Crab Cavities for LHeC

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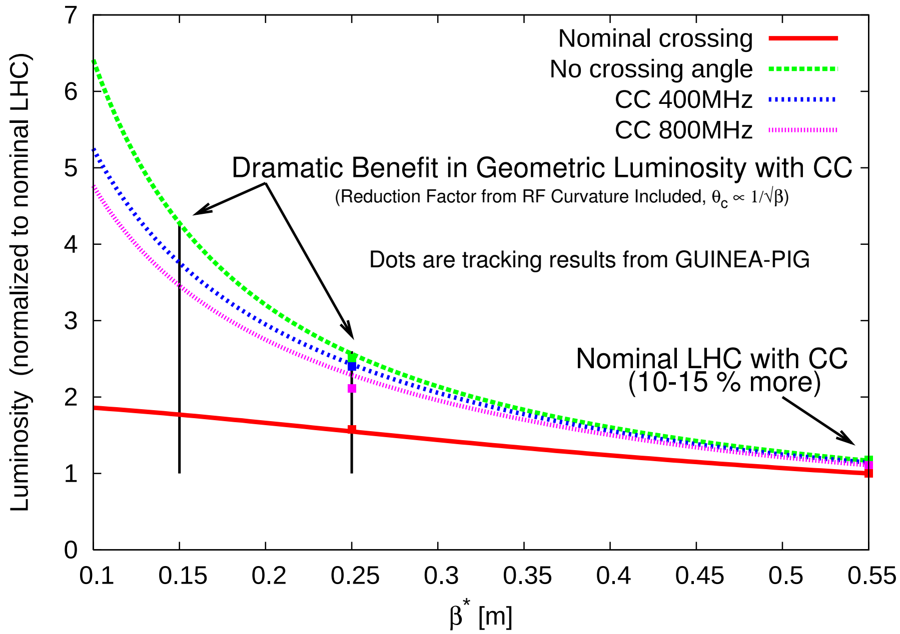
Ack: O. Brüning, F. Zimmermann

Luminosity Gain



800 MHz CC, Baseline
based on RF technology & physical space

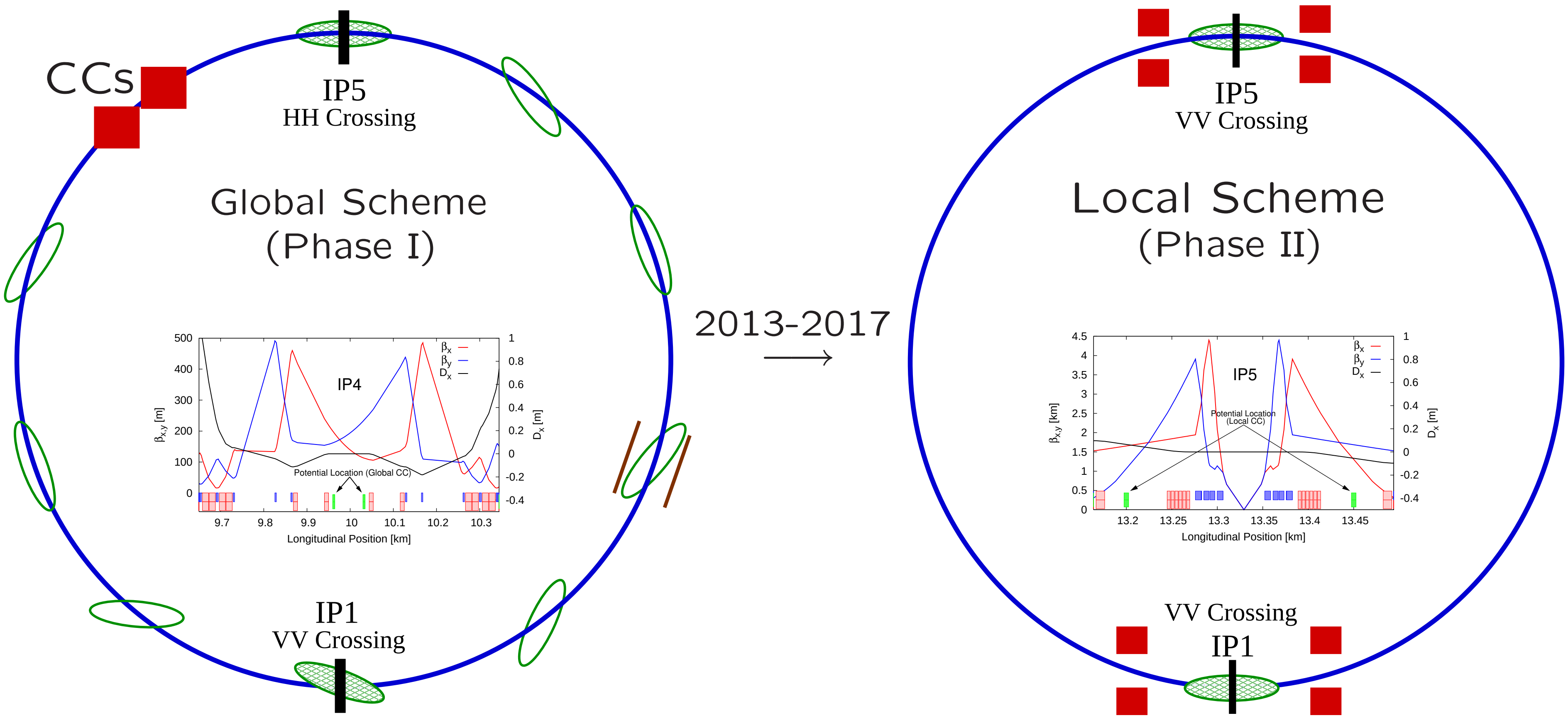
$\Delta L/L >$ 50% for $\beta^* = 0.25$cm

