CARE-HHH-APD Mini-Workshop on

Electron-Cloud Mitigation "ECM'08"

CERN, 20-21 November 2008

organized by Vincent Baglin, Sergio Calatroni, Giovanni Rumolo, Frank Zimmermann

Welcome and Goals

Frank Zimmermann
CERN, Geneva, 20 November 2008

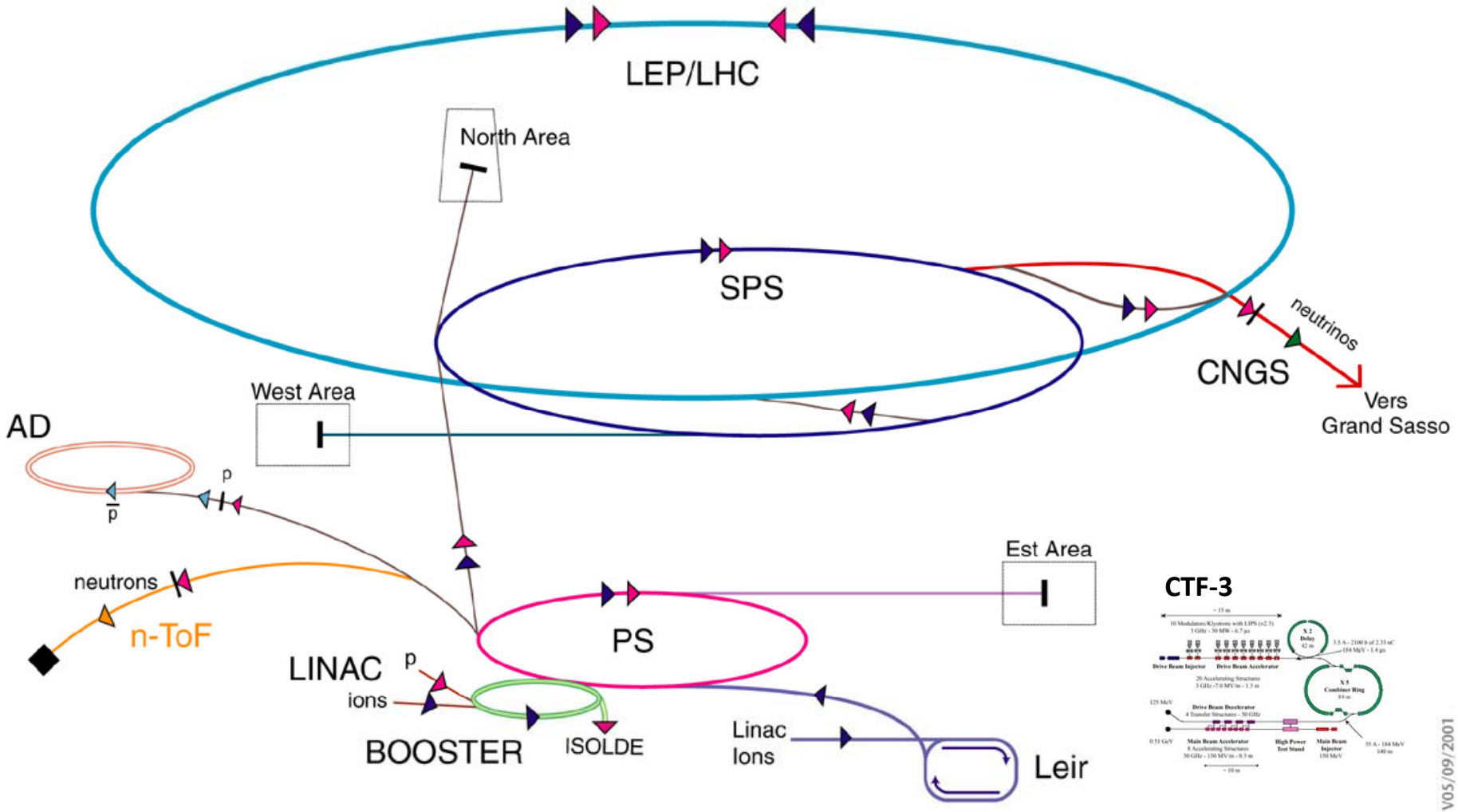
We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

CERN main accelerators

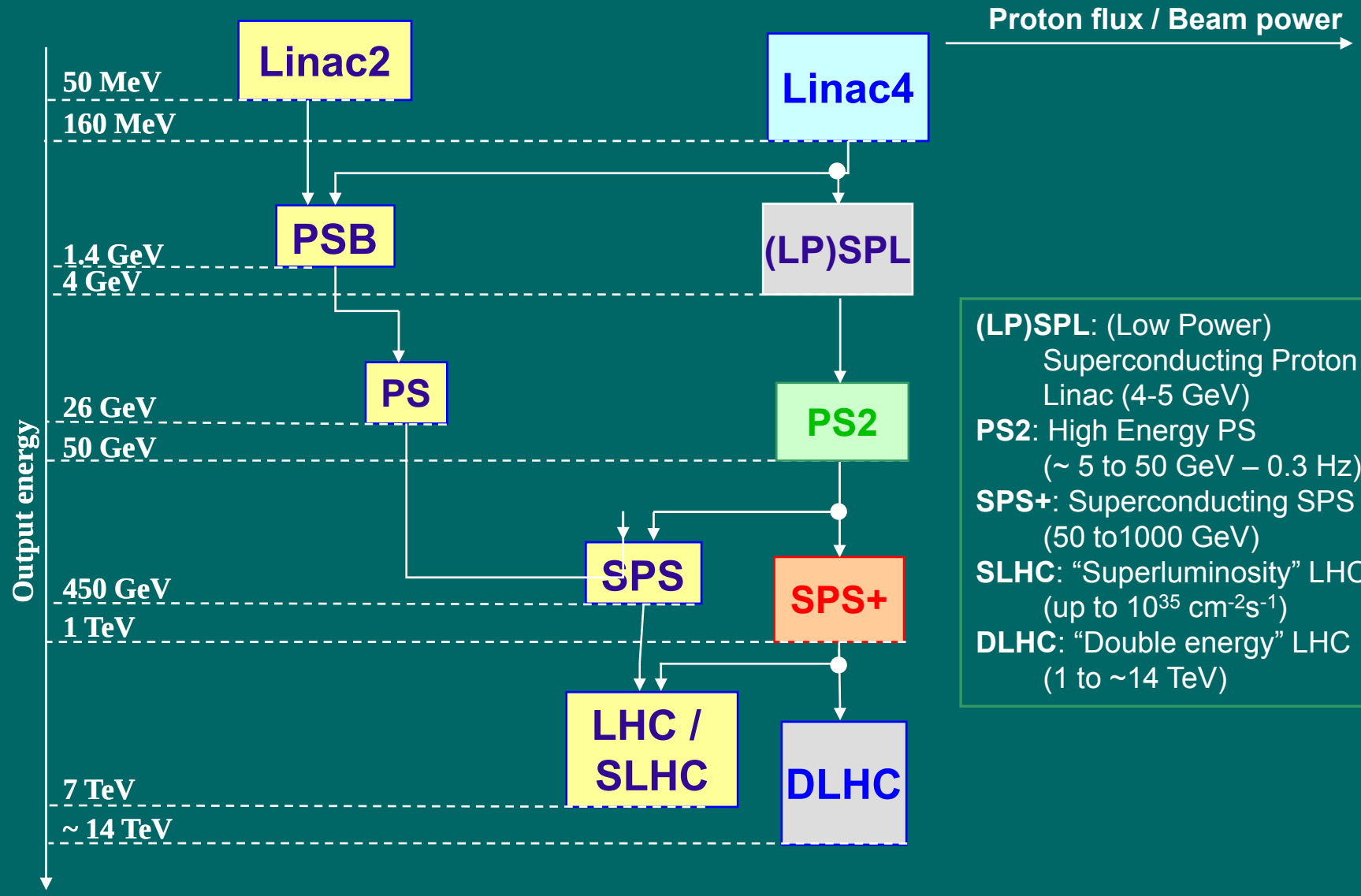
- PS - Proton Synchrotron (1959-)
  first strong-focusing proton ring !
- ISR - Intersecting Storage Rings (1971-1985)
  first hadron collider!
  first proton-antiproton collider!
- SPS - Super Proton Synchrotron (1976-)
- LEP - Large Electron-Positron storage ring (1989-2001)
  highest energy e+e- collider!
- LHC - Large Hadron Collider (2008-)
  highest energy proton/ion collider!
- SLHC - Super LHC (~2017-)
- CLIC - Compact Linear Collider (~2023?-)

colour code: stopped, in operation, planned

Accelerator chain of CERN (operating or approved projects)



accelerator upgrade plan



(LP)SPL: (Low Power) Superconducting Proton Linac (4-5 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (1 to ~14 TeV)

