B-Factory Interaction Regions:

Can we use what we have learned for the FCC-ee?

M. Sullivan, March 25, 2015

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Outline

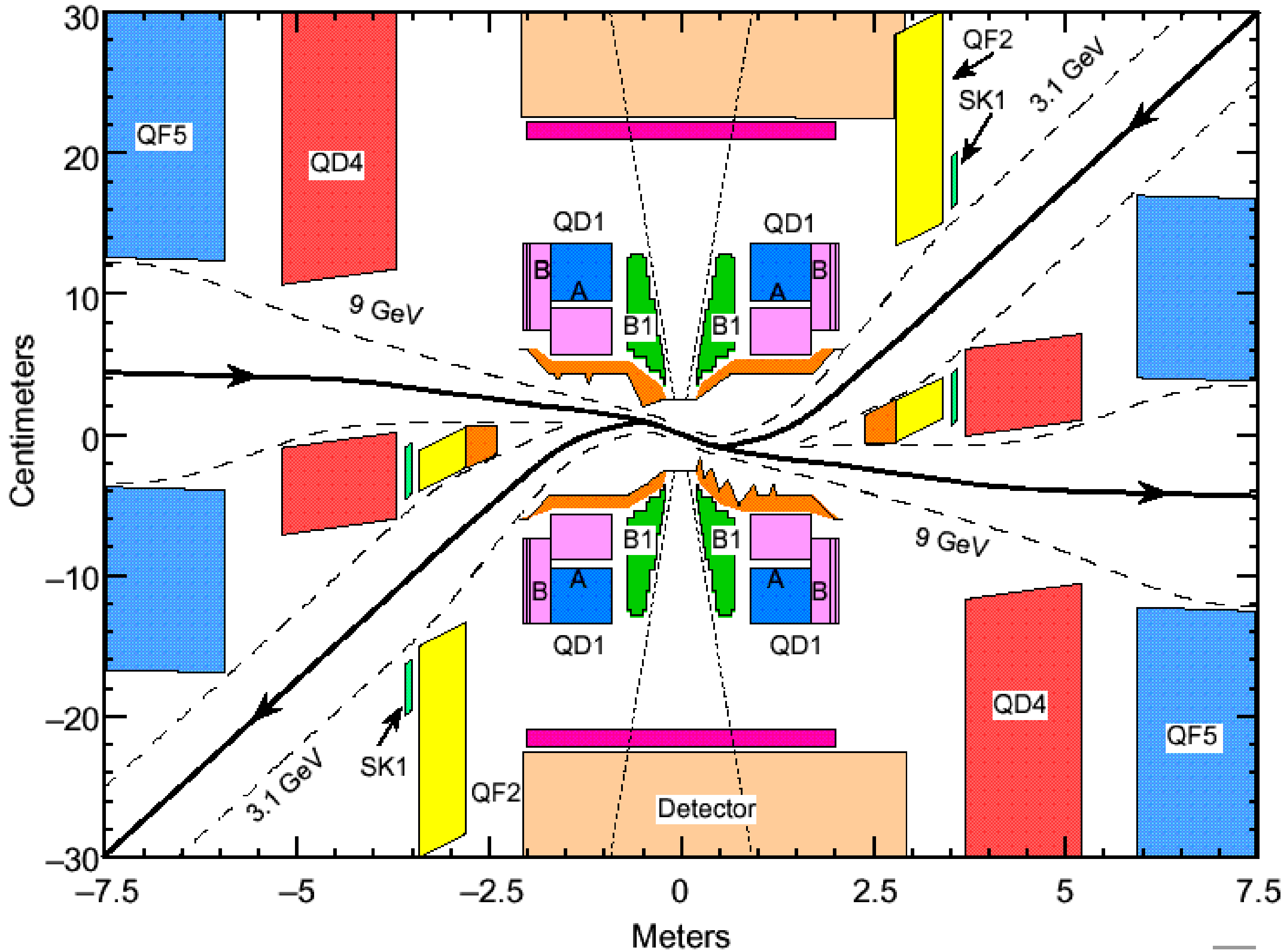
B Factory IR Designs

- **Geometry**
  - Controlling SR power and background
- **Backgrounds**
  - Luminosity
  - Beam related
- **New Backgrounds at Higher Energies?**
  - Penetrating SR
  - Muons
- **B-Factory IR techniques for FCC?**
- **Summary**
- **Conclusions**

