

XCC Status

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LC Thinking Group
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Agenda

- Modifications to e beam sources
- bunch train formats
- bypass lines
- nominal beam energy levels
- FEL footprint
- IP layout
- Options for staging 130 GeV COM initial machine or 250 GeV COM initial machine

We'd like to discuss CCC at Michael Peskin's meeting on Aug. 12th since multiple events with Snowmass EF are coming up in Sept./Oct.

Modifications to e^- sources

Start with the UCXFEL gun described in

J.B. Rosenzweig, et al., Phys Rev Accel and Beams 22, 023403 (2019)

“Next generation high brightness electron beams from ultrahigh field cryogenic rf photocathode sources”

which has $Q_b = 0.1 \text{ nC}$ $\gamma\epsilon_x = \gamma\epsilon_y = 36 \text{ nm}$ $\tau_{\text{pulse}} = 10 \text{ psec}$ $\text{Pol}_{e^-} = 0\%$

For XCC we specify

$Q_b = 1.0 \text{ nC}$ $\gamma\epsilon_x = \gamma\epsilon_y = 120 \text{ nm}$ $\tau_{\text{pulse}} = 10 \text{ psec}$ $\text{Pol}_{e^-} = 90\%$

The emittance was obtained by scaling the UCXFEL number by $\sqrt{Q_b}$

The 90% electron polarization is used to achieve an ILC-like Higgs production rate:

Machine	Polarization	$N_{\text{Higgs}} / (10^7 \text{ s})$	$N_{\text{Hadronic Events}} (\sqrt{s} > 60 \text{ GeV}) / N_{\text{Higgs}}$	$N_{\text{minbias/BX}}$
XCC	0% e^-	5,000	220	9.5
XCC	90% e^-	25,000	70	9.5
ILC	-80% e^- +30% e^+	42,000	230	1.3
ILC	+80% e^- -30% e^+	28,000	55	1.3

- Full simulation with $Q_b = 1 \text{ nC}$ is needed to verify the $\sqrt{Q_b}$ scaling assumption.
- R&D on a polarized gun is required; this will benefit both C³ – 250 & XCC

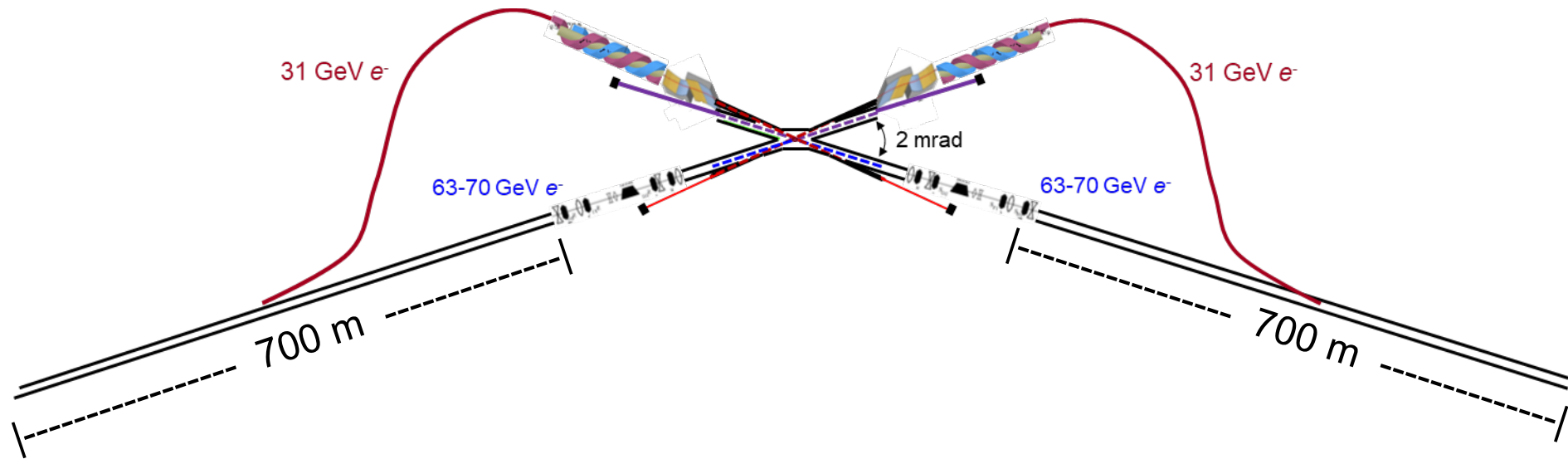
Bunch Train Format

For XCC the bunch train format depends on the e^- energy.

E_{e^-} (GeV)	Q_b (nC)	Rep Rate (Hz)	N_b /train	bunch spacing (ns)
0–31	1	240	76	3.3
31–70	1	240	38	6.6