(my) brief history of e-cloud studies at CERN

1971 ISR e-cloud with coasting beam (Hereward, Keil, Zotter)

1977 beam-induced multipacting at ISR (Grobner)

1995 e-cloud at KEK Photon Factory: “Ohmi effect”

1997 1st simulation of e-cloud in LHC (Zimmermann); start of CERN e-cloud crash program (Ruggiero)

1999 first observation of e-cloud effects with LHC beam in SPS (Arduini, Collier, Cornelis, Hofle,..)

2000 SPS e- diagnostics (Baglin, Hilleret, Jimenez,…); single-bunch ec effects (Ohmi, Zimmermann); simulation codes development (Rumolo)

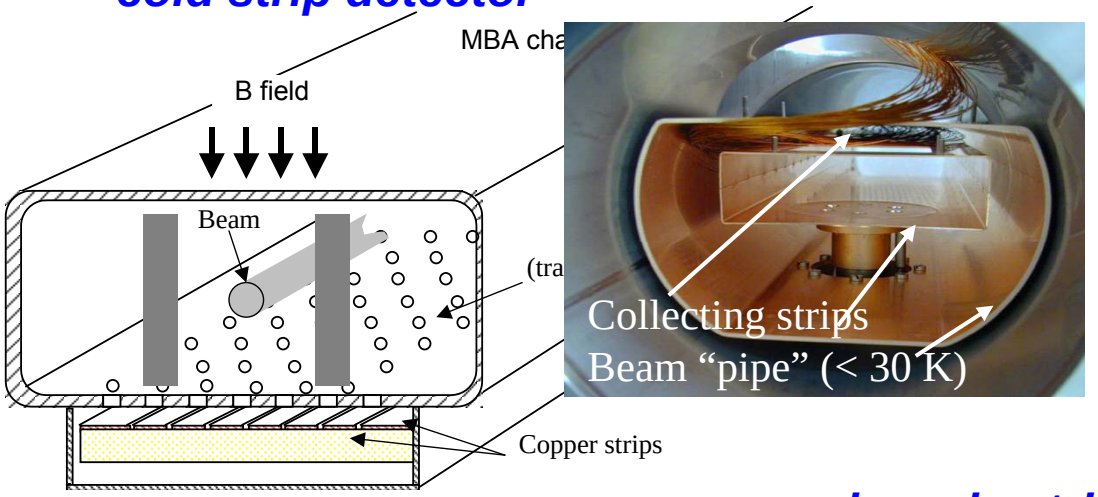
2001 first observation of e-cloud effects with LHC beam in the PS (Cappi, Giovannozzi, Metral,…)

2004 incoherent ec effects (Franchetti, Benedetto,…)

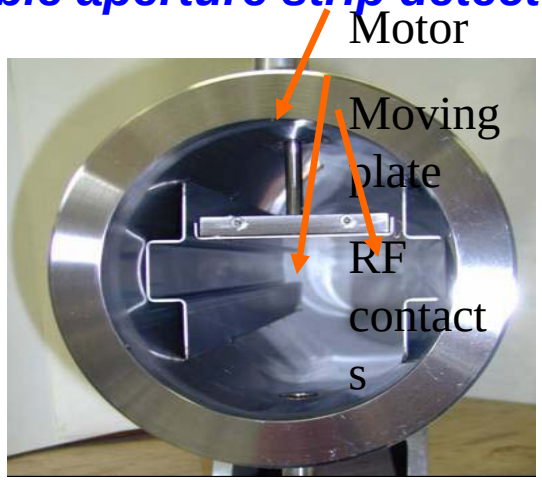
2007 SPS+ mitigation studies (Calatroni, Caspers, Chiggiato, Mahner, Shaposhnikova, Taborelli,…)

