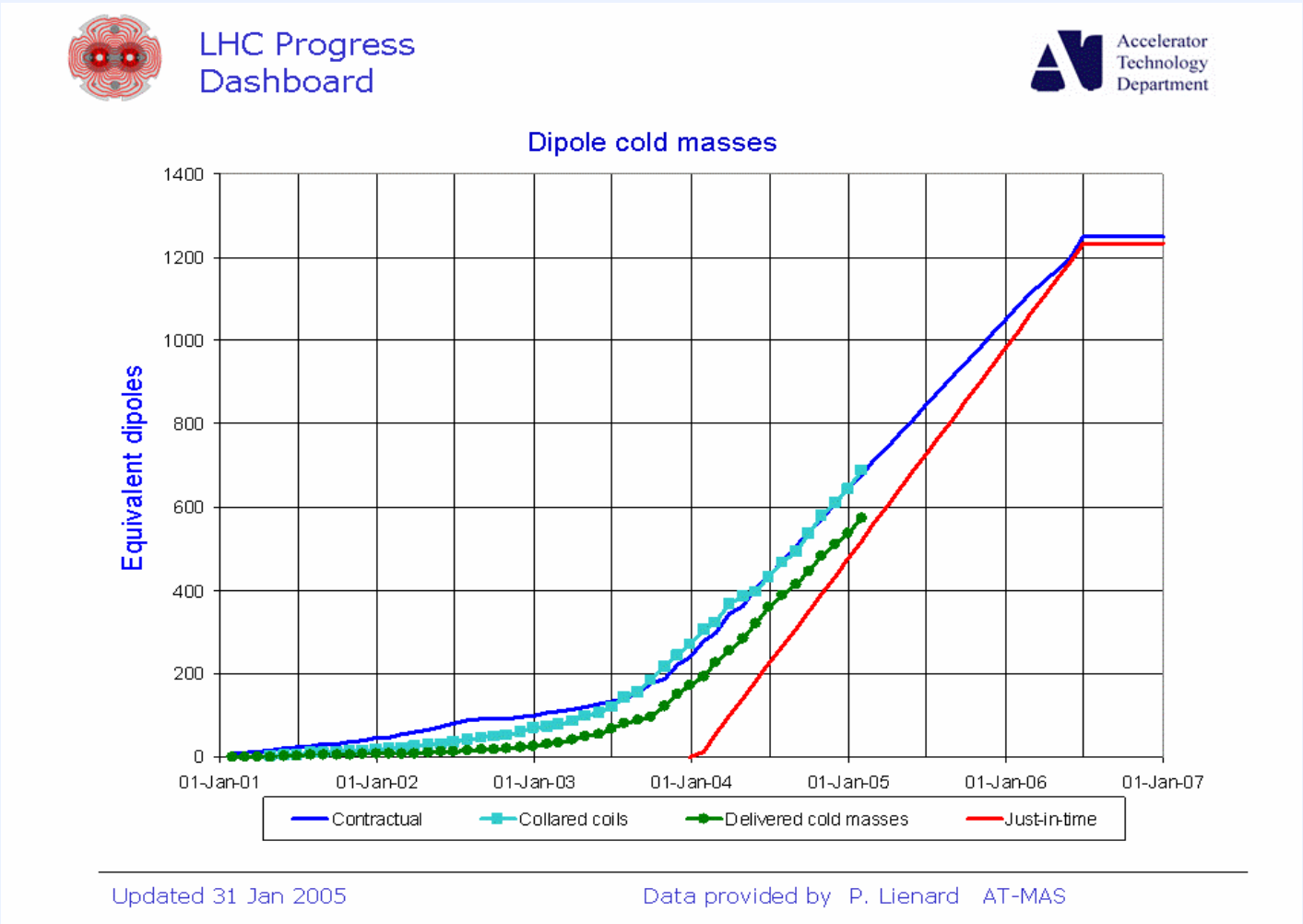
Results of TI8 test



Cable 1


LHC Progress Dashboard
Accelerator Technology Department
Superconducting cable 1
Equivalent dipoles
1400
1200
1000
800
600
400
200
0
01-Jan-01
01-Jan-02
01-Jan-03
01-Jan-04
01-Jan-05
01-Jan-06
01-Jan-07
Contractual
Accepted strands
Delivered
Just in time
Updated 31 Jan 2005
Data provided by A. Verweij AT-MAS

