JLEIC R&D at SLAC

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Outline

Introduction

Budget summary for SLAC

Lattice work for the electron and ion rings

Interaction region and polarimeter synchrotron radiation issues with the high-current electron beam

Summary and conclusions

Introduction

The JLEIC accelerator design has several unique features

- **The figure eight layout**
- **The high-current electron beam**
- **The wide range of beam energies**
- **Extreme forward detectors**

Introduction (2)

SLAC has expertise in:

- **lattice design**
  - Non-linear aspects
  - Dynamic aperture studies
- **Interaction region design**
  - Machine and detector interface
  - Synchrotron radiation backgrounds
- **Synchrotron radiation power issues**

Budget

The budget values for the previous years are listed below

FY12	FY13	FY14	FY15	FY16	Totals
$75.5k	$83k	$134k	$134k	$80k	$506.5k
	$79k	$59k	$124k	$161k	$426k

Lattice design

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Over this past year a great deal of work has been done for both the ion and electron ring lattices

- In particular, nonlinear chromaticity optical systems in both rings have been designed and extensively studied

- Dynamic aperture (DA) studies related to the above issue with and without errors have also been explored

Ion ring lattice

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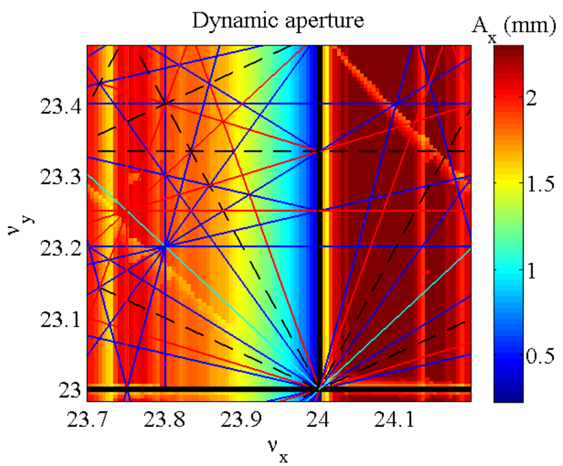
The ion ring has non-linear chromaticity compensation blocks (CCBs) that are based on –I sextupole pairs

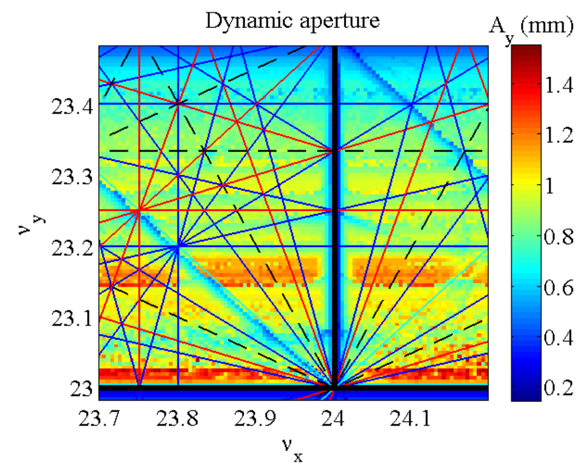
- **The on-momentum and off-momentum DA has been optimized by looking at tune scans**

X aperture at the IP



On-momentum
X aperture
and
Y aperture
tune scans

Y aperture at the IP



Multipole Field Errors

Multipole errors were initially used from the PEP-II magnet measurements

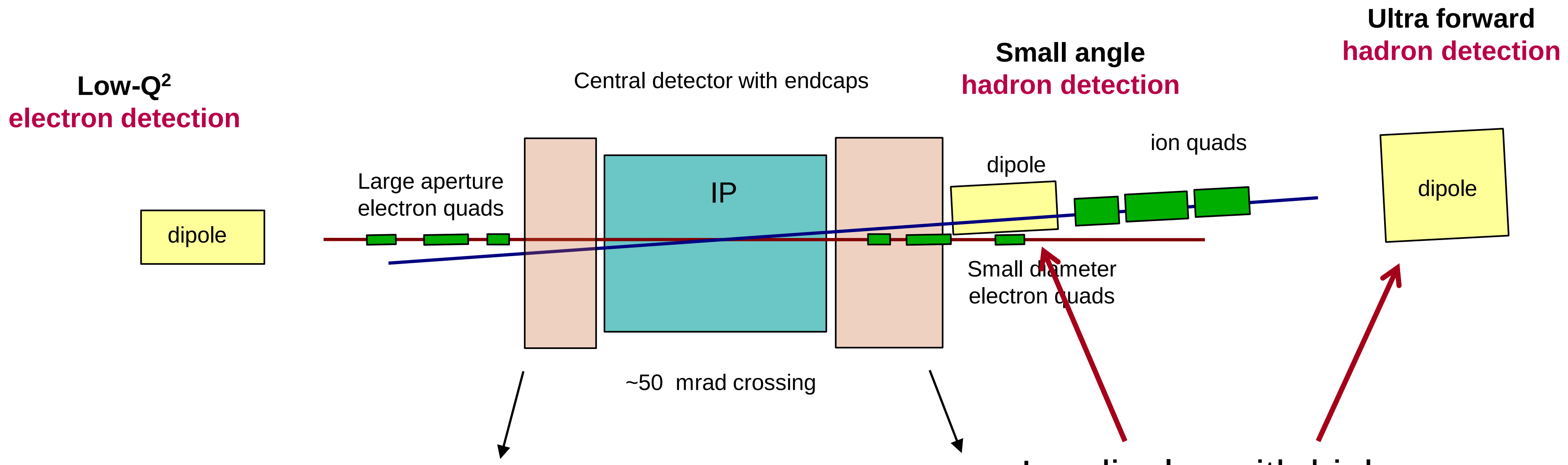
- Introducing systematic multipole errors had only a small effect on the DA
- But random PEP-II field errors in the arc bend magnets significantly affected the DA
- Expected field quality estimates from the super-ferric dipoles in the JLEIC design also had an impact on the DA