e- cloud diagnostics @ SPS

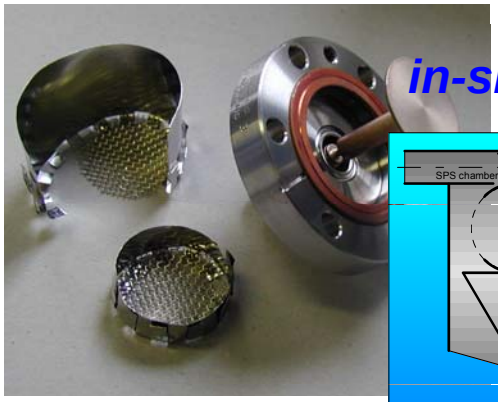
cold strip detector



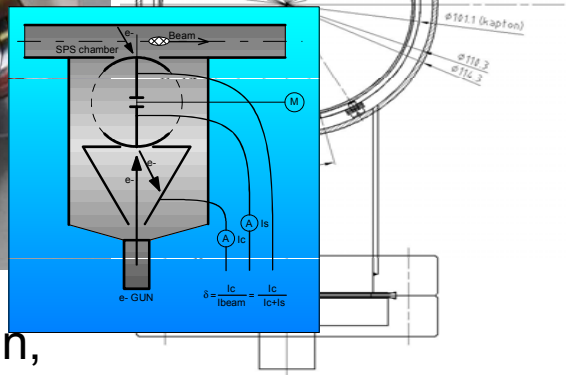
variable aperture strip detector



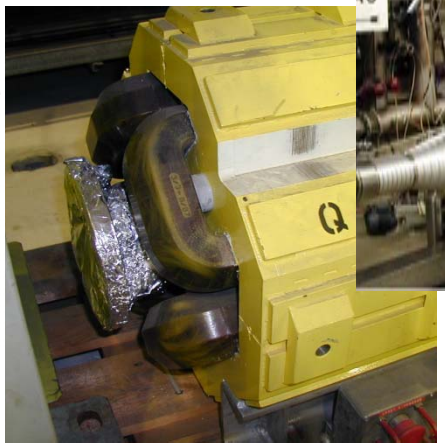
shielded pick ups



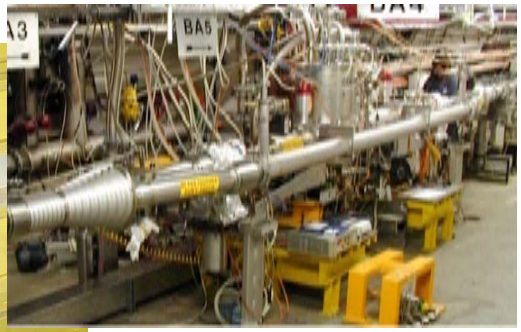
in-situ δ_{max}



quadrupole strip detector



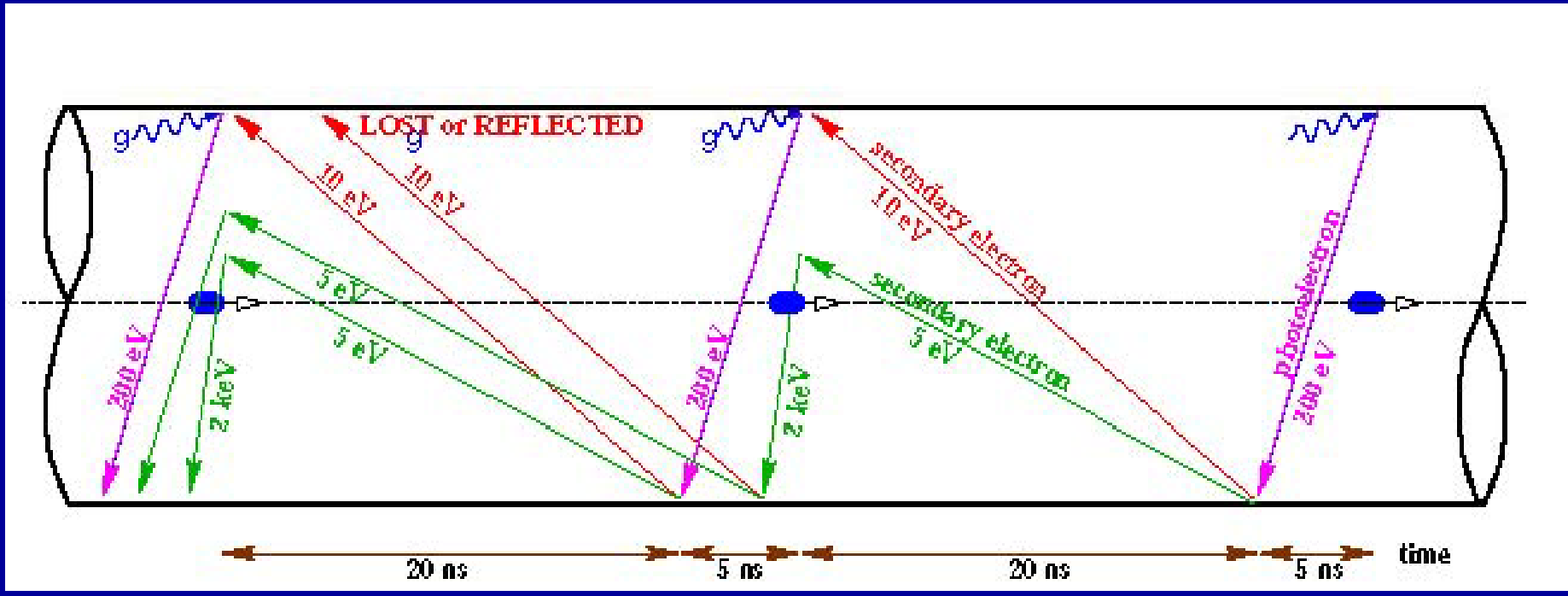
COLDEX



+ WAMPAC1-4
+ pick-up calor.
+ SD1-2 + RGAs…

J.M.Jimenez, V. Baglin,
N. Hilleret et al.

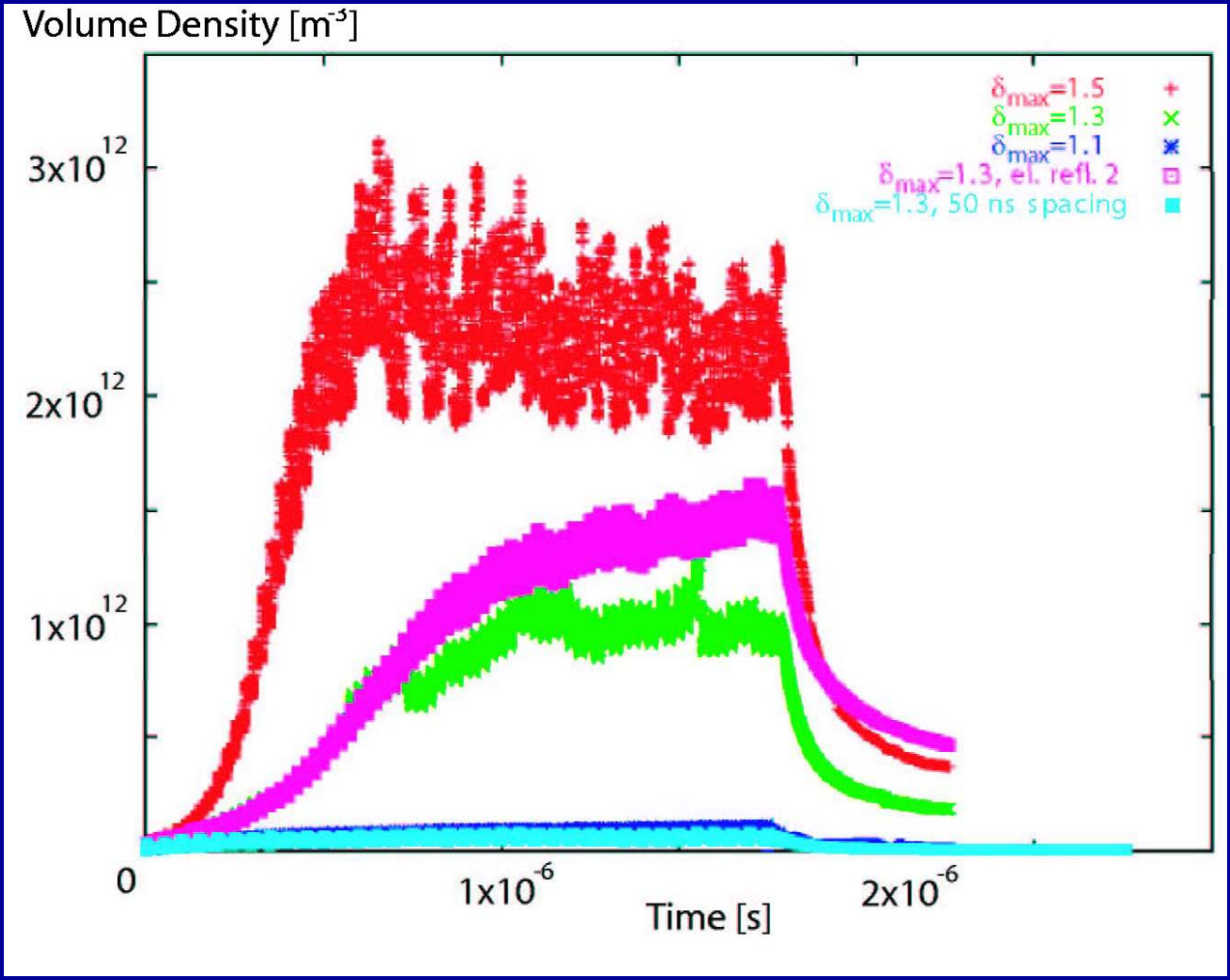
electron cloud in the LHC



schematic of e- cloud build up in the arc beam pipe, due to **photoemission** and **secondary emission**

[F. Ruggiero]

electron build up



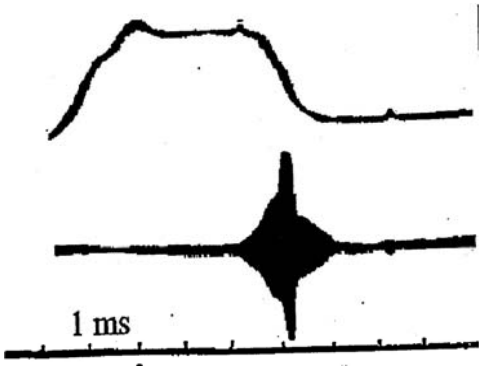
LHC arc dipole simulated by ECLOUD code, 2004

electron cloud effects

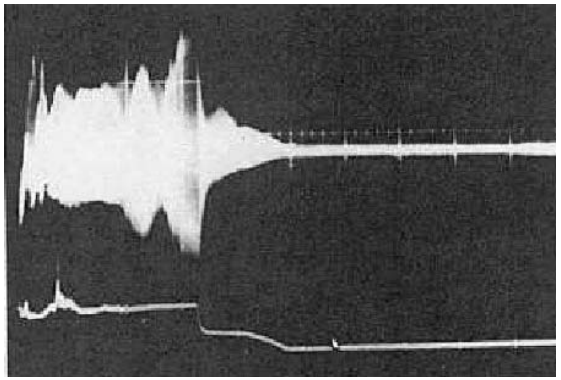
impact on beam diagnostics
sparking (el.-static septum)
outgassing (ferrite kickers)
vacuum pressure rise
heat load (inside cold magnets)
multi-bunch instability (beam loss)
single-bunch instability (beam loss)
incoherent (beam lifetime)