Dipoles


LHC Progress Dashboard
Accelerator Technology Department
Dipole cold masses
Equivalent dipoles
1400
1200
1000
800
600
400
200
0
01-Jan-01
01-Jan-02
01-Jan-03
01-Jan-04
01-Jan-05
01-Jan-06
01-Jan-07
Contractual
Collared coils
Delivered cold masses
Just-in-time
Updated 31 Jan 2005
Data provided by P. Lienard AT-MAS

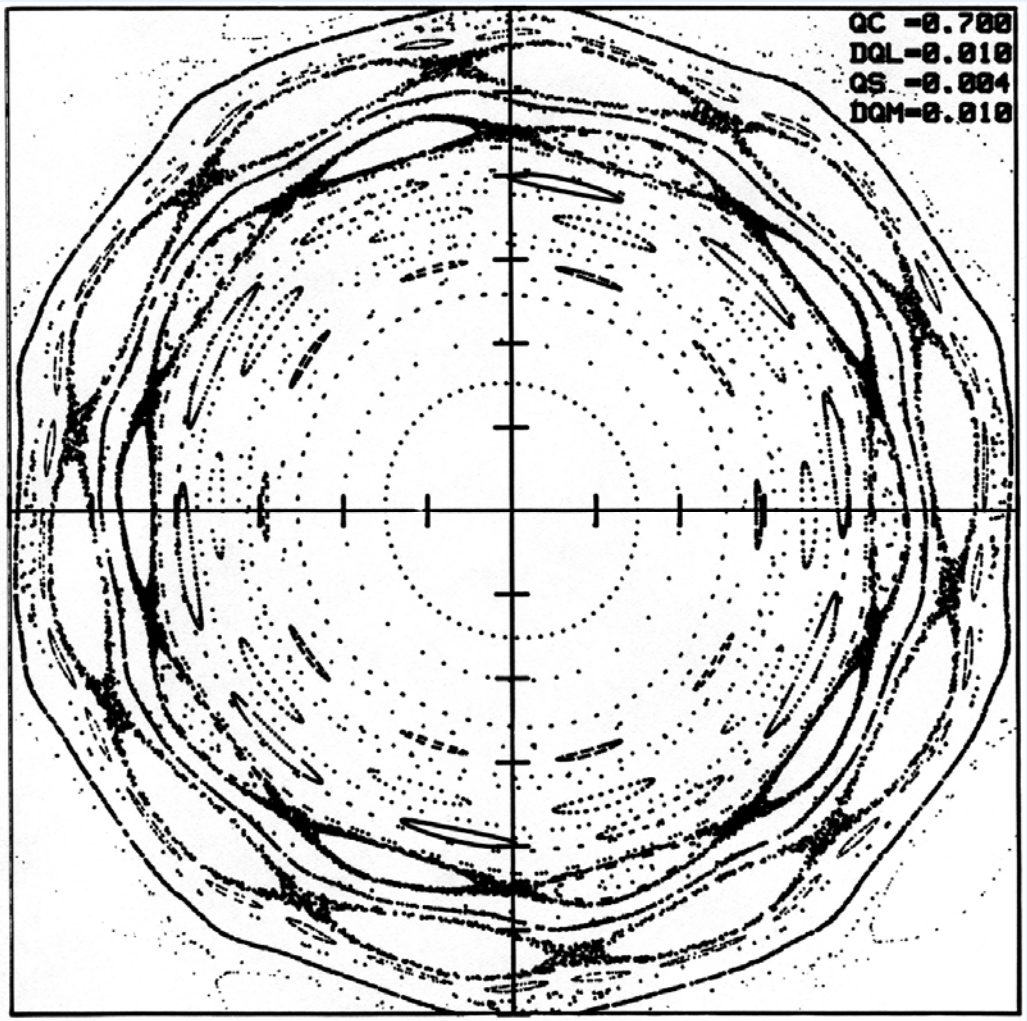
Intrabeam Scattering

- Energy transfer due to Coulomb scattering of particles in the same bunch causes blowing-up of longitudinal and radial emittance.
- For protons, IBS growth rate can be reduced by pre-emptive blow-up of longitudinal emittance from 1 eV.s. to 2.5 eV.s. This fixes maximum RF voltage of 16 MV per beam.
- For Pb ions, IBS is an important limitation to luminosity lifetime together with electron capture by pair production (~ 300 barns).