Bypass Lines

Two 350 m transport lines needed for the 31 GeV e^- beams that feed the XFEL's



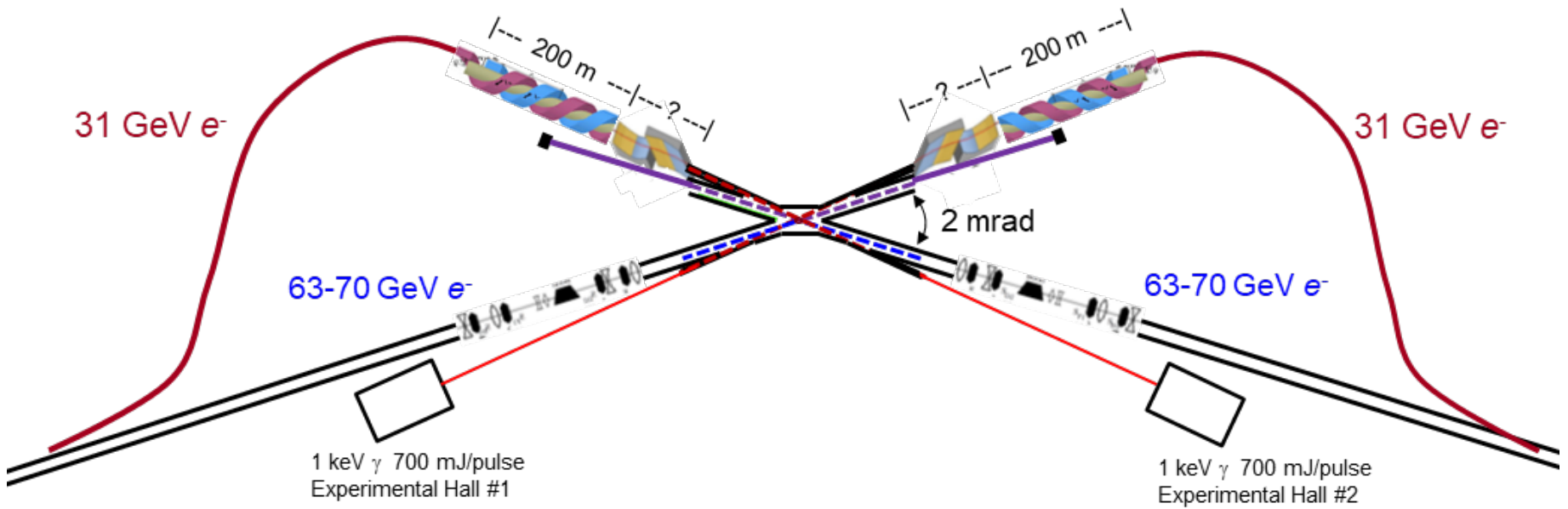
XCC e^- Energy Levels

31 GeV e^- beam is always used to drive the XFEL to produce 1 keV x-rays.

The final E_{e^-} then determines the Compton-scattered γ energy:

E_{e^-} (GeV)	HEP program
63	Resonance production $\gamma\gamma \rightarrow H$
70	$e^- \gamma \rightarrow e^- H$ for Higgs coupling calibration
140–175	$\gamma\gamma \rightarrow HH$ to study the Higgs potential
175–200	$\gamma\gamma \rightarrow t \bar{t}$ top mass meas. $\Rightarrow$ EW vacuum stability

IP Layout incl. XFEL footprint



XCC Staging Options, incl. prototyping

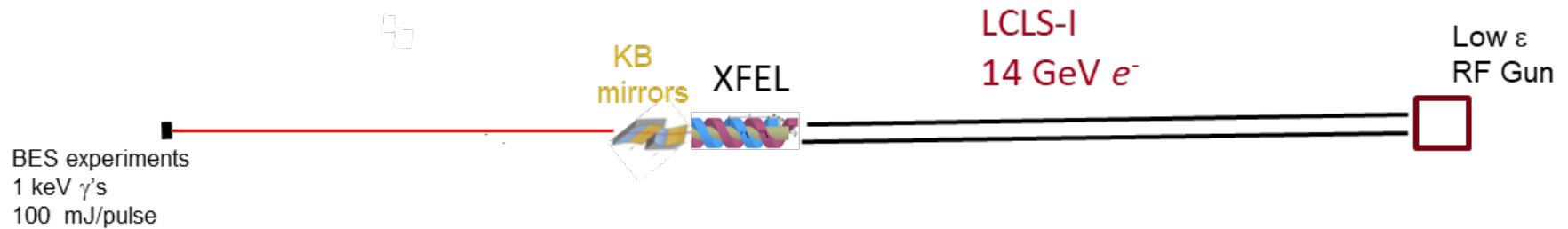
Year	E_{e^-} (GeV)	Pol_{e^-} (%)	N_b / train	Program
2025	14 (LCLS-I)	0	8	1 keV γ , 100 mJ/pulse for BES
2027	14 (LCLS-I) / 5 (C ³)	0 / 90	8	10^{18} 5 GeV γ 's / year via Compton collision at x=80
2032	63 – 70	90	76	Model independent Higgs couplings at 25,000 Higgs/yr
2034	63 – 70	90	200	Model independent Higgs couplings at 65,000 Higgs/yr
2042	140 – 175	90	200	$\gamma\gamma \rightarrow \text{HH}$ to study the Higgs potential
2046	175 – 200	90	200	$\gamma\gamma \rightarrow t\bar{t}$ top mass meas. $\Rightarrow$ EW vacuum stability

Path to 1 keV γ , 100 mJ/pulse by 2025

Year	FTE	Activity
2021	0.1	Full simulations of undulator and cryo RF gun
2021	0.1	Very preliminary study of X-ray focusing system
2021	0.1	Initial look at possible BES science programs
2022	1	Full start-to-end simulation incl. bunch compressor optimization, bypass design etc
2022	1	Detailed design of X-ray focusing system
2022	0.1	Further work on BES science programs
2022	1	Detailed design of cryo RF run

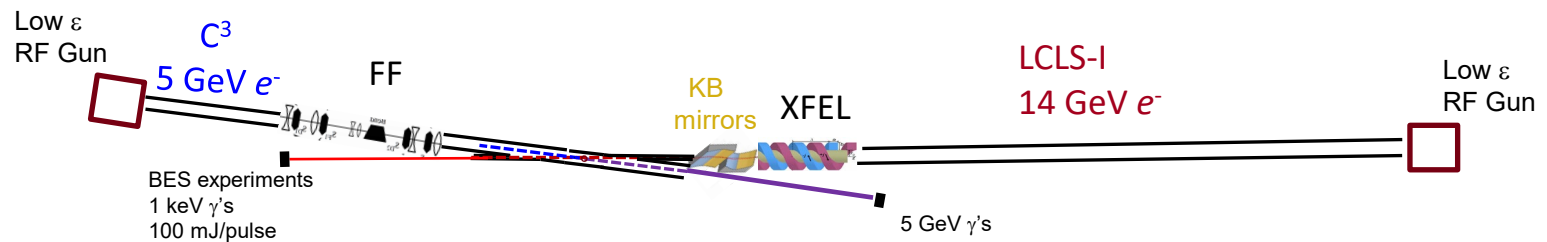
1 keV γ , 100 mJ/pulse XFEL for BES Exp.