PEP-II B-Factory

Beam Energies	9 GeV x 3.1 GeV
Maximum currents	2.1A x 3.2A
Typical currents	1.8A x 2.8A
Collision angle	0
# Bunches	1722
Collision frequency	238 MHz
Bunch spacing	1.26 m (4.2 ns)
L*	0.9 m
Luminosity	$1x10^{34}$
IR SR power	400 kW

PEP-II Interaction Region



PEP-II Features

Head-on collision

- Strong bending magnets near the IP
- SR from HEB escapes detector

Asymmetric beam energies

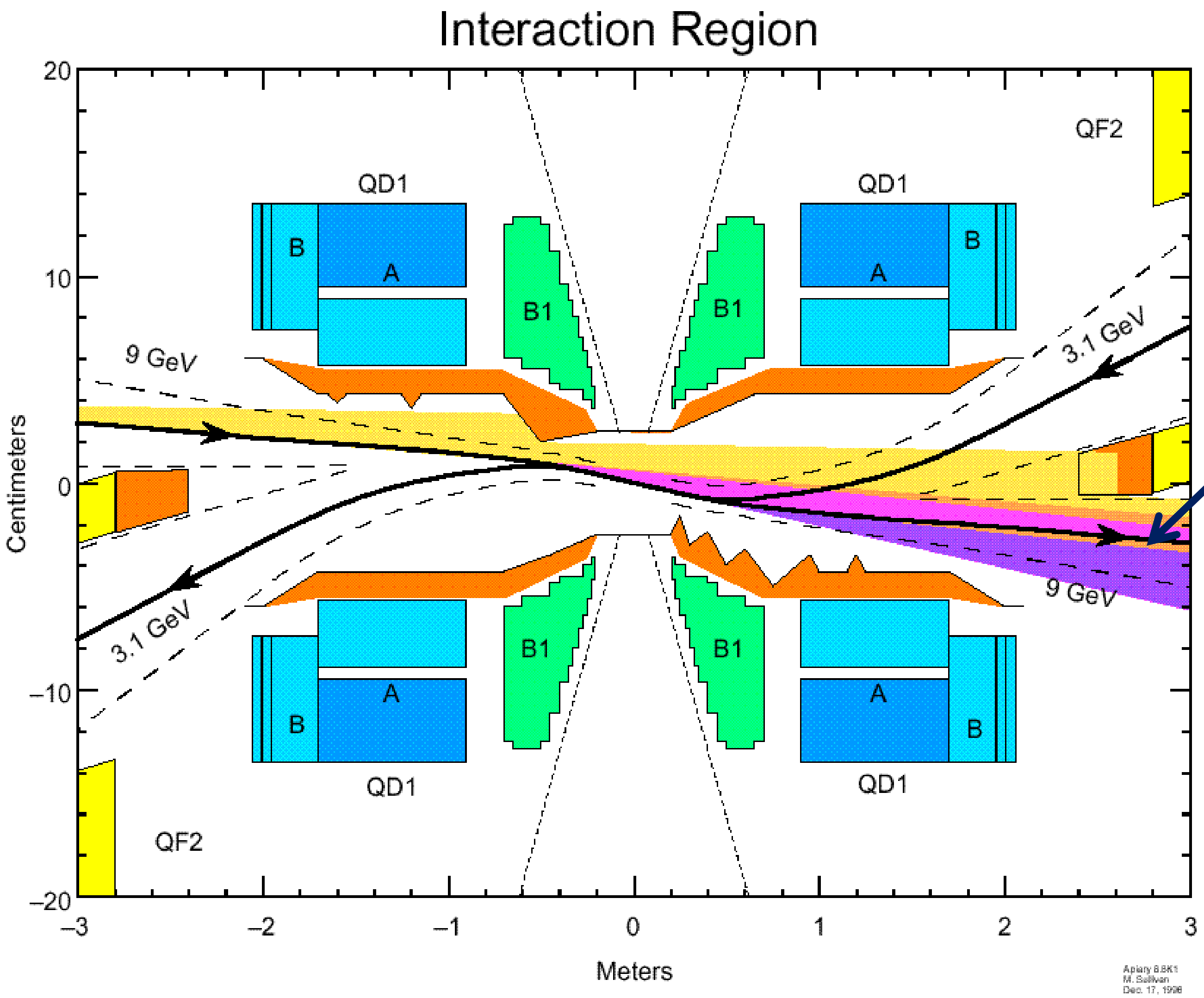
Asymmetric Optics

High beam currents