electron-cloud driven beam instabilities

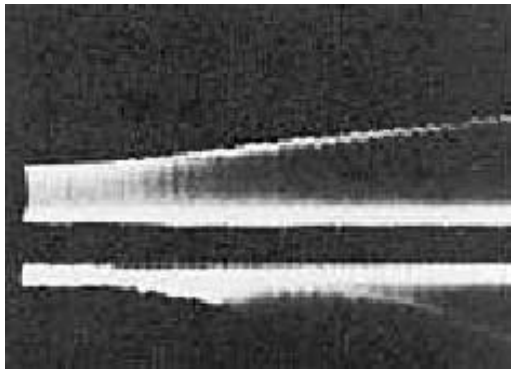
INP Novosibirsk, 1965



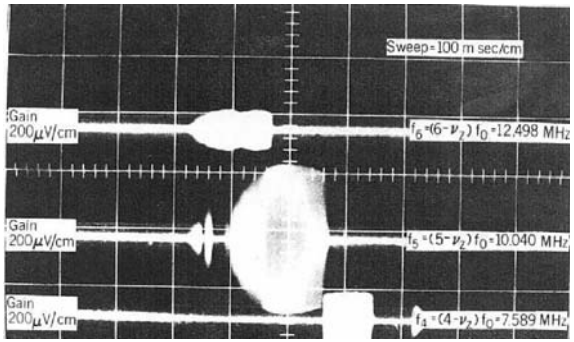
Argonne ZGS,1965



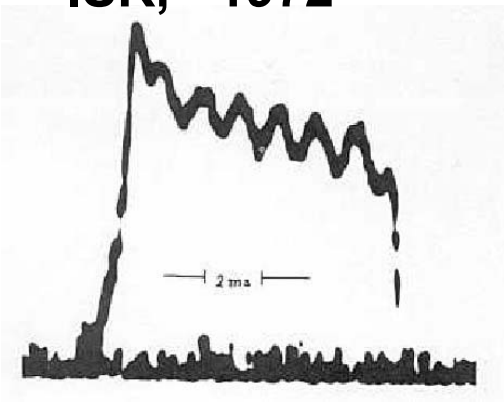
BNL AGS, 1965



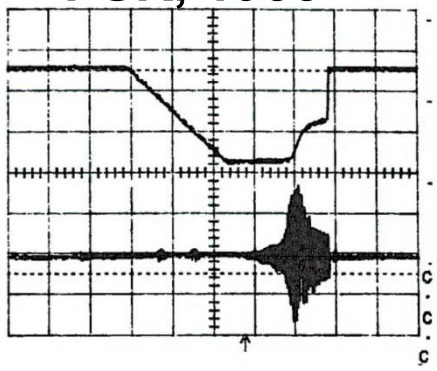
Bevatron, 1971



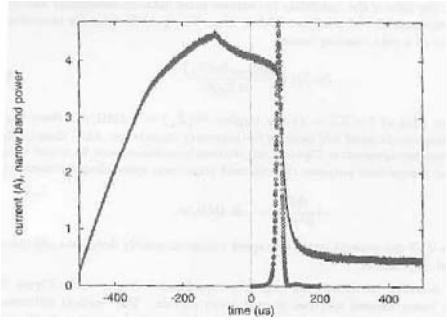
ISR, ~1972



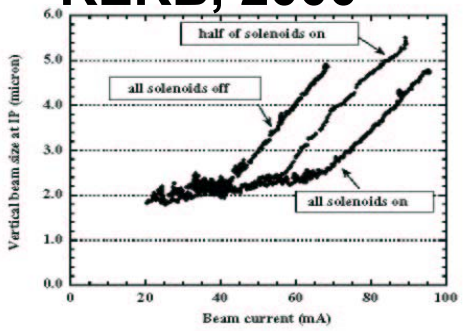
