HHH

LHC Phase-II Upgrade Scenarios

W. Scandale, F. Zimmermann

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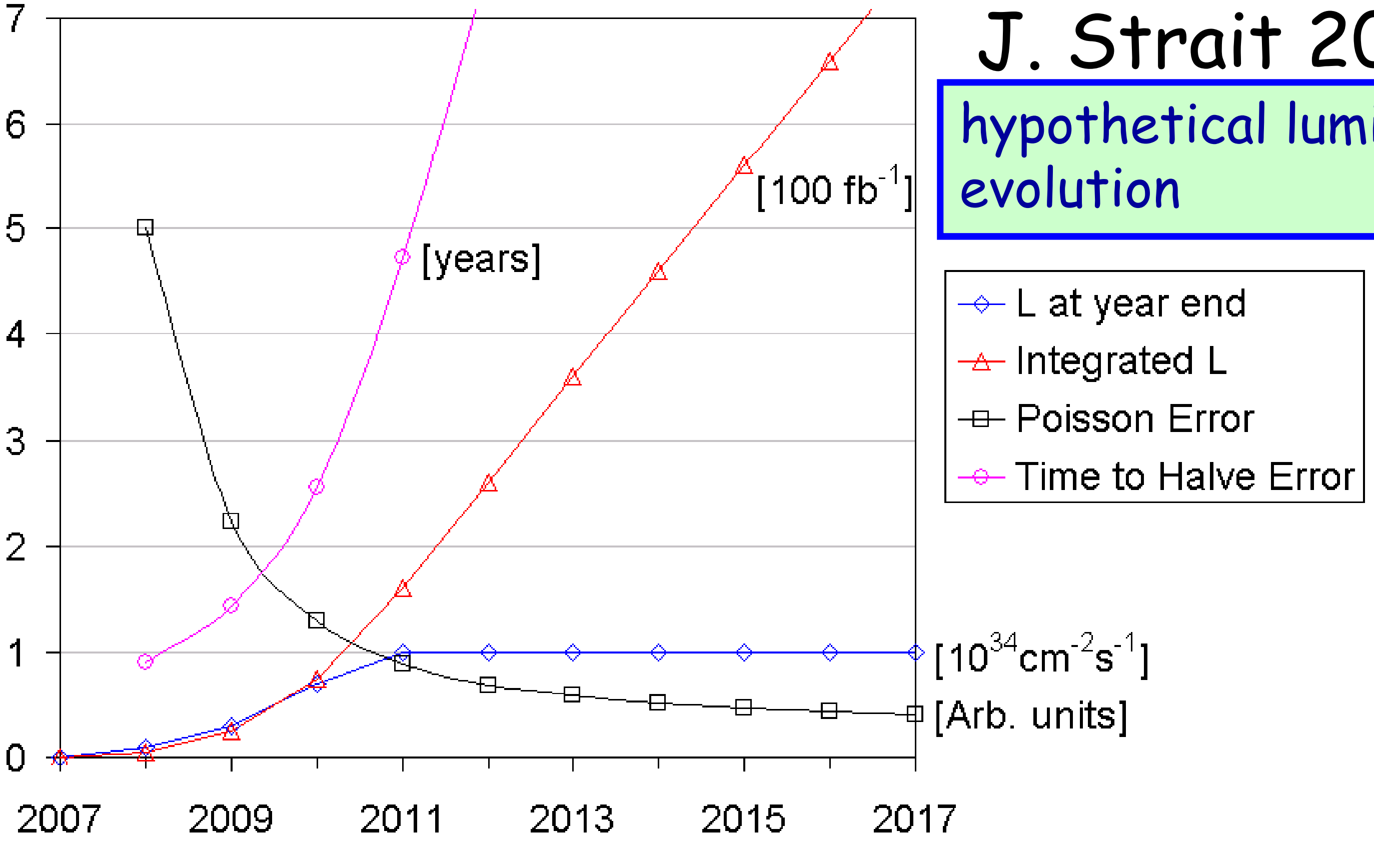
outline

- ✓ motivation & staged approach
- ✓ upgrade scenarios
  & luminosity levelling
- ✓ injector upgrade & schedule
- ✓ crab cavities
- ✓ complementary advanced schemes
  - *LR + HO beam-beam compensation, e-cloud mitigation, crystal collimation, cooling, crab waists,…*
- ✓ strategy for “phase 2”

motivation & staged approach

Three Strong Reasons for LHC Upgrade



J. Strait 2003

hypothetical luminosity evolution

1) after few years, **statistical error** hardly decreases
2) **radiation damage** limit of **IR quadrupoles** (~700 fb^{-1})
reached by ~2016 =→ time for an upgrade!
3) **extending physics potential**! (A. de Roeck et al)

staged approach to LHC upgrade

"phase 1" 2013:

new triplets, D1, TAS, $\beta^*=0.25$ m in IP1 & 5,
reliable LHC operation at ~2-3x luminosity;
beam from new Linac4

"phase 2" 2017:

target luminosity 10x nominal,
possibly Nb_3Sn triplet & $\beta^*\sim 0.15$ m

+ injector upgrade

complementary measures 2010-2017:

e.g. long-range beam-beam compensation,
crab cavities, new/upgraded injectors, advanced
collimators, coherent e- cooling??, e- lenses??

phase-2 might be just phase 1 plus complementary measures

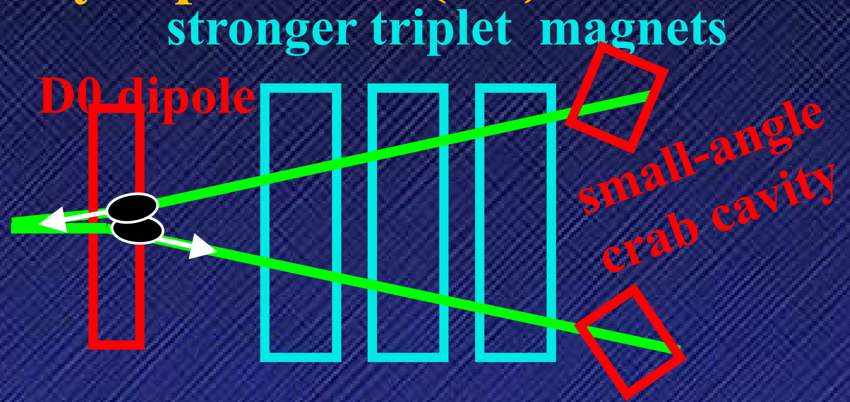
longer term (2020?): energy upgrade, LHeC,…

upgrade scenarios
& luminosity leveling

LHC phase-2 upgrade paths for IP1 & 5

early separation (ES)

J.-P. Koutchouk

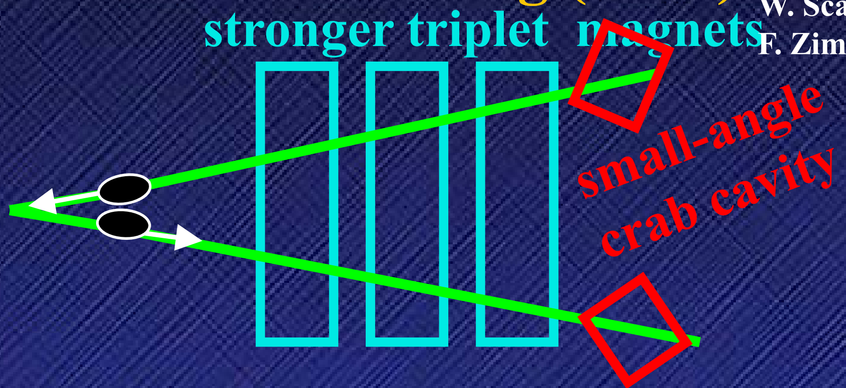


- ultimate beam ($1.7x10^{11}$ p's/bunch, 25 ns spacing), β* ~10 cm
- early-separation dipoles in side detectors , crab cavities

→ hardware inside ATLAS & CMS detectors,
first hadron crab cavities; off-δ β

full crab crossing (FCC)

L. Evans,
W. Scandale,
F. Zimmermann

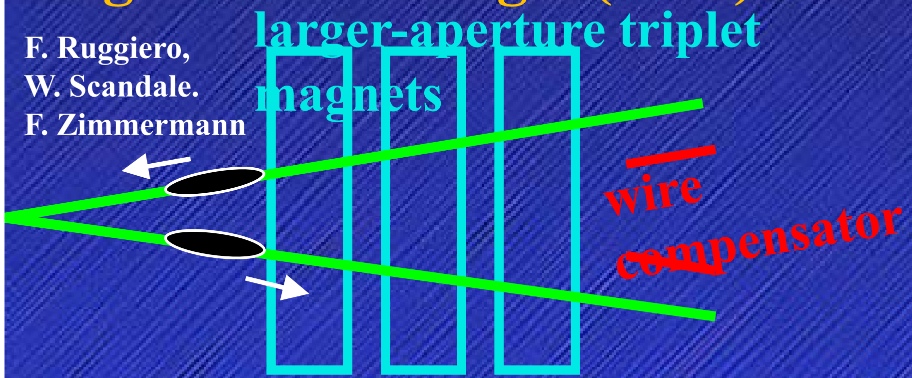


- ultimate LHC beam ($1.7x10^{11}$ p's/bunch, 25 ns spacing)
- β* ~10 cm
- crab cavities with 60% higher voltage

→ first hadron crab cavities, off-δ β-beat

large Piwinski angle (LPA)

F. Ruggiero,
W. Scandale.
F. Zimmermann

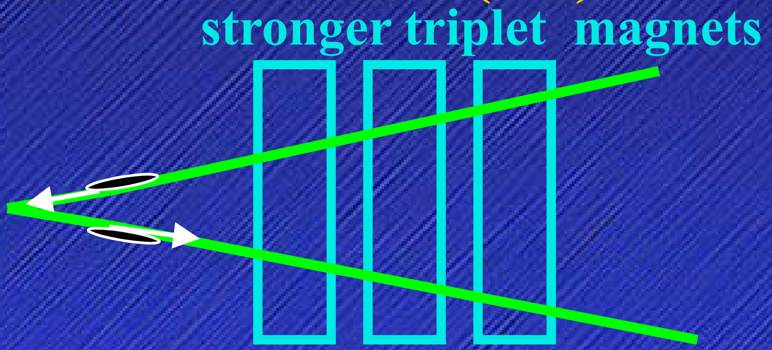


- 50 ns spacing, longer & more intense bunches ($5x10^{11}$ p's/bunch)
- β*~25 cm, no elements inside detectors
- long-range beam-beam wire compensation

→ novel operating regime for hadron colliders, beam generation

low emittance (LE)

R. Garoby



- ultimate LHC beam ($1.7x10^{11}$ p's/bunch, 25 ns spacing)
- β* ~10 cm
- smaller transverse emittance

→ constraint on new injectors, off-δ β-beat

"LE": rationale for lower emittance (R. Garoby); fundamental equations of LHC performance

$$\Delta Q_{bb} \cong -\frac{N_b}{\varepsilon_N} \frac{r_p}{2\pi\sqrt{1+\phi^2}}$$

$$\phi = \theta\sigma_Z/(2\sigma^*)$$

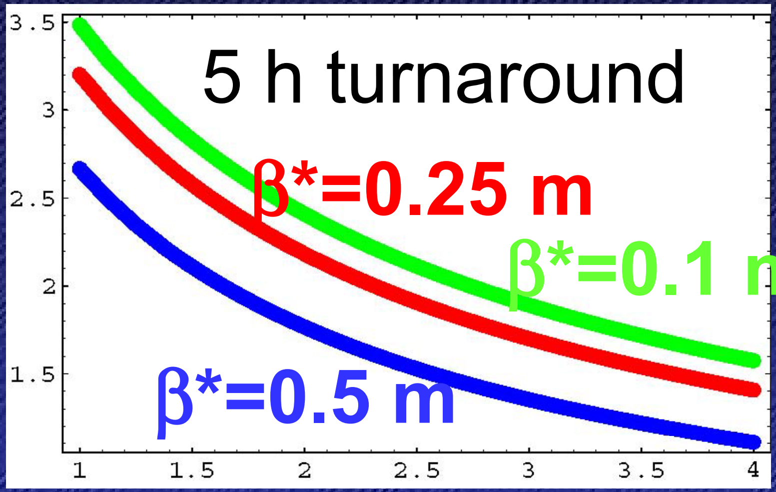
$$L = \frac{f_{rev}\gamma}{2r_p} n_b \frac{1}{\beta^*} N_b \Delta Q_{bb} F_{profile} F_{hg}$$

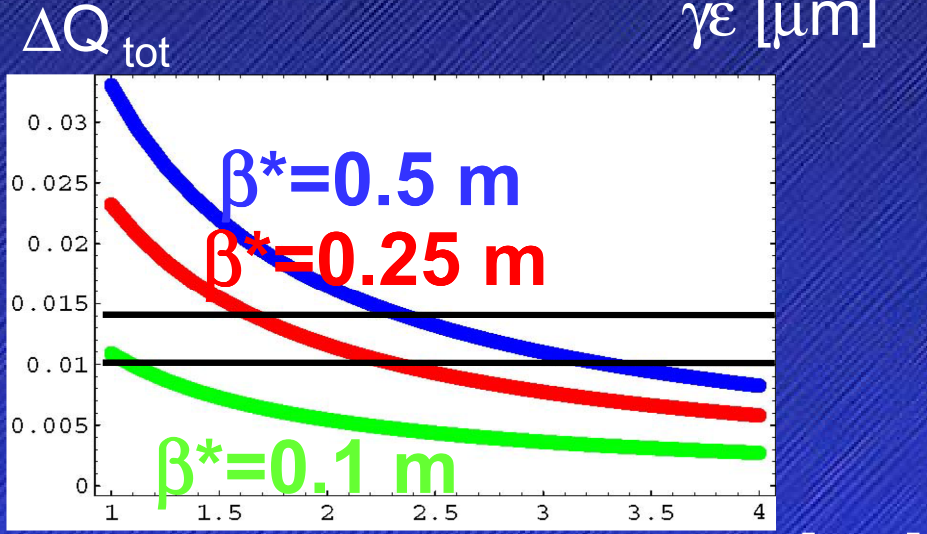
basic idea: reduce ε to compensate for larger Piwinski angle and get the full benefit of IR upgrade; at the same time the smaller emittance relaxes aperture constraints
→ possible implications for the injection design

<*L*> and ΔQ vs. emittance

ultimate Gaussian bunches,

<L> [10^{34} cm^{-2}s^{-1}] **25 ns**

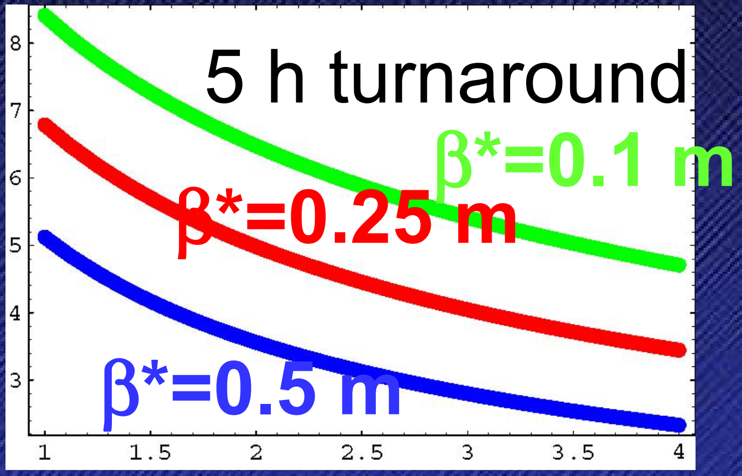


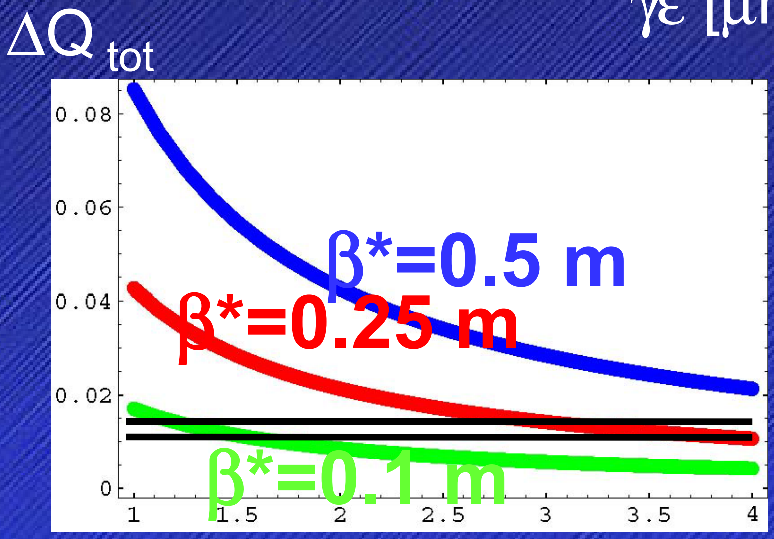


2808 bunches with 7.55 cm length, ultimate bunch intensity 1.7x10^{11}, 9.5 σ sep.

long flat "LPA" bunches,

<L> [10^{34} cm^{-2}s^{-1}] **50 ns**





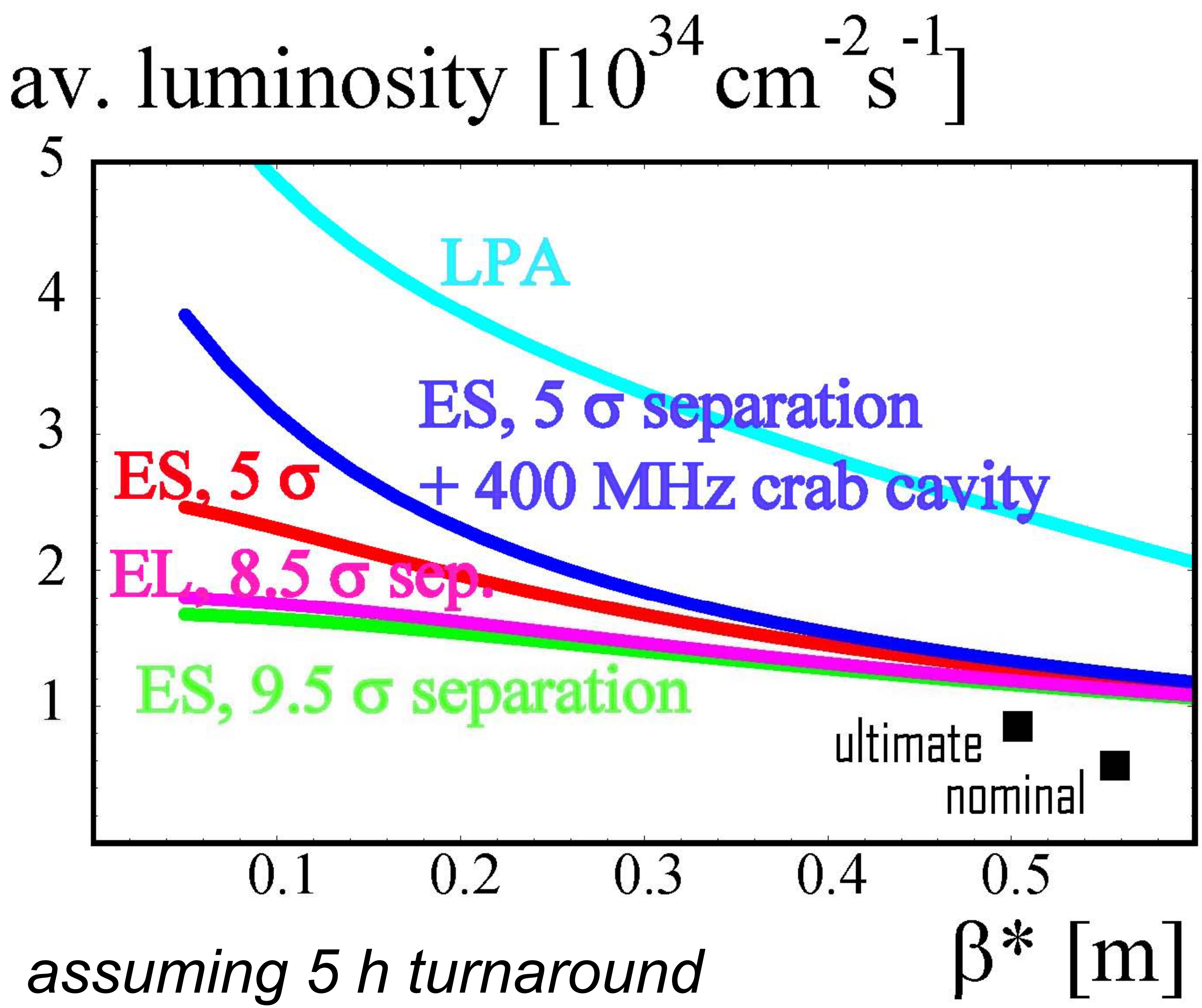
1404 bunches with 41 cm full length, bunch intensity 4.9x10^{11}, 8.5 σ sep.