Test 100 mJ/pulse XFEL
and focusing of 1 keV γ 's

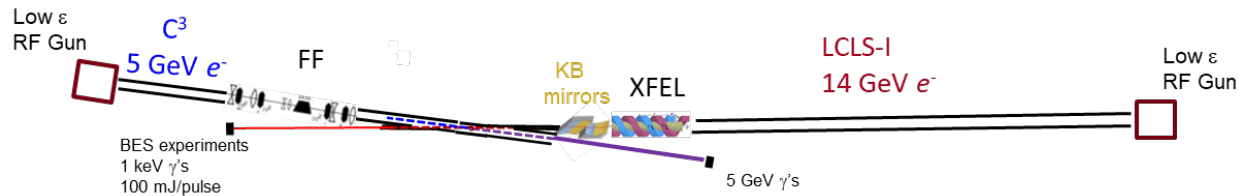


Add 5 GeV C^3 Linac to Produce 5 GeV γ 's (BES + HEP)

Test Compton scattering of 1 keV γ 's on 5 GeV e^-

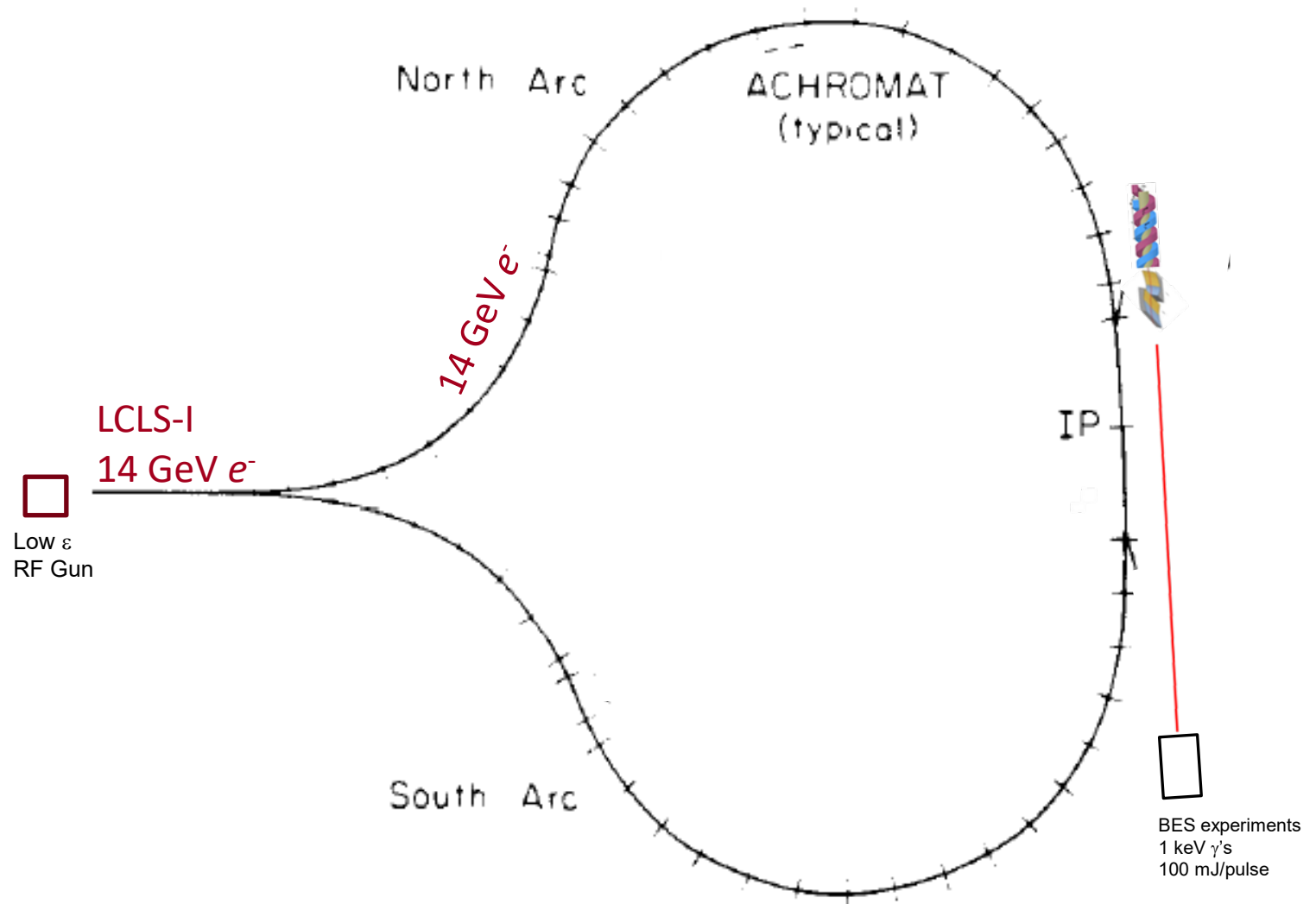


Where to add 5 GeV C^3 Linac to Produce 5 GeV γ 's ?



This setup has multiple problems. Michael suggested using one of the SLC arcs.

Stage 1 BES - concurrent with C3 development



Emittance growth in SLC Arcs

From Tor Raubenheimer, An SLC-Like Higgs Factory, SLAC Retreat 27Sep2012 :

- ISR in arcs – very strong function of beam energy

$$E_{\text{arc}}[\text{GeV}] = 8.846 \times 10^{-5} \frac{(E[\text{GeV}])^4 \theta}{2\rho[\text{m}] \pi} \rightarrow \Delta E \sim 3 \text{ GeV for } 180^\circ \text{ at } 85 \text{ GeV and } \rho = 800 \text{ m}$$