PSR, 1988



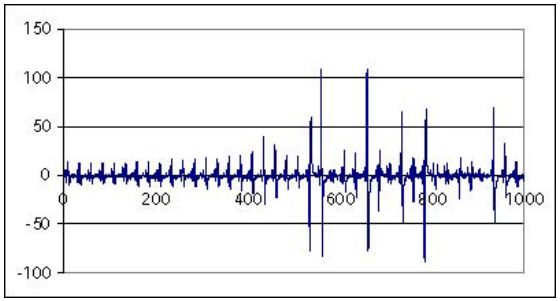
AGS Booster, 1998/99



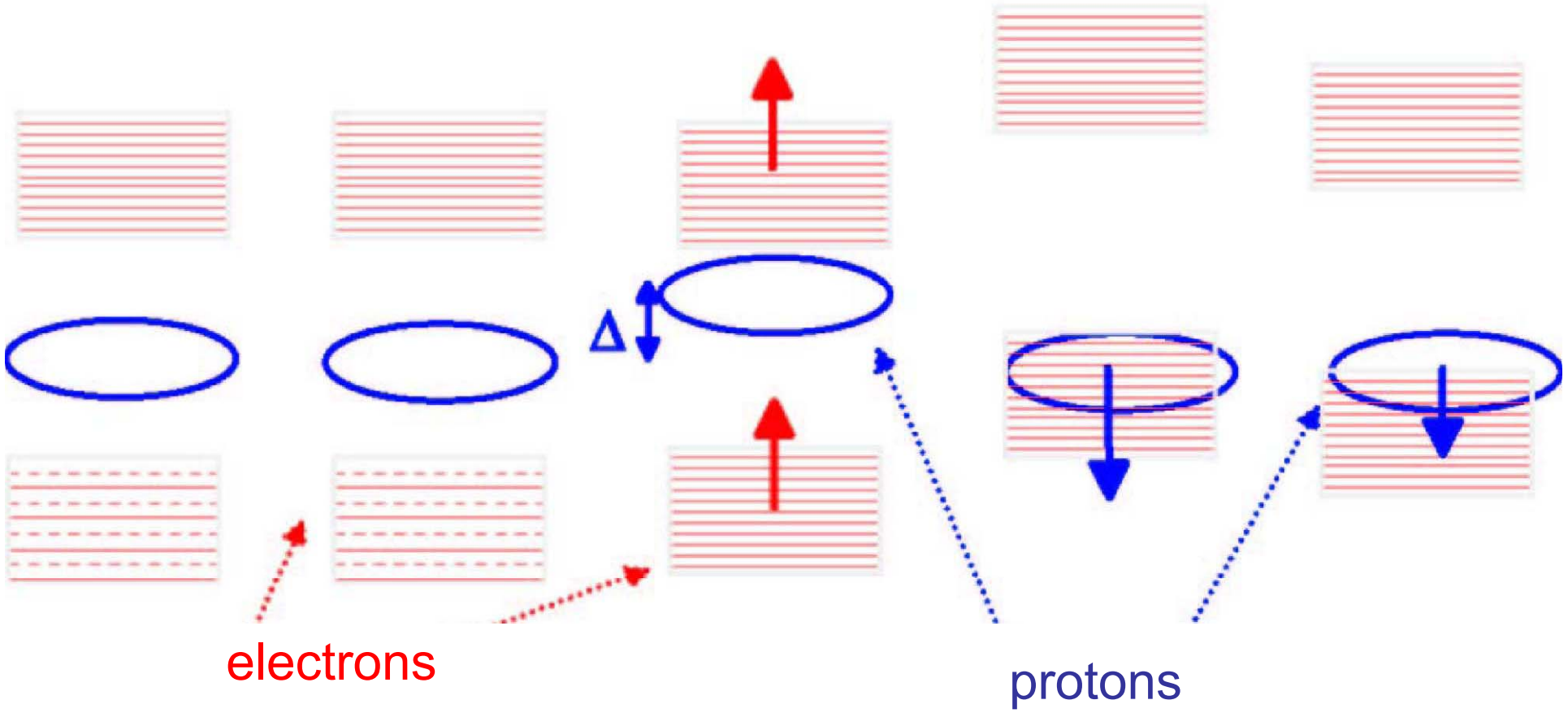
KEKB, 2000



CERN SPS, 2000



coupled-bunch instability

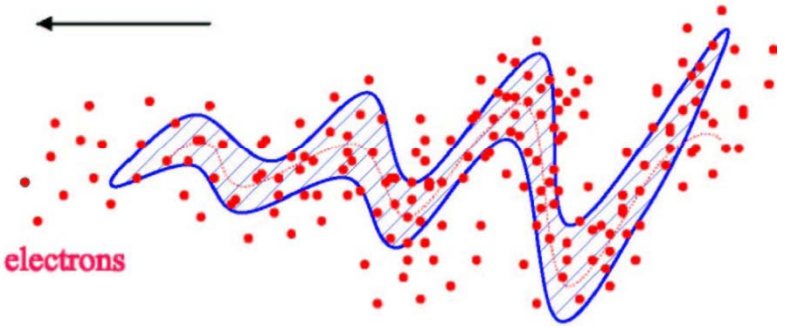


extrapolating instability threshold from SPS to LHC

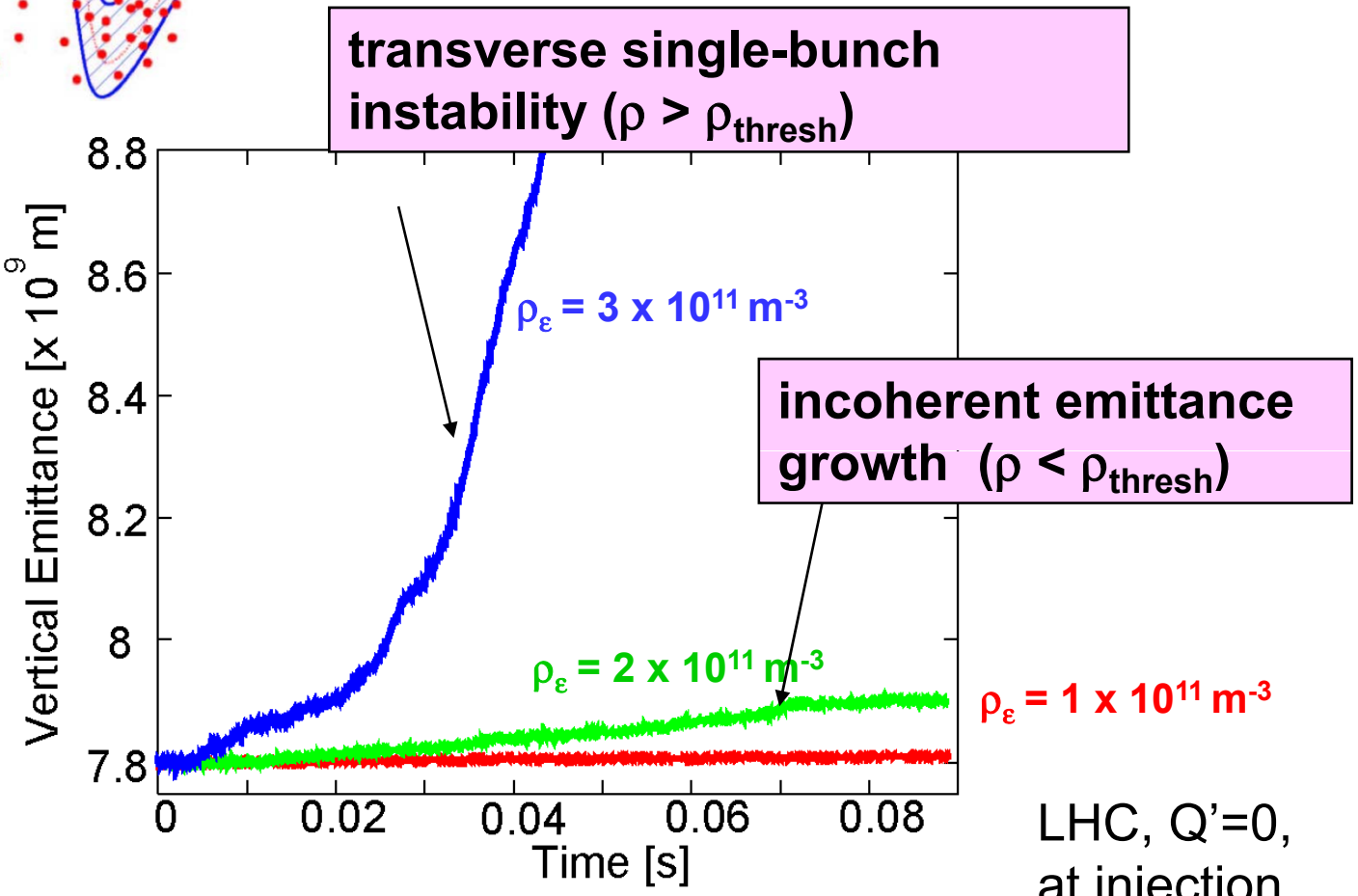
$$\tau_{CB} \approx \frac{\gamma}{2\pi r_p c\ \beta\rho}$$