Piwinski Angle: $\Phi_p \sim \frac{\theta_c}{2\sqrt{2}\sigma_x^*}\sqrt{\sigma_{z,1}^2 + \sigma_{z,2}^2}$

Par	KEK-B	LHC			LHeC		eRHIC
		Nominal	Phase I	LPA	RR	LR	
θ_c [mrad]	22.0	0.285	0.420	0.381	1.0	0.0 (?)	0.0 (5.0)
σ_z [cm]	0.7	7.55	7.55	11.8	7.55 (0.7†)		20/1.2†
σ_x^* [μm]	103	16.6	11.2	11.2	30 (15.8*)		**32**
Φ	0.75	0.64	1.4	2.0	**0.9 (1.6*)**	0.0	0.0 (11.0)

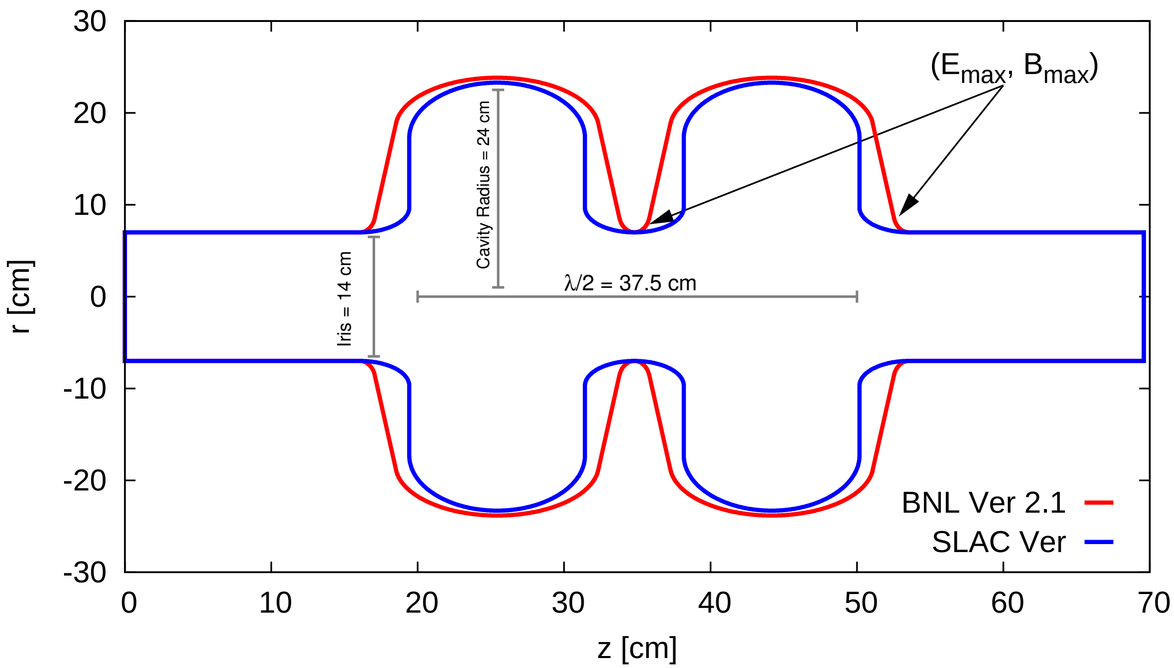
† for electrons
∗ vertical plane

Two Schemes for LHC



Par	Unit	Nominal [G]	Upgrade [L]
IP$_{\{1,5\}}$ β^*	[cm]	55 (25)	25 (15$_{\text{ES,CC}}$)
θ_C	[mrad]	0.3	0.44 (0.58)
β_{CC}	[km]	0.8	3.0
CC Volt	[MV]	4.7 (10.5)	3.5 ($\leq$ 5)