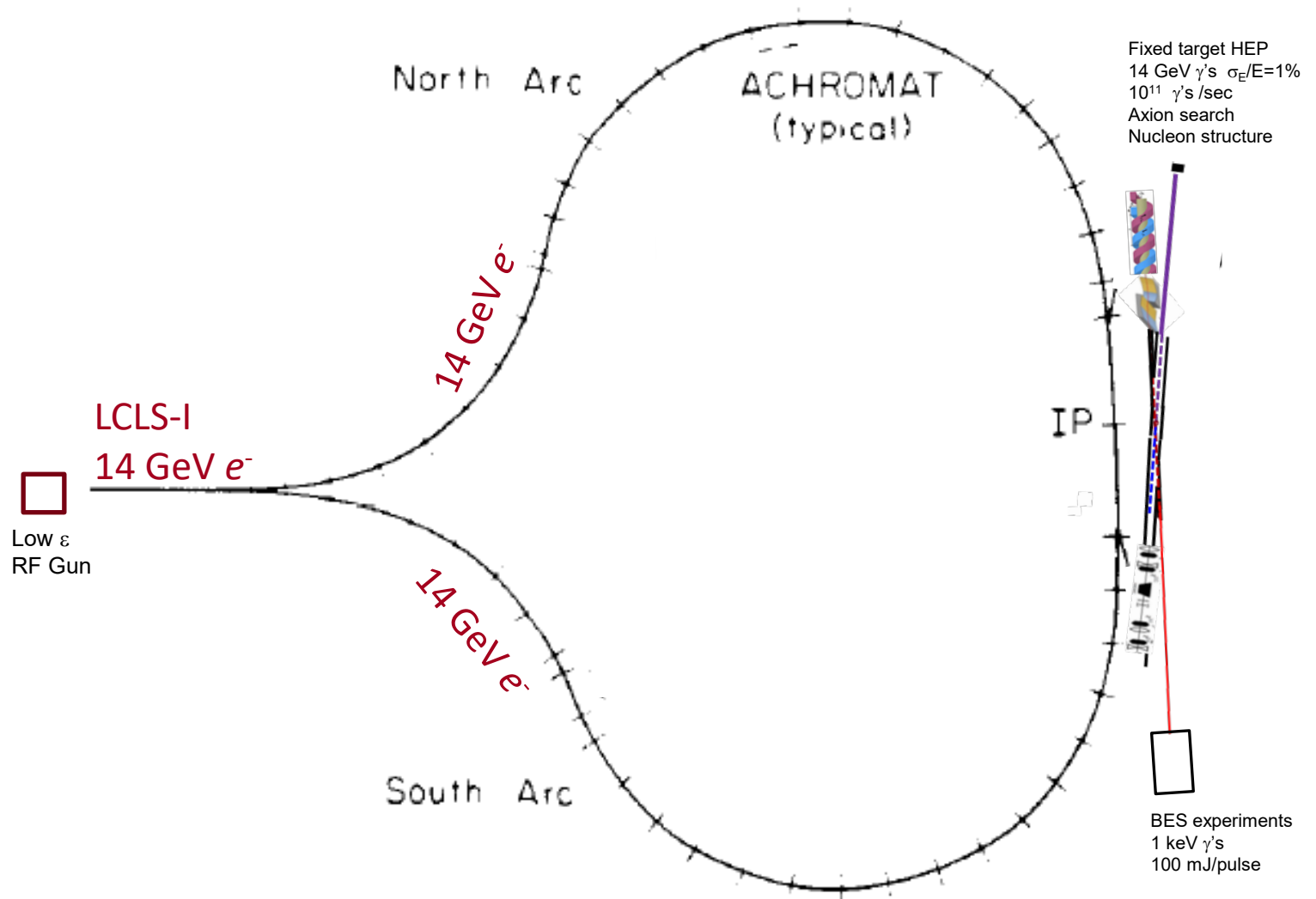
$$\Delta\sigma_E^2 = \frac{55\alpha(\hbar c)^2}{48\sqrt{3}} \gamma^7 \frac{\pi \theta}{\rho^2 \pi} \rightarrow \Delta E/E \sim 8\text{e-}4 \text{ for } 180^\circ \text{ at } 85 \text{ GeV and } \rho = 800 \text{ m}$$

$$\Delta\epsilon_{/N} = \frac{2\pi c_q r_e}{3} \frac{\gamma^6 \langle H \rangle \theta}{\rho^2 \pi} \rightarrow \Delta\epsilon_{/N} \sim 1\text{e-}6 \text{ for } 180^\circ \text{ with } 5.2 \text{ m SLC Arc cell at } 85 \text{ GeV and } \rho = 800 \text{ m} \quad \Delta\epsilon \sim 6 \times 10^{-12}$$

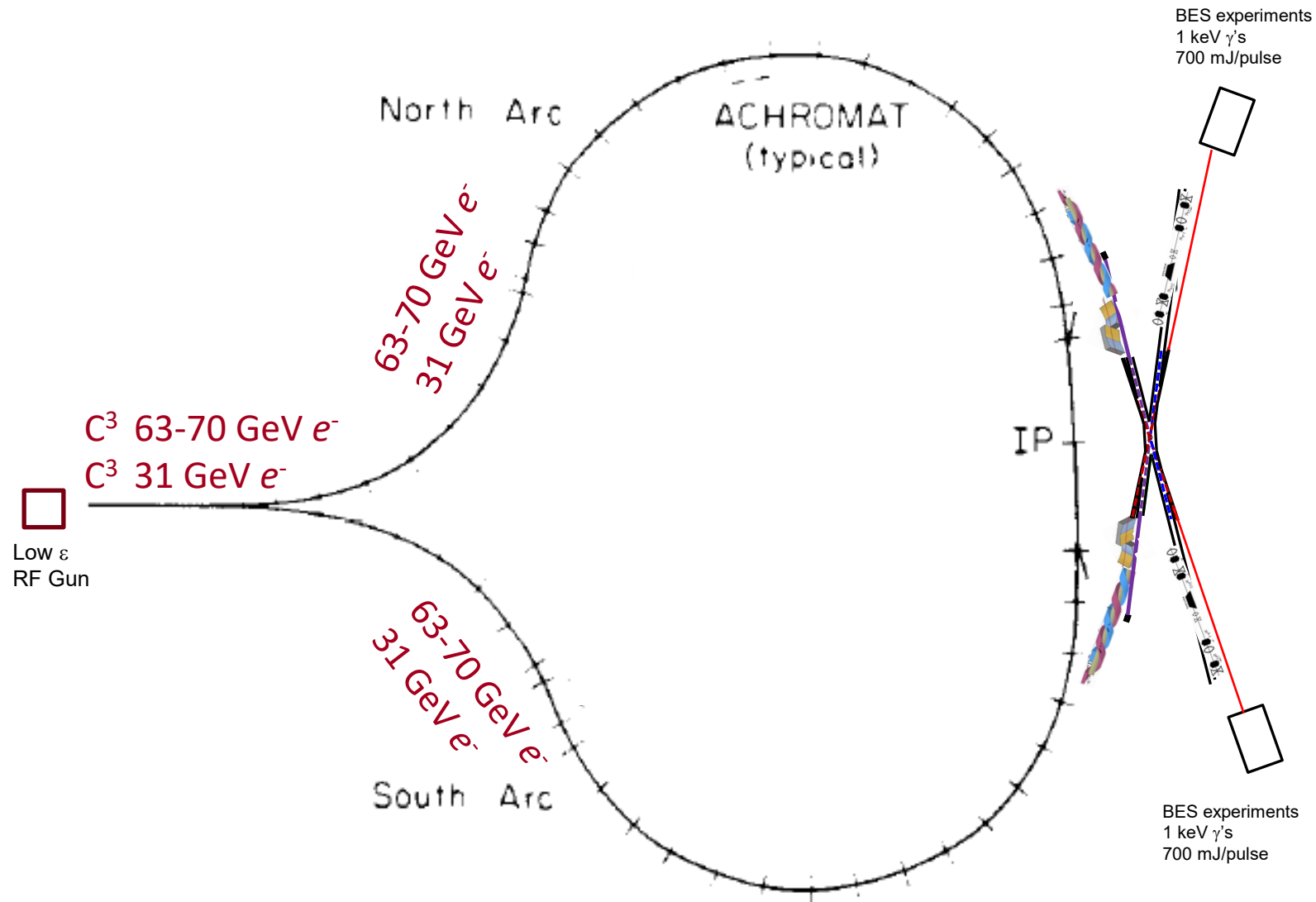
For SLC Arcs $\rho = 280 \text{ m}$

E_{out} (GeV)	$\Delta E/E$ (%)	$\Delta\gamma\epsilon$ (nm)	emittance dilution
14	0.0025	0.2	negligible
31	0.018	19	acceptable
62.6	0.106	1300	$\gamma\gamma \rightarrow H$ rate reduced by factor of 5
70	0.141	2550	$e^-\gamma \rightarrow e^-H$ rate reduced by factor of 7

Stage 2 BES+HEP - still concurrent with C3 development (which takes place independently in NLCTA, e.g.)