SPS: 26 GeV/c, β~40 m; LHC: 450 GeV/c, β~100 m
→ CBI is ~7 times weaker in LHC

single-bunch instability



fast ε growth above e- density threshold; slower ε growth below



LHC, Q'=0, at injection

E. Benedetto

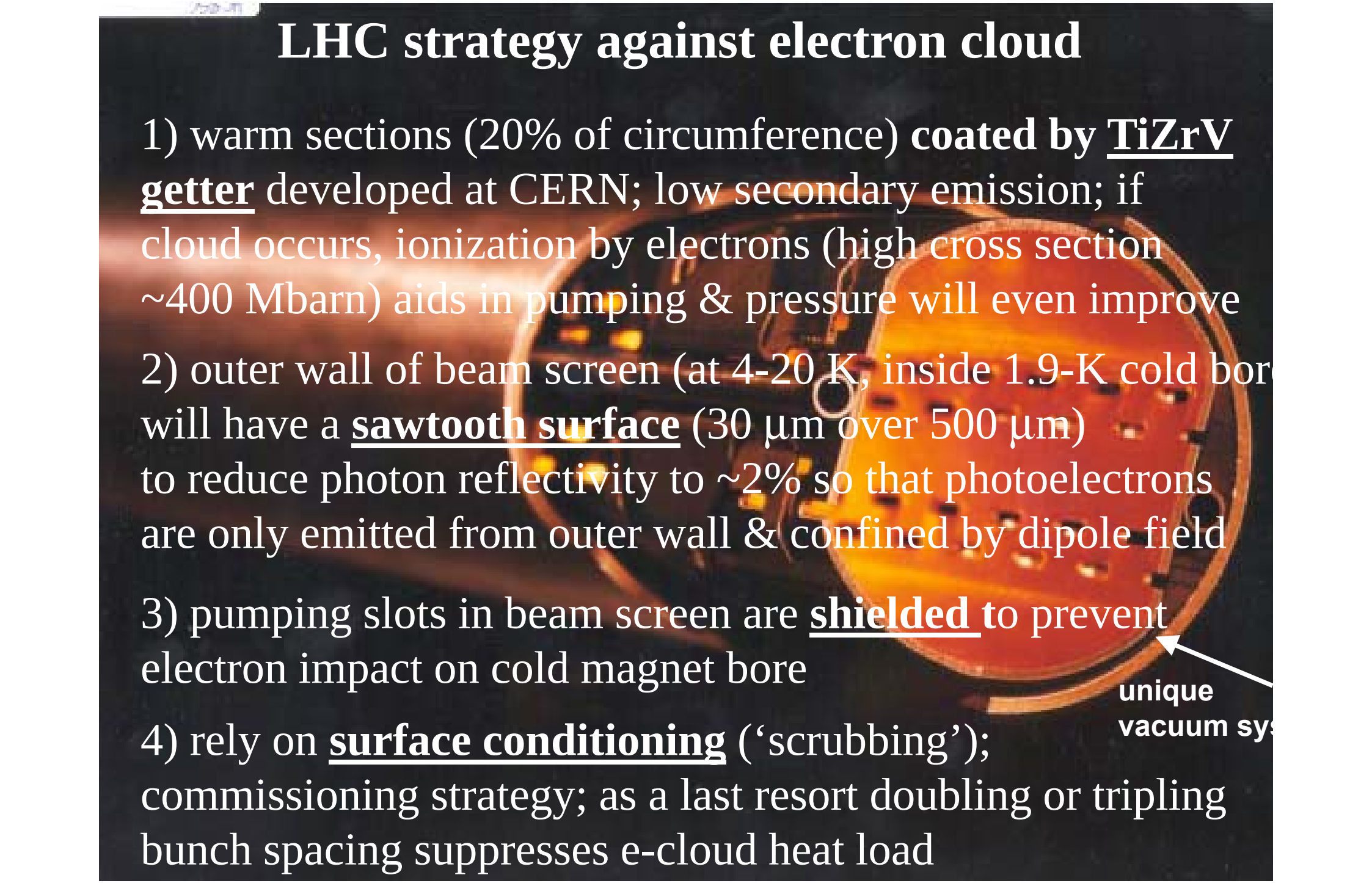
LHC strategy against electron cloud

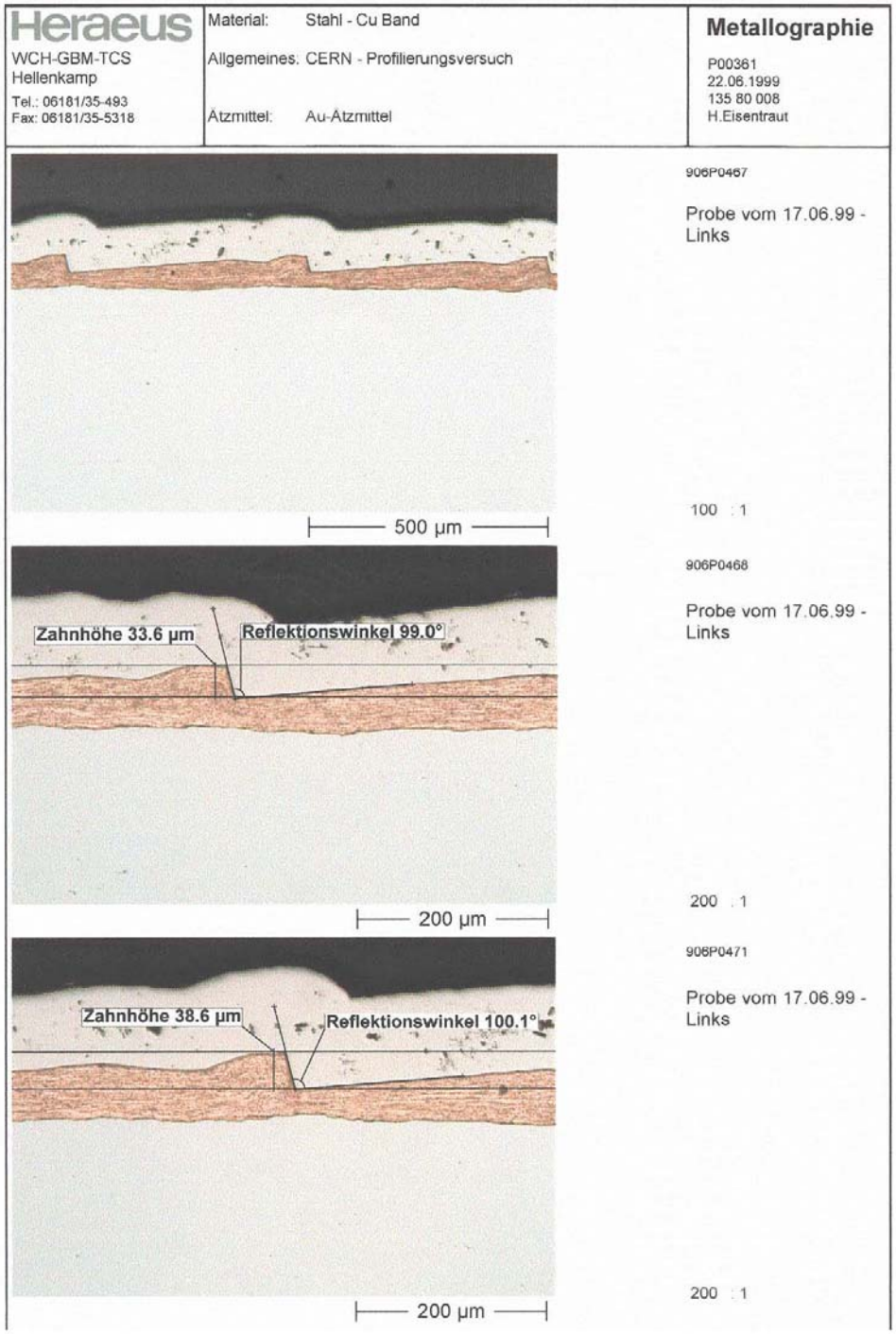
1) warm sections (20% of circumference) **coated by TiZrV getter** developed at CERN; low secondary emission; if cloud occurs, ionization by electrons (high cross section ~400 Mbarn) aids in pumping & pressure will even improve

2) outer wall of beam screen (at 4-20 K, inside 1.9-K cold bor will have a **sawtooth surface** (30 μm over 500 μm) to reduce photon reflectivity to ~2% so that photoelectrons are only emitted from outer wall & confined by dipole field

3) pumping slots in beam screen are **shielded** to prevent electron impact on cold magnet bore

4) rely on **surface conditioning** ('scrubbing'); commissioning strategy; as a last resort doubling or tripling bunch spacing suppresses e-cloud heat load