luminosity gain from smaller emittance

- for Gaussian ultimate bunches and β^*~0.1-0.25 m, emittance reduction from 3.75 to **2 micron yields ~40-50% higher integrated luminosity**; a smaller emittance reduction to **2.6 micron gives ~22-27% av. luminosity increase**
- for long flat bunches and β^*~0.25, emittance can be reduced only to 3 micron (tune shift limit), and the luminosity gain here is 13%
- for comparison the luminosity gain from crab cavities would be ~90% for β^*~0.1 m

parameter	symbol	nominal	ultimate	**ES**	**FCC**	**LE**	**LPA**
transverse emittance	ε [μm]	3.75	3.75	**3.75**	**3.75**	**1.0**	**3.75**
protons per bunch	N_b [10^{11}]	1.15	1.7	**1.7**	**1.7**	**1.7**	**4.9**
bunch spacing	Δt [ns]	25	25	**25**	**25**	**25**	**50**
beam current	I [A]	0.58	0.86	**0.86**	**0.86**	**0..86**	**1.22**
longitudinal profile		Gauss	Gauss	**Gauss**	**Gauss**	**Gauss**	**Flat**
rms bunch length	σ_z [cm]	7.55	7.55	**7.55**	**7.55**	**7.55**	**11.8**
beta* at IP1&5	$\beta*$ [m]	0.55	0.5	**0.08**	**0.08**	**0.1**	**0.25**
full crossing angle	θ_c [μrad]	285	315	**0**	**0**	**311**	**381**
Piwinski parameter	$\phi=\theta_c\sigma_z/(2*\sigma_x*)$	0.64	0.75	**0**	**0**	**3.2**	**2.0**
geometric reduction		1.0	1.0	**0.86**	**0.86**	**0.30**	**0.99**
peak luminosity	L [10^{34} cm^{-2}s^{-1}]	1	2.3	**15.5**	**15.5**	**16.3**	**10.7**
peak events per #ing		19	44	**294**	**294**	**309**	**403**
initial lumi lifetime	τ_L [h]	22	14	**2.2**	**2.2**	**2.0**	**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**	**2.5**
	$T_{run,opt}$ [h]	21.2	17.0	**6.6**	**6.6**	**6.4**	**9.5**
effective luminosity ($T_{turnaround}$=5 h)	L_{eff} [10^{34} cm^{-2}s^{-1}]	0.56	1.15	**3.6**	**3.6**	**3.7**	**3.5**
	$T_{run,opt}$ [h]	15.0	12.0	**4.6**	**4.6**	**4.5**	**6.7**
e-c heat SEY=1.4(1.3)	P [W/m]	1.1 (0.4)	1.04(0.6)	**1.0 (0.6)**	**1.0 (0.6)**	**1.0 (0.6)**	**0.4 (0.1)**
SR heat load 4.6-20 K	P_{SR} [W/m]	0.17	0.25	**0.25**	**0.25**	**0.25**	**0.36**
image current heat	P_{IC} [W/m]	0.15	0.33	**0.33**	**0.33**	**0.33**	**0.78**
gas-s. 100 h (10 h) τ_b	P_{gas} [W/m]	0.04 (0.4)	0.06 (0.6)	**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**	**1.5**	**5.3**
comment		nominal	ultimate	**D0 + crab**	**crab**		**wire comp.**

average luminosity vs β*



assuming 5 h turnaround

2008 progress with all 4 scenarios

ES: 2008 SPS beam studies;
beam-beam working meeting August 2008;
detailed design & discussion with experiments;
→ *G. Sterbini, J.-P. Koutchouk*

FCC: two mini-workshops, global collaboration, joint studies with KEKB team; staged approach
→ *R. Calaga*

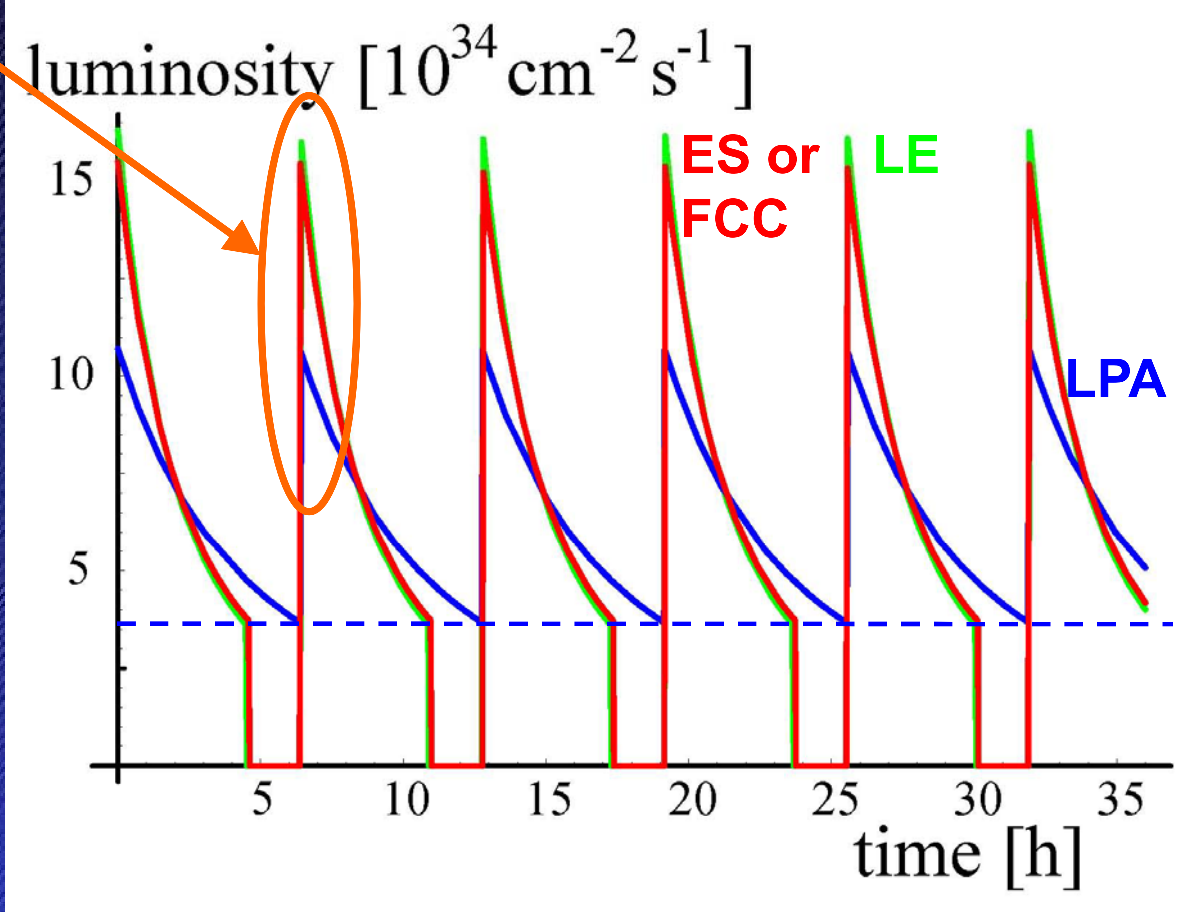
LPA: 2008 simulations & PS beam study
→ *C. Bhat*

LE: 2008 proposal (R. Garoby); parameter study
→ *discussion?!*

luminosity leveling

initial luminosity peak may not be useful for physics (set up & tuning?)

experiments prefer ~constant luminosity, less pile up at start of run, higher luminosity at end

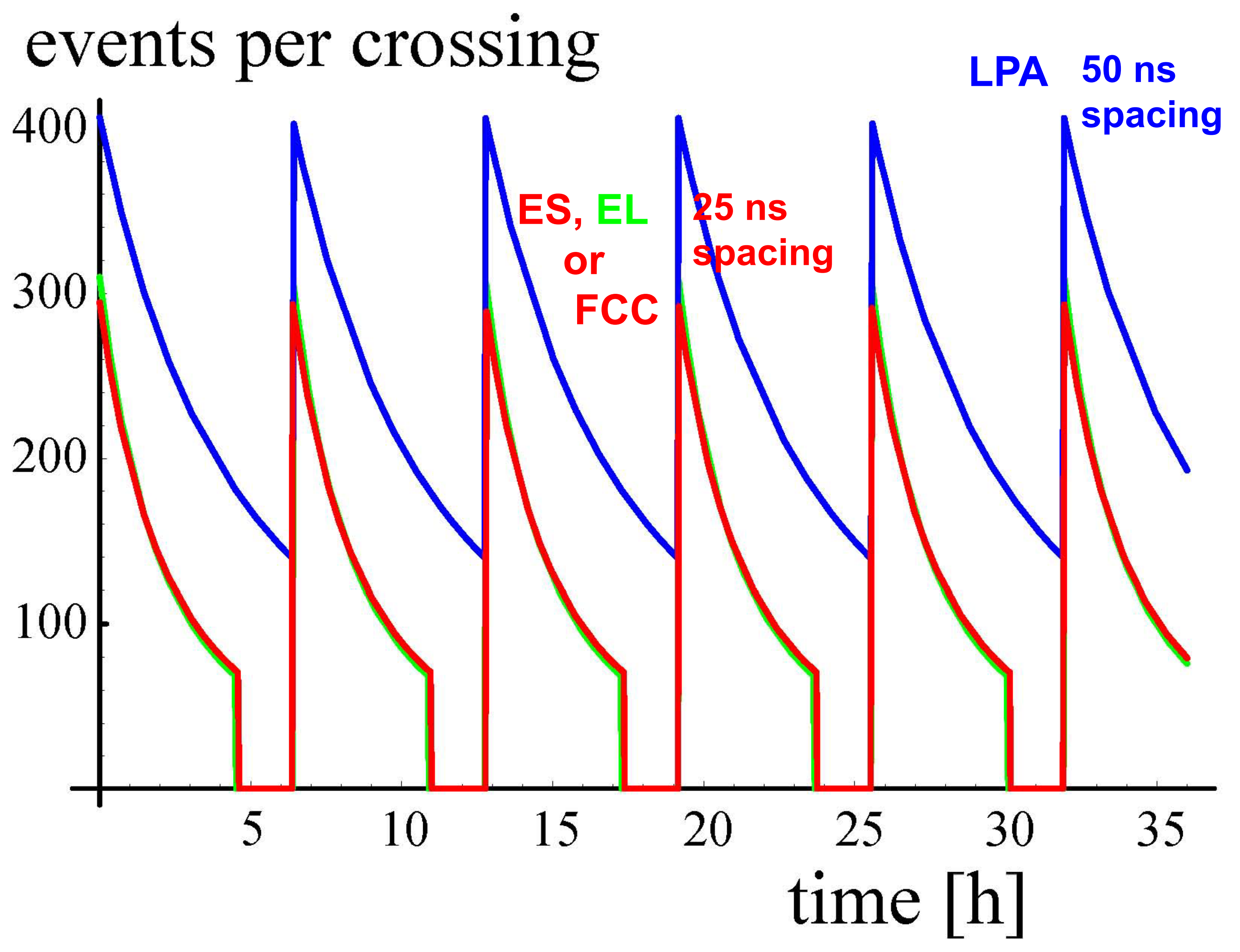


average luminosity

how can we achieve this?

ES, or FCC: dynamic β squeeze, or dynamic θ change (either IP angle bumps or varying crab voltage); LE: β or θ change; LPA: dynamic β squeeze, or dynamic change of bunch length

IP1& 5 event pile up for 25 & 50-ns spacing w/o leveling



run time & average luminosity

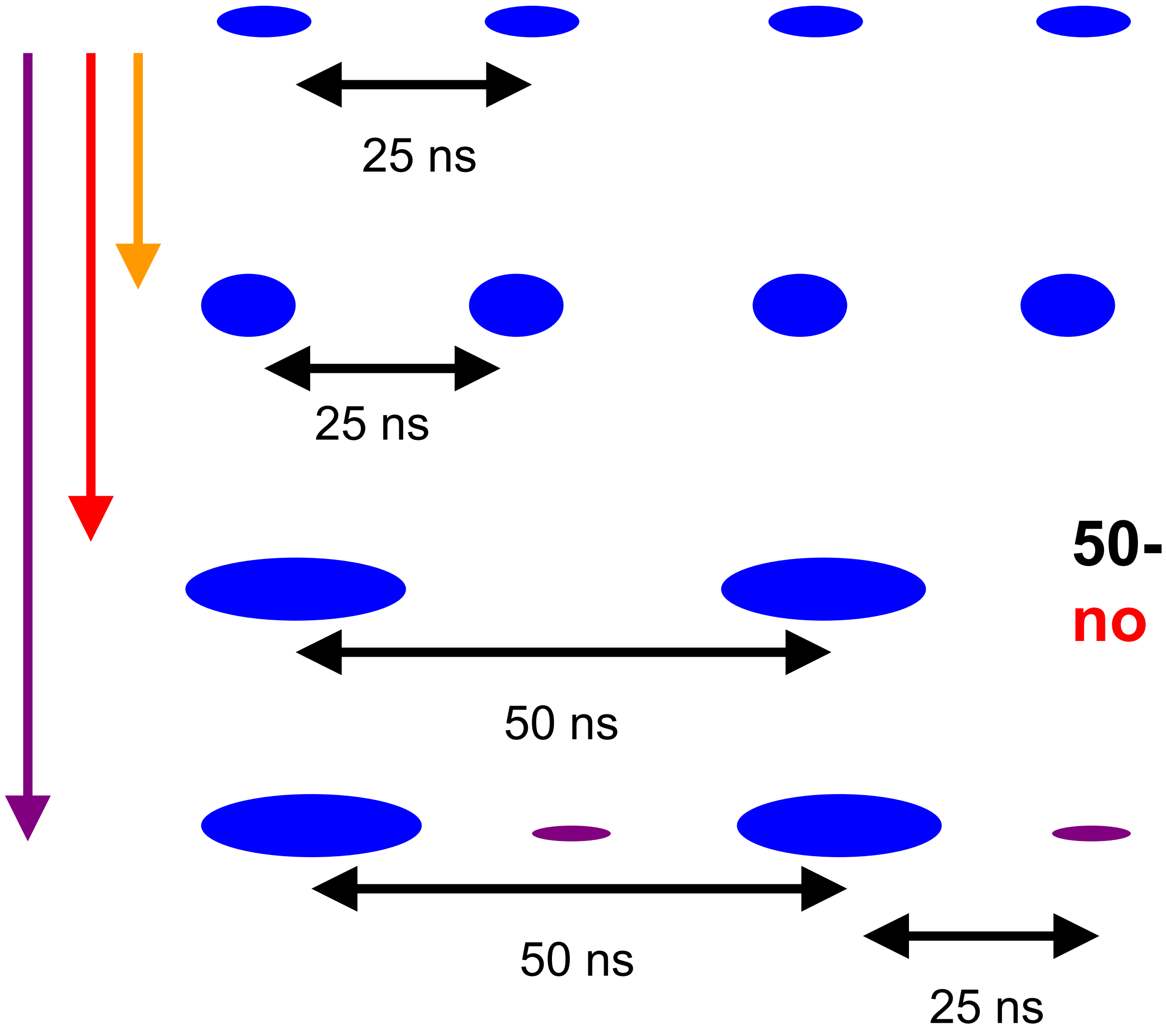
	w/o leveling	with leveling
luminosity evolution	$L(t)=\frac{\hat{L}}{\left(1+t/\tau_{eff}\right)^2}$	$L=L_0\approx const$
beam current evolution	$N(t)=\frac{N_0}{\left(1+t/\tau_{eff}\right)}$	$N=N_0-\frac{N_0}{\tau_{lev}}t$
optimum run time	$T_{run}=\sqrt{\tau_{eff}T_{turn-around}}$	$T_{run}=\frac{\Delta N_{\max}\tau_{lev}}{N_0}$
average luminosity	$L_{ave}=\hat{L}\frac{\tau_{eff}}{\left(\tau_{eff}^{1/2}+T_{turn-around}^{1/2}\right)^2}$	$L_{ave}=\frac{L_0}{1+\frac{L_0\sigma_{tot}n_{IP}}{\Delta N_{\max}n_b}T_{turn-around}}$

$$\tau_{eff}=\frac{N_0 n_b}{n_{IP}\hat{L}\sigma_{tot}} \qquad \tau_{lev}=\frac{N_0 n_b}{n_{IP}L_0\sigma_{tot}}$$

examples	ES, low β^*, with leveling	LPA, long bunches, with leveling
events/crossing	300	300
run time	N/A	2.5 h
av. luminosity	N/A	$2.6\mathrm{x}10^{34}\mathrm{s}^{-1}\mathrm{cm}^{-2}$
events/crossing	150	150
run time	2.5 h	14.8 h
av. luminosity	$2.6\mathrm{x}10^{34}\mathrm{s}^{-1}\mathrm{cm}^{-2}$	$2.9\mathrm{x}10^{34}\mathrm{s}^{-1}\mathrm{cm}^{-2}$
events/crossing	75	75
run time	9.9 h	26.4 h
av. luminosity	$2.6\mathrm{x}10^{34}\mathrm{s}^{-1}\mathrm{cm}^{-2}$	$1.7\mathrm{x}10^{34}\mathrm{s}^{-1}\mathrm{cm}^{-2}$

assuming 5 h turn-around time

upgrade bunch structures



nominal

ultimate
& 25-ns upgrade
(ES & FCC)

50-ns upgrade (LPA),
no collisions in LHCb!