High beta regions

The large effect on the DA from multipole errors was tracked down to the regions of high beta (>1km). These places are:

- **The final focus (FF) quads**
- **The chromaticity correction block quads**
- **The high beta dipoles in the interaction region (IR)**
  - **These dipoles are connected to the very forward region of the detector**

Detector Layout

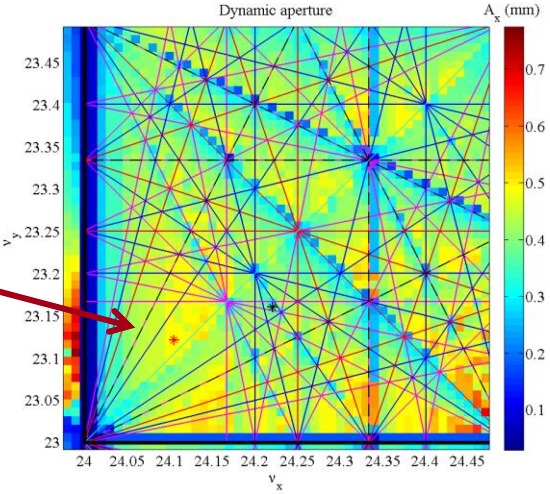


Ion dipoles with high beta functions mentioned previously

Multipole error conclusions

- The magnetic fields of the high beta region magnets will require a more stringent field quality
- Using the PEP-II multipole field errors, the working point in the tune plane was re-optimized with a 30% improvement in the on-momentum horizontal DA

Optimized working point



On-momentum tune plot with new working point

Beta squeeze

The ion beam must go through a beta squeeze process to reach the low beta* values needed for collisions

- Large beta* values are needed for the injection and energy ramp in order to keep beam size within BSC of FF quads
- One method studied was to use matching quadrupoles located outside of the IR and CCB quads thus preserving the IR chromaticity correction scheme
- However this limited the range of beta* values to 3-5 times the collision betas which is too small for injection

- This was revisited at JLAB and another scheme has been devised with better beta range. However, the new scheme is more complicated in that the matching now involves more quadrupole families.

Electron ring lattice

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Chromaticity correction for the electron ring has been studied

- **Used dedicated sextupoles located in the adjacent arcs near the IR**
  - **Two non-interleaved –I pairs at a high beta point**
    - **This is derived from extensive studies for the PEP-II and SuperB IR designs done at SLAC**
  - **Same as above but with 40% lower betas at sextupoles**
  - **Four interleaved –I pairs at nominal arc beta function values**

Electron lattice chromaticity

The various non-linear correction schemes were compared

- It was concluded that moderately high beta functions at the sextupoles gave a reasonable compromise between the conflicting requirements of:
  - Quality of chromaticity compensation
  - Emittance growth
  - Dynamic aperture

Electron emittance growth

- The emittance growth seen in the previous correction schemes stems primarily from the nominal dipole configuration of the arcs in the CCBs

- This has led to including the requirement of preserving the beam emittance in the CCBs