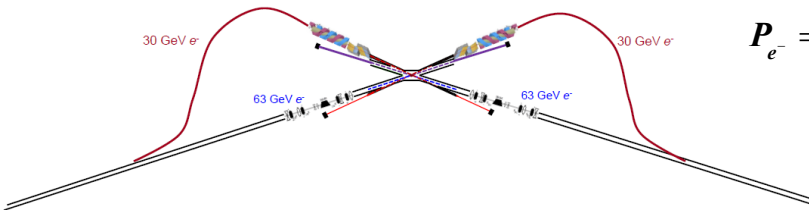
Stage 3 XCC $125 \text{ GeV} < E_{\text{cm}} < 140 \text{ GeV}$



Emittance growth in SLC Arcs

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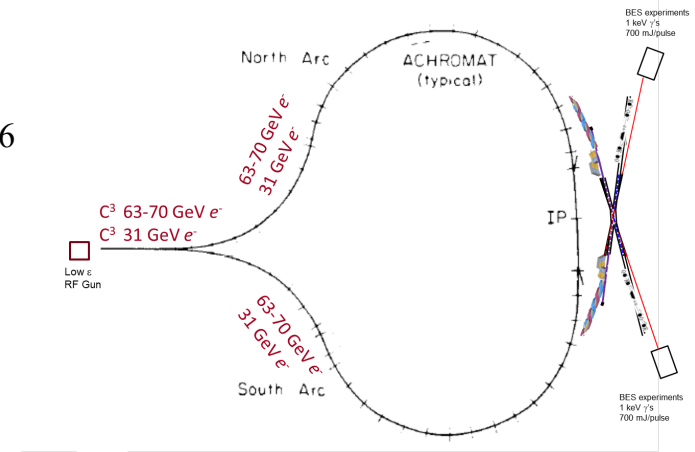
$$\sigma_{ez} = 20 \mu\text{m} \quad \sigma_{\gamma z} = 20 \mu\text{m}$$

$$P_{e^-} = 90.0\% \quad \xi_{\text{non-linear QED}}^2 = 0.16$$

$$d_{\text{cp}} = 60 \mu\text{m}$$

$$N_{\text{Higgs}} / \text{yr} = 25,000$$

$$\gamma\epsilon_x = 120 \text{ nm} \quad \gamma\epsilon_y = 120 \text{ nm} \quad \sigma_E / E = 0.05\%$$



$$N_{\text{Higgs}} / \text{yr} = 5,000$$

$$\gamma\epsilon_x = 1300 \text{ nm} \quad \gamma\epsilon_y = 120 \text{ nm} \quad \sigma_E / E = 0.1\%$$

Emittance growth in SLC Arcs

$$\Delta\epsilon_{/N} = \frac{2\pi}{3} \frac{c_q r_e}{\rho^2} \gamma^6 \langle H \rangle \frac{\theta}{\pi}$$

$$\langle H \rangle = \langle \gamma \eta^2 + 2\alpha \eta \eta' + \beta \eta'^2 \rangle$$

If we could reduce the lattice parameter $\langle H \rangle$ by a factor of 10
then the emittance growth at E=63 and 70 GeV would be under control.

$$\Delta\gamma\epsilon_x = 1300 \text{ nm} \rightarrow 130 \text{ nm at E=62.6 GeV}$$

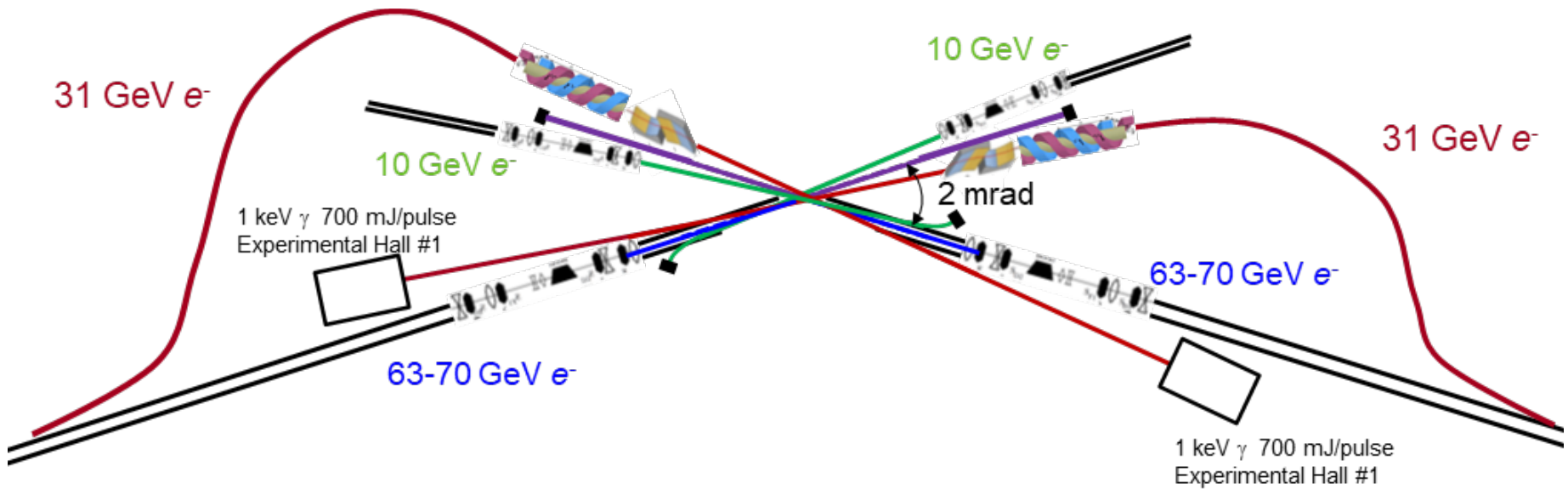
$$\Delta\gamma\epsilon_x = 2550 \text{ nm} \rightarrow 255 \text{ nm at E=70.0 GeV}$$

