Welcome

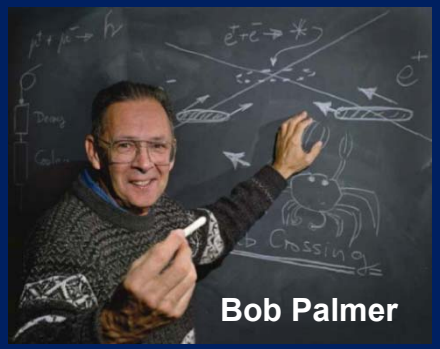
CARE-HHH

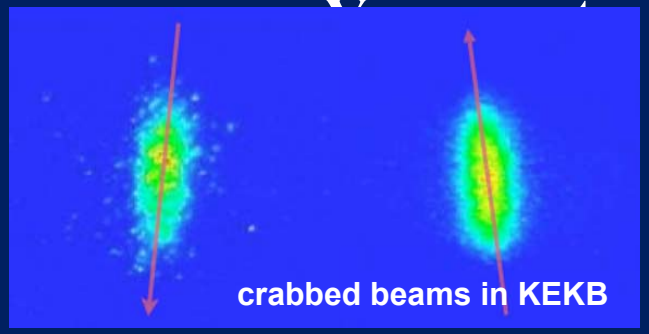
LHC Crab Cavity Validation

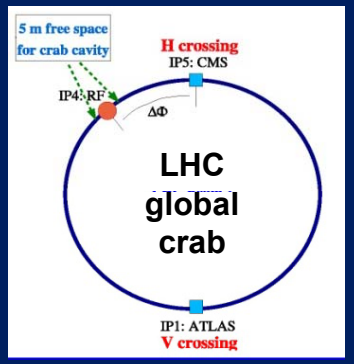
Mini-Workshop

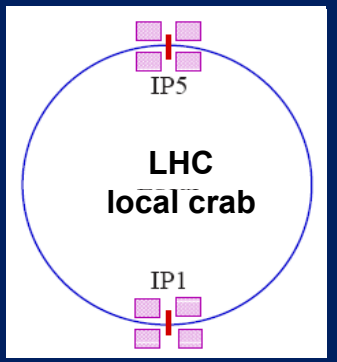
Organizers: Rama Calaga, Rogelio Tomas, Frank Zimmermann

Acknowledgements: Walter Scandale, Yi-Peng Sun, Jean-Pierre Koutchouk, Ilan Ben-Zvi, Steve Peggs, Katsunobu Oide, Akira