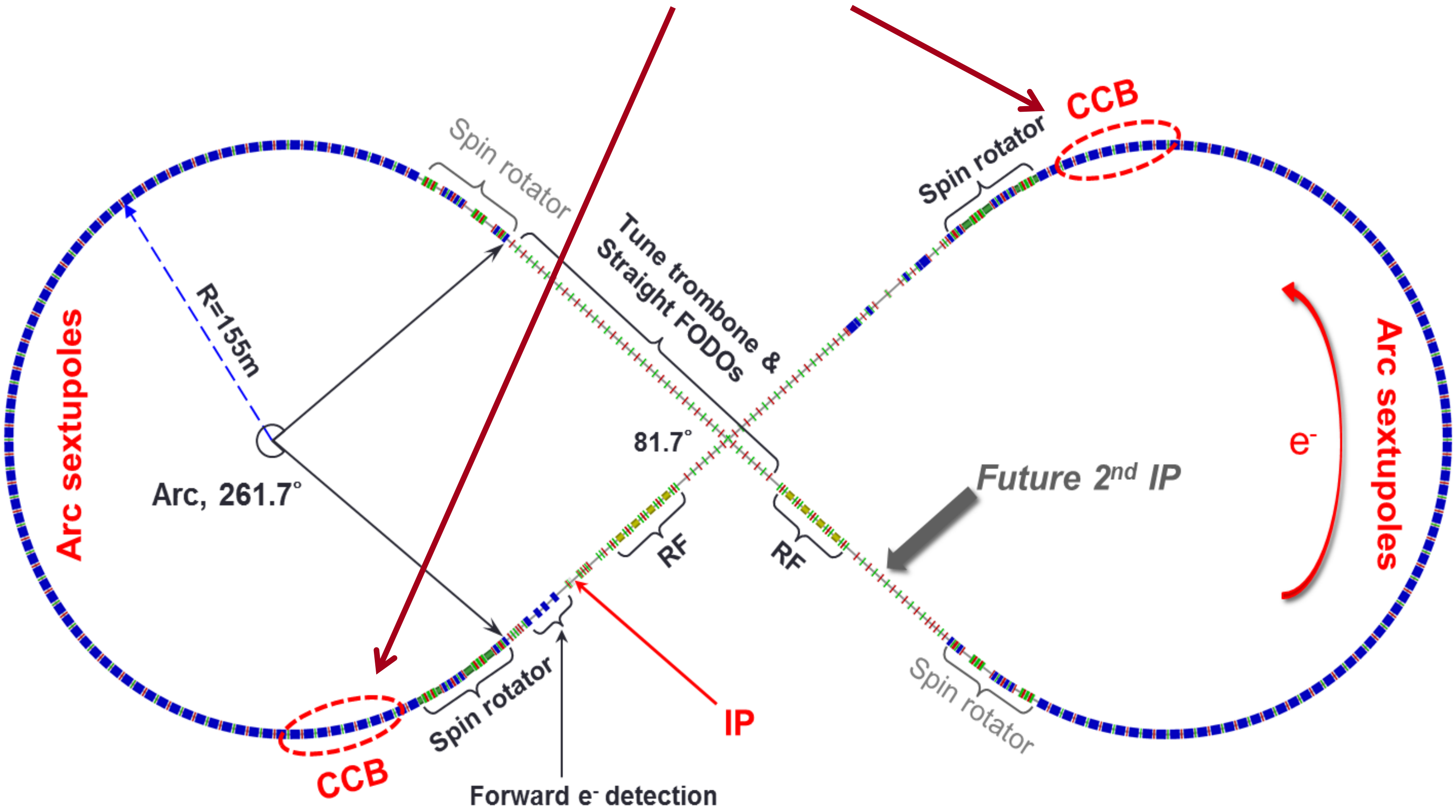
Emittance preservation

The added constraint of emittance preservation has led to modifying the dipole structure in the CCBs

- **Five different CCB schemes have been explored**
- **All are based on non-interleaved –I sextupole pairs**
- **Reducing the number of dipoles in the CCBs in order to minimize emittance growth leads to overall ring geometry changes**

Ring layout

Chromaticity correction blocks



Ring Geometry

- **Of the 5 schemes, the first 4 designs tried to preserve the ring geometry**
- **However, these schemes all resulted in some amount of emittance growth and in these cases much stronger bend magnets were required (x2)**
- **The last scheme (5) produces a smaller emittance than that of the arc cells but results in a geometry change as the CCB bending angles are smaller making the ring circumference increase**

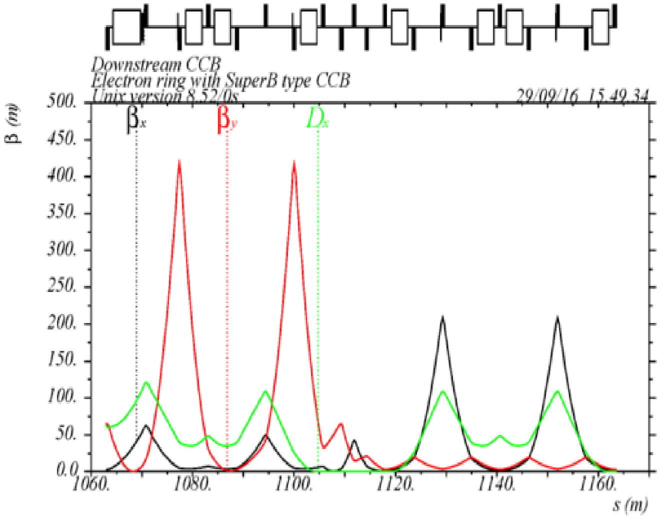
Electron CCB Conclusions

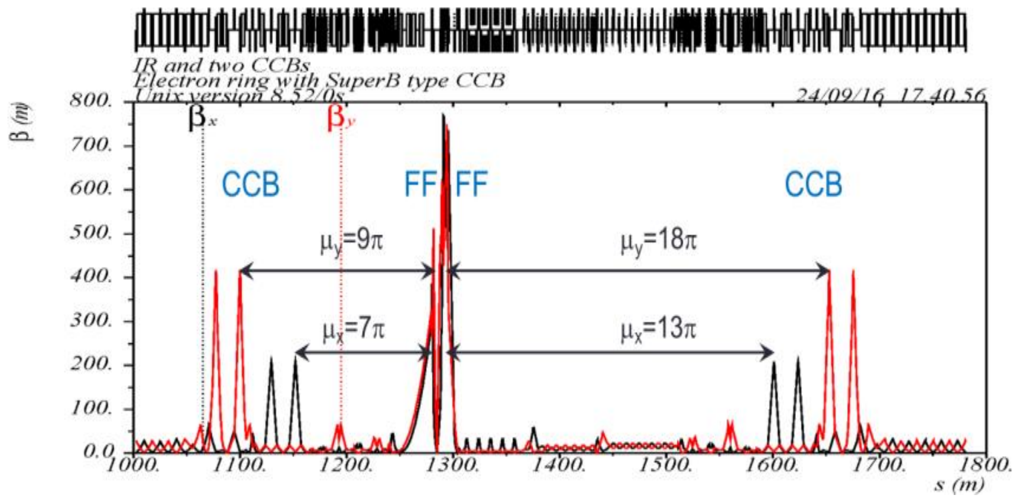
- The latest CCB schemes do provide adequate chromaticity correction with momentum acceptance of at least 10σ and a DA exceeding 20σ without errors