50-ns upgrade
with 25-ns
collisions
in LHCb

experimenters' choice (LHCC July 2008)

- ✓ no accelerator components inside detector
- ✓ lowest possible event pile up
- ✓ possibility of easy luminosity levelling

→ full crab crossing upgrade

→ and/or low-emittance upgrade?

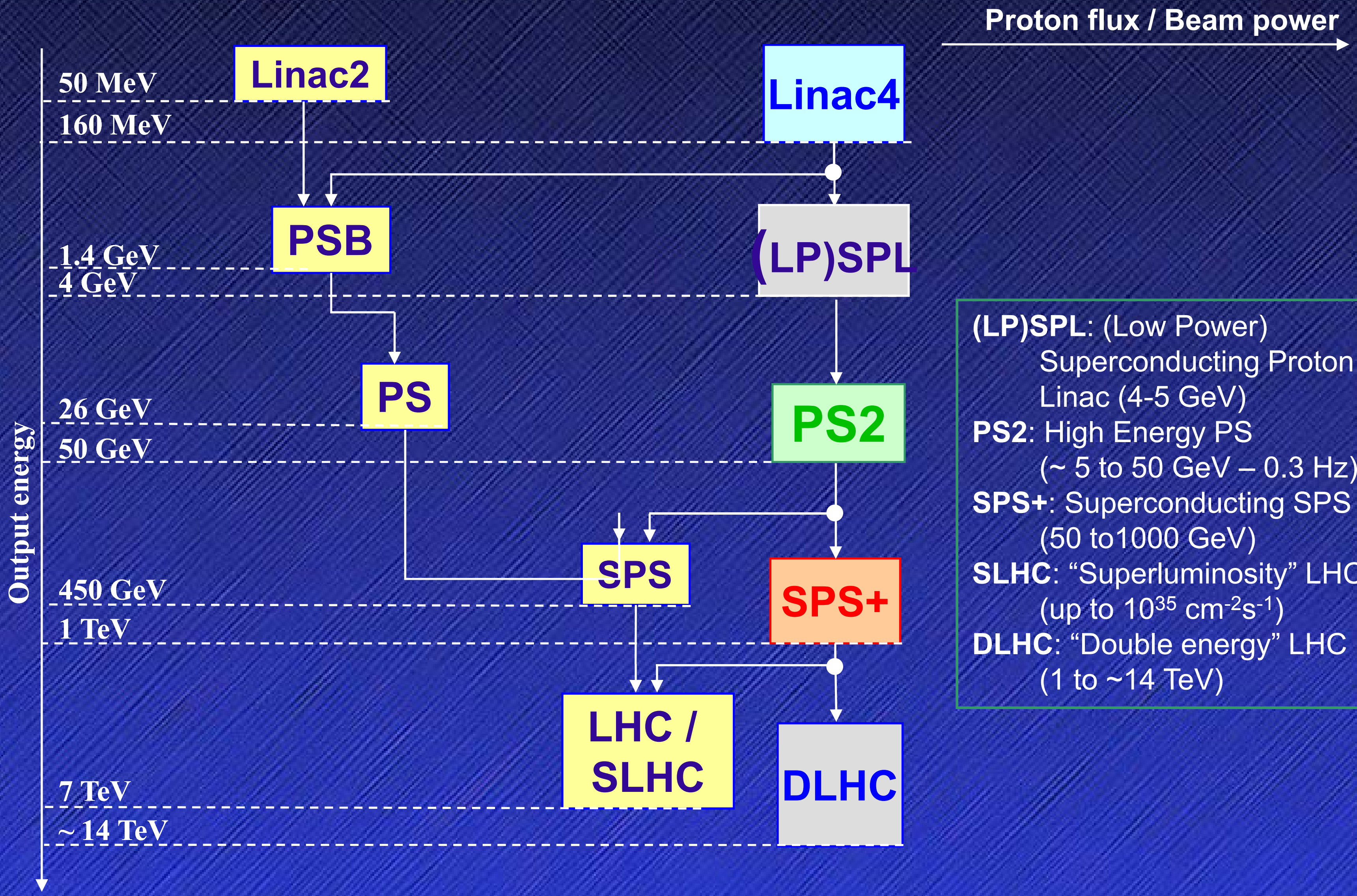
injector upgrade & schedule

LHC injector upgrade

Reasons:

- need for reliability:
  - accelerators are old [Linac2: 1978, PSB: 1975, PS: 1959, SPS: 1976]
  - they operate far from their design parameters and close to hardware limits
  - the infrastructure has suffered from the concentration of resources on LHC during the past 10 years
- need for better beam characteristics

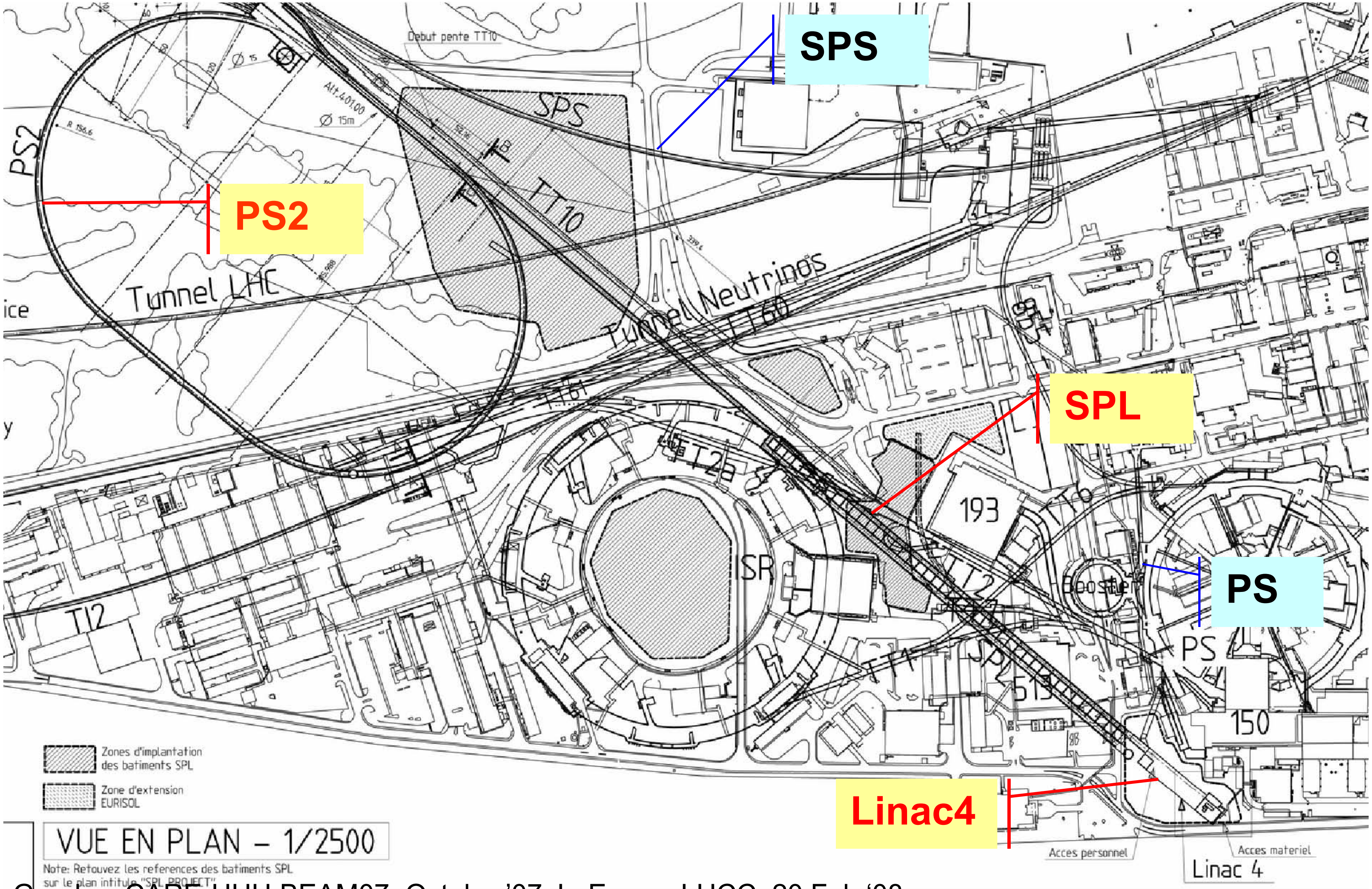
present and future injectors



(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)

Roland Garoby, LHCC 1July ‘08

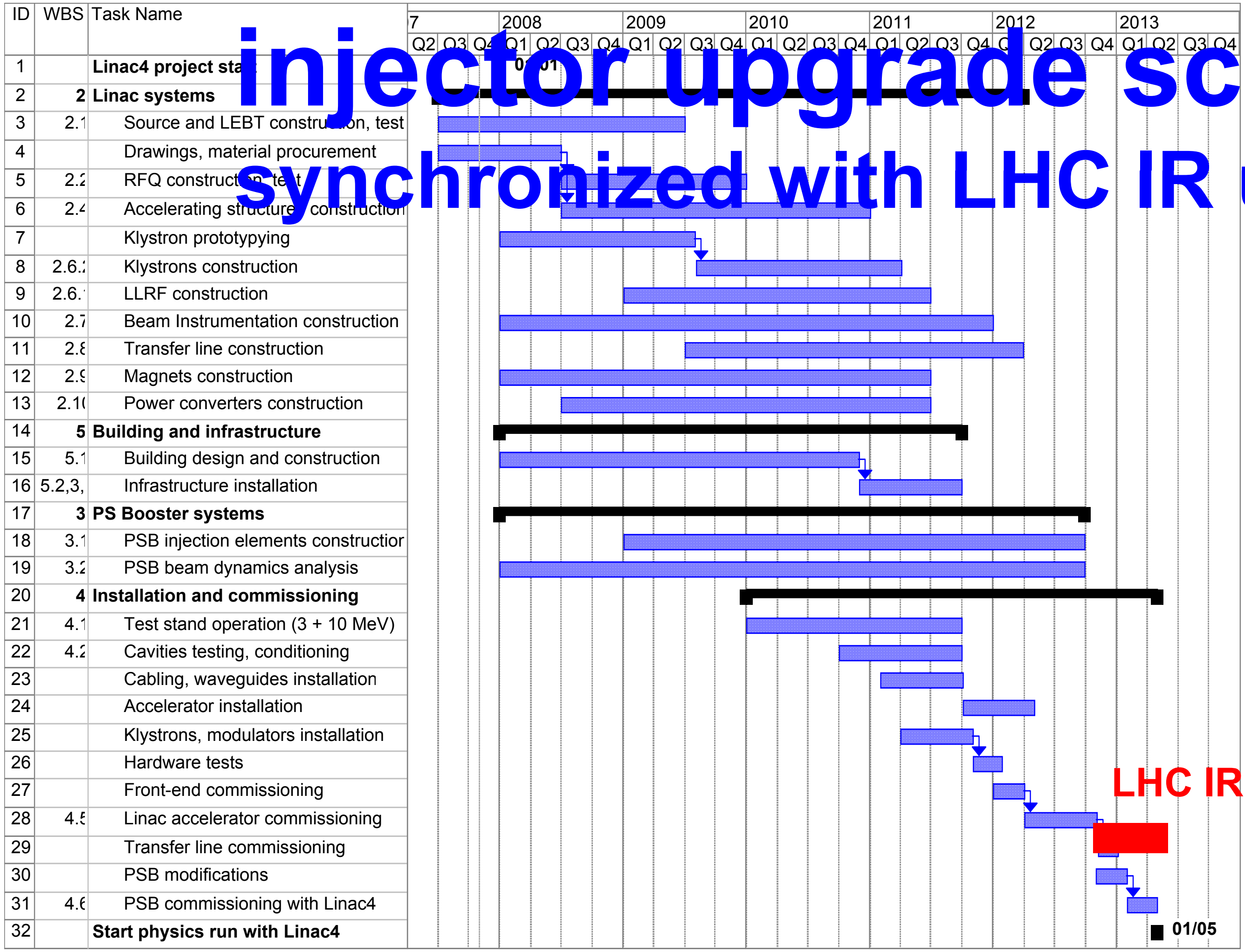
layout of the new injectors



R. Garoby, CARE-HHH BEAM07, October'07; L. Evans, LHCC, 20 Feb '08

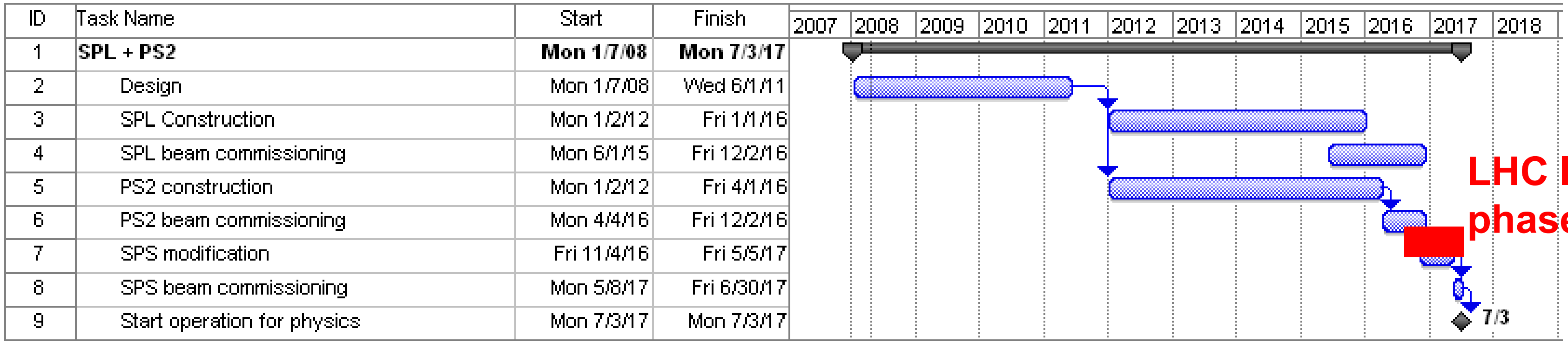
injector upgrade schedule synchronized with LHC IR upgrades

R. Garoby,
LHCC 1 July 2008



ID	WBS	Task Name
1		**Linac4 project sta**
2	**2**	**Linac systems**
3	2.1	Source and LEBT construction, test
4		Drawings, material procurement
5	2.2	RFQ construction, test
6	2.4	Accelerating structure construction
7		Klystron prototypying
8	2.6.2	Klystrons construction
9	2.6.1	LLRF construction
10	2.7	Beam Instrumentation construction
11	2.8	Transfer line construction
12	2.9	Magnets construction
13	2.10	Power converters construction
14	**5**	**Building and infrastructure**
15	5.1	Building design and construction
16	5.2,3,	Infrastructure installation
17	**3**	**PS Booster systems**
18	3.1	PSB injection elements constructior
19	3.2	PSB beam dynamics analysis
20	**4**	**Installation and commissioning**
21	4.1	Test stand operation (3 + 10 MeV)
22	4.2	Cavities testing, conditioning
23		Cabling, waveguides installation
24		Accelerator installation
25		Klystrons, modulators installation
26		Hardware tests
27		Front-end commissioning
28	4.5	Linac accelerator commissioning
29		Transfer line commissioning
30		PSB modifications
31	4.6	PSB commissioning with Linac4
32		**Start physics run with Linac4**

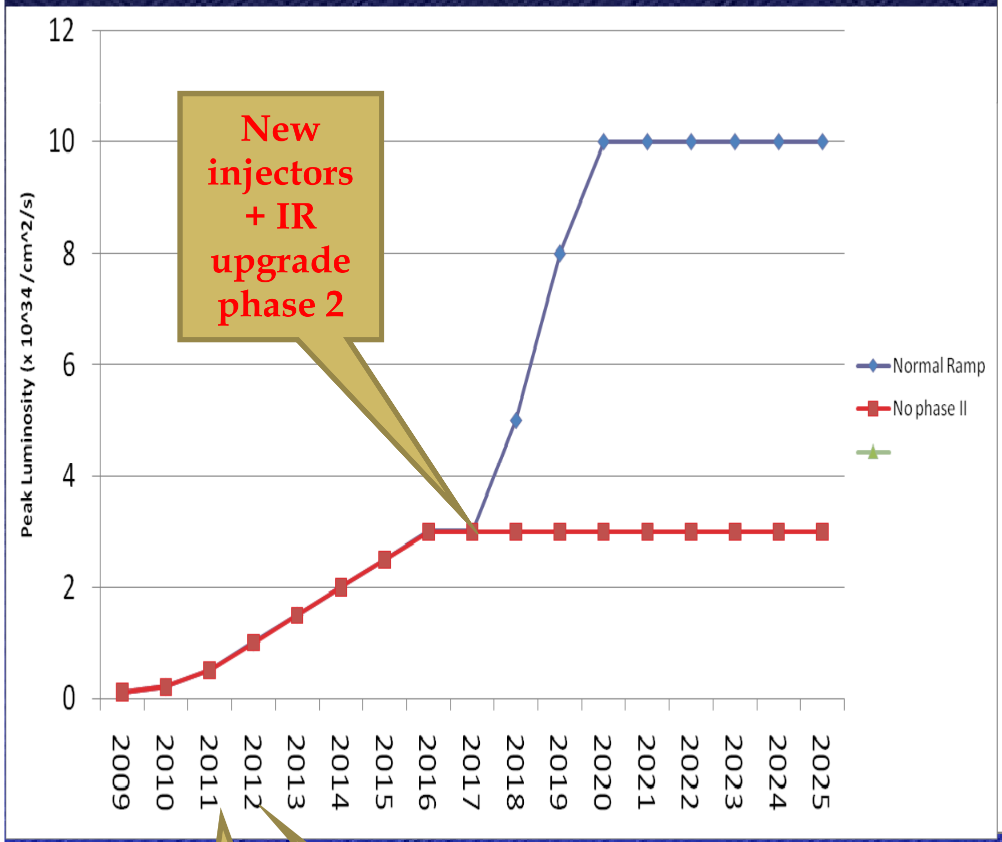
LHC IR phase 1



ID	Task Name	Start	Finish
1	**SPL + PS2**	**Mon 1/7/08**	**Mon 7/3/17**
2	Design	Mon 1/7/08	Wed 6/1/11
3	SPL Construction	Mon 1/2/12	Fri 1/1/16
4	SPL beam commissioning	Mon 6/1/15	Fri 12/2/16
5	PS2 construction	Mon 1/2/12	Fri 4/1/16
6	PS2 beam commissioning	Mon 4/4/16	Fri 12/2/16
7	SPS modification	Fri 11/4/16	Fri 5/5/17
8	SPS beam commissioning	Mon 5/8/17	Fri 6/30/17
9	Start operation for physics	Mon 7/3/17	Mon 7/3/17