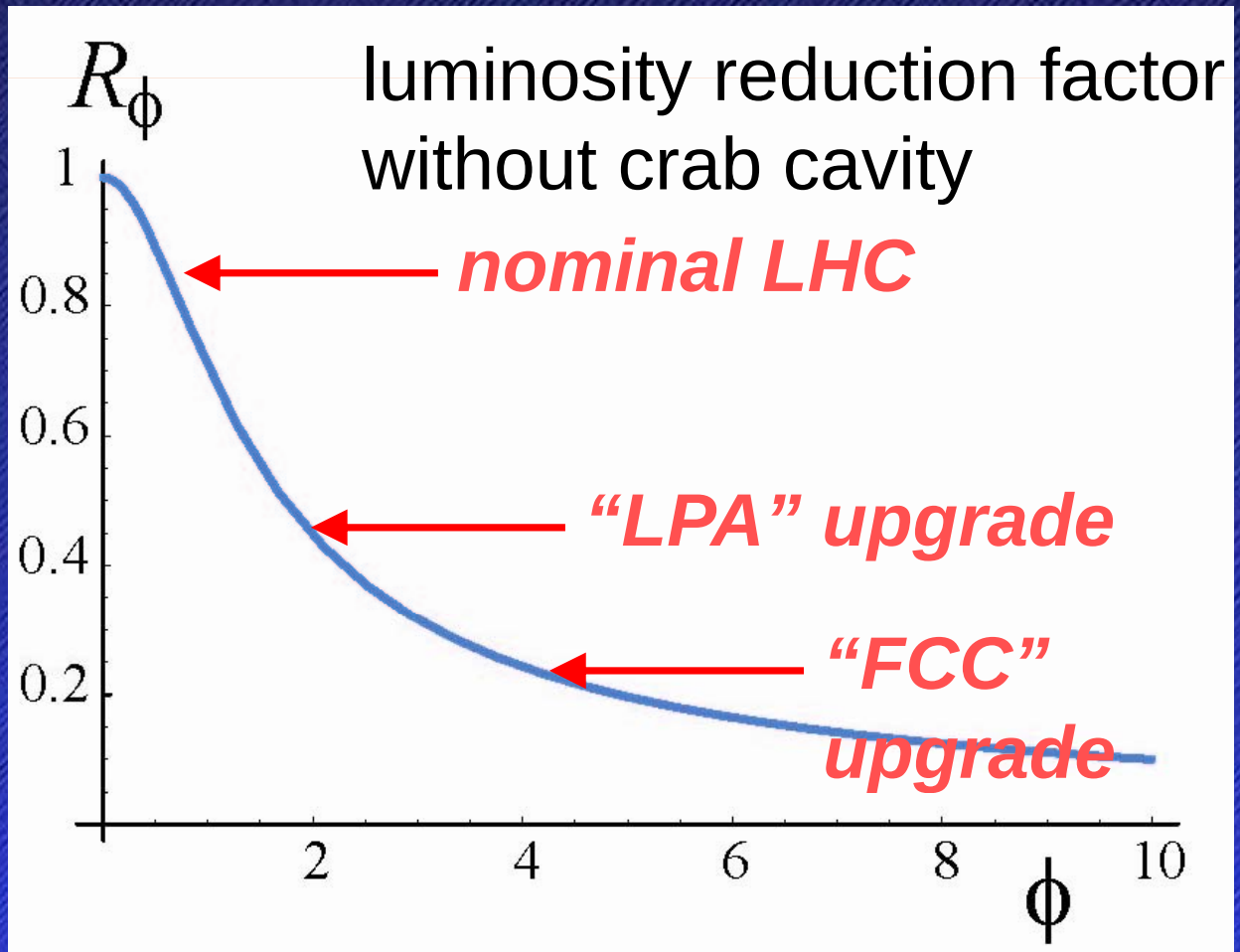


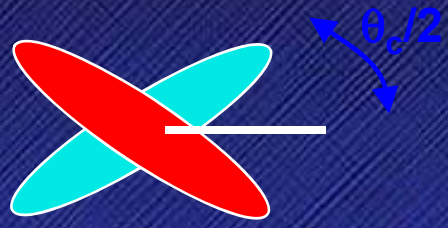
We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

motivation

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

"Piwinski angle"





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

brief history

1970s : CERN/Karlsruhe s.c. deflecting cavities for Kaon separation (2.86 GHz)

1988: Bob Palmer proposes crab cavities for linear colliders

1989: proposal of crab cavities for e+e- factories (Katsunobu Oide & Kaoru Yokoya)

1991: Cornell 1.5 GHz scaled model crab cavity

1993: KEK 500 MHz crab cavity with extreme polarization

2001: crab cavity option in LHC upgrade feasibility study , LHC Project Report 626

2004-2006: LHC crab cavities in CARE-HHH workshops HHH-2004, LUMI-05, LUMI-06

2006/07: launch of US-LARP crab activities

2007: KEKB crab cavity operation

2007: launch of LHC-ILC crab collaboration & LHC-crab twiki pages

2008: 25-26. February, Joint BNL/US-LARP/CARE-HHH mini-workshop on LHC crab cavities, LHC-CC08

2008: April, ICFA Mini-Workshop on Deflecting/Crabbing Cavities, Shanghai

2008: July, launch of joint CERN-KEK crab cavity meetings

2008: 20. August LHC Crab-Cavity Validation Mini-Workshop

Piwinski angles in LHC and KEKB

	LHC nominal	LHC "ultimate"	LHC "FCC" upgrade	LHC "LPA" upgrade	KEKB	Super-KEKB
σ_z [mm]	75.5	75.5	75.5	118.0	7.0	3.0
σ_x^* [μm]	16.6	15.8	6.3	11.2	103	69.3
θ_c [mrad]	0.285	0.315	0.673	0.381	22.0	30.0
ϕ	0.64	0.75	4.1 (w/o crab)	2.0	0.75 (w/o crab)	0.65 (w/o crab)

mini-workshop goals

- ✓ discuss prospects of crab cavities in LHC upgrades
- ✓ review status of cryomodule development and beam dynamics
- ✓ establish validity requirements for crab cavities necessary prior to their installation into the LHC
- ✓ provide guidance & coordination for global collaborators