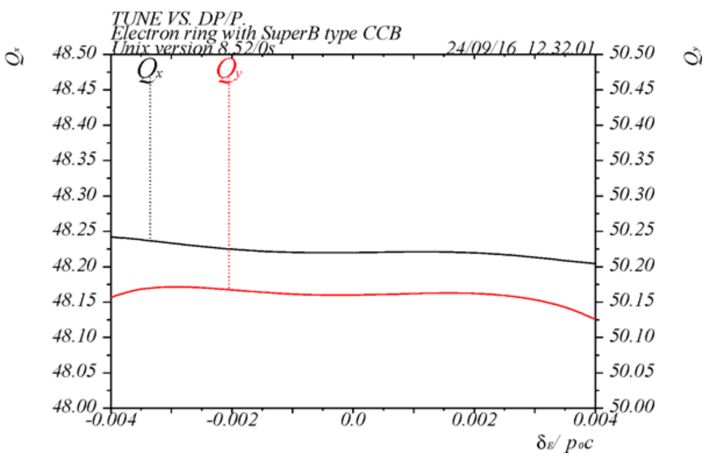
- The best results for emittance preservation require re-matching the ring geometry

Electron ring CCB optics and DA plot

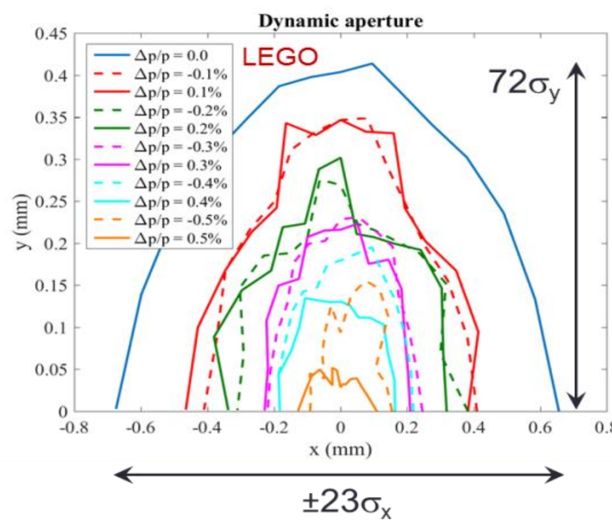
SuperB CCB design







Tune vs $\Delta P/P$



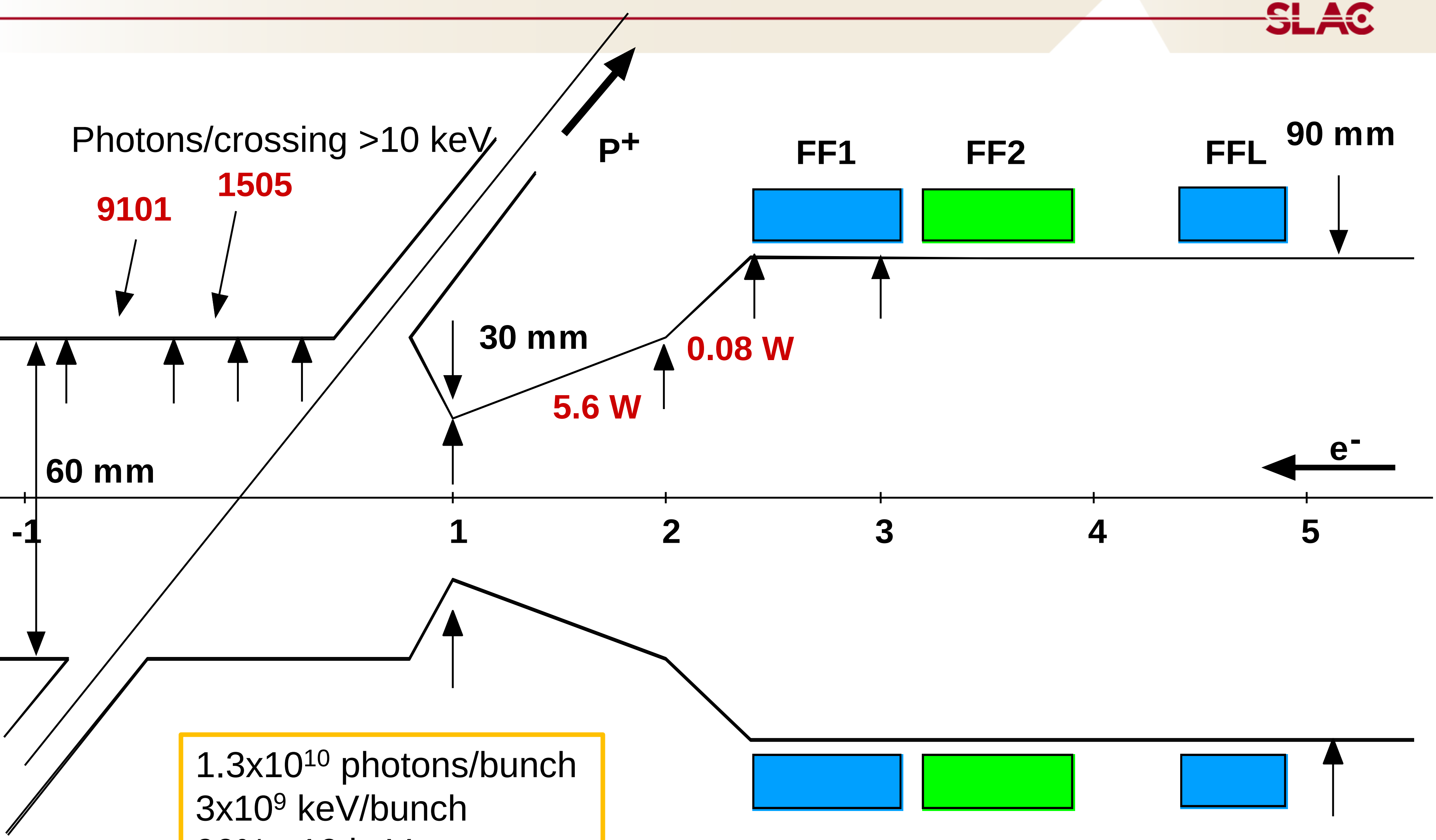
Dynamic aperture without errors

Synchrotron radiation backgrounds

The JLEIC design calls for a high-current (3-0.75 A) electron beam over a wide energy range (3-10 GeV)