LHC IR phase 2

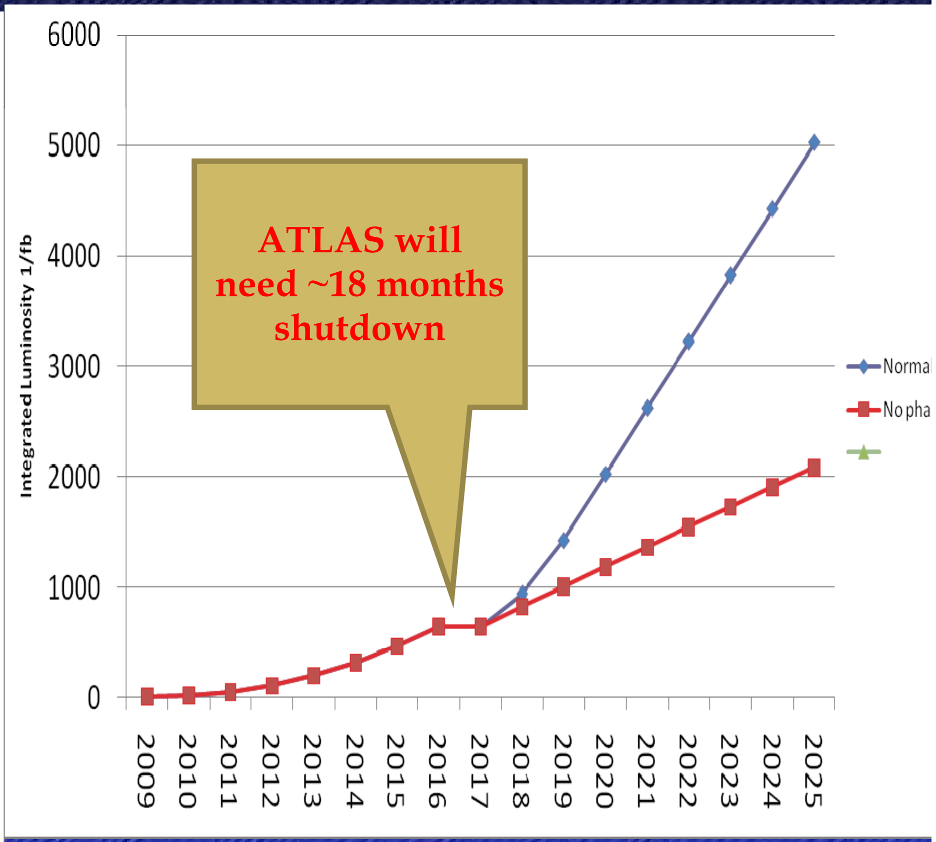
forecast peak & integrated luminosity evolution



New injectors + IR upgrade phase 2

Collimation phase 2

Linac4 + IR upgrade phase 1



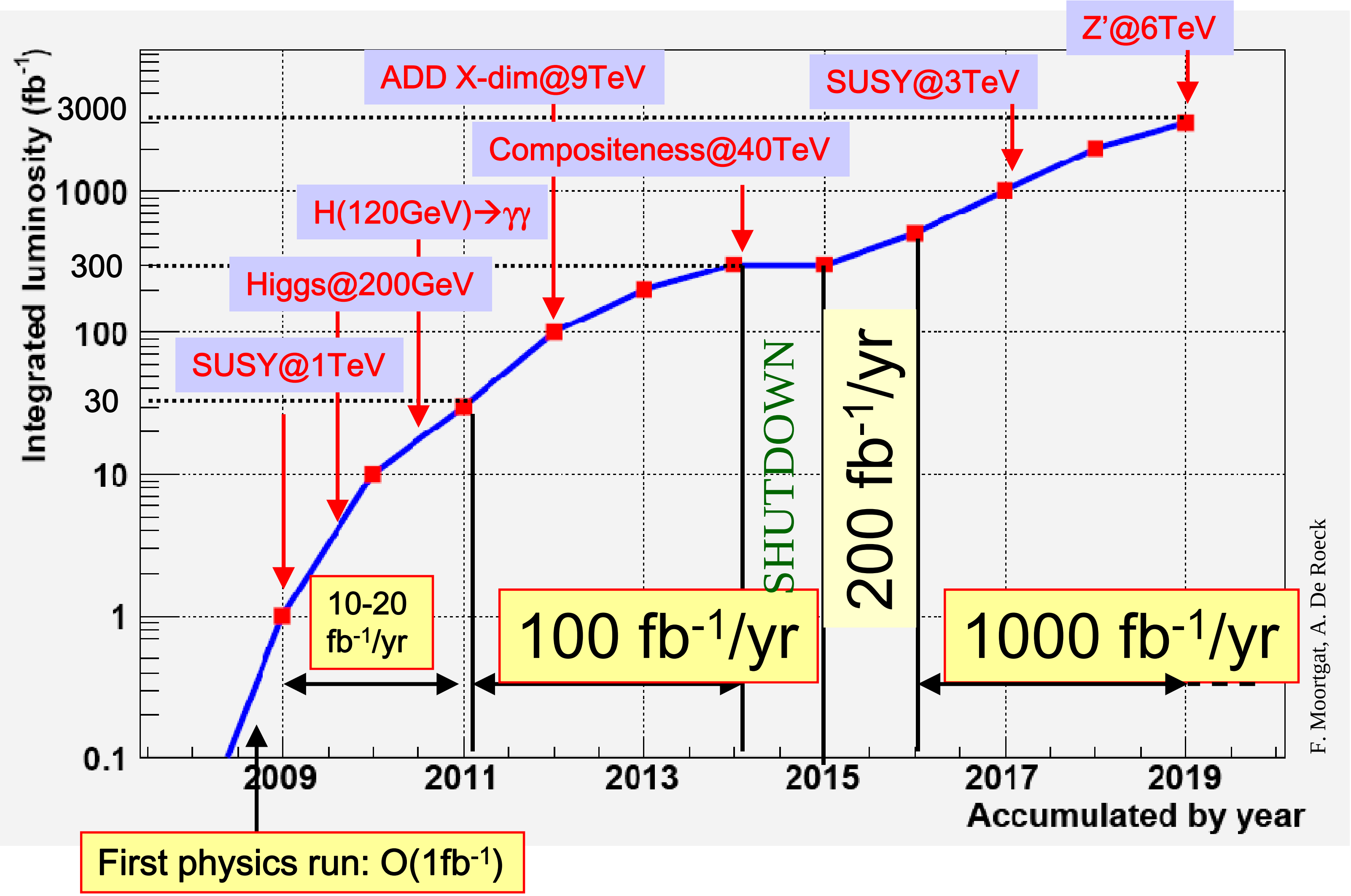
ATLAS will need ~18 months shutdown

goal for ATLAS Upgrade:
3000 fb^{-1} recorded

cope with ~400 pile-up events each BC

M. Nessi, CARE-HHH LHC crab-cavity validation mini-workshop August 2008, R. Garoby, LHCC July 08

LHC Luminosity/Sensitivity with time



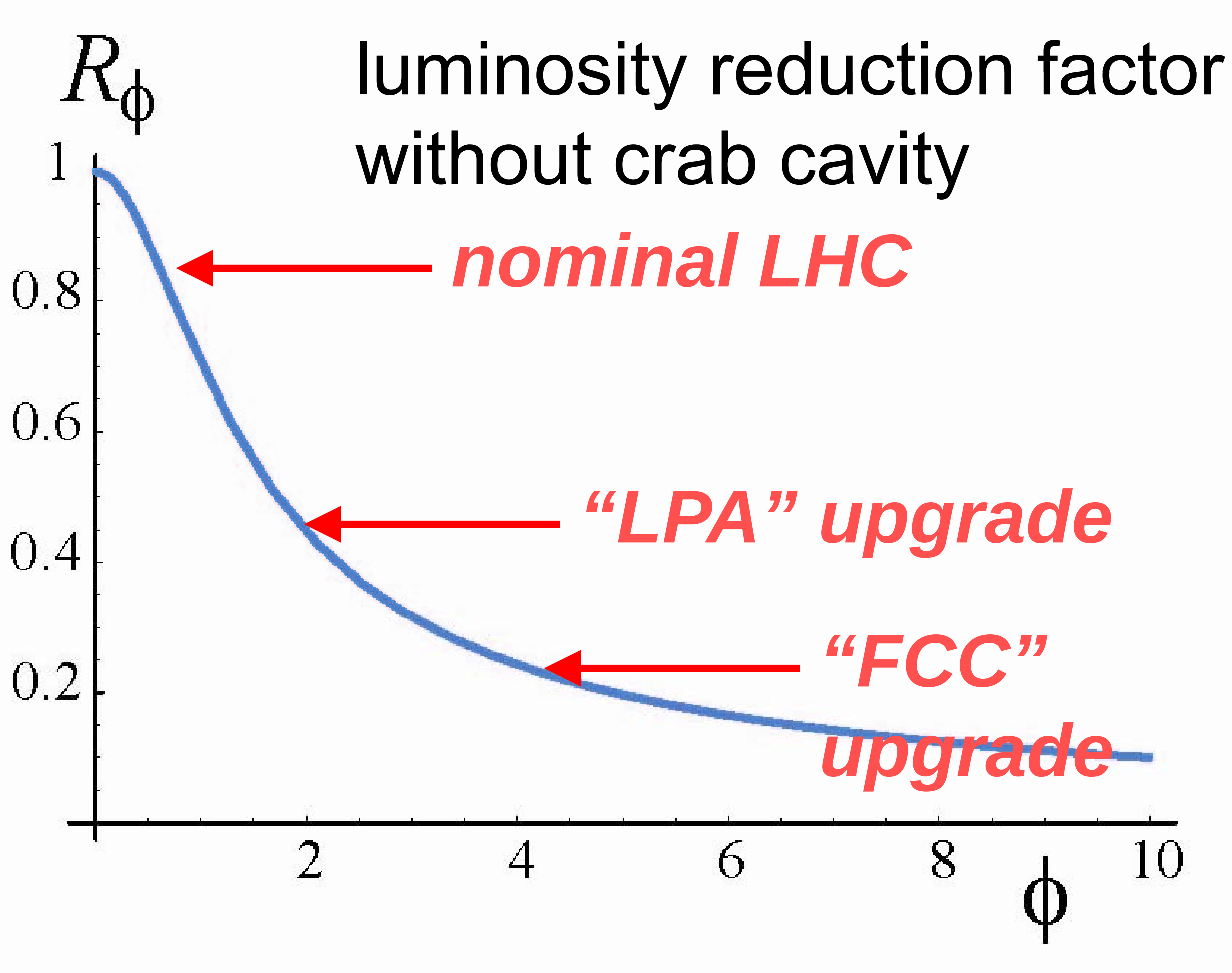
A. de Roeck, 2007

crab cavities

crab cavity motivation →HHH→

$$R_\phi = \frac{1}{\sqrt{1+\phi^2}}; \quad \phi \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$

"Piwinski angle"

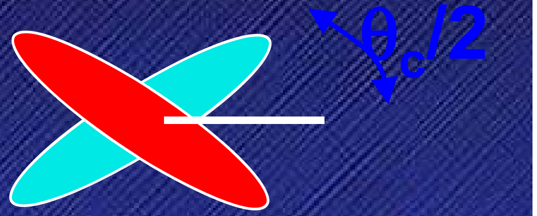


luminosity reduction factor without crab cavity

nominal LHC

"LPA" upgrade

"FCC" upgrade

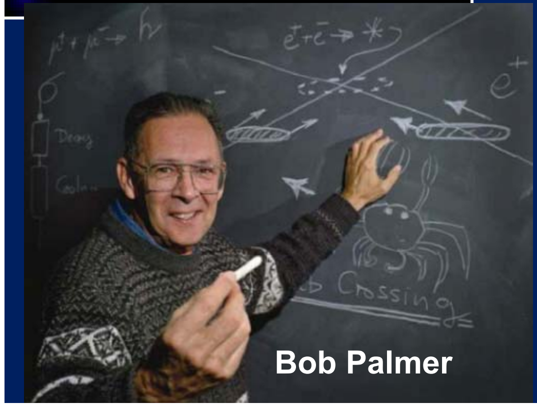


effective beam size $\sigma \rightarrow \sigma/R_\phi$

CARE-HHH

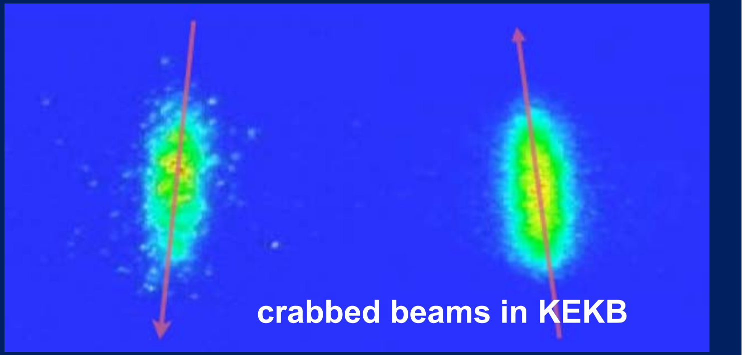
LHC Crab Cavity Validation

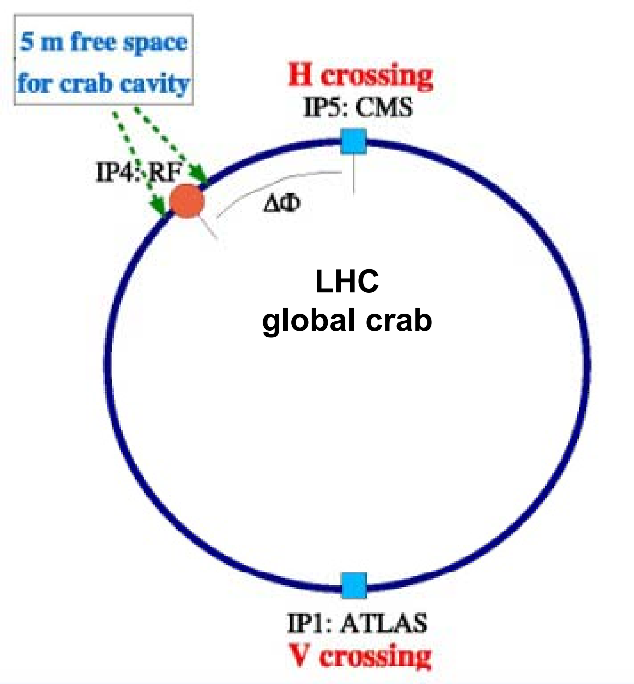
Mini-Workshop, 21 August 2008

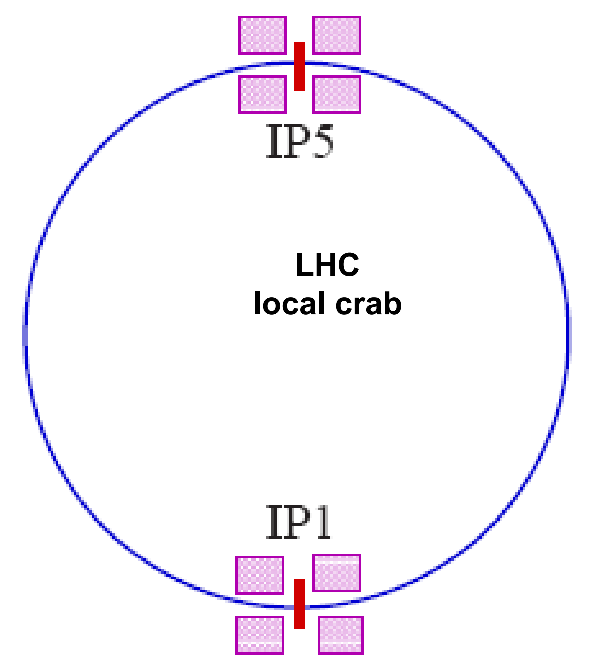

Bob Palmer

invention
1988

first use in operating
ring collider 2007


crabbed beams in KEKB





global & local schemes considered for LHC

- KEKB experience
- R&D plan
- phased approach:

(1) prototype

(2) “global” crab cavity test in IR4,

(3) “local” crab cavities in IR1 & 5

- EuCARD, US-LARP & international collaboration

global crab-cavity simulation & theory effort

1. Beam-beam studies:

a. K. Ohmi (KEK) - white noise - SS & WS simulations , **BBSS code**,
scaling law with respect to noise correlation time,
effect of ***RF curvature***, ***luminosity*** estimates

b. Y.-P. Sun, U. Dorda, R. Tomas (CERN); R. Calaga (BNL) –
single particle dynamics , **Sixtrack/MADX/BBTRACK code**
WS simulations, ***footprints***, luminosity, ***noise spectrum***,…

c. J. Qiang (LBNL), SS simulations, **BeamBeam3D code**

2. Collimation & impedance:

a. Y.-P. Sun, R. Tomas, J. Barranco, F. Zimmermann (CERN);
R. Calaga (BNL) – **Sixtrack/Colltrack** tracking, ***cleaning efficiency***

b. F. Zimmermann, E. Metral (CERN); R. Calaga (BNL),…:
impedance estimates and ***HOM damping requirements***

3. Operational scenarios:

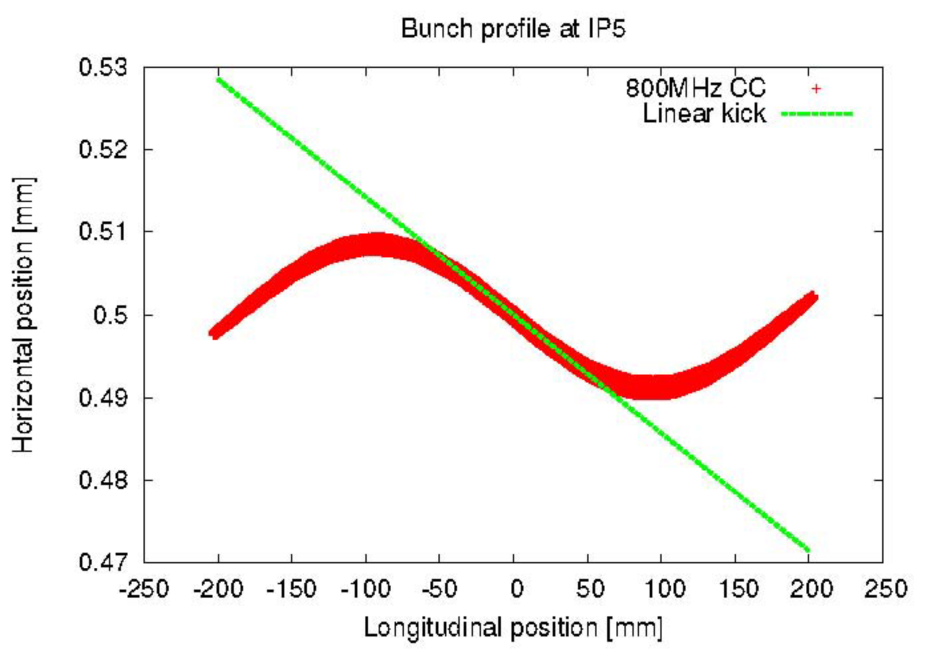
a. A. Morita (KEK); R. Calaga (BNL); R. Tomas, F. Zimmermann (CERN):
crab ramping/detuning studies

