

SUPERB:  
A DETECTOR  
FOR A VERY HIGH  
LUMINOSITY  
ELECTRON POSITRON  
COLLIDER @  $\Upsilon(4S)$

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FOR

THE SUPERB COLLABORATION

# MACHINE AT A GLANCE

$$\mathcal{L} \approx f_{\text{coll}} \frac{N^+ N^-}{4\pi \sigma_y \sqrt{\sigma_x^2 + \sigma_z^2 \tan^2 \vartheta}} \geq 10^{36} \text{Hz/cm}^2$$

Parameter	LER	HER
Particle type	$e^+$	$e^-$
Energy (GeV)	4	7
Luminosity ( $\text{cm}^{-2}\text{s}^{-1}$ )	$1.0 \times 10^{36}$	
Circumference (m)	2250	
Number of bunches	1733	
Particles/bunch $\times 10^{10}$	6.16	3.52
Beam current (A)	2.28	1.30
$\beta_y$ (mm)	0.30	
$\beta_x$ (mm)	20	
$\epsilon_y$ (pm-rad)	4	
$\epsilon_x$ (nm-rad)	1.6	
$\sigma_y^*$ (nm)	35	
$\sigma_x^*$ ( $\mu\text{m}$ )	5.657	
Bunch length (mm)	6	
RF Power (MW)	17	

# DETECTOR DESIGN ~ BABAR

- Driving forces

- Machine: lower boost (smaller longitudinal separation of secondary vertices)

- ✳ Vertex detector with higher resolution

- Physics goals: higher luminosity (hence bkg.rates)