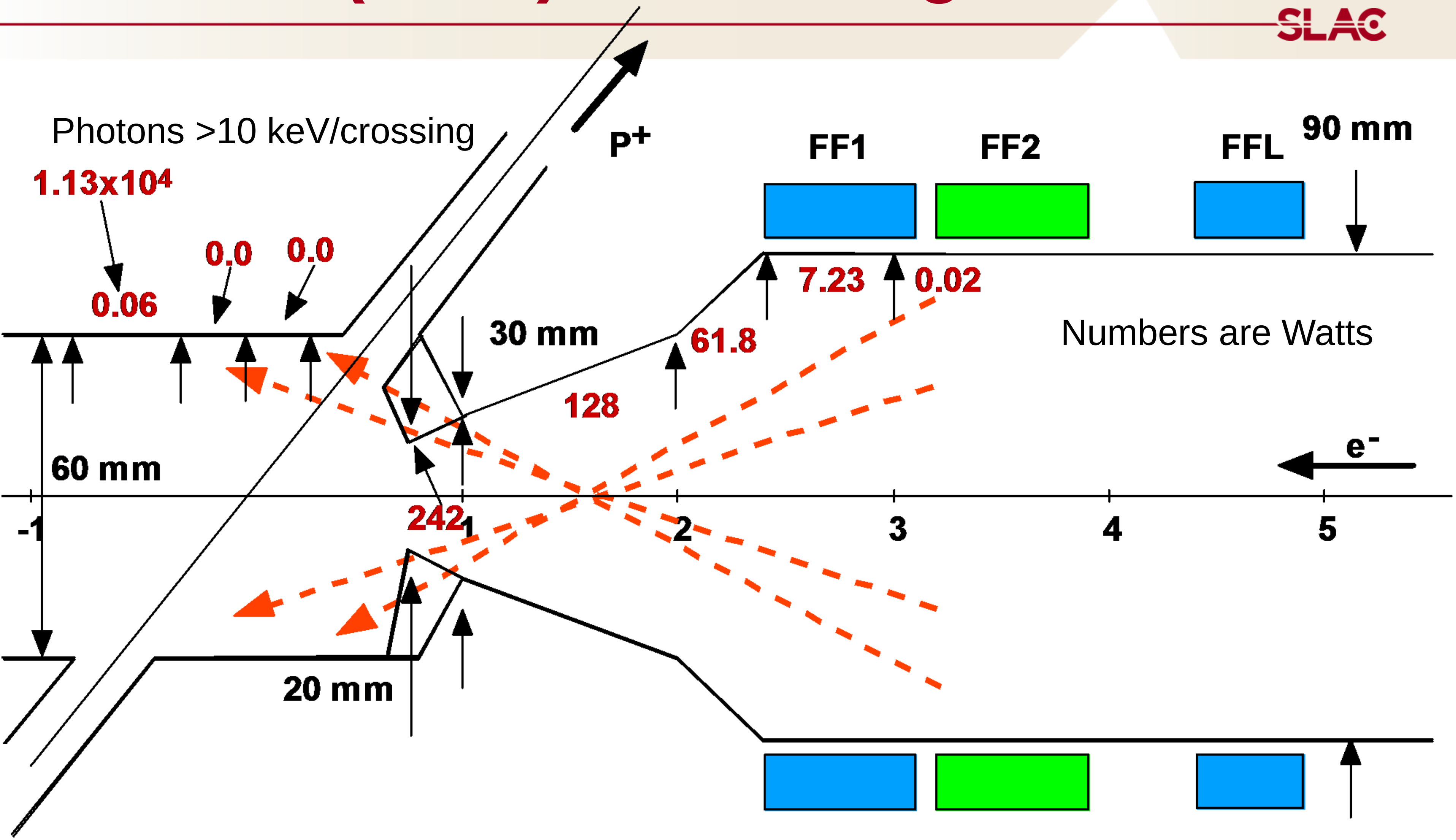
- This is unique and makes designing a single IR challenging
  - The B-factories were fixed energy machines
- Background masking designs have to work with different beam conditions

SR masking design for 5 GeV (3 A)