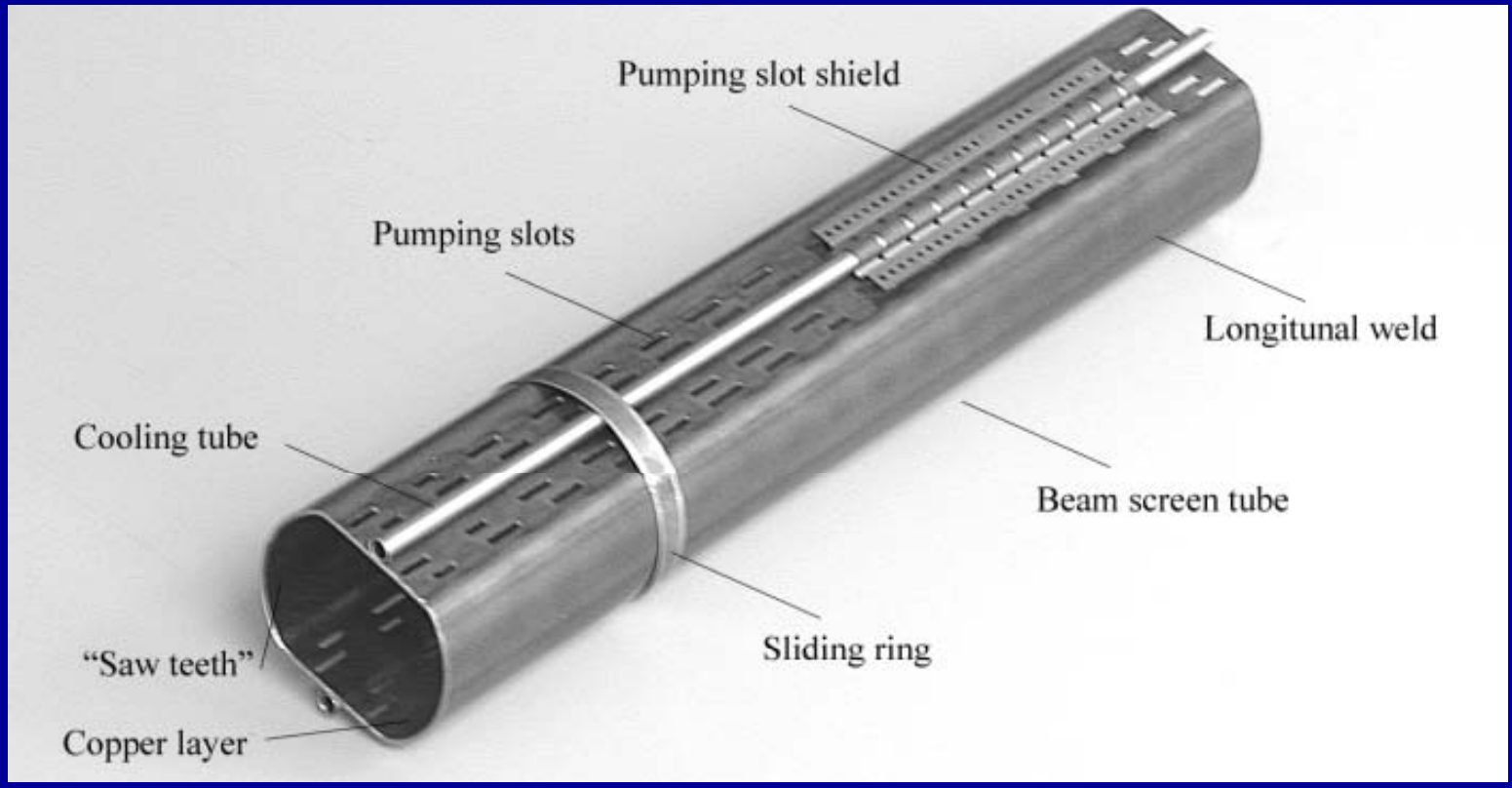




LHC
"sawtooth"
chamber

perpendicular
photon impact
→
reduced
photoemission
yield

beam-screen shield



"Finally, as it was recognized that electron clouds could deposit significant power into the cold bore through the pumping slots, the latter are shielded with a structure made of copper beryllium and clipped onto the cooling tubes. The net pumping speed for hydrogen is reduced by a factor of two [10], which remains acceptable." [LHC Design Report 2004]

parameter	symbol	nominal	ultimate	Early Sep.	Full Crab Xing	L. Piw Angle
transverse emittance	ε [μm]	3.75	3.75	3.75	3.75	3.75
protons per bunch	N_b [10^{11}]	1.15	1.7	1.7	1.7	4.9
bunch spacing	Δt [ns]	25	25	25	25	50
beam current	I [A]	0.58	0.86	0.86	0.86	1.22
longitudinal profile		Gauss	Gauss	Gauss	Gauss	Flat
rms bunch length	σ_z [cm]	7.55	7.55	7.55	7.55	11.8
beta* at IP1&5	β* [m]	0.55	0.5	0.08	0.08	0.25
full crossing angle	θ_c [μrad]	285	315	0	0	381
Piwinski parameter	$\phi=\theta_c\sigma_z/(2*\sigma_x*)$	0.64	0.75	0	0	2.0
hourglass reduction		1.0	1.0	0.86	0.86	0.99
peak luminosity	L [10^{34} $cm^{-2}s^{-1}$]	1	2.3	15.5	15.5	10.7
peak events per #ing		19	44	294	294	403
initial lumi lifetime	τ_L [h]	22	14	2.2	2.2	4.5
effective luminosity ($T_{turnaround}$=10 h)	L_{eff} [10^{34} $cm^{-2}s^{-1}$]	0.46	0.91	2.4	2.4	2.5
	$T_{run,opt}$ [h]	21.2	17.0	6.6	6.6	9.5
effective luminosity ($T_{turnaround}$=5 h)	L_{eff} [10^{34} $cm^{-2}s^{-1}$]	0.56	1.15	3.6	3.6	3.5
	$T_{run,opt}$ [h]	15.0	12.0	4.6	4.6	6.7
e-c heat SEY=1.4(1.3)	P [W/m]	1.07 (0.44)	1.04 (0.59)	1.04 (0.59)	1.04 (0.59)	0.36 (0.1)
SR heat load 4.6-20 K	P_{SR} [W/m]	0.17	0.25	0.25	0.25	0.36
image current heat	P_{IC} [W/m]	0.15	0.33	0.33	0.33	0.78
gas-s. 100 h (10 h) τ_b	P_{gas} [W/m]	0.04 (0.38)	0.06 (0.56)	0.06 (0.56)	0.06 (0.56)	0.09 (0.9)
extent luminous region	σ_l [cm]	4.5	4.3	3.7	3.7	5.3
comment		nominal	ultimate	D0 + crab	crab	wire comp.

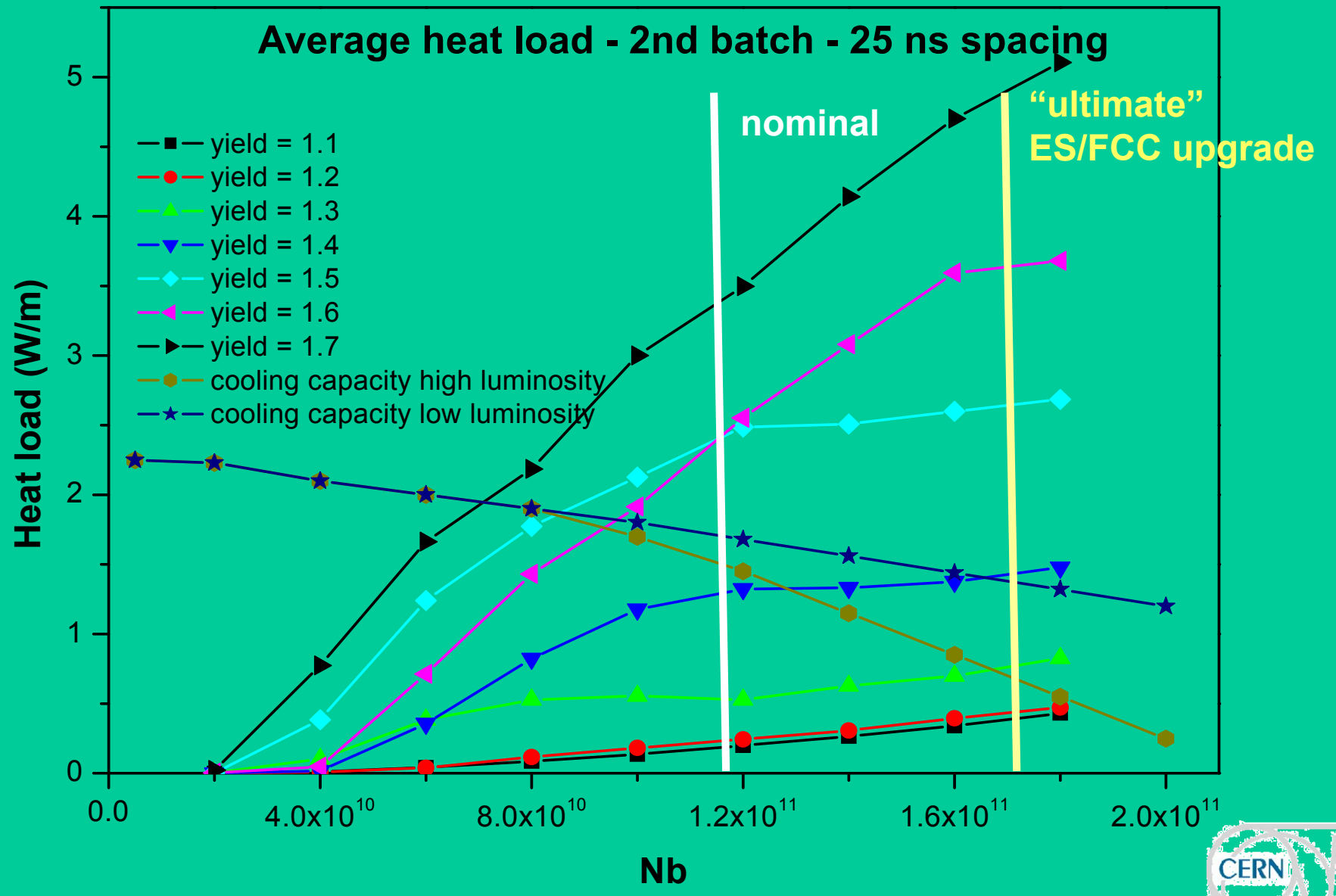
proposed LHC upgrades

early separation (ES)