- ✳ Faster & more robust detectors

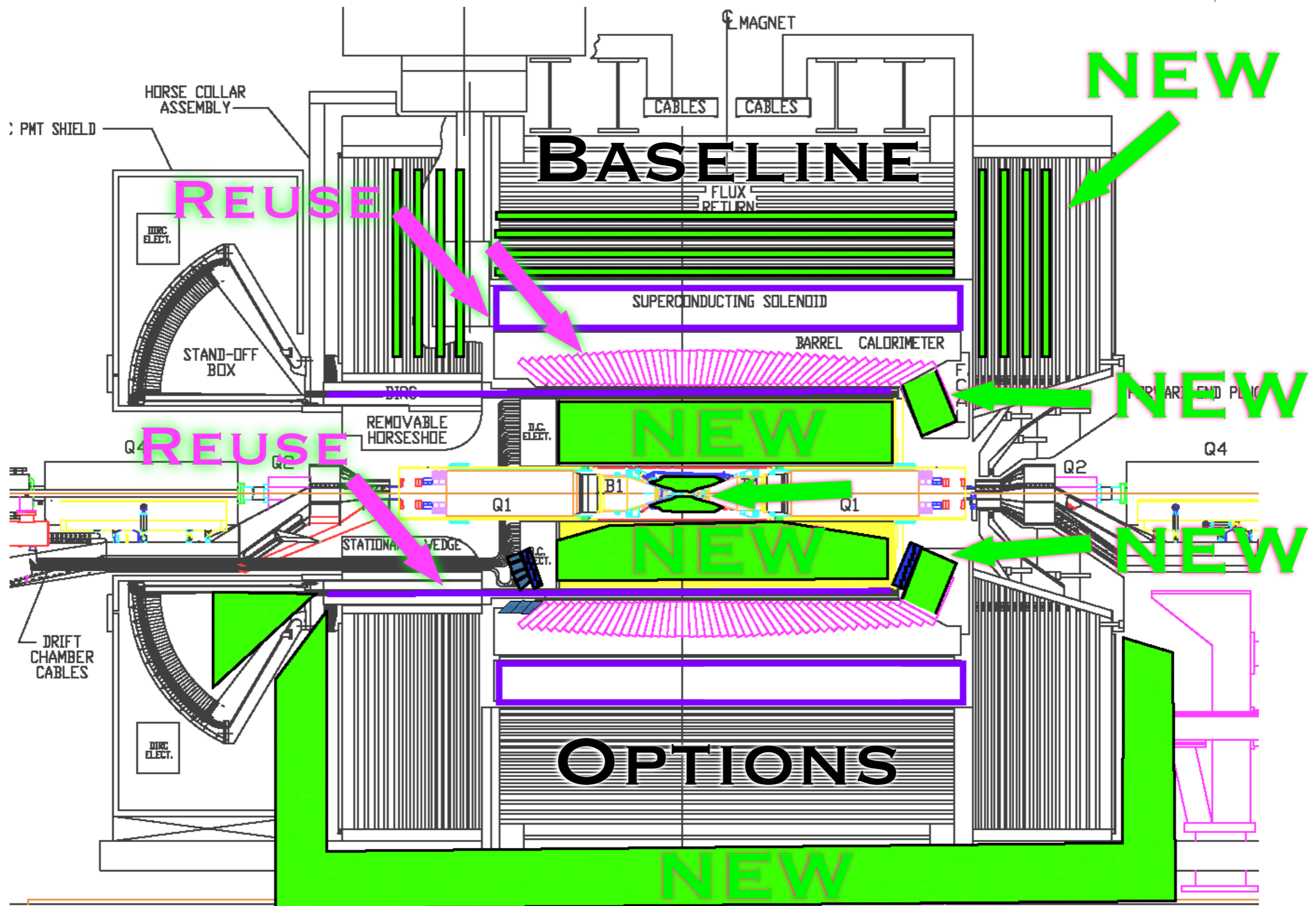
- Common sense: costs

- ✳ Reuse as much as possible & reasonable

- BaBar/Belle will fit the requirements

- Improve performances where needed & feasible

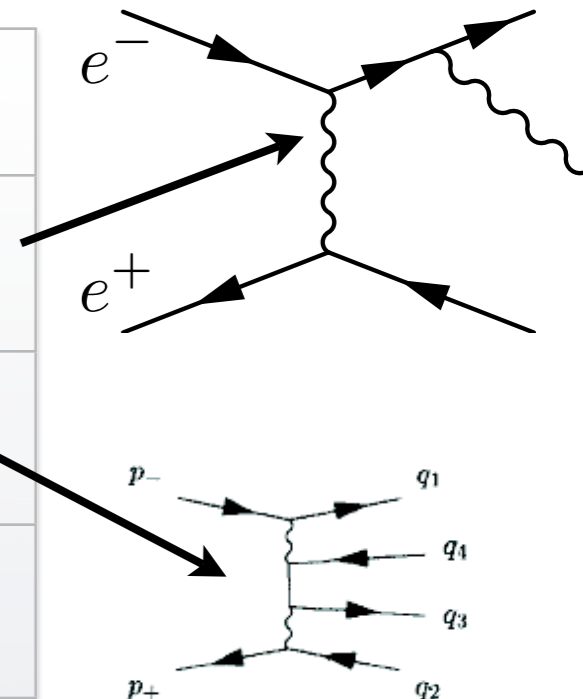
# DETECTOR LAYOUT



# BACKGROUNDS ISSUES

- Luminosity scaling backgrounds are the main issue
- Huge QED cross sections at the IP
  - Low currents / high luminosity
    - Beam-gas backgrounds are not a problem
    - Synchrotron radiation light from the Final Focus can be shielded