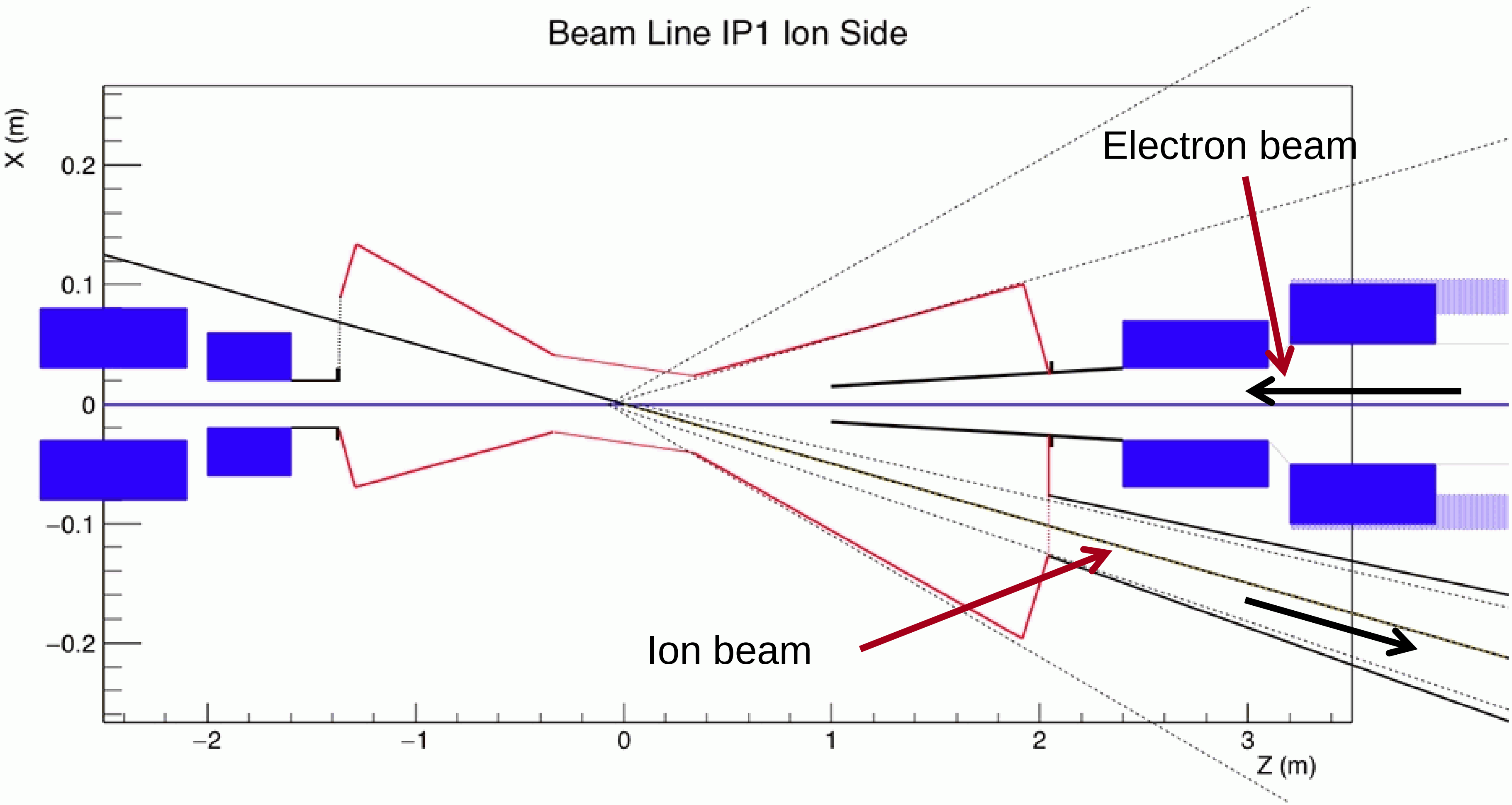


1.3x10^{10} photons/bunch
3x10^{9} keV/bunch
90% <10 keV

10 GeV (0.7 A) needs a tighter mask



Initial pipe design with masking



Courtesy of C. Hyde (ODU)

SR background conclusions

- More iterations are needed between masking designs, vacuum design issues and detector requirements before a feasible IR design can be completed
- High order RF multipole (HOM) power issues also need to be included in the design iterations

SR in the polarimeter chicane

It is important to be able to measure the polarization of both beams

- **A chicane has been designed into the lattice just downstream of the collision point to do this in the electron ring**
  - **The bend magnets for this chicane generate a large amount of SR**
  - **Handling the power from the SR and enabling the detection of the beam polarization is challenging**