Stage 4 C3 e+e-, $350 \text{ GeV} < E_{\text{cm}} < 700 \text{ GeV}$



BACKUP SLIDES

IP Layout with 10 GeV Deflector Beams



XCC Staging Options, incl. prototyping

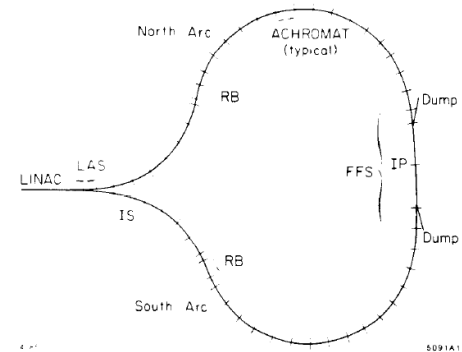
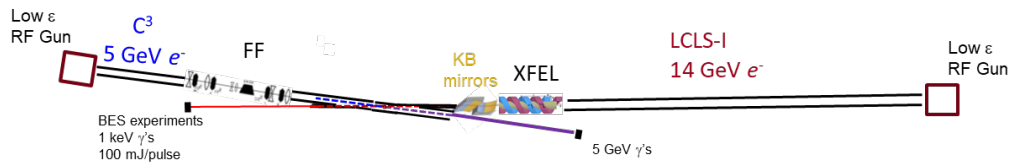
Consider deflector beam option

Year	E_{e^-} (GeV)	Pol_{e^-} (%)	10 GeV Defl. Beams?	N_b / train	Program
2025	14 (LCLS-I)	0	no	8	1 keV γ , 100 mJ/pulse for BES
2027	14 (LCLS-I) / 5 (C ³)	0 / 90	no	8	10^{18} 5 GeV γ 's / year via Compton collision at x=80
2032	63 – 70	90	no	76	Model independent Higgs couplings at 25,000 Higgs/yr
2034	63 – 70	90	yes	76	Model independent Higgs couplings at 30,000 Higgs/yr
2036	63 – 70	90	yes	200	Model independent Higgs couplings at 80,000 Higgs/yr
2042	140 – 175	90	yes	200	$\gamma\gamma \rightarrow HH$ to study the Higgs potential
2046	175 – 200	90	yes	200	$\gamma\gamma \rightarrow t\bar{t}$ top mass meas. $\Rightarrow$ EW vacuum stability

Emittance growth in SLC Arcs

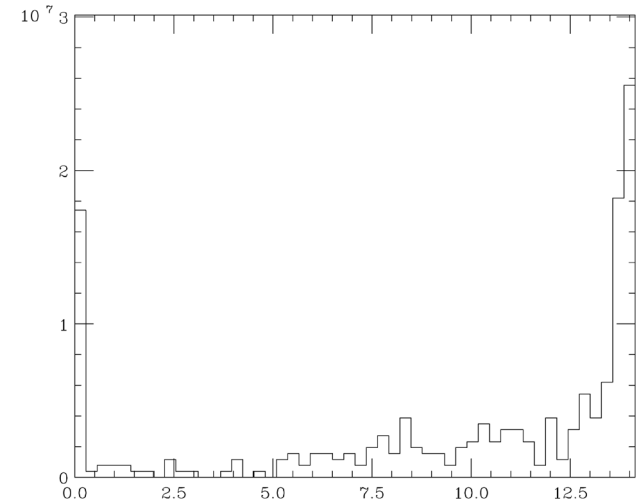
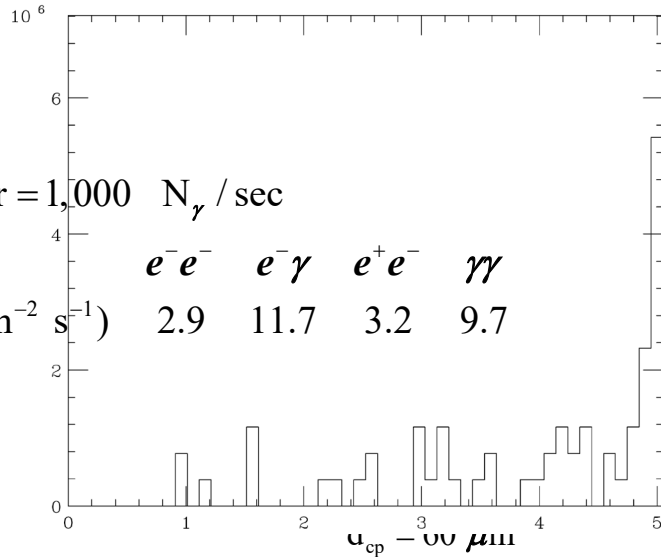
For SLC Arcs $\rho = 280$ m

E_{out} (GeV)	ΔE (GeV)	$\Delta E/E$ (%)	$\Delta\gamma\epsilon$ (m)	$\Delta\epsilon$ (m)
14	0.0062	0.0025	1.63×10^{-10}	5.95×10^{-15}
31	0.15	0.018	1.92×10^{-8}	3.16×10^{-13}
62.6	2.52	0.106	1.30×10^{-6}	1.06×10^{-11}
70	3.94	0.141	2.55×10^{-6}	1.86×10^{-11}

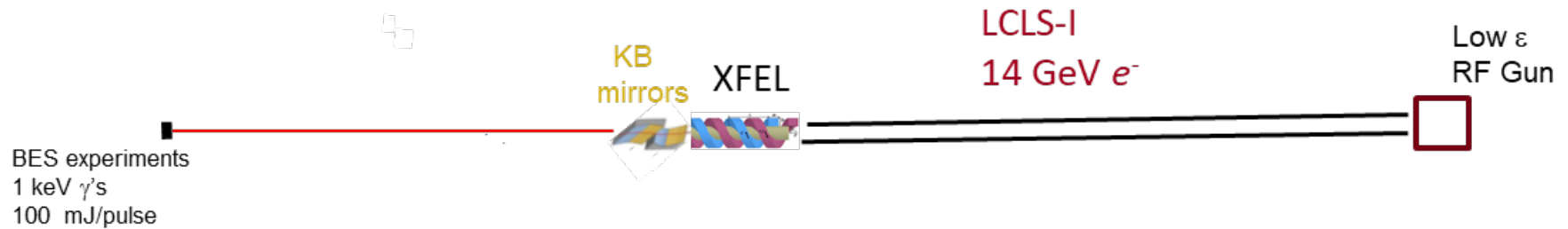


$$N_{\text{Higgs}} / \text{yr} = 1,000 \quad N_{\gamma} / \text{sec}$$

$$\begin{array}{ccccc} \gamma\epsilon_x = 120 & e^-e^- & e^-\gamma & e^+e^- & \gamma\gamma \\ L(10^{33} \text{ cm}^{-2} \text{ s}^{-1}) & 2.9 & 11.7 & 3.2 & 9.7 \\ \gamma\epsilon_x = 1200 & & & & \end{array}$$