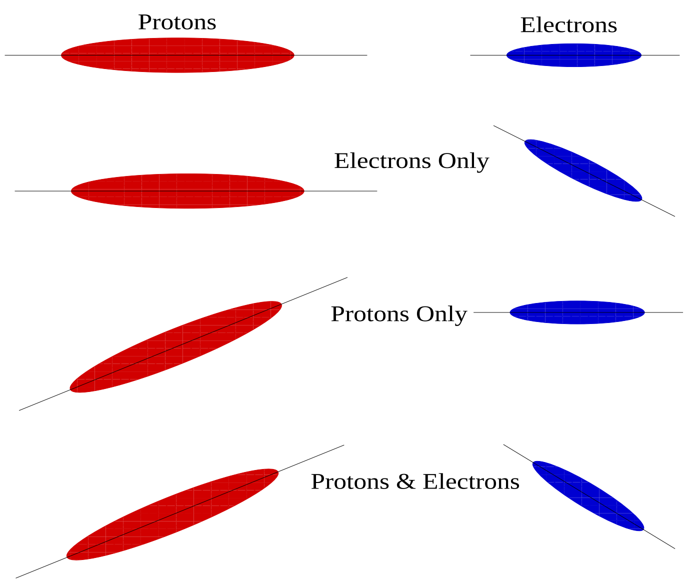
Baseline LHC Cavity, 800 MHz



- 800 MHz elliptically sqaushed cavities (~2.5 MV/module)
- RR: 1 mrad ⇒ **approx 7.6 MV** (assuming $\beta_{cc} = 420$ m & $\beta^* = 180$ cm)
- Will need VV crossing with current IR configuration. Transverse space should be considered in the IR design for flexibility
- Infrastructure is identical & will be available from LHC, so no big R&D.
- Compact cavities under development for LHC, so maybe available for LHeC

Ring-Ring Option

Parameter	unit	Ring-Ring	
		$e^{\pm}$	p
Beam Energy	GeV	70	7000
Beam Current	mA	74	544
Part/Bunch	10^{10}	1.4	17
θ_c	mrad	1 - 2	
$\epsilon_{x,y}$	nm	7.6/3.8	0.501
$\beta_{x,y}$	cm	12.7/7.1	180/50
σ_z	cm	0.7	7.55
Rep. Frequency	MHz	40	



Scenario	L/L_0
Head-On (with CCs)	1.88 (1.48)
Uncross only e^-	1.007
Uncross only p^+	1.48
X-Angle (**1 mrad**)	1.0

Actual geometric luminosity gain

48% - 88%

(Not including gain ξ_{BB})

Linac-Ring

Parameter	unit	Linac-Ring			
		$e^{\pm}$[CW 4P]	$e^{\pm}$[ERL 4P]	p	p^* (LPA)
Beam Energy	GeV	20	60	7000	7000
Beam Current	mA	0.4	2.05	500	?
Part/Bunch	10^{10}	0.006	0.3	17	50
$\epsilon_{x,y}$	nm	0.5	0.5	0.5	?
$\beta_{x,y}$	cm	25	14	25	10
σ_z	cm	0.001	0.001	7.55	11.8
Rep. Frequency	MHz	40			

Basic assumption: $\sqrt{\beta_{cc} \times \beta^*} \sim$ constant

Luminosity gain will depend on the crossing angle required to reduce the synchrotron radiation constraints.

The gain should be similar as in ring-ring option as the proton parameters dominate.

Conclusions

- Crab cavities have very high potential for LHC upgrade. R&D is being pursued aggresively, expected to be ready by 2013

- LHeC has similar constraints as the LHC and technologically similar challenges

- For $\theta_c > 0.5$ mrad, luminosity gain is considerable with crabbed protons

- RR (1 mrad): Assuming $\beta_{cc} = 420$ m & $\beta^* = 180$ cm, $V_{cc} \approx 7.6$ MV (LR option is similar)

- For $\theta_c > 2$ mrad will need several cryomodules, challenging but gain is significant. Full Crab Scheme: $\langle E_\uparrow L_\uparrow C_\uparrow \rangle$

- Crabbed $e^{\pm}$: Extra knob to control synchro-radiation fan density