Polarimeter chicane for the e⁻ beam

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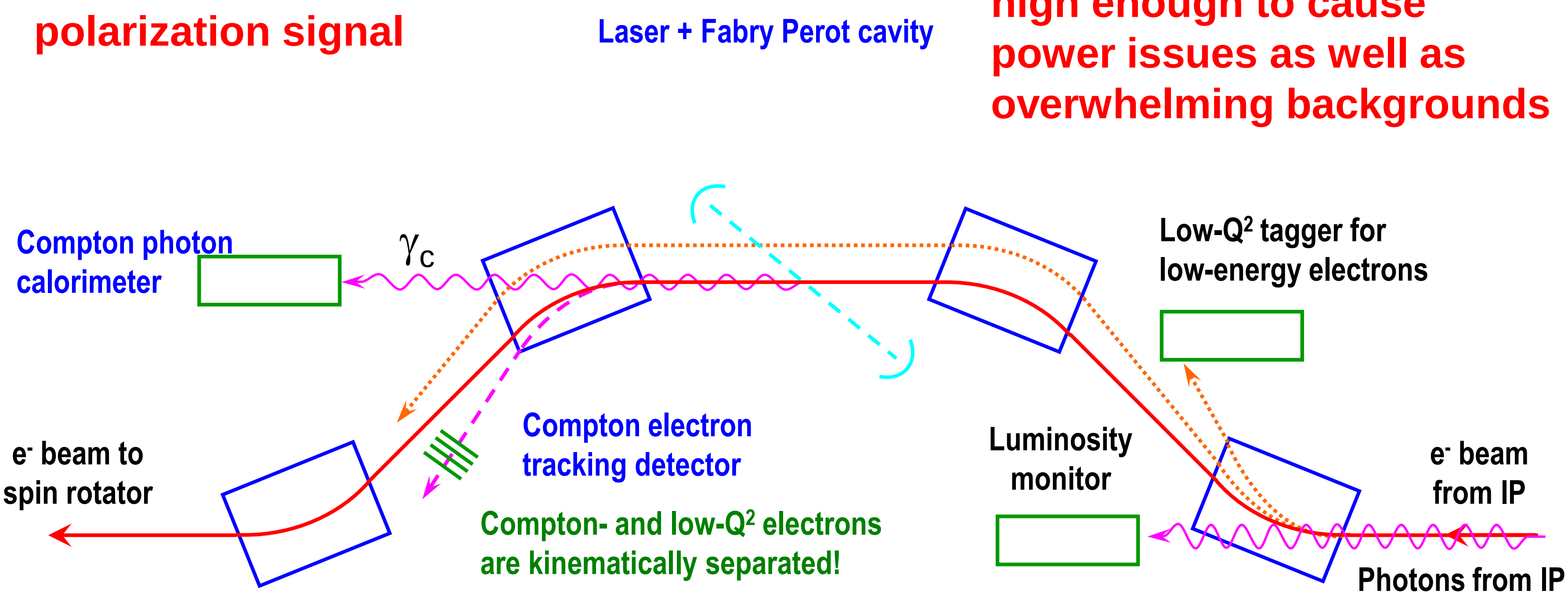
Work has concentrated on the detection of the polarization signal

SR photon numbers are high enough to cause power issues as well as overwhelming backgrounds



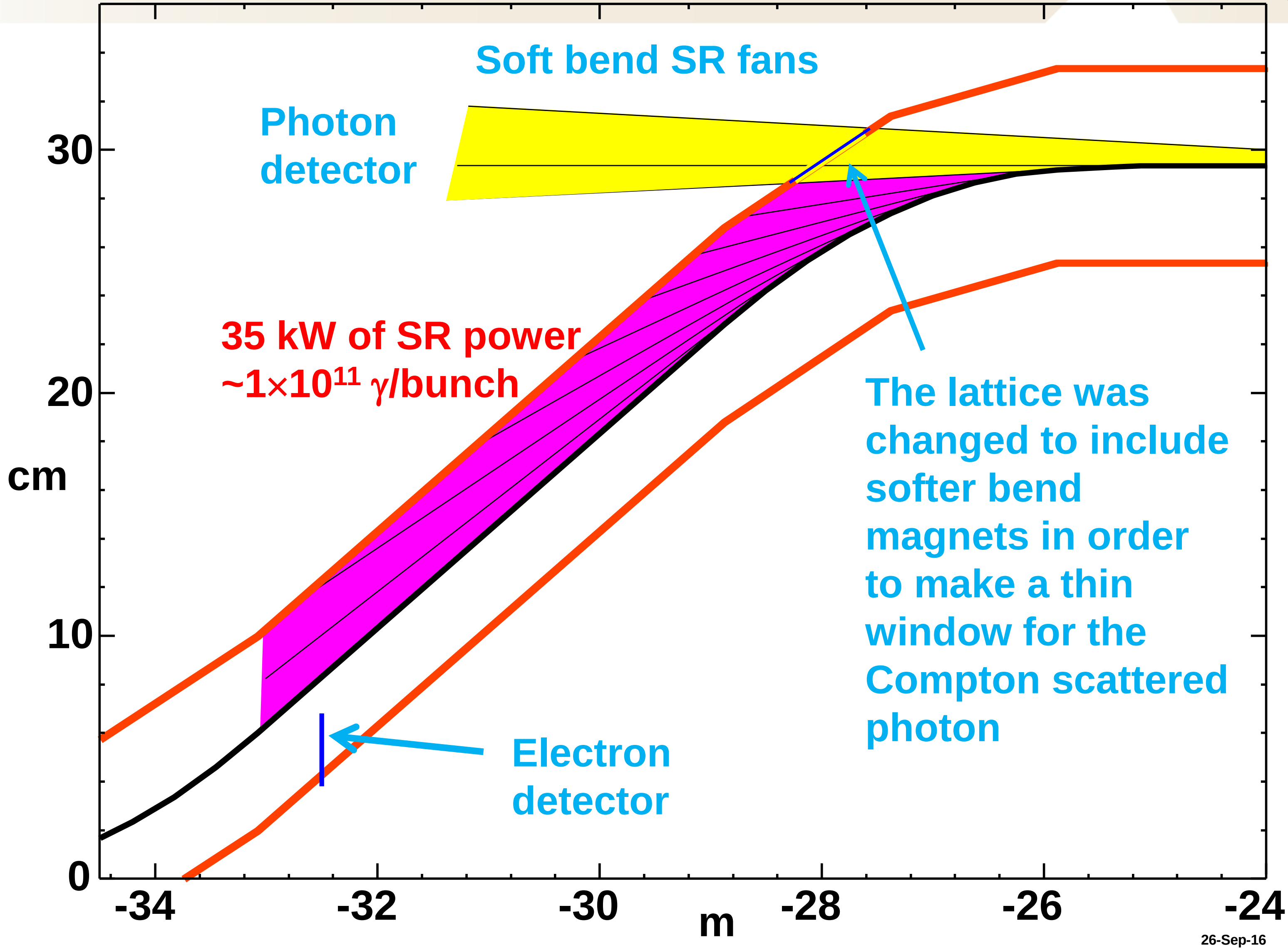
Thanks to Alexandre Camsonne

Photon and electron detection of the Compton scattered event

- An earlier study pointed out the need for softer bend magnets just before and after the Compton scatter point in order to make a beam pipe window that would be able to handle the SR power and still permit the Compton scattered photon to pass through and be detected