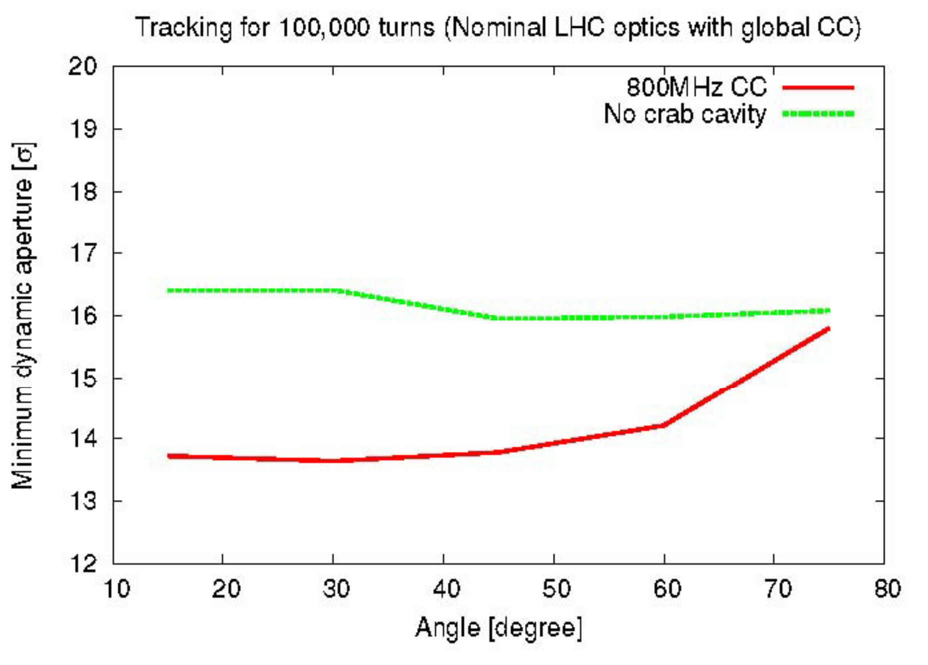
b. K. Oide et al (KEK): joined ***KEKB machine experiments & studies*** example:

tracking for global 800-MHz crab cavity

IP bunch shape

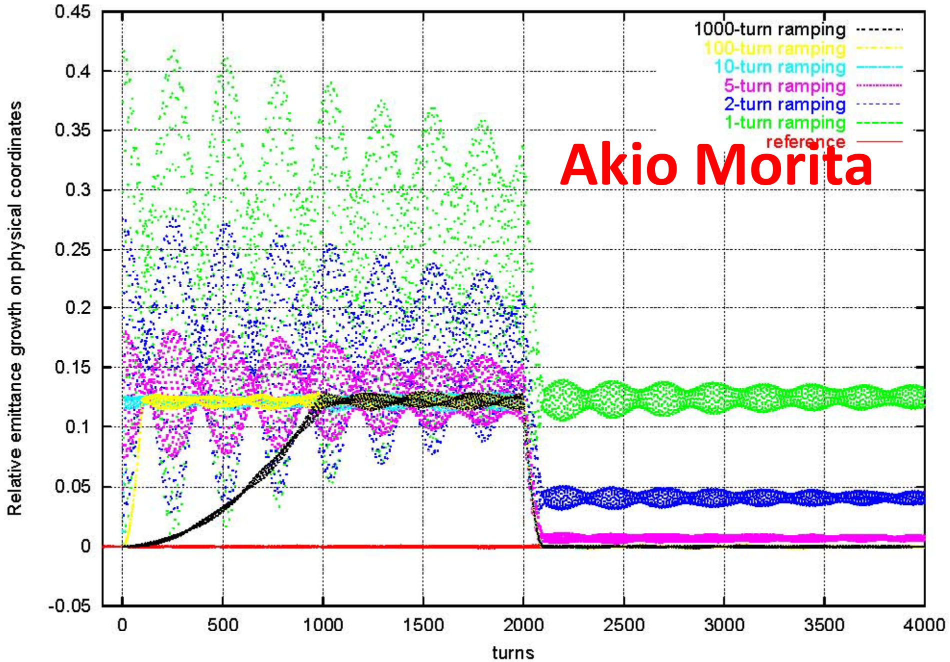
dynamic aperture

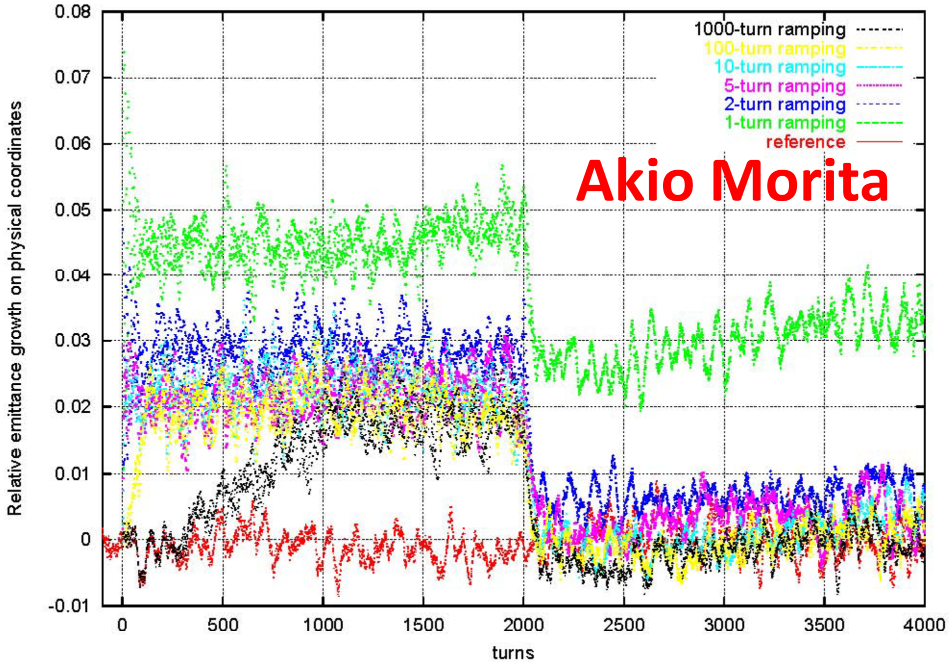




Yi-Peng Sun

another example:
emittance growth due to crab up/down ramping





w/o tune spread

with tune spread

→ no emittance dilution for ramp time > 10 turns

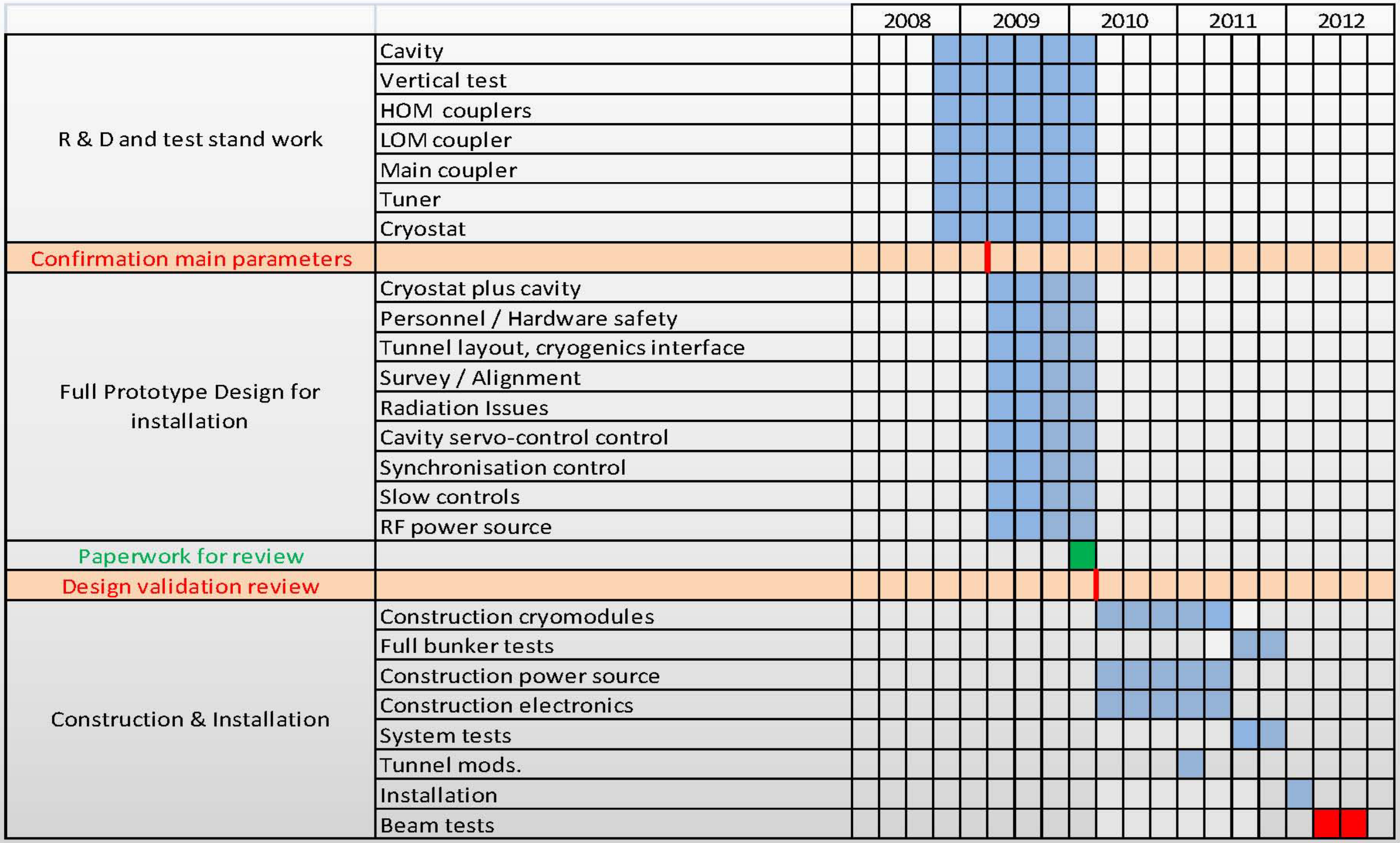
→ voltage ramping not a problem for $Q_{\text{loaded}}>10^6$

Akio Morita

tentative schedule for crab-cavity prototype & first beam tests

Schedule

T. Linnecar, HHH Crab-Cavity Validation Workshop August 2008



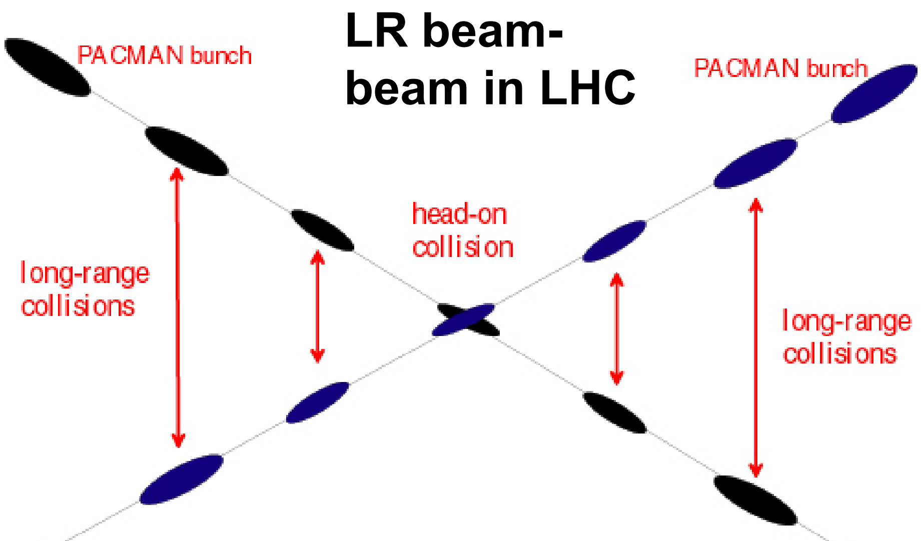
		2008				2009				2010				2011				2012			
R & D and test stand work	Cavity				🟦	🟦	🟦	🟦	🟦	🟦											
	Vertical test				🟦	🟦	🟦	🟦	🟦	🟦											
	HOM couplers				🟦	🟦	🟦	🟦	🟦	🟦											
	LOM coupler				🟦	🟦	🟦	🟦	🟦	🟦											
	Main coupler				🟦	🟦	🟦	🟦	🟦	🟦											
	Tuner				🟦	🟦	🟦	🟦	🟦	🟦											
	Cryostat				🟦	🟦	🟦	🟦	🟦	🟦											
Confirmation main parameters							▍														
Full Prototype Design for installation	Cryostat plus cavity						🟦	🟦	🟦	🟦											
	Personnel / Hardware safety						🟦	🟦	🟦	🟦											
	Tunnel layout, cryogenics interface						🟦	🟦	🟦	🟦											
	Survey / Alignment						🟦	🟦	🟦	🟦											
	Radiation Issues						🟦	🟦	🟦	🟦											
	Cavity servo-control control						🟦	🟦	🟦	🟦											
	Synchronisation control						🟦	🟦	🟦	🟦											
	Slow controls						🟦	🟦	🟦	🟦											
	RF power source						🟦	🟦	🟦	🟦											
Paperwork for review										🟩											
Design validation review											▍										
Construction & Installation	Construction cryomodules										🟦	🟦	🟦	🟦	🟦						
	Full bunker tests															🟦	🟦				
	Construction power source										🟦	🟦	🟦	🟦	🟦						
	Construction electronics										🟦	🟦	🟦	🟦	🟦						
	System tests															🟦	🟦				
	Tunnel mods.													🟦							
	Installation																	🟦			
	Beam tests																		🟥	🟥	

local crab cavities together with IR phase-2 ~2017 ?

complementary advanced schemes:

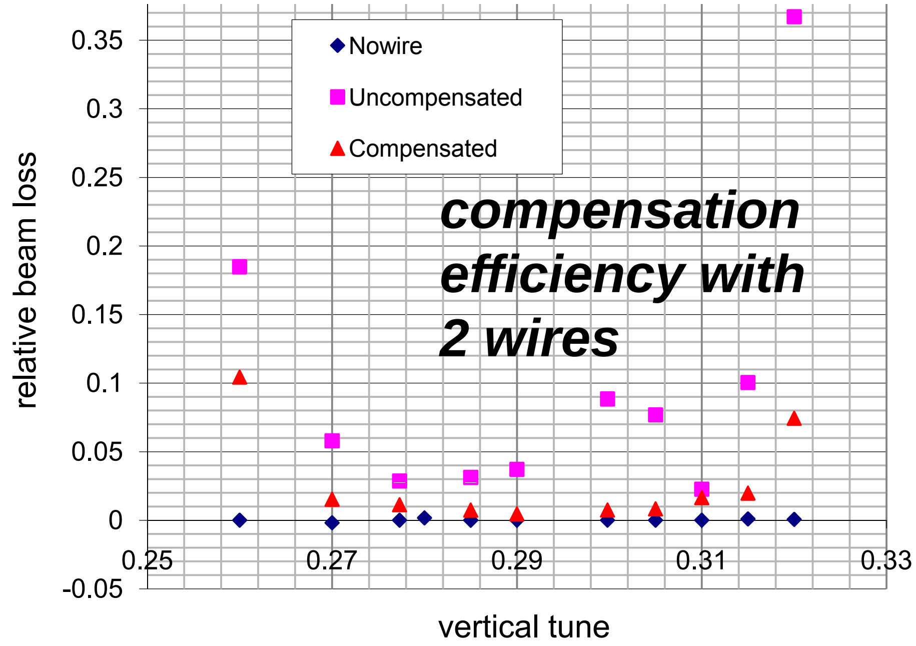
- beam-beam compensation
- crab waist collision
- electron-cloud mitigation
- crystal collimation
- cooling