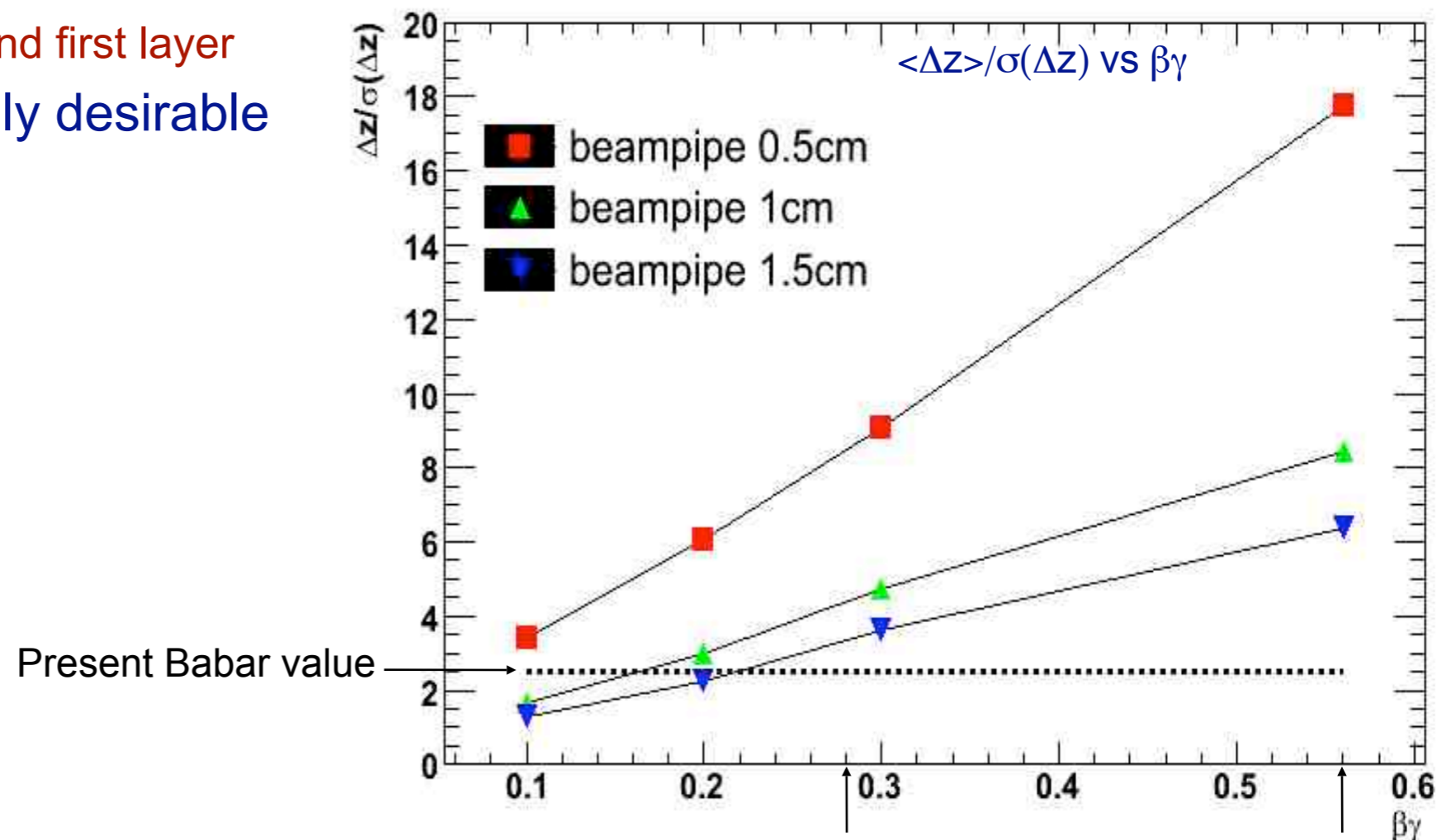
	Cross section	Evt/bunch xing	Rate
Radiative Bhabha	$\sim 340$ mbarn ( $E_\gamma/E_{\text{beam}} > 1\%$ )	$\sim 680$	0.3THz
$e^+e^-$ pair production	$\sim 7.3$ mbarn	$\sim 15$	7GHz
Elastic Bhabha	$O(10^{-5})$ mbarn (Det. acceptance)	$\sim 20/\text{Million}$	10KHz
$\Upsilon(4S)$	$O(10^{-6})$ mbarn	$\sim 2/\text{million}$	1 KHz