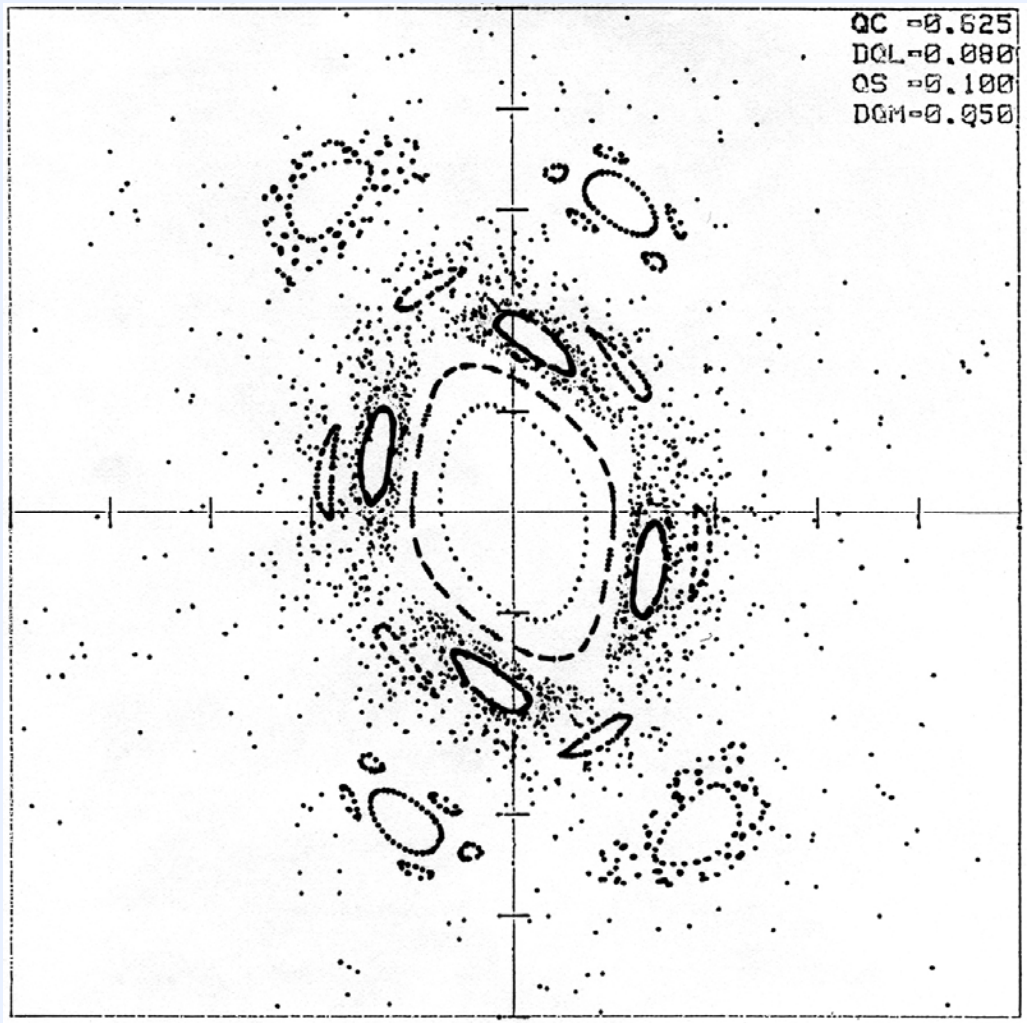
Beam – Beam Interaction

- The non-linear field of the beam-beam interaction excites resonances and causes tune spread.
- The LHC working point is chosen to accommodate a tune footprint of 0.01 in resonance – free region near diagonal between 3rd and 10th order resonances.
- Beam-beam parameter of 0.003 with two collision points has been achieved routinely in SPS (strong-weak regime).