The downstream scattered electron detector has also be investigated and scattered SR photons from the upstream beam pipe overwhelm the signal by depositing too much energy into the detector

SR fans at Polarimeter Detectors



Scattered SR to the electron detector

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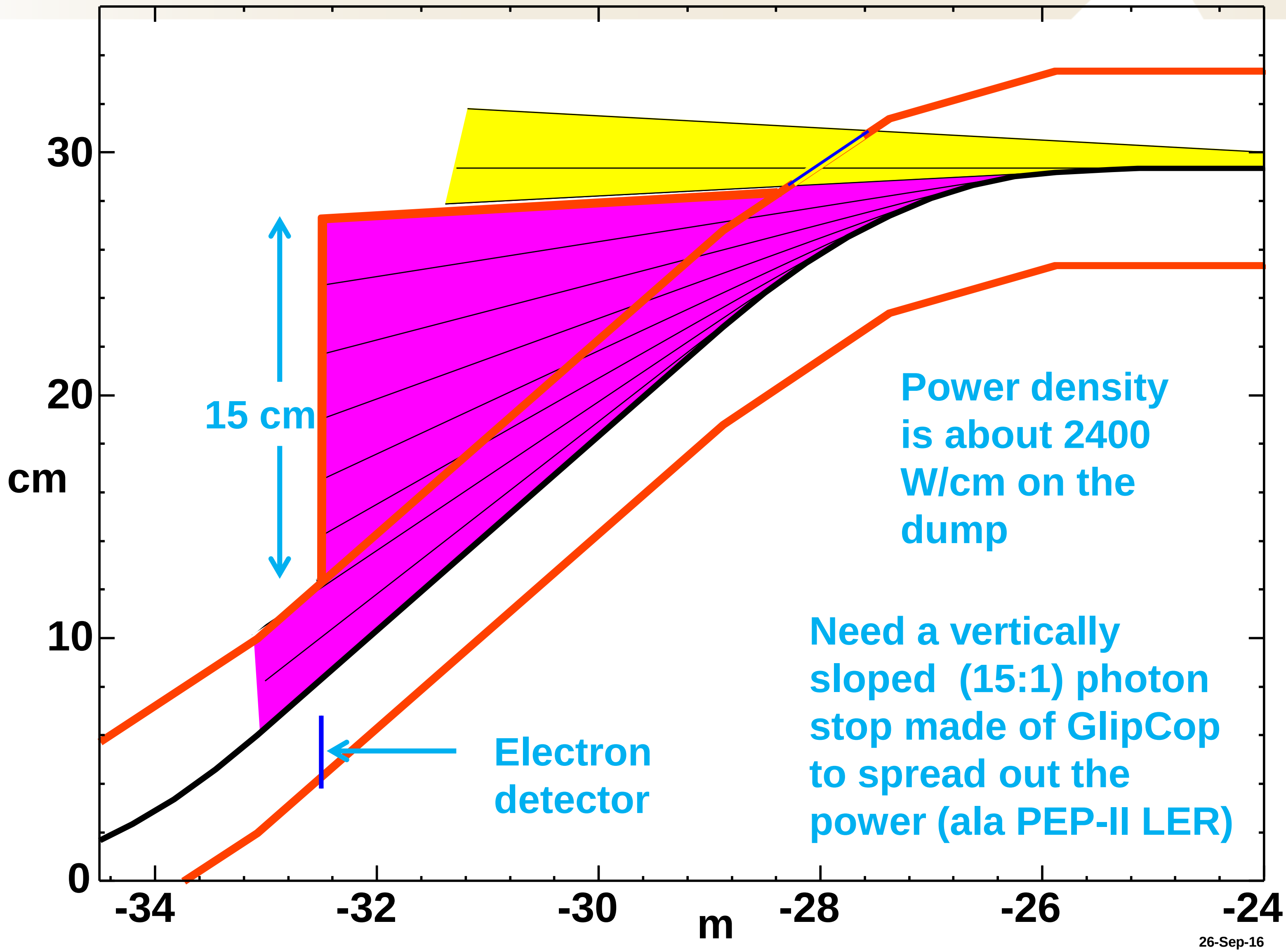
- The power density on a straight beam pipe is high but manageable with special materials (GlidCop)

- But too many SR x-ray photons scatter off of the beam pipe and hit the electron detector

- Putting mask tips inside the beam pipe to shield the electron detector makes slope surfaces that intercept too much SR power (unable to properly cool)

- An ante-chamber beam pipe design looks feasible and is very similar to the PEP-II design for controlling the SR from the Low-energy ring arc magnets

Ante-chamber solution



Other locations with high power SR

- We have started a list of other locations in the electron ring that need investigation concerning high SR power
  - Zero degree luminosity detector at the beginning of the polarimeter chicane
  - Bend magnets in the spin rotator sections
  - Magnets near the cryogenic RF
  - Magnets near the crab cavity locations
  - ….

Summary and conclusions

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- The JLEIC accelerator design has many unique features that make the machine an exciting new challenge
- SLAC has a great deal of experience in high-current storage rings and in interaction region design issues
- The SLAC team looks forward to future collaboration with the JLEIC design team