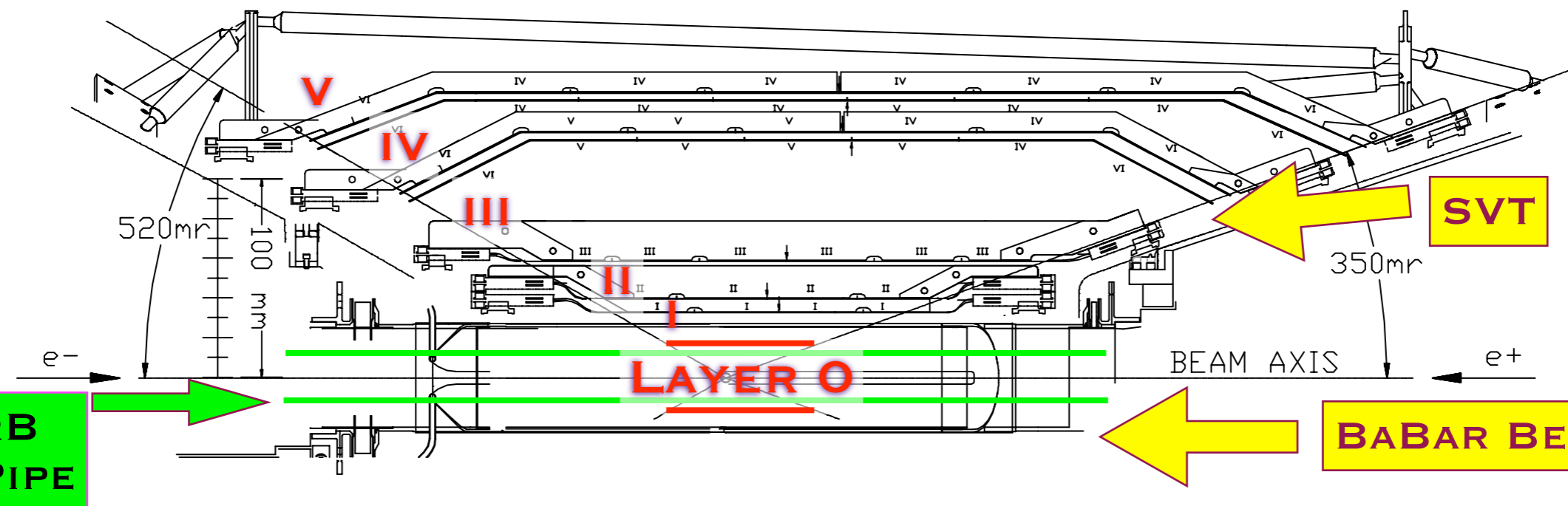


# ENERGY ASYMMETRY

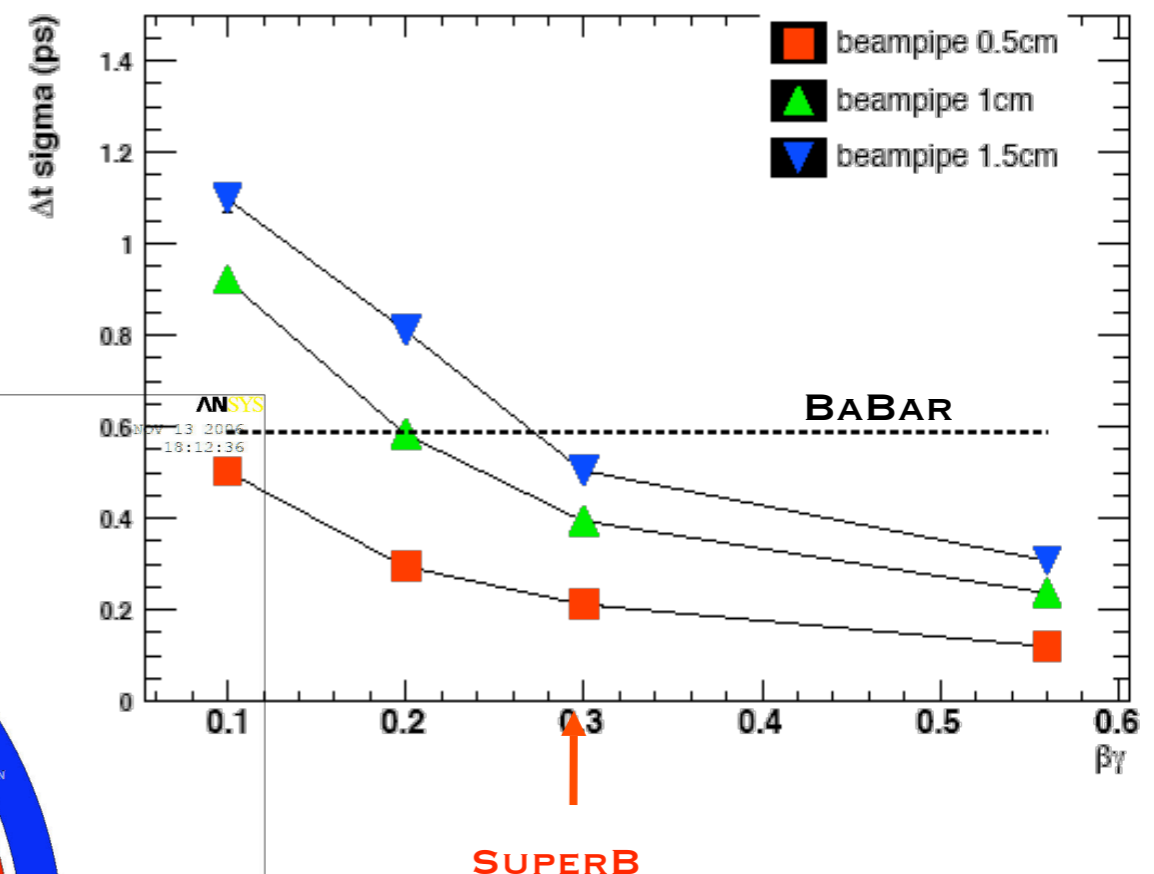
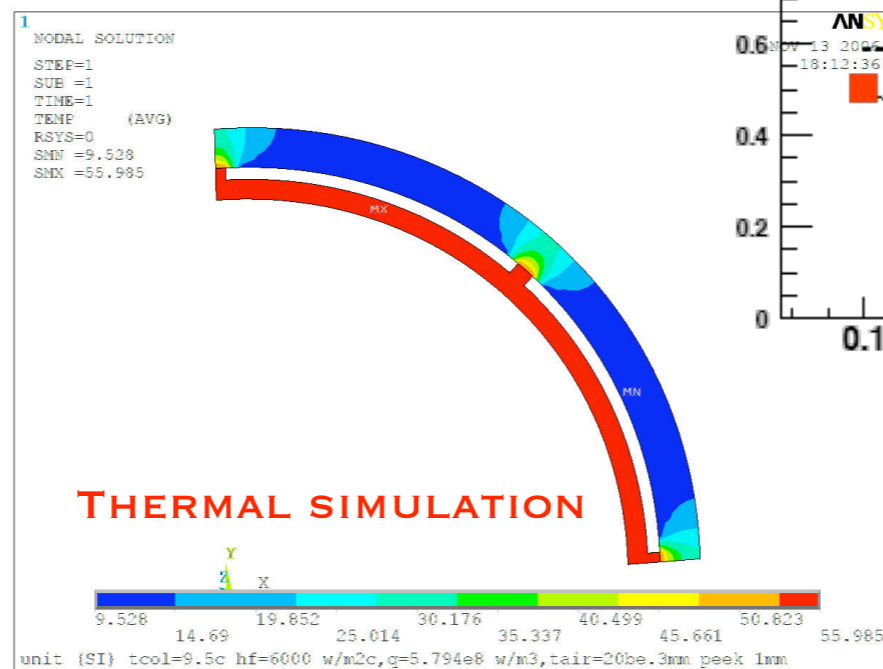
- SuperB emittances cannot be achieved with the present B-factories energy asymmetries
- Lower energy to boost the B mesons
  - Babar: 9 GeV+ 3.1 GeV  $\beta\gamma=0.56$
  - Belle: 8 GeV+ 3.5 GeV  $\beta\gamma=0.45$
  - SuperB: 7GeV + 4 GeV  $\beta\gamma=0.28$
- Time dependent analyses are possible only if the vertexing resolution is able to distinguish the two B decay vertices:
  - small radius beam pipe
  - very little material in b.p. and first layer
- A b.p. with  $r \sim 1\text{cm}$  is highly desirable



# SILICON VERTEX TRACKER



- Baseline: use an SVT similar to the Babar one, complemented by one or two inner layers.
  - Cannot reuse because of radiation damage
- Beam pipe radius is of paramount importance
  - inner radius: 1.0cm,
  - layer0 radius: 1.2cm,
  - thickness: 0.5%  $X_0$