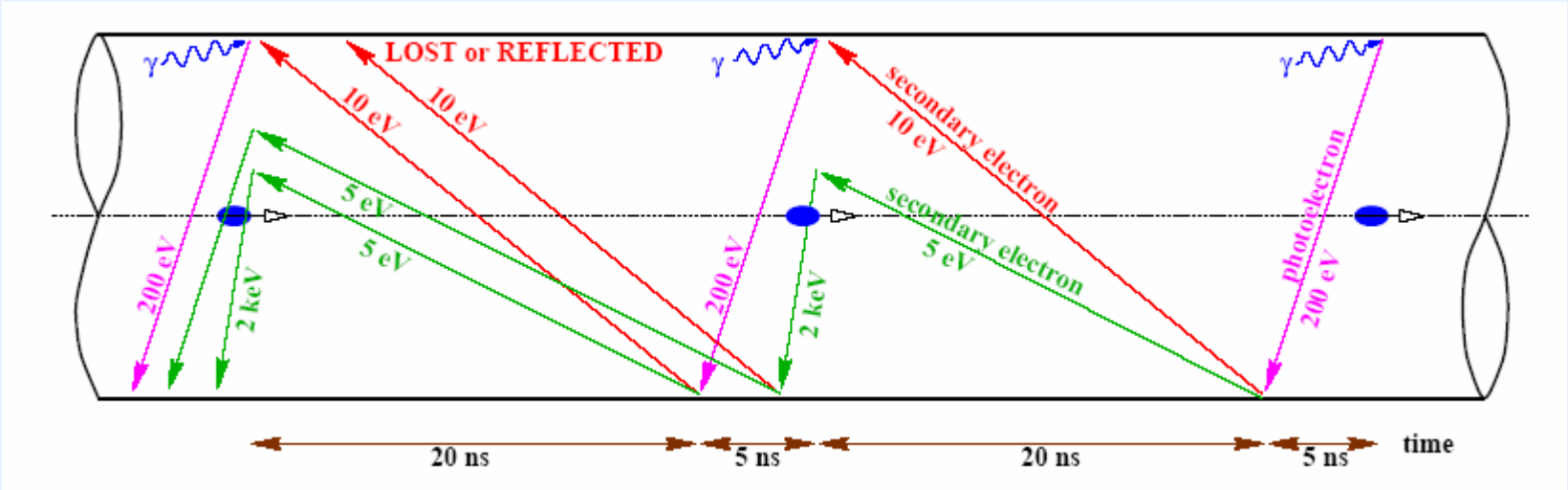
The Beam – Beam interaction



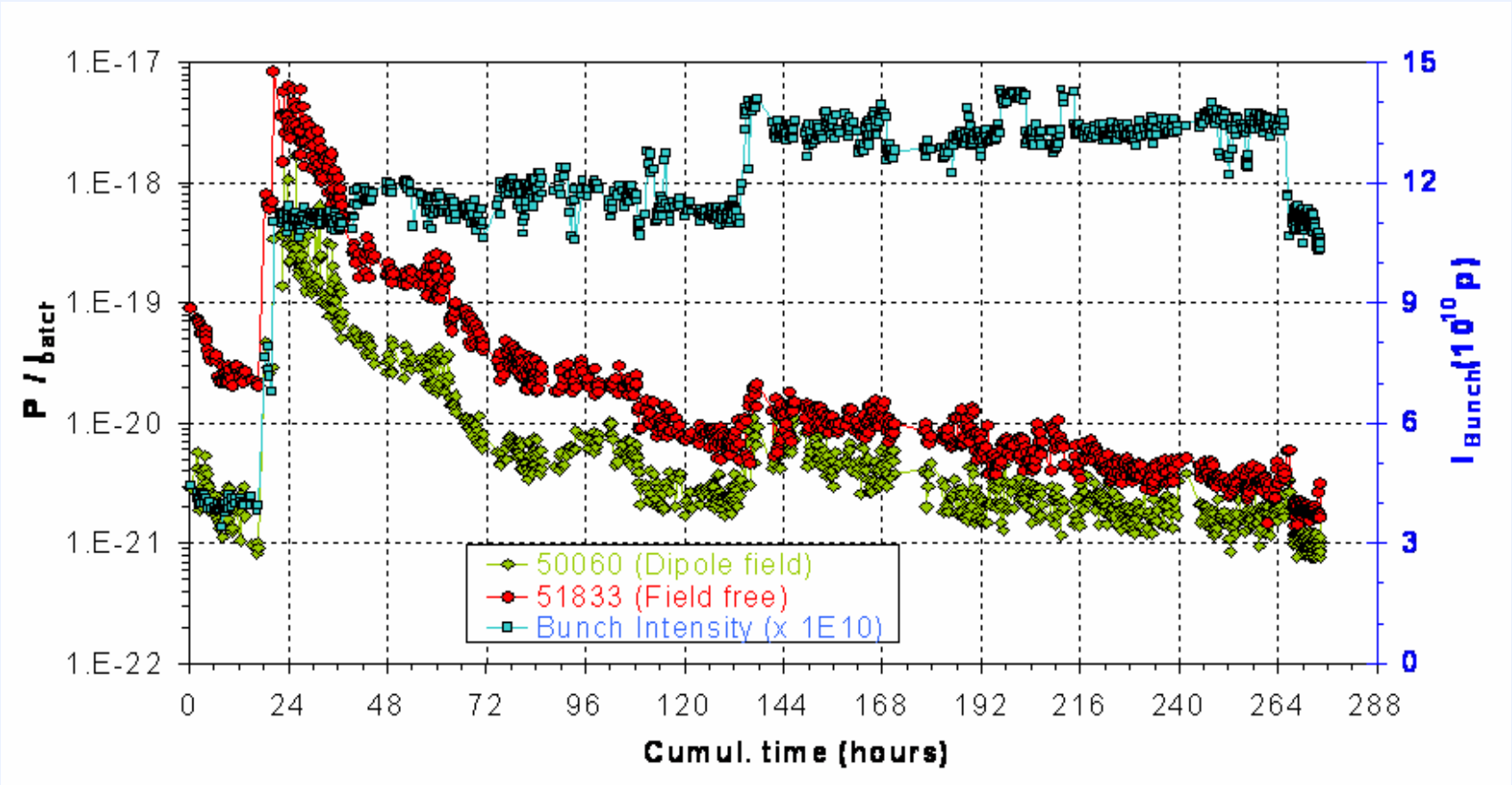
The Beam – Beam interaction