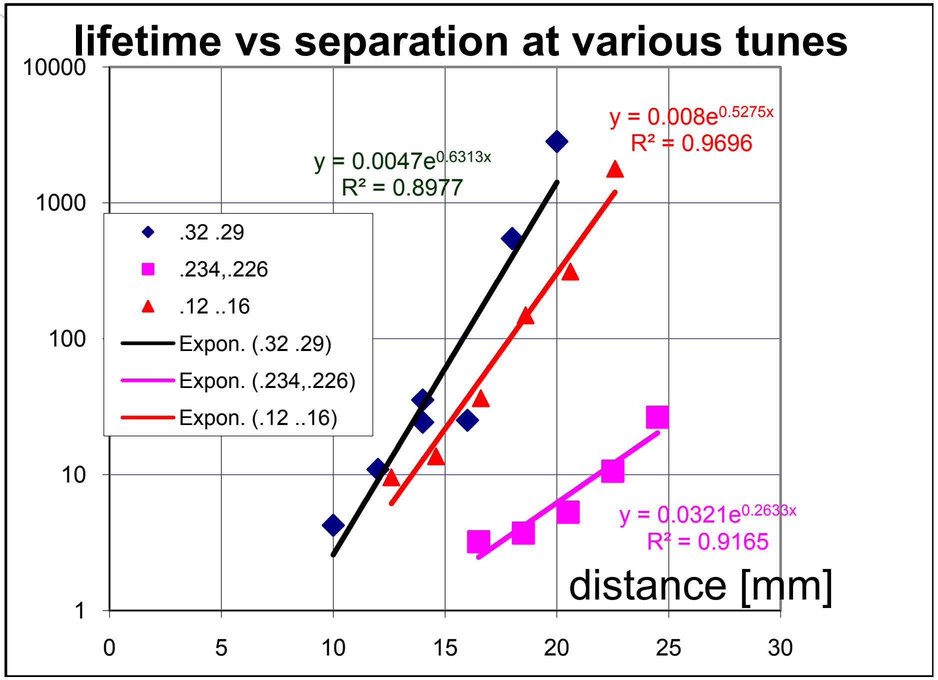
long-range beam-beam compensation

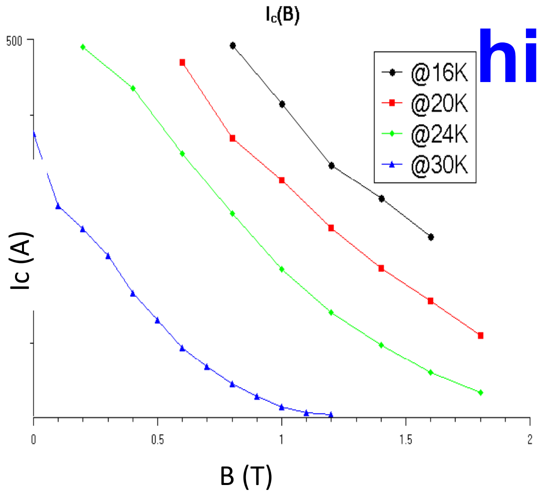

LR beam-beam in LHC


prototype compensator in the SPS

G. Sterbini, J.-P. Koutchouk U. Dorda, et al, SPS MD August 2008


compensation efficiency with 2 wires


lifetime vs separation at various tunes



high-Tc s.c. LRBB compensator

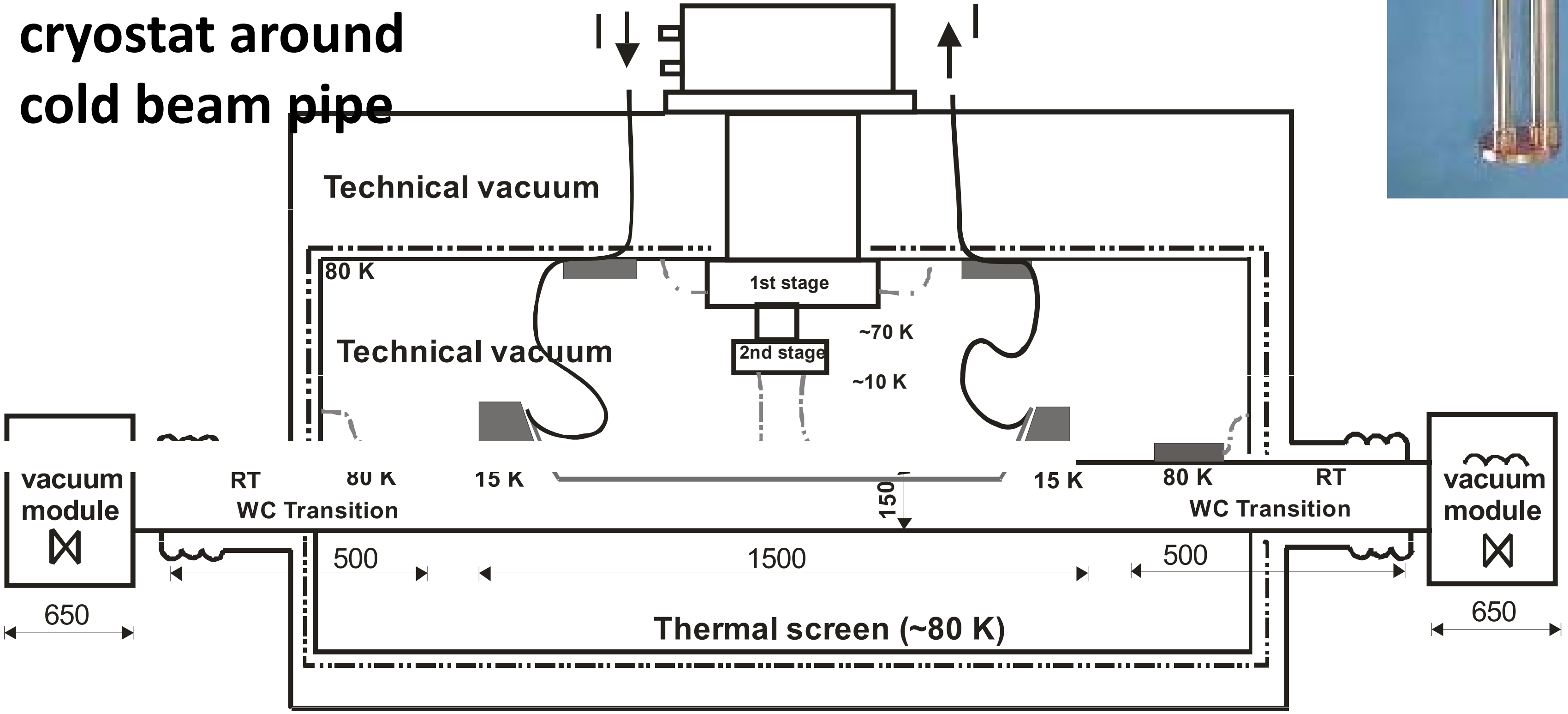
A.Ballarino, CARE-HHH
mini-workshop, 28 August 2008

MgB_2 conductor

Ex-situ, 1.1 mm Φ MgB_2 wire (Columbus)

two-stage pulse tube cryocooler

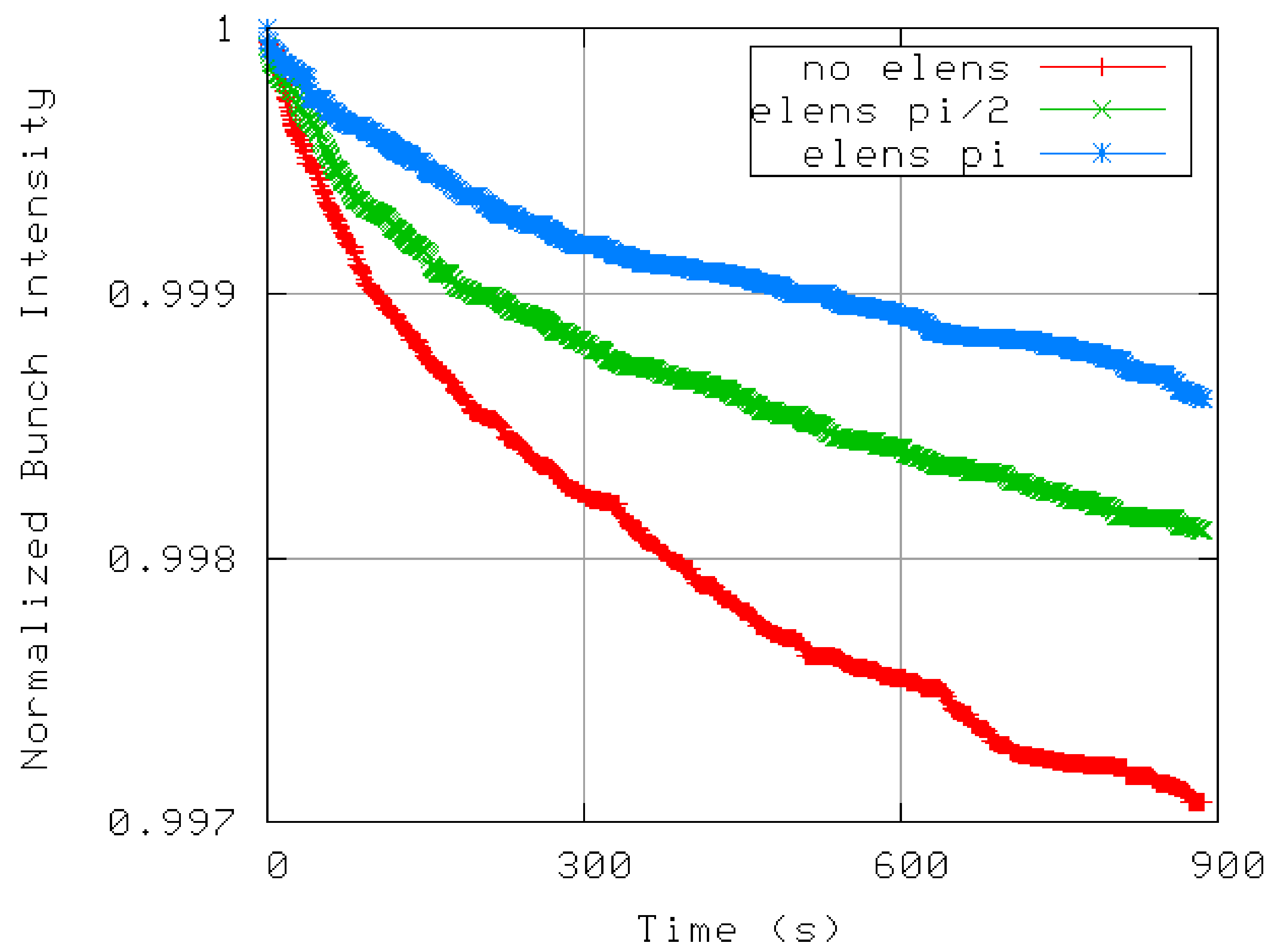
cryostat around cold beam pipe



LTOT ~4 m (including vacuum modules)
Lcryostat ~2.5 m
HTOT ~1.2 m

electron lens

use of e-lens as tune-spread compressor improves simulated LHC beam lifetime (phase to IP important)

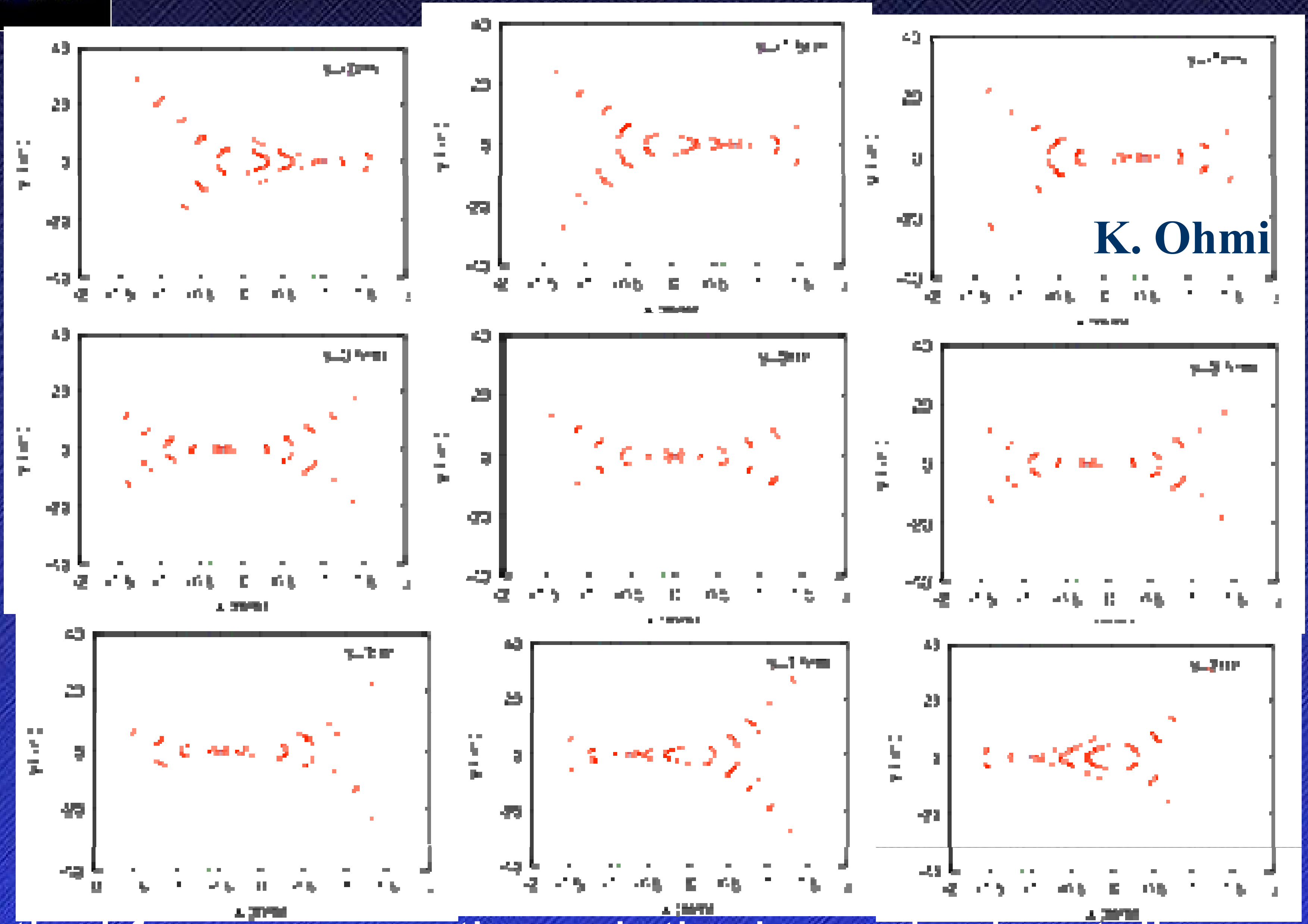


A.Valishev,
CARE-HHH
mini-workshop
on beam-beam
Compensation,
28 August 2008

complementary advanced schemes:

- beam-beam compensation
- crab waist collision
- electron-cloud mitigation
- crystal collimation
- cooling

crab-waist collisions



K. Ohmi

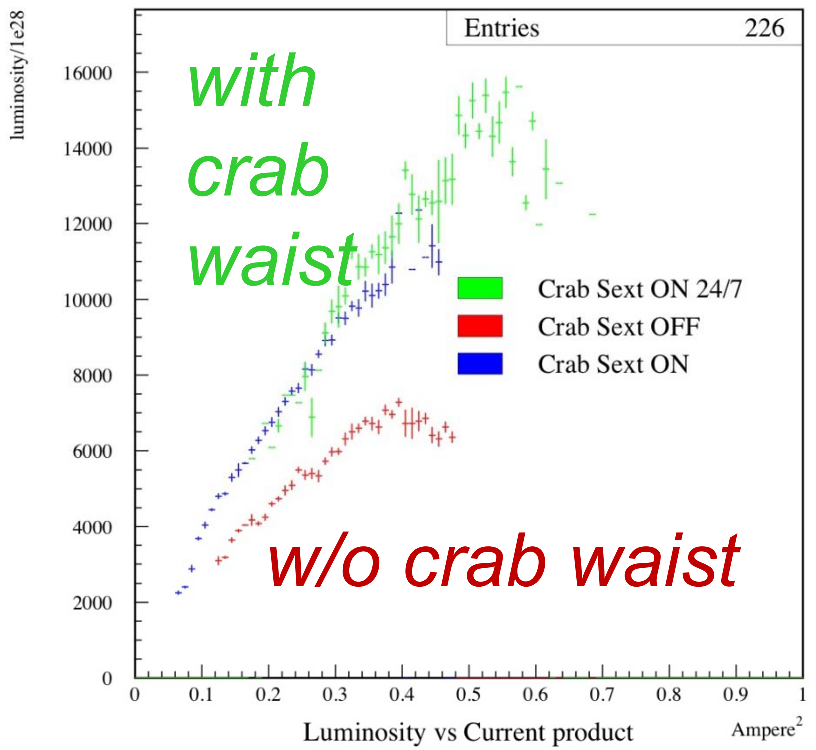
vertical focus moves through the beam horizontally

“crab-waist” collisions at DAFNE

(note: no crab cavities but sextupoles!)

luminosity

C. Milardi



current product

can we make
use of
crab waists
at the LHC?

crab waist in LHC?

K. Ohmi
CARE-HHH
mini-workshop
28 August '08

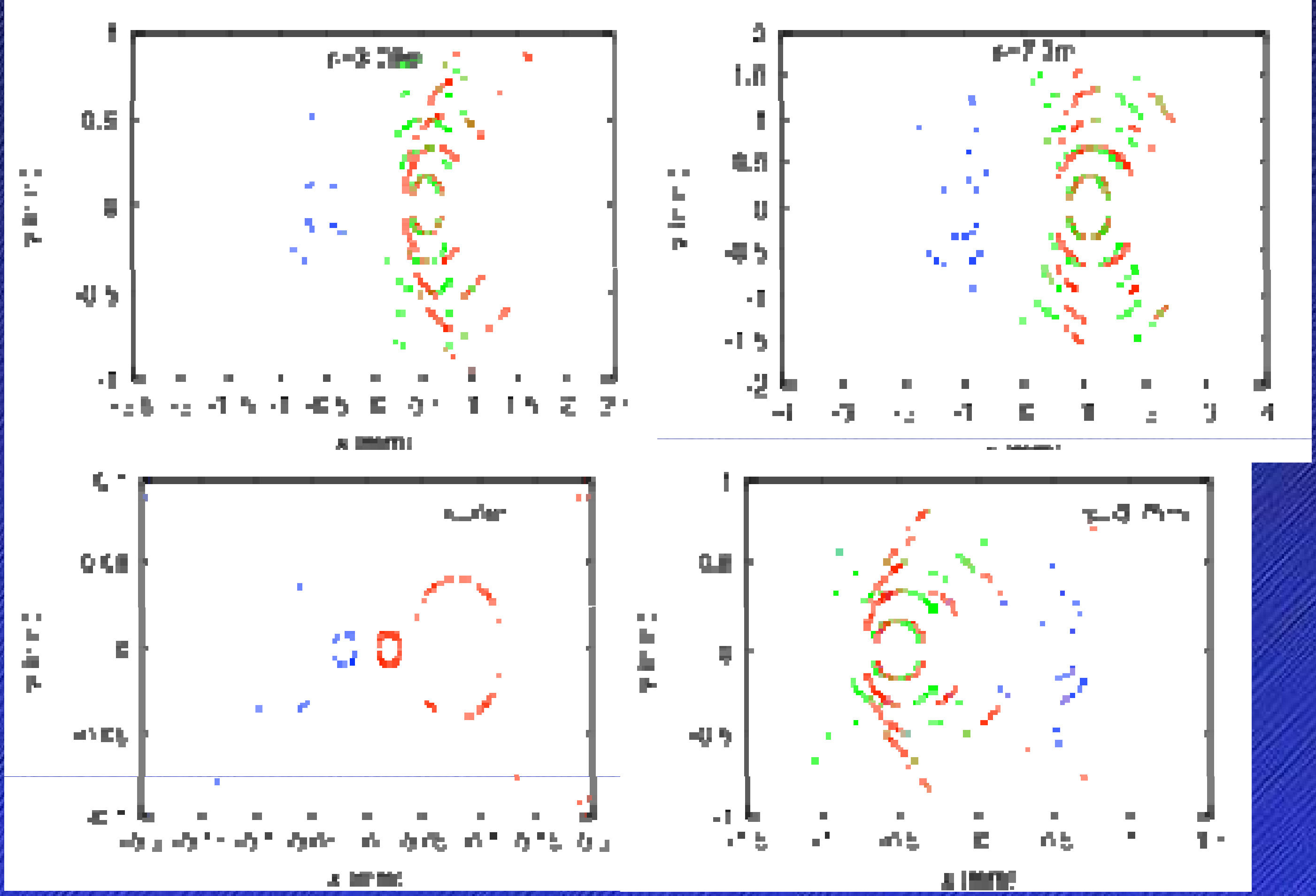
one example:

ϕ=3.5 in LPA option
β_y squeezed to σ_x/ϕ=2.1cm (*extreme!*)

→ L increases $(14/2.1)^{1/2}$=2.6 times
→ ξ_y decreases and ξ_x is small for LPA

→ "crab waist has a chance to work!"

another use of “crab-waist”: push beam halo away from opposing beam at LR collisions