statistics & organization

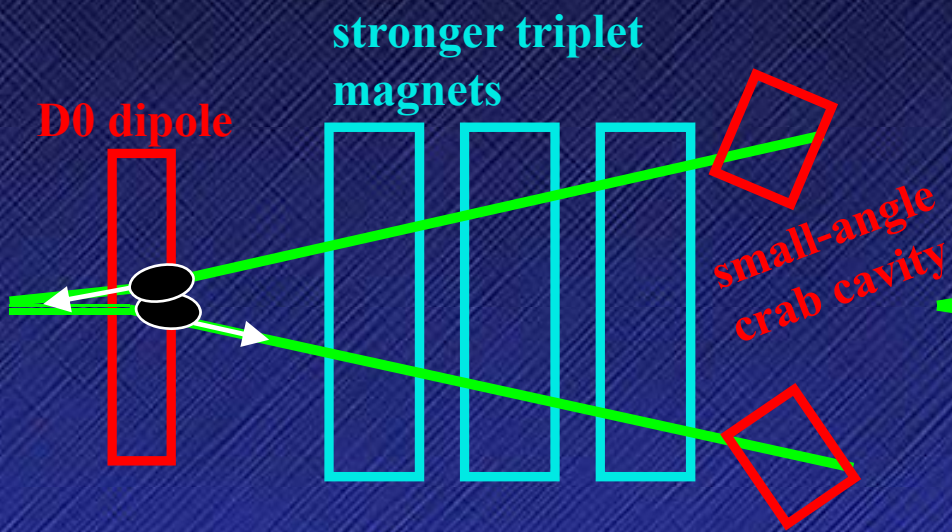
- 28 registered participants

  16 CERN, 4 KEK, 2 CI/DL, 2 BNL, 2 SLAC, 1 FNAL, 1 NIKHEF, 1 Oslo
- some US + additional KEK participation via WebEx
- 4 sessions, each ending with 30-60 minutes discussion
- possibility of no-host dinner if interest

thank you for attending
& good luck!

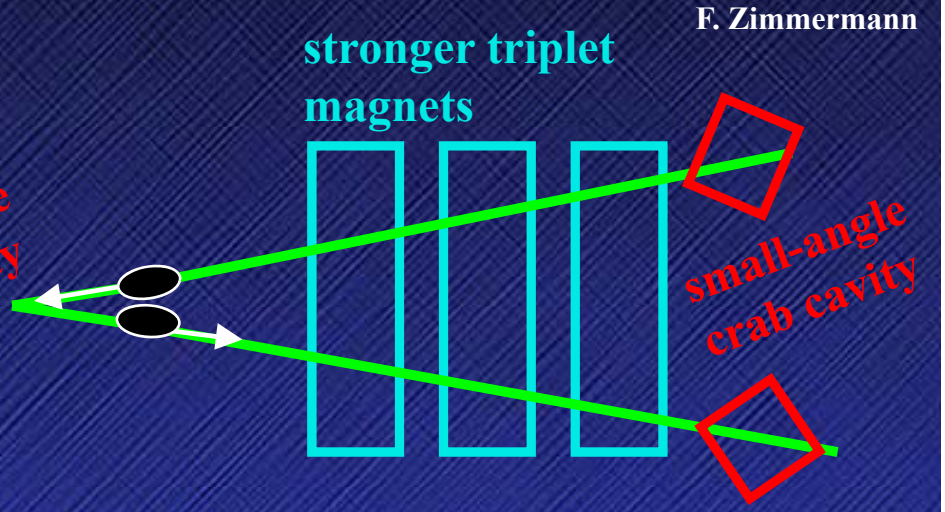
Reminder: LHC upgrade paths

early separation (ES) J.-P. Koutchouk



- ultimate beam (1.7x10^{11} protons/bunch, 25 spacing), β* ~10 cm
- early-separation dipoles in side detectors , crab cavities
  → hardware inside ATLAS & CMS detectors,
  first hadron crab cavities; off-δ β

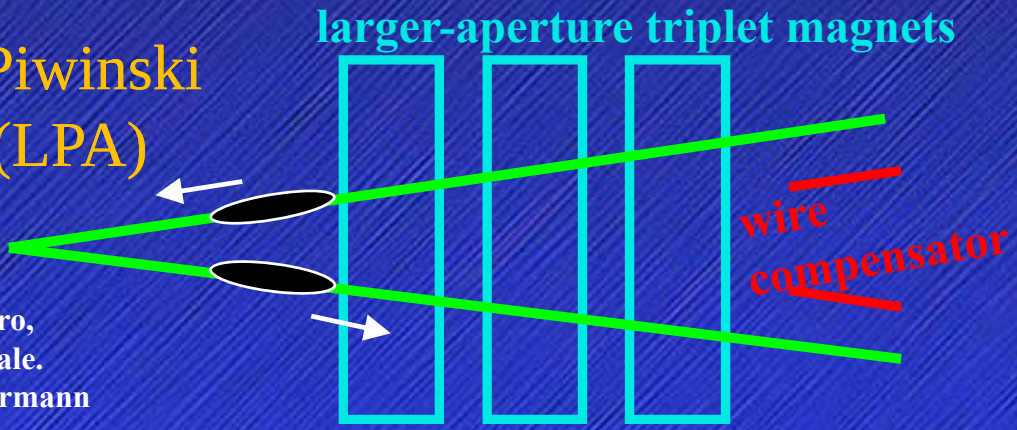
full crab crossing (FCC) L. Evans, W. Scandale, F. Zimmermann



- ultimate LHC beam (1.7x10^{11} protons/bunch, 25 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} protons/bunch)
- β*~25 cm, no elements inside detectors
- long-range beam-beam wire compensation

→ novel operating regime for hadron colliders,
beam generation

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	1	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.

early separation (ES)

full crab crossing (FCC)

large Piwinski angle (LPA)