full crab crossing (FCC)

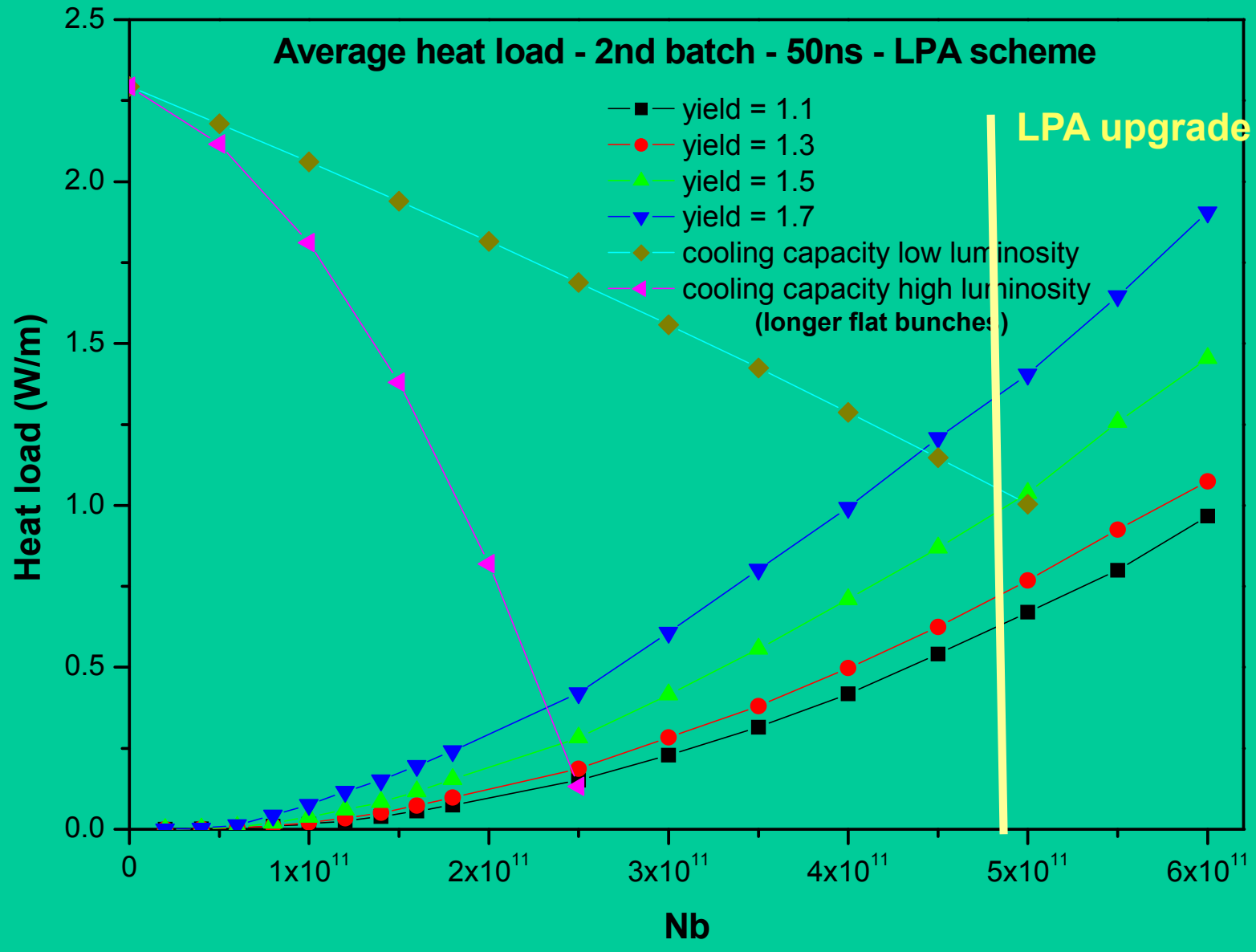
large Piwinski angle (LPA)

e- heat load simulated by ECLOUD code



Humberto Maury Cuna, CINVESTAV, Mexico, HELEN summer student 2008

e- heat load simulated by ECLOUD code



Humberto Maury Cuna, CINVESTAV, Mexico, HELEN summer student 2008

past e-cloud workshops:

…
2-Stream Instabilities, Santa Fe, USA, 2000
2-Stream Instabilities, KEK, Japan, 2001
ECLOUD'02 CERN
ECLOUD'04 Napa, USA
ECL2 CERN, March 2007
…
ECM'08, November 2008!

ECM'08 was first suggested by Walter Scandale

what is new?

ideas and initiatives from/since ECL2:

- development & tests of novel coatings (carbon, black metals,…)
- conventional & enamel electrodes
- updated simulations (Mexico)
- microwave diagnostics
- transverse high-bandwidth feedback
- beam studies (e.g. coating, & scaling)
- possible synergies with ESA satellite community
- locally modulated static magnetic field

MULCOPIM'08

multipactoring, corona and passive intermodulation in high-power microwave systems for satellite applications

Valencia 24-26 September 2008

jointly organized by ESA, Polytechnical University of Valencia, U. of Valencia & AURORASAT

130-140 participants, 50 plenary talks

1st time accelerator community was invited (3 papers)

3 CERN participants supported by CARE-HHH: Fritz Caspers, Giovanni Rumolo, Frank Zimmermann

a lot of overlap with accelerator studies (simulations, surface models, mitigation schemes,…)

ECM'08 goals

- discuss surface treatments
- review 2007/8 lab & beam measurements (PS & SPS)
- discuss solutions for PS2 & SPS+
- revisit e-cloud & diagnostics for LHC
- review e-cloud at ANKA, DAFNE, CESR, KEKB
- review simulation codes
- explore areas of collaboration with ESA/satellite community

workshop agenda:

session 1: overview of e-cloud related activities & projects (**6 talks**; conv: R. Cimino, G. Rumolo)

session 2: mitigation methods - coatings, electrodes, feedback (**10 talks**; conv: L. Galan, S. Calatroni)

session 3: beam measurements (**9 talks**; conv: J. Fox, V. Baglin)

session 4: electron-cloud simulations (**10 talks**; conv: D. Raboso, F. Zimmermann)

& no-host dinner in Auberge Communale Meyrin

CERN

20:00 dinner
total price 65-70 CHF

19:45 meeting in
front of restaurant 1

CERN drivers?

useful links:

ECM'08 workshop
http://indico.cern.ch/conferenceDisplay.py?confId=42645

LHC electron cloud web site:
http://ab-abp-rlc.web.cern.ch/ab-abp-rlc-ecloud/

CARE-HHH web site
http://care-hhh.web.cern.ch/CARE-HHH/

CARE-HHH accelerator code web repository
http://oraweb.cern.ch/pls/hhh/code_website.startup


happy clouds!