Shared FF optics

- QD1

HER SR fans

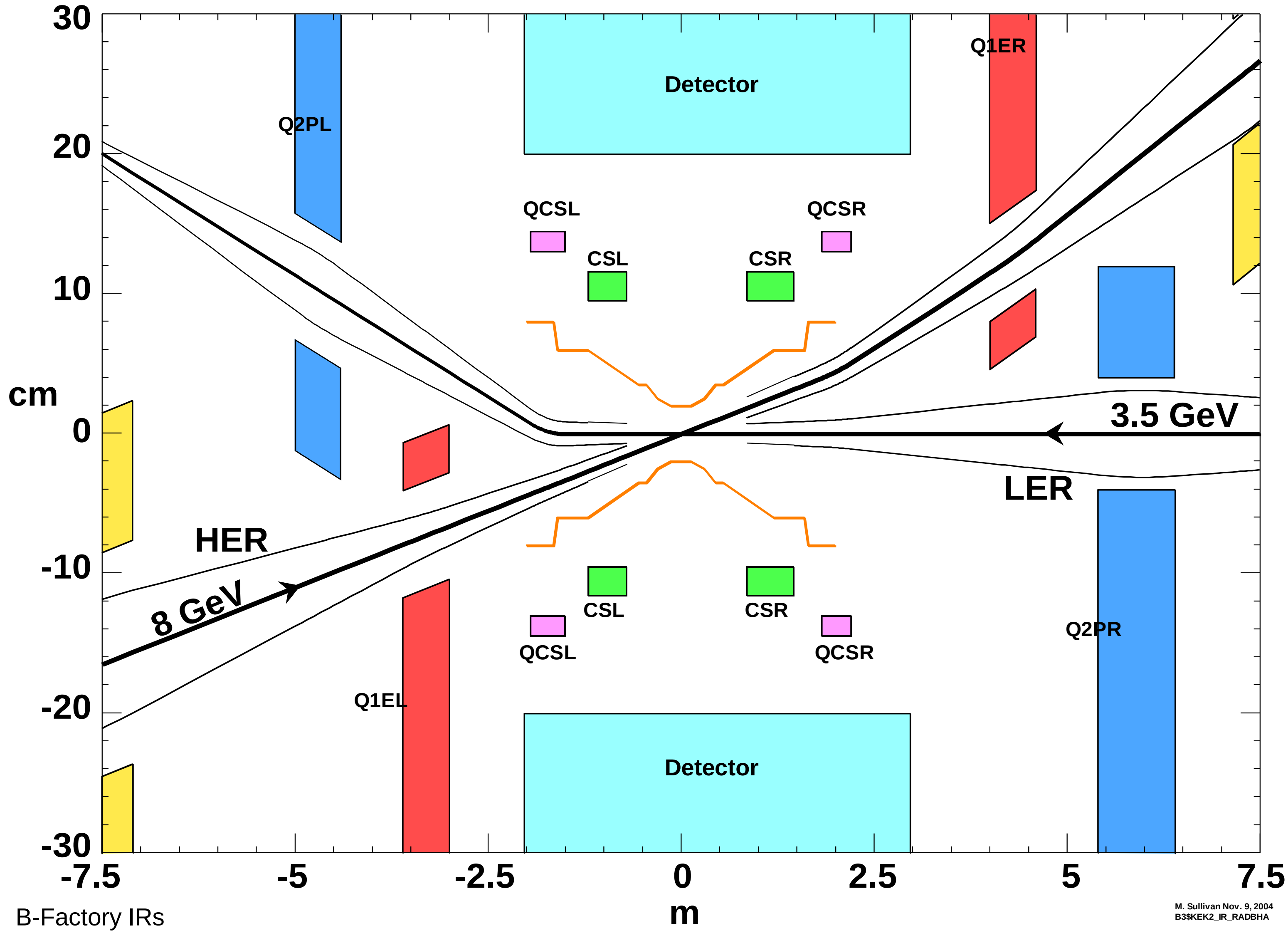


HEB SR fans from the bend magnets (B1) overlap and miss all local surfaces and strike the beam pipe wall starting at 10 m from the IP. k_c was 40 keV. Fan power was ~200 kW.

KEKB B-Factory

Beam Energies	8 GeV x 3.5 GeV
Maximum currents	1.4A x 2.0A
Typical currents	1.3A x 1.7A
Collision angle	22 mrad
# Bunches	5027
Collision frequency	495 MHz
Bunch spacing	0.59 m (2 ns)
L*	1.5/1.8 m
Luminosity	$2x10^{34}$
SR power	80 kW