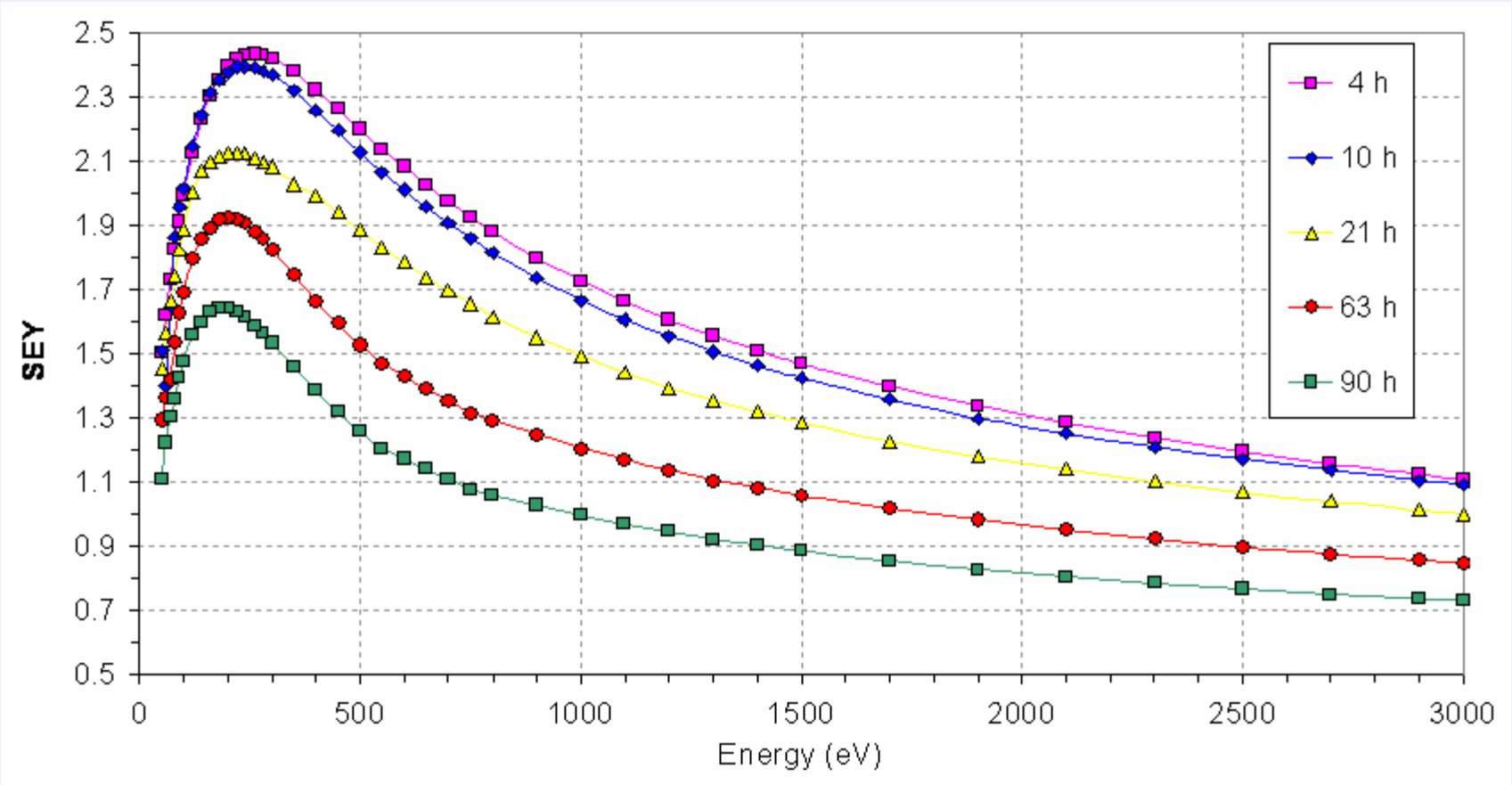
Electron Cloud Effect



Electron Cloud Effect



Electron Cloud Effect

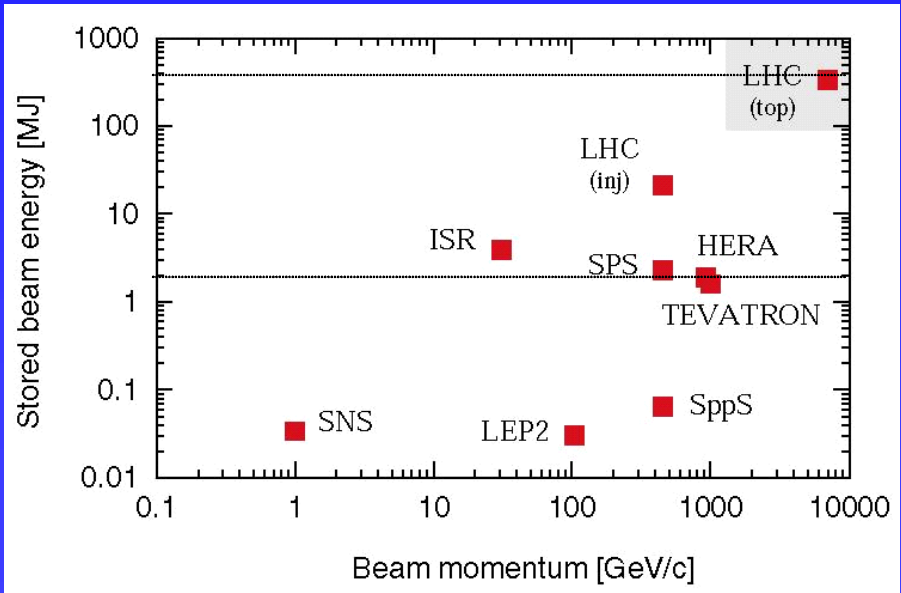


The LHC Collimation Challenge

The LHC machine:

Physics ➔ High luminosity at high energy:
Great discovery potential!