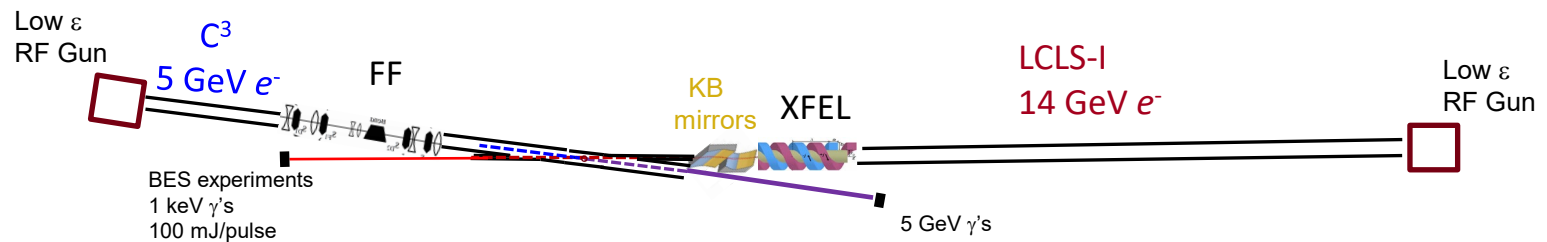


Test 100 mJ/pulse XFEL
and focusing of 1 keV γ 's

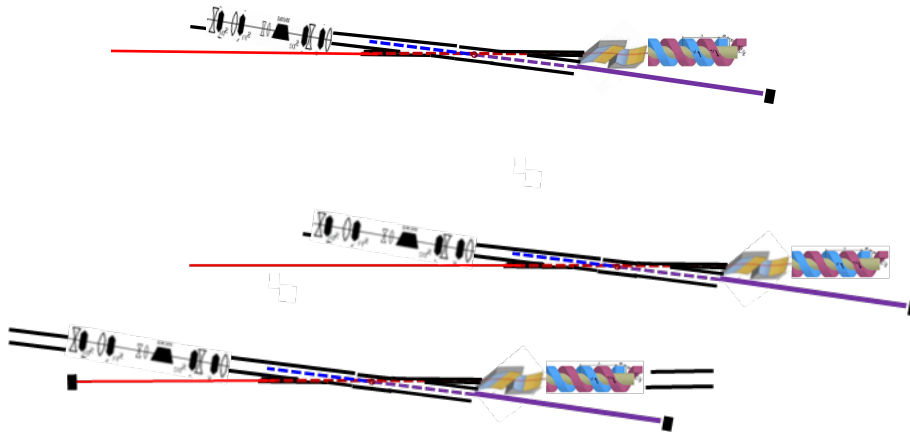


Add 5 GeV C^3 Linac to Produce 5 GeV γ 's (BES + HEP)

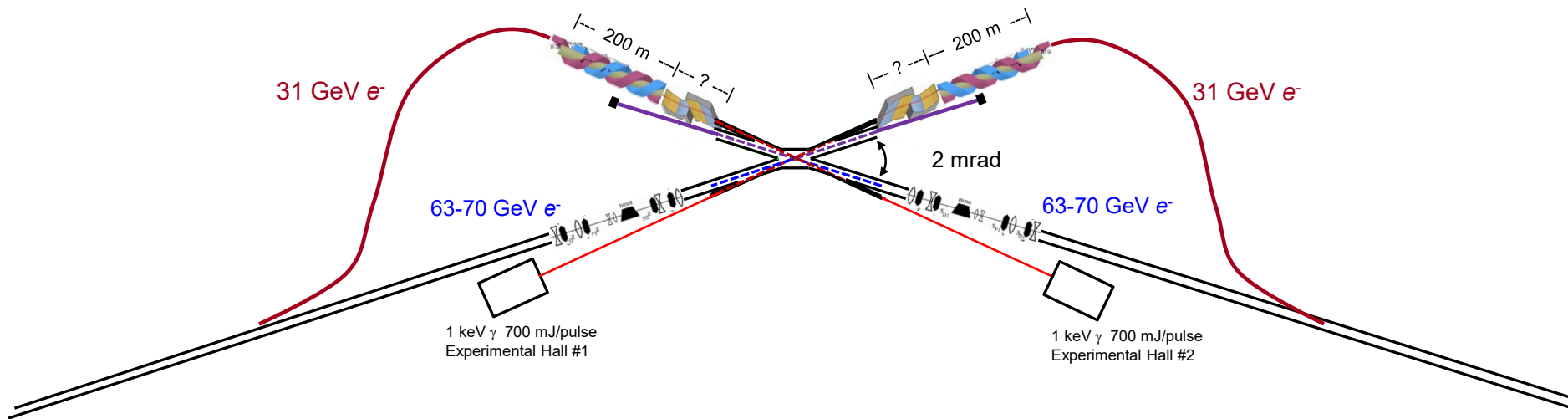
Test Compton scattering of 1 keV γ 's on 5 GeV e^-