KEKB Interaction Region



KEKB Features

Asymmetric beam energies

Crossing angle

±11 mrad

Nearly symmetric optics

Shared FF optics

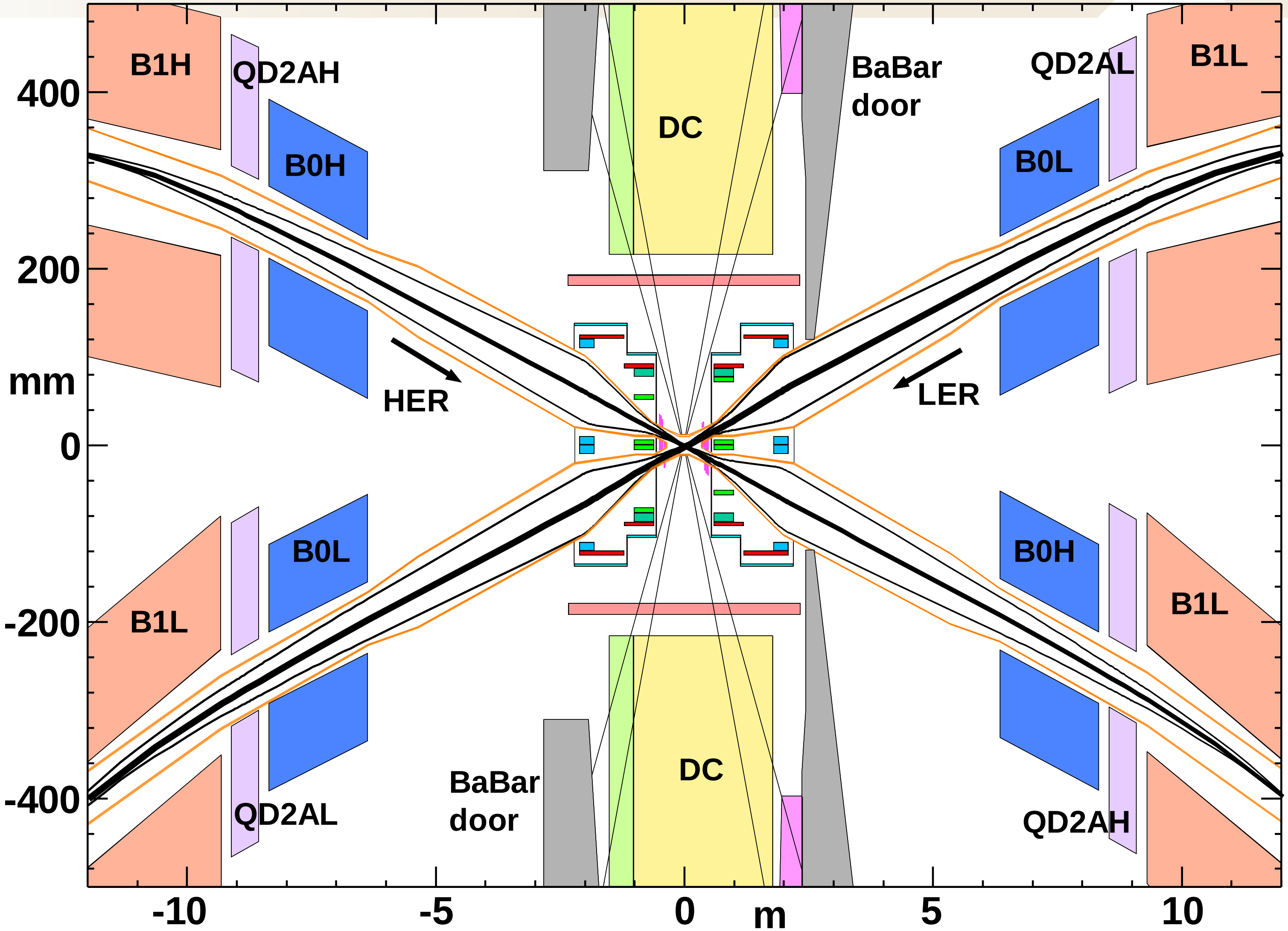
QCS

Straight orbit for incoming beams

SuperB

Beam Energies	7 GeV x 4 GeV
Design currents	2.12A x 2.12A
Collision angle	60 mrad
# Bunches	1011
Collision frequency	238 MHz
Bunch spacing	1.25 m (4.2 ns)
L*	0.42/0.36 m
Luminosity	$1x10^{36}$
SR power (inc. first bends)	72 kW