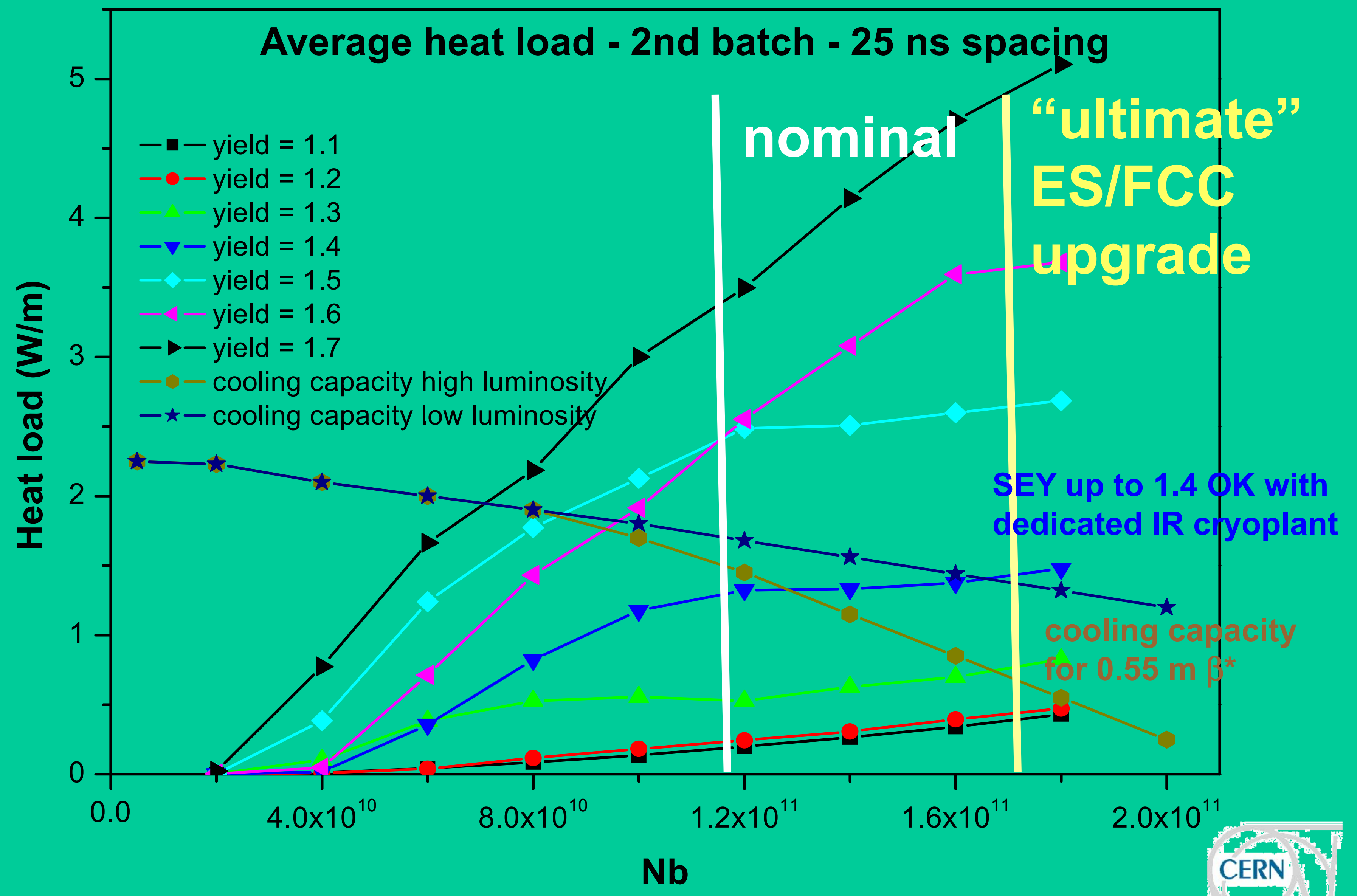


K. Ohmi

complementary advanced schemes:

- beam-beam compensation
- crab waist collision
- electron-cloud mitigation
- crystal collimation
- cooling

e- heat load for 25 ns spacing

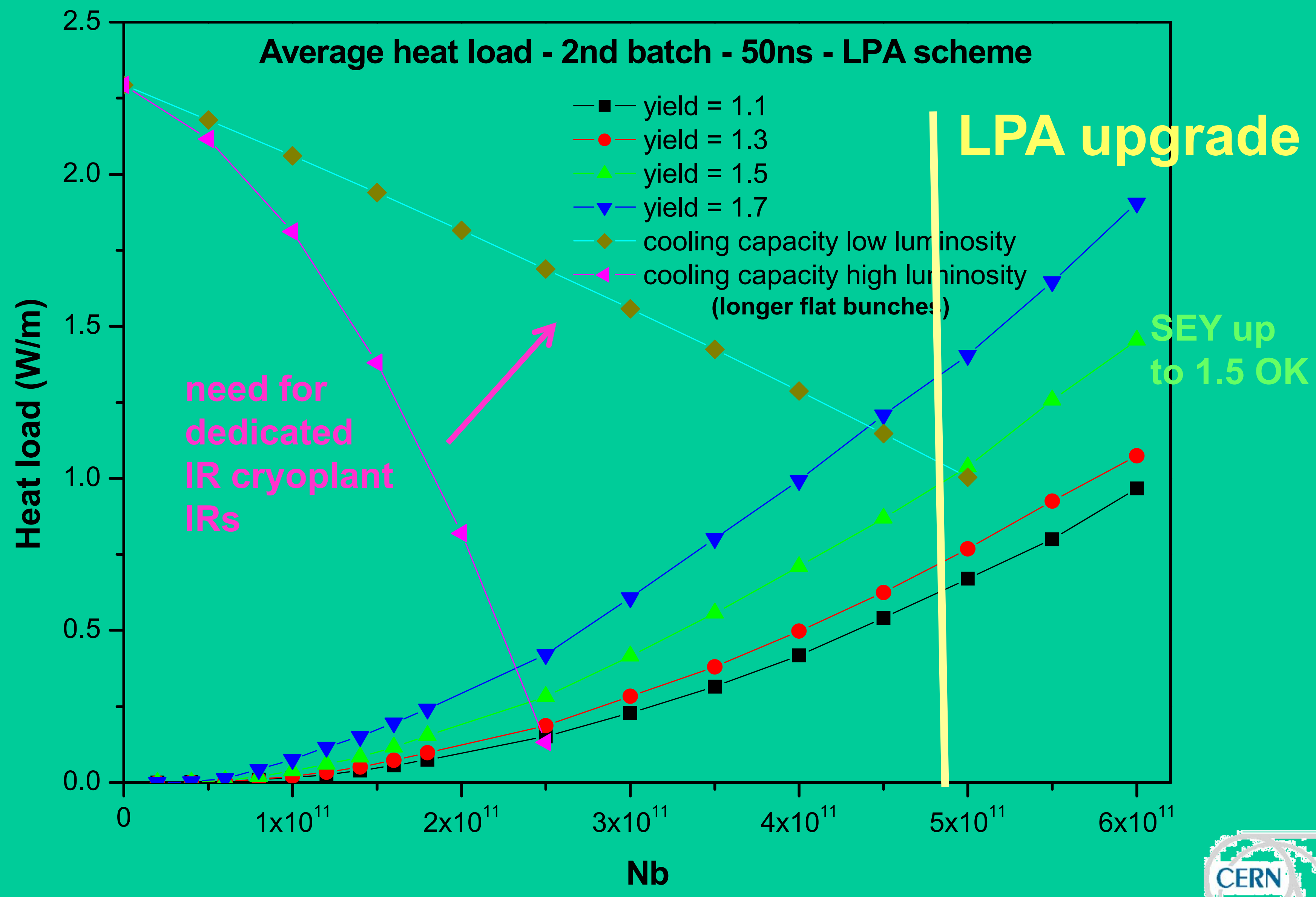


SEY up to 1.4 OK with dedicated IR cryoplant

cooling capacity for 0.55 m β^*

Humberto Maury Cuna, CINVESTAV, Mexico, FP7 EUROLUMI collaboration!

e- heat load for 50 ns spacing



LPA upgrade

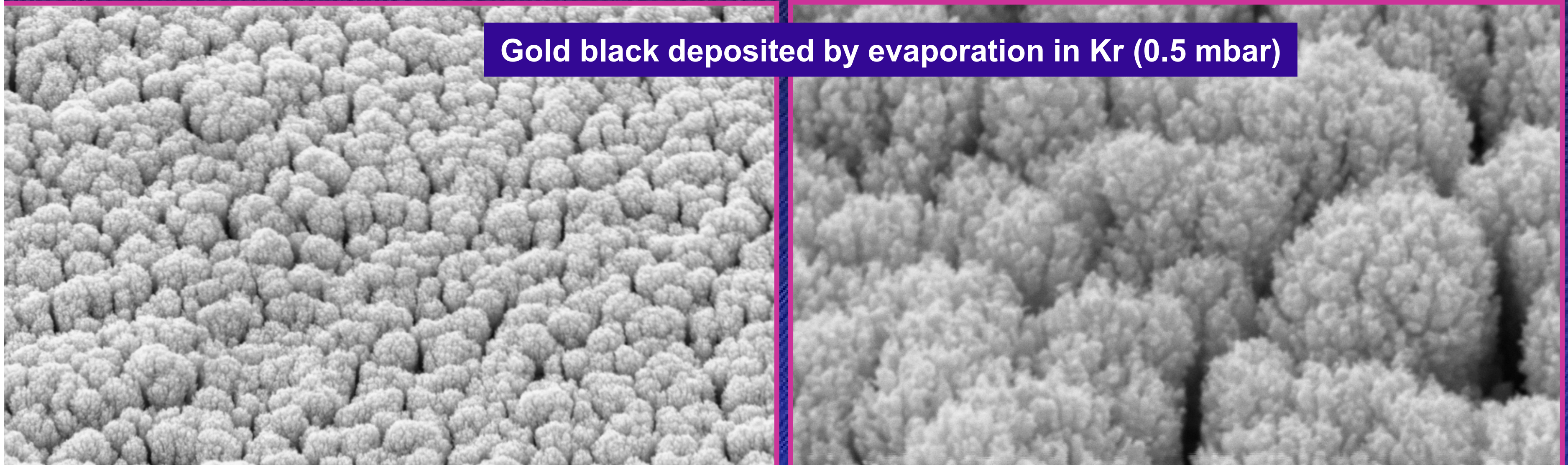
SEY up to 1.5 OK

need for dedicated IR cryoplant IRs

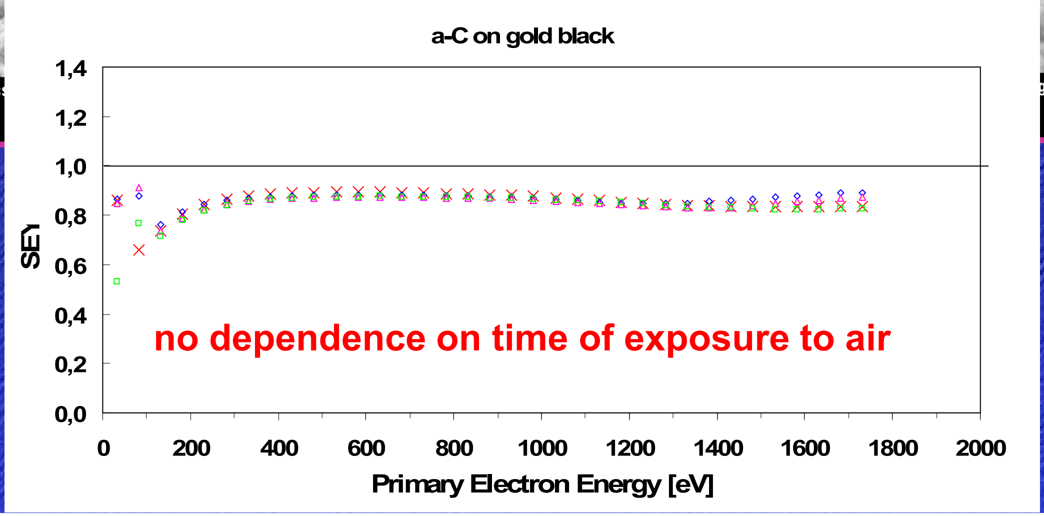
Humberto Maury Cuna, CINVESTAV, Mexico, FP7 EUROLUMI collaboration!

e-cloud mitigation

Evaporation of metals in relatively high pressure of a rare gas produces very rough and porous films. Already mentioned in the literature, “gold black” has been produced and characterized.



Gold black deposited by evaporation in Kr (0.5 mbar)



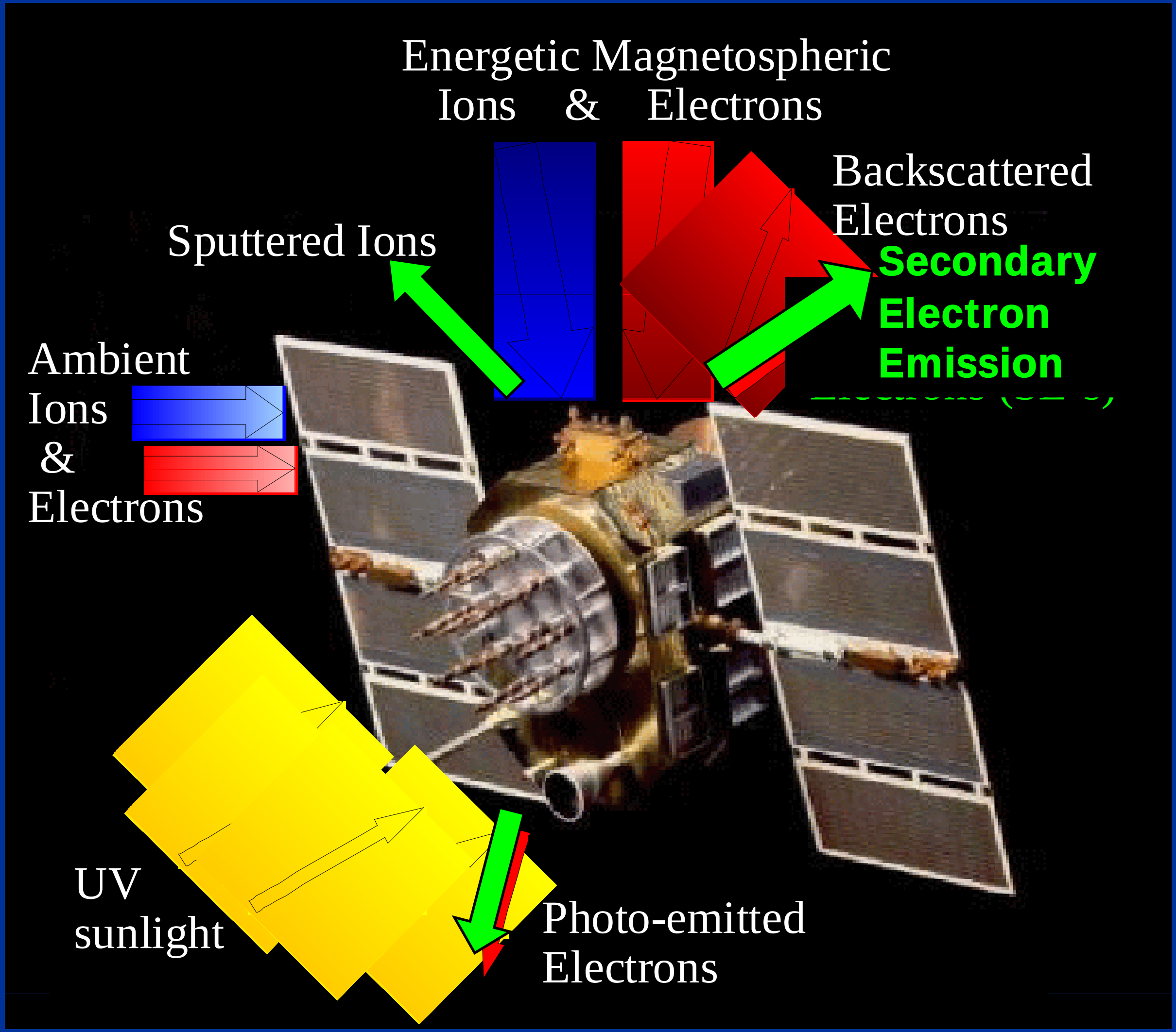
no dependence on time of exposure to air

for PS2 & SPS upgrade; effort triggered by HHH ECL’2 workshop

P. Chiggiato
et al

promising:
graphite coating on black gold substrate

Space Plasma Environment and Spacecraft Charging



incident and emitted currents that result in spacecraft charging

ESA funded R&D

synergies with satellite R&D

MULCOPIM
(24th-September-2008)
Invited paper

"Multipactor breakdown: Present status and where are we heading"

David Raboso (ESA)

Multipactor: SEY

Secondary emission: Lines of Investigation

- Create low loss surface coatings with stable SEY over time (POROUS COATINGS)
- Always measure the SEY of the component with a separate sample
  - Same batch metal and same coating bath as component
- Run prediction software only with the related measured SEY data (DATA BASE)
- Concentrate more in the surface profile rather than the material properties

Multipactor: internal R&D

ESA resources for R&D

In 2008 ESA (ESTEC) enhanced the internal resources (both human and equipment) dedicated to R&D in the field of Multipactor effect (Also Corona and PIM).

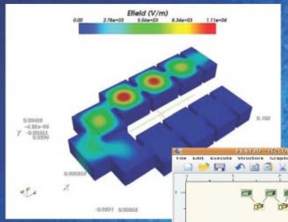
- Facilities dedicated to R&D
- Trainees 100% dedicated to R&D
- Support from Universities and industry

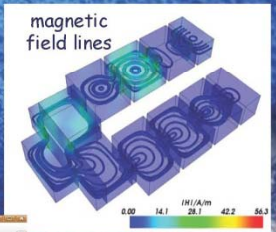
Simulation and prediction

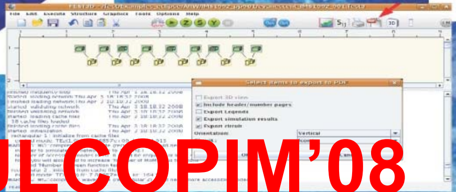
Simulation and prediction software: FEST3D

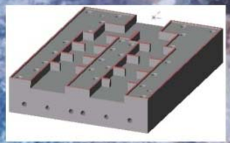
ESA funded several simulation/prediction software packages along many years. However, main efforts were concentrated in the development of FEST3D.