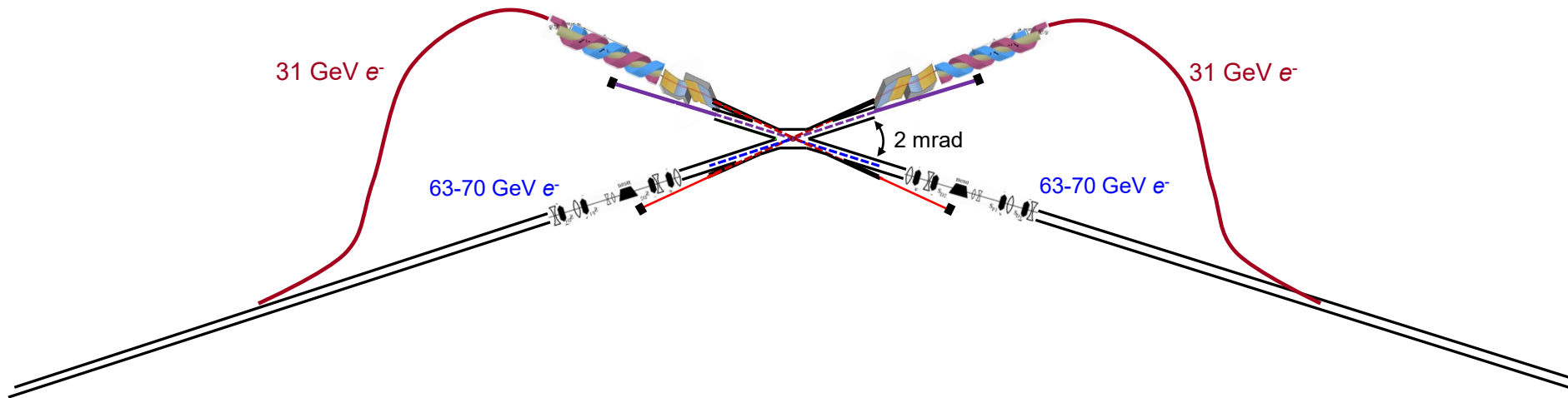
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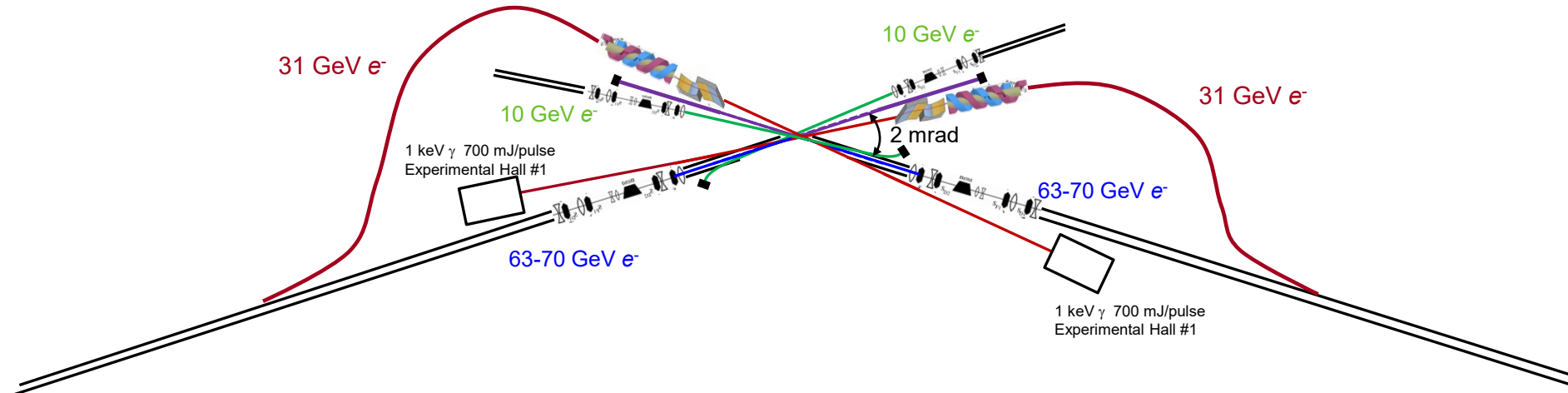
Backup Layout Slide 1



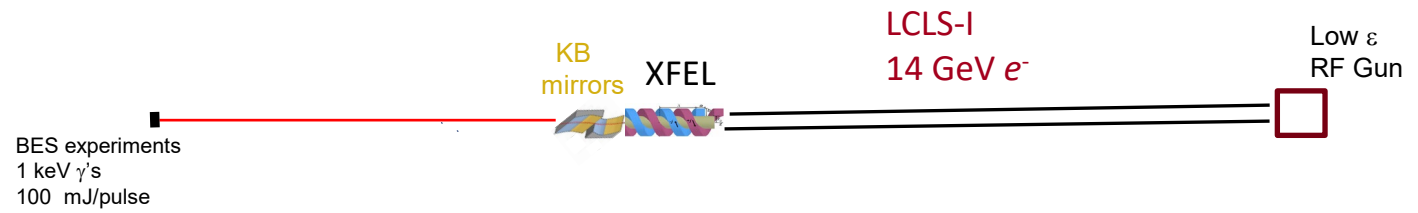
Backup Layout Slide 2



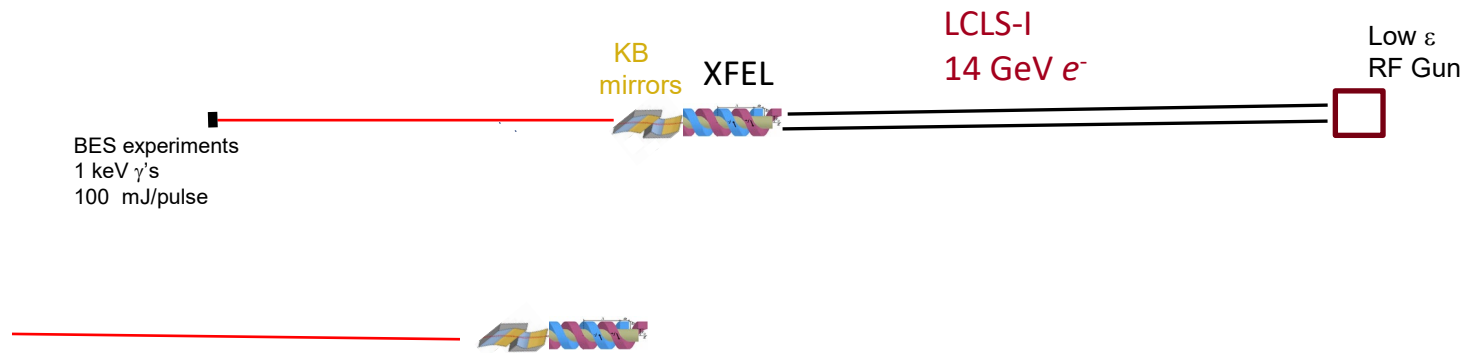
Backup Layout Slide 3



XCC – XFEL Compton Collider



XCC – XFEL Compton Collider



XCC – XFEL Compton Collider