Accelerator design ➔ Handling of ultra-intense beams
in a super-conducting environment:
Great risk of quenching & damage!

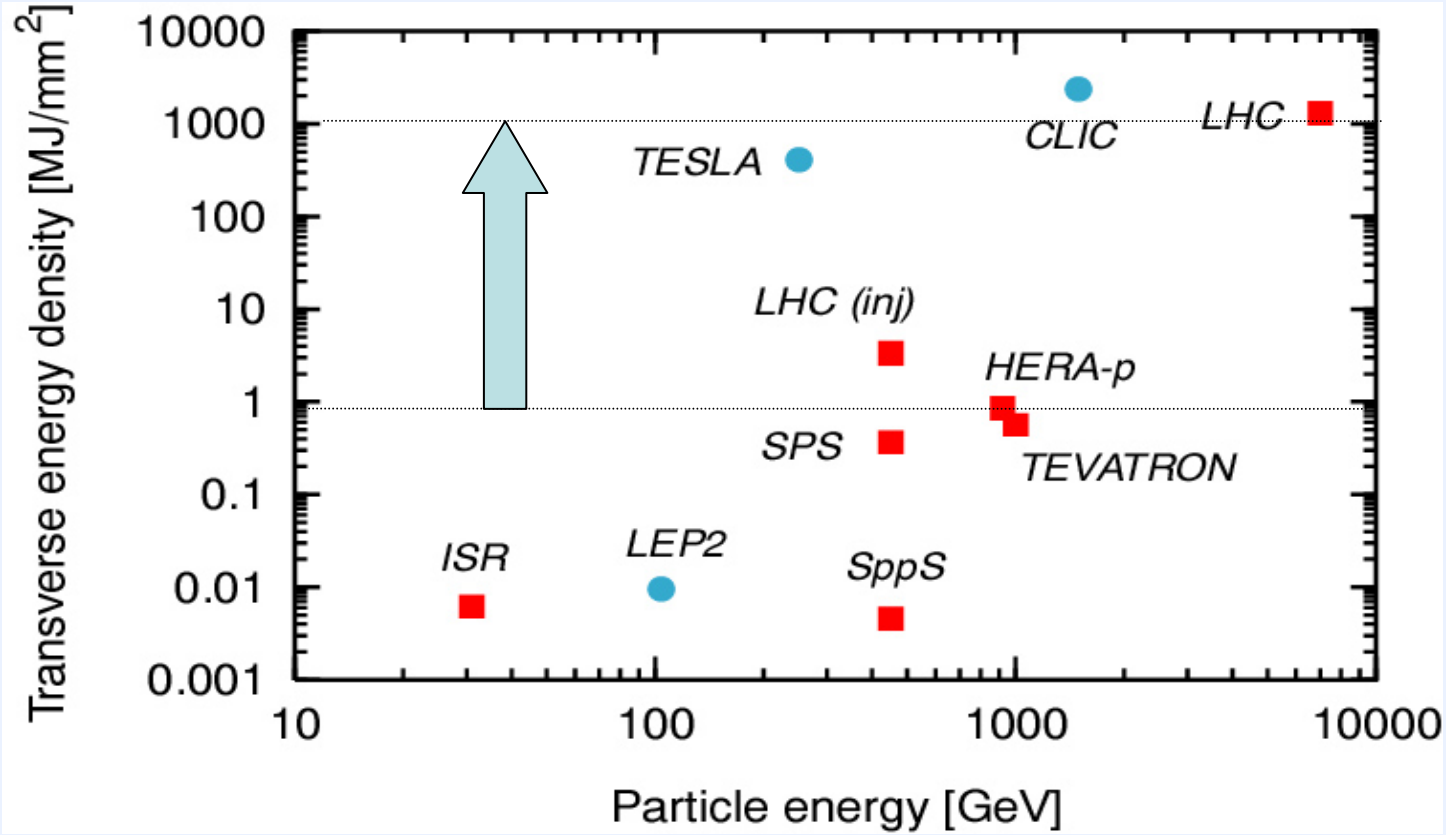


Factor ~ 200

Control losses ~ 1000 times better than present state-of-the-art!