Distributed by ASAT and ItLink







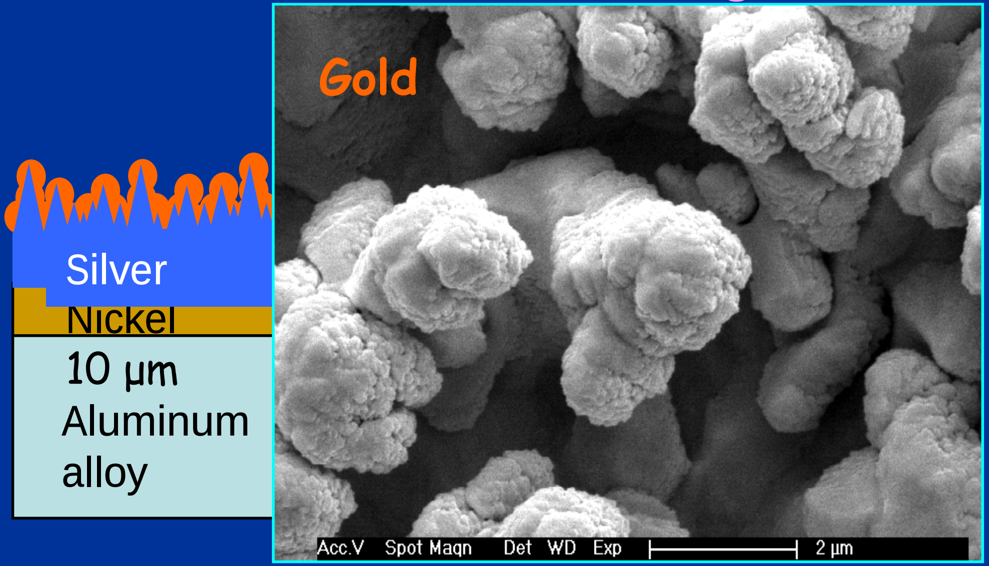


D. Raboso (ESA/ESTEC), MULCOPIM'08

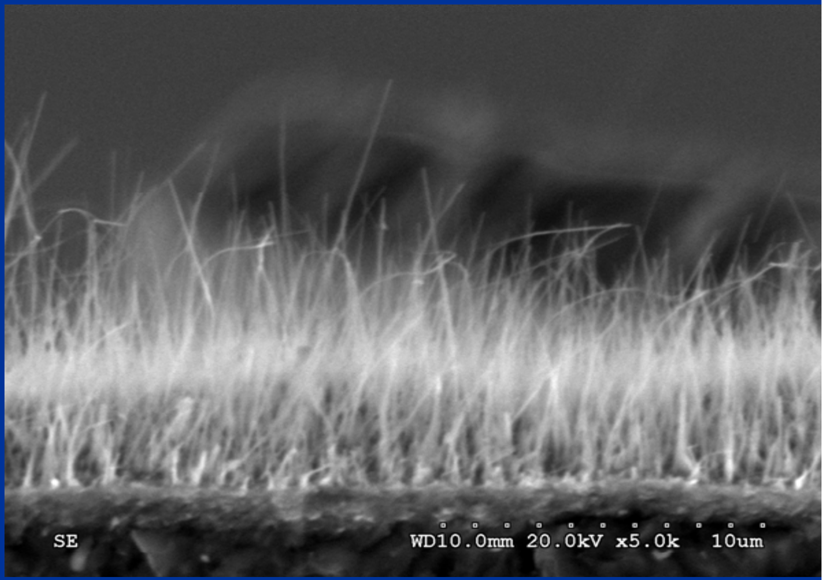
ESA funded SEY research (UAM & CSIC)

Chemical Etching and Sputtering

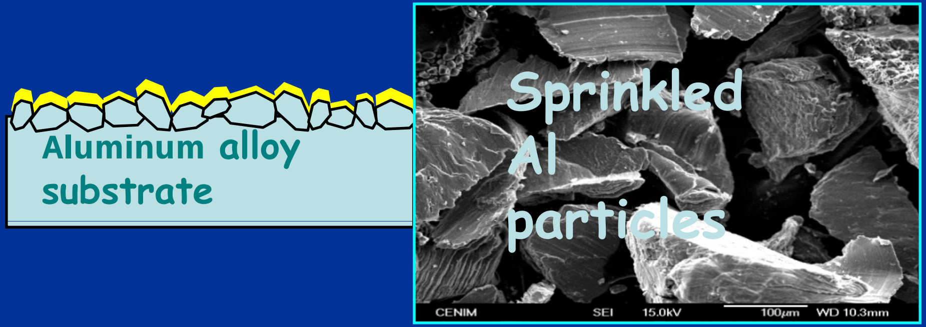
Micro-structured Gold Coating



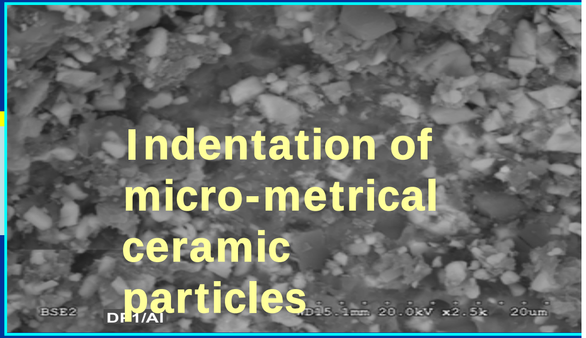
CuO Nanowires Growth



Gold-Coated Aluminum Particles

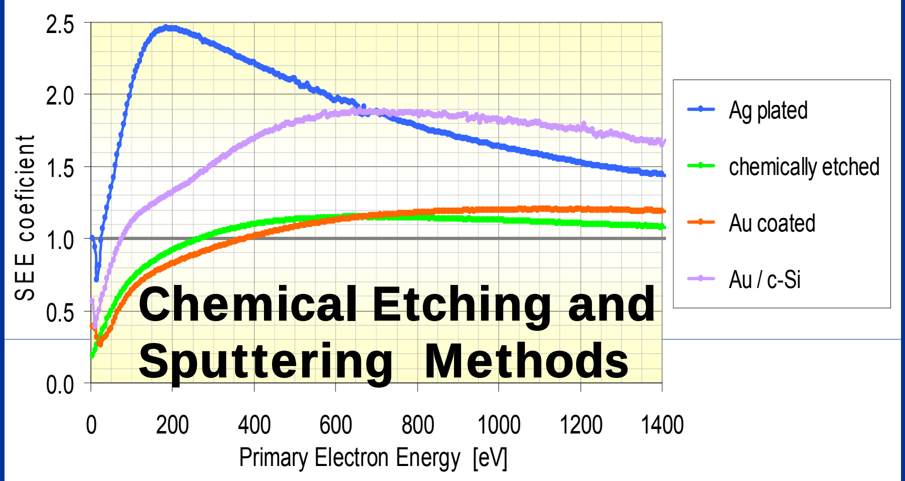


Gold-Coated Micrometrical Ceramic Particles



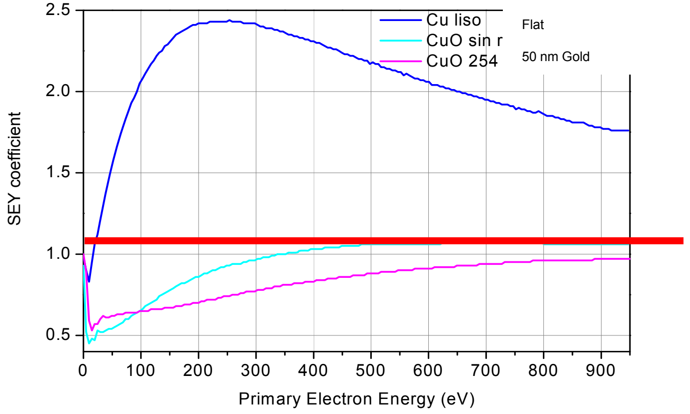
ESA funded SEY research (UAM & CSIC)

Micro-structured Gold Coating

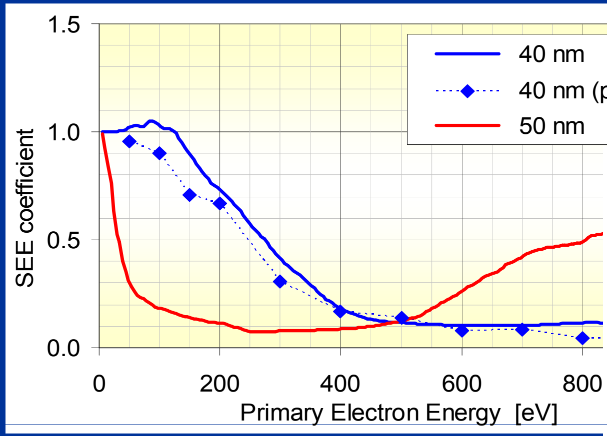


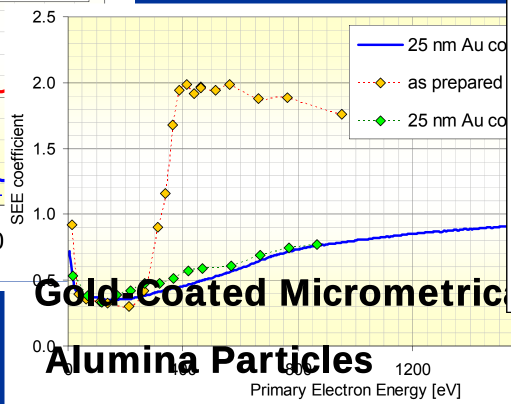
Chemical Etching and Sputtering Methods

CuO Nanowires Growth



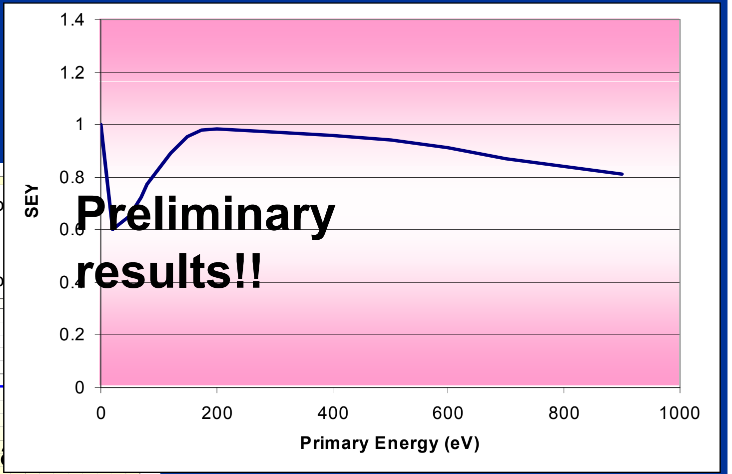
Gold-Coated Dispersed Nanometrical Alumina Particles





Gold-Coated Micrometrical Alumina Particles

Dispersed Micrometrical Magnetic Particles



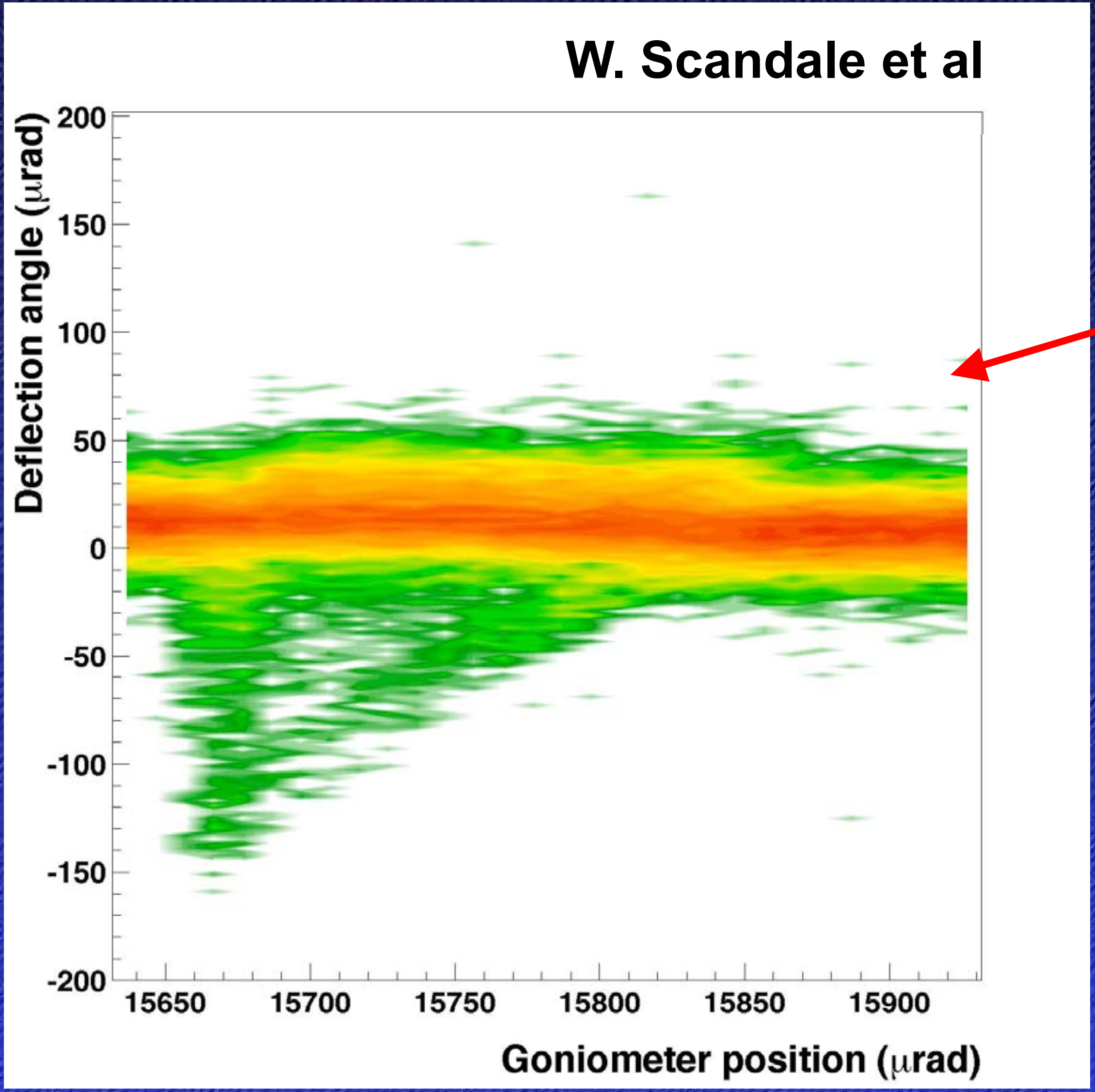
Preliminary results!!

I. Montero, HHH ECM'08 mini-workshop

complementary advanced schemes:

- beam-beam compensation
- crab waist collision
- electron-cloud mitigation
- crystal collimation
- cooling

crystal collimation



experiments
in SPS North
area since 2005

2008 result:
crystal deflection
of negative pions
and muons

parallel simulation
effort

approved experiment
in SPS ring proper

complementary advanced schemes:

- beam-beam compensation
- crab waist collision
- electron-cloud mitigation
- crystal collimation
- cooling

cooling

lower beam emittance

- can compensate for luminosity loss due to large crossing angle [R. Garoby]
- may be provided by new injectors
- and/or by "coherent e- cooling" [V. Litvinenko]

damping times in hours:

Collider	Species	Energy, GeV/n	Synchrotron radiation	Electron cooling	**Coherent electron cooling**
RHIC	Au ions	100	$\sim 2\ 10^4$	~ 1	**0.015**
RHIC	proton	2,750	$\sim 4\ 10^4$	> 30	**0.3**
LHC	Pb ions	450	10	$>4\ 10^4$	**0.15**
LHC	protons	7,000	13	∞	**~ 1**

promise of
1-hr damping
time at 7 TeV!

CeC proof-of-Principle experiment at RHIC in 2012

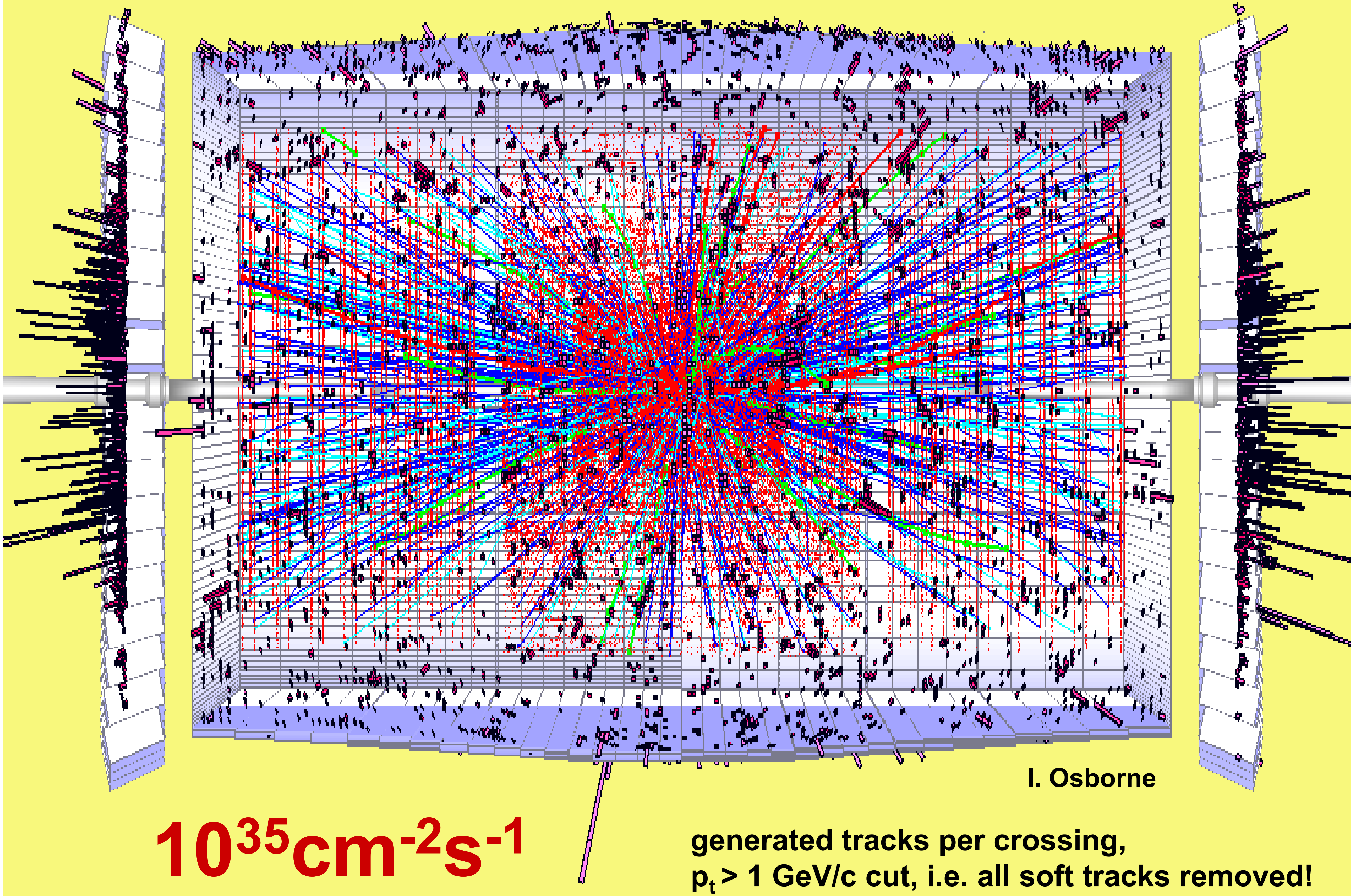
strategy for “phase-2”

HHH

strategy for “phase 2”

- ✓ **R&D program for larger-aperture higher-field magnets**
- ✓ in parallel **crab-cavity development and testing**
- ✓ design, production & installation of **wire compensator** already in “phase 0”
- ✓ monitor **complementary schemes**, like crab waist, coherent e-cooling, e-lenses, crystal collimation; integrate them into upgrade plan when they become available
- ✓ validation **generation method for long flat bunches**
- ✓ identify **main limitations of the real LHC**
- ✓ **LHC & injector machine studies** to explore upgrade scenarios, e.g. LPA and LE
- ✓ close coordination with **detector upgrades**

thank you for your attention!



I. Osborne

$10^{35}cm^{-2}s^{-1}$

generated tracks per crossing,
p_t > 1 GeV/c cut, i.e. all soft tracks removed!