SuperB Interaction Region



SuperB Features

Asymmetric beam energies

Large crossing angle

± 30 mrad

Symmetric Optics

No shared FF optics

FF warm bores

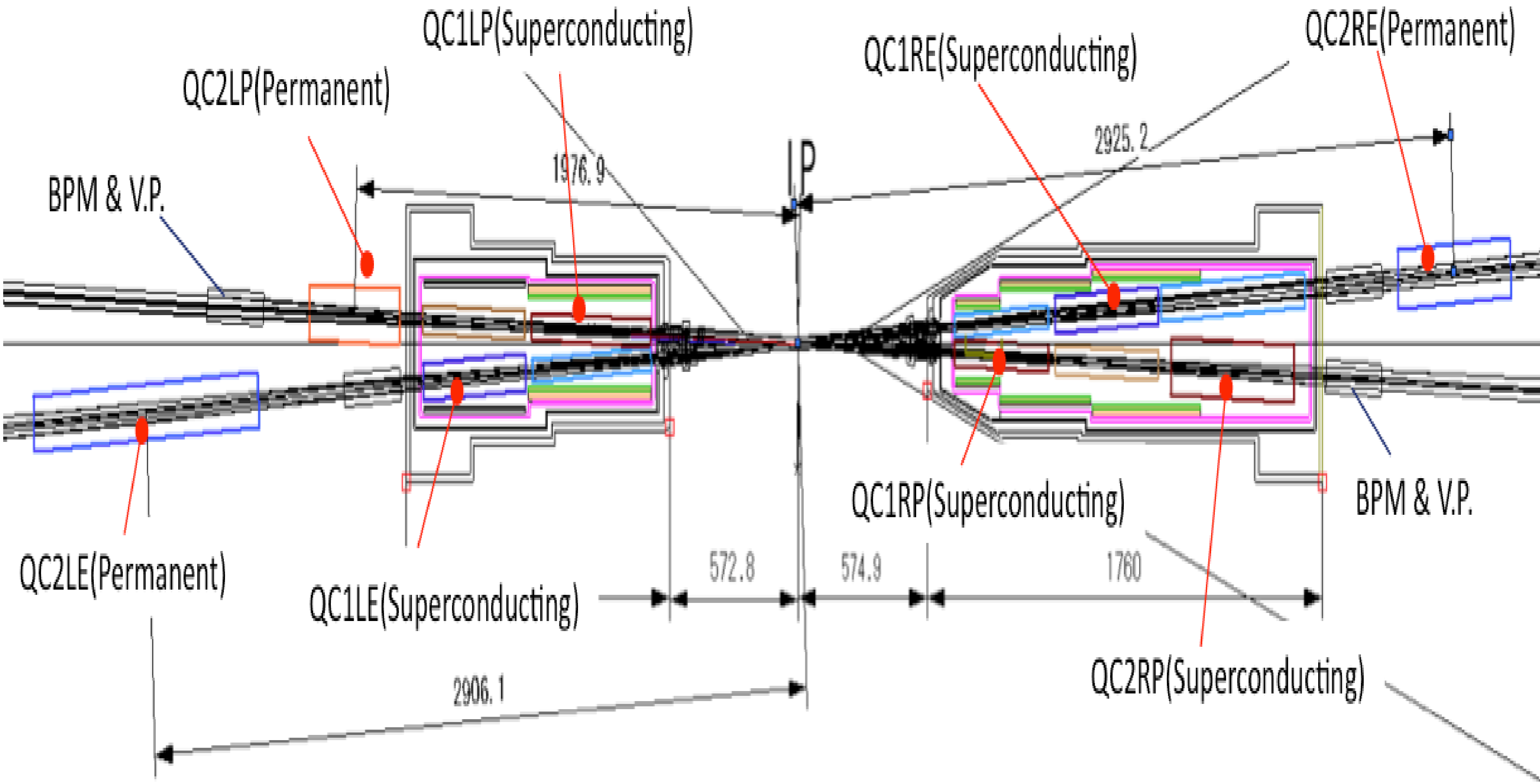
Very soft final bend magnets

$k_c < 1$ keV

SuperKEKB

Beam Energies	7 GeV x 4 GeV
Design currents	2.6A x 3.6A
Collision angle	83 mrad
# Bunches	5027
Collision frequency	495 MHz
Bunch spacing	0.59 m (2 ns)
L*	0.6/0.6 m
Luminosity	8×10^{35}
SR power (quad only)	0.5 kW

SuperKEKB Interaction Region



SuperKEKB Features

Asymmetric beam energies

Largest crossing angle

±41.5 mrad

No shared FF optics

FF cold bores

Very soft final bend magnets far from IP

B-Factory Backgrounds

Standard backgrounds

- Beam-gas
- Synchrotron Radiation
- Coulomb
- Touschek

Unexpected backgrounds (Luminosity)

- Radiative Bhabha
- Two-photon ($e^+e^- \rightarrow e^+e^-e^+e^-$)
- Neutrons

Luminosity backgrounds affected super B-Factory designs

Higher energy backgrounds

Muons

- First seen in the SLC?

High Energy SR

- Penetration
- Long range backscatter sources
- Nuclear resonances (neutron production)

Luminosity backgrounds

- Beamstrahlung
- $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$
- Perhaps something not thought of

B-Factory and Super B-Factory Tricks

- To minimize SR backgrounds
  - Incoming beams straight
  - Incoming beams bend magnets very soft
    - Low k_c
    - Much lower than arc magnets
  - Outgoing beams also straight (rad. Bhabha)
- No shared optics elements
  - Reduces Radiative Bhabha background
  - Reduces neutron background
- Warm bores in FF?