R. Assmann

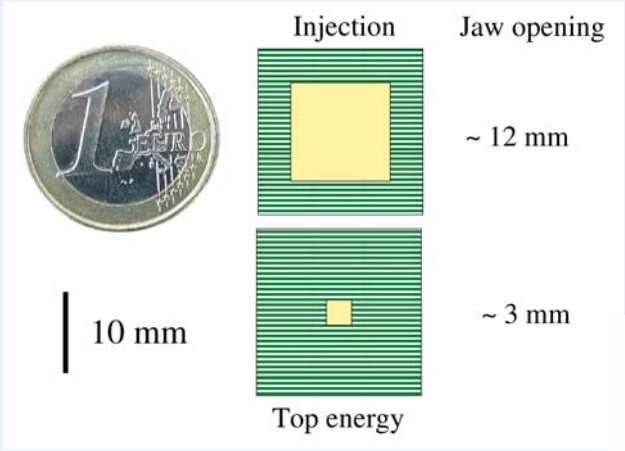
Collimation



At less than 1% of nominal intensity LHC enters new territory. Collimators must survive expected beam loss.

Courtesy of R. Assmann

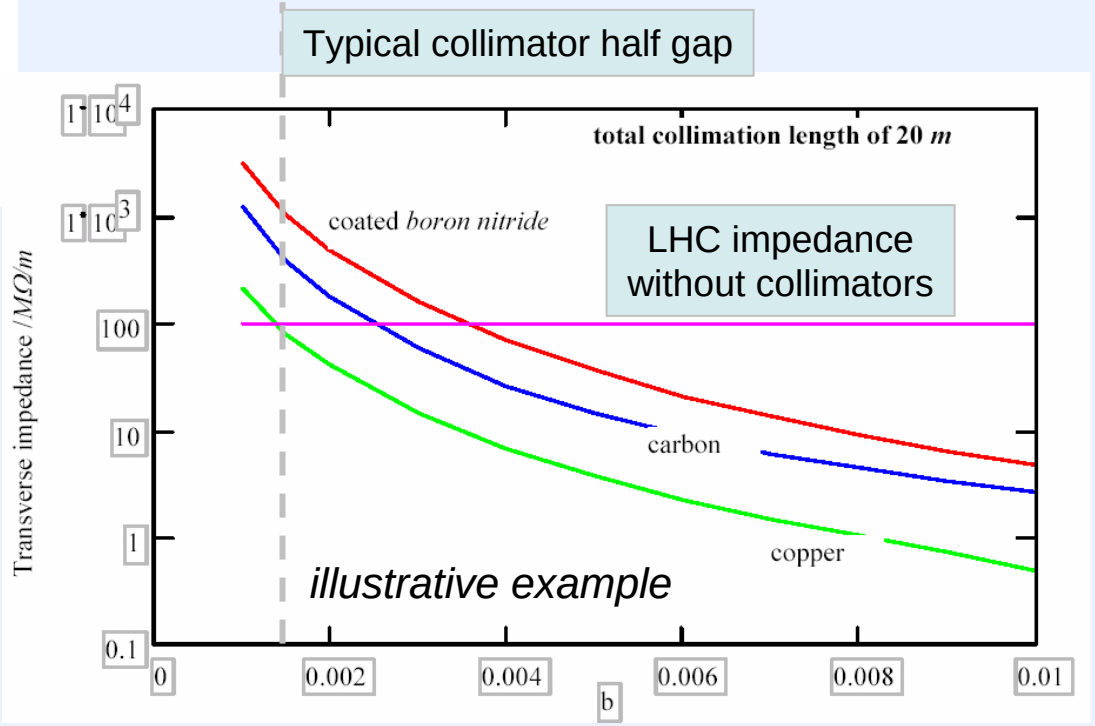
Collimating with small gaps



LHC beam will be physically quite close to collimator material and collimators are long (up to 1.2 m)!

Machine impedance increases while closing collimators (Carbon curve).

LHC will operate at the **impedance limit** with collimators closed!



Courtesy of R. Assmann

Collimator Test – Beam Impact