Crazy Ideas?

#1 Strong bending magnets very close to the IP

- Similar to PEP-II
- Increase crossing angle separation at FF magnets
- Or smaller crossing angle
- Generated SR must escape detector

#2 Beam energy asymmetry

- Particularly for the Z running
- One higher energy beam (~55 GeV?)
- One lower energy beam (~35 GeV?)
- Easier to bend low energy beam

Crazy idea #1

May be possible to use PM dipoles

One example here

- **Guess at FF optics and β^* values**
- **±15 mrad crossing angle**
- **45 GeV beams**
- **Need to keep SR fans inside BSC envelope**
- **0.5 T bend magnets at 0.5-0.8 m from IP**
- **Sets maximum bend angle to about 1 mrad**
- **Decrease crossing angle down to ±14 mrad**

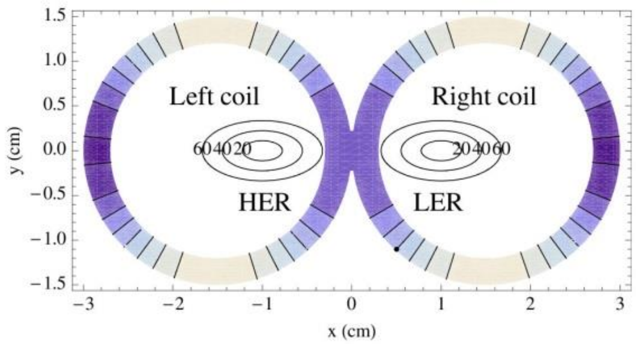
Does not look very encouraging but could be done if needed for some reason

More on Crazy idea #1

Might be something to consider for 11 mrad crossing angle design

More separation at FF or make the crossing angle smaller

±5.5 mrad → ±4.5 mrad or less



This design has more room on the outside which would allow for a bigger angle from inside bend magnets.

However, beams are closer together so may be too difficult to get strong bend magnets between QD0 and IP

Crazy idea #2

- Put energy asymmetry into collision for Z or W running
  - Would physics want boosted Z?
    - Can't think of any reason to want this
  - Boosted W+W-?
- Asymmetric energy beams might make it easier to separate beams
  - One beam could be bent more than the other
  - Might reduce the crossing angle

Summary

Main lessons from the B Factories

SR shielding

Lot of effort went into shielding detector from SR

Upstream bending magnets are weaker than arc magnets (10% or less)

High beam currents mean secondary and even tertiary bounces can be trouble (10^{20} photons/sec is a large number)

Summary (2)

Luminosity backgrounds

Somewhat unexpected but now planned for in super B-factory designs

Even downstream bending can cause trouble

I expect we might find some surprise if we manage to reach 10^{36} with these high beam energies and currents

Summary (3)

- Nonzero crossing angle is much harder than head-on
  - Maximum luminosity with a crossing angle
    - Maximum number of bunches
  - If total current is limited we have fewer bunches
    - Fewer bunches → larger bunch separation
    - Zero crossing angle becomes possible
  - With zero crossing angle FF elements become shared
    - Makes FF design much easier
    - Allows for smaller IR beam pipe
- Have to separate beams before CCB optics sections
  - Unless bunch spacing is very large

Summary (4)

Crazy ideas usually turn out to be just crazy

But we need to consider as many options as we can think of. Need to think outside the box! This is where new inexperienced people can help.

New tricks or even recycled tricks can lead to improved machine flexibility

We need to incorporate as many tricks or alternatives as we can in the design

Conclusions

IR designs are always challenging

Detector people will say they can handle any luminosity but this usually means tightening up the trigger and limiting searches for unexpected physics

High levels of background can make the detector unworkable – again triggers become more restrictive

As usual, close cooperation between detector and machine groups is crucial for the success of the project

Thanks!