# SVT LAYER ZERO

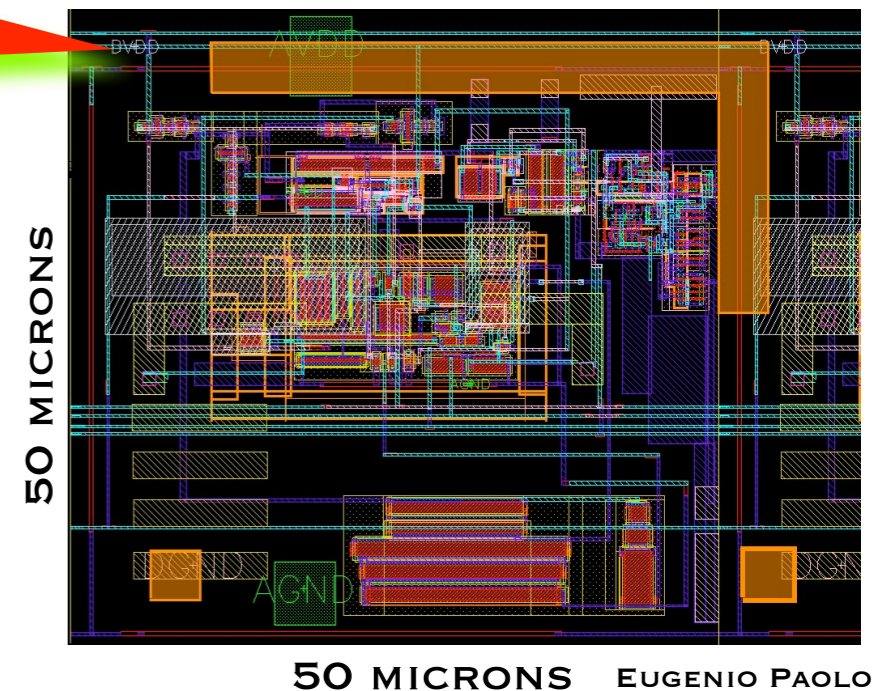
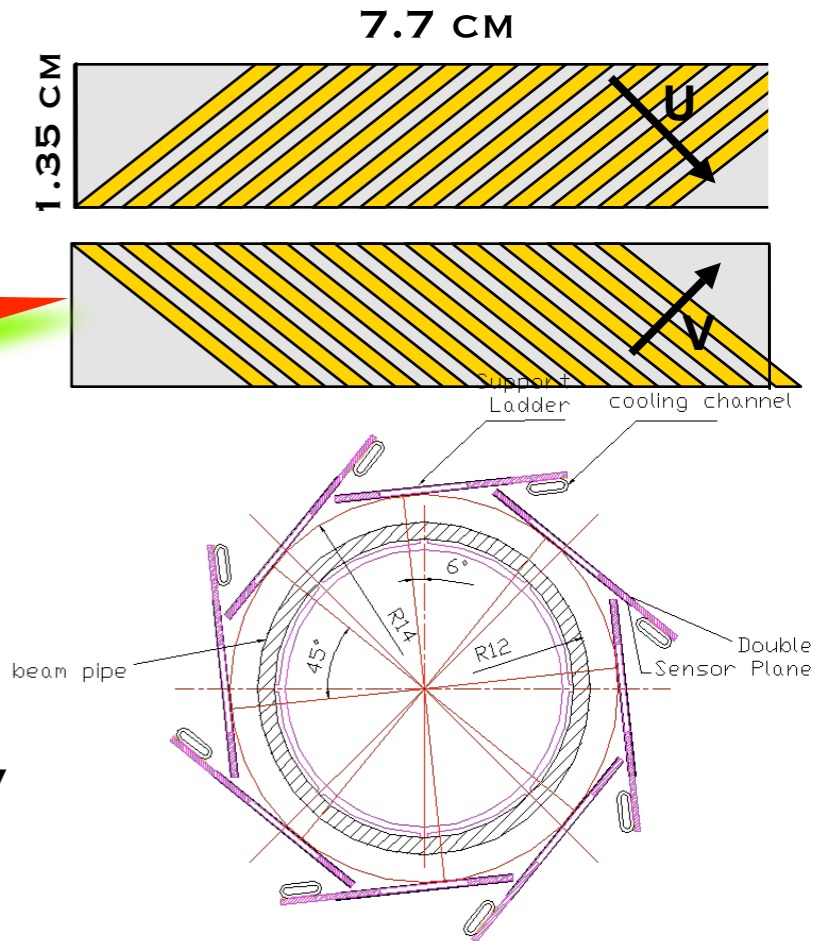
## ■ Severe background from pairs production ( $e^+e^- \rightarrow e^+e^-e^+e^-$ )

### ● Striplets (baseline)

- Basically already available technology but more sensitive to background. OK up to  $\sim \text{MHz}/\text{cm}^2$
- Some margin to improve background sensitivity

### ● Monolithic Active Pixel (option)

- Big safety margin in terms of performance and occupancy
- Cooling and mechanical issues need to be addressed
- But R&D is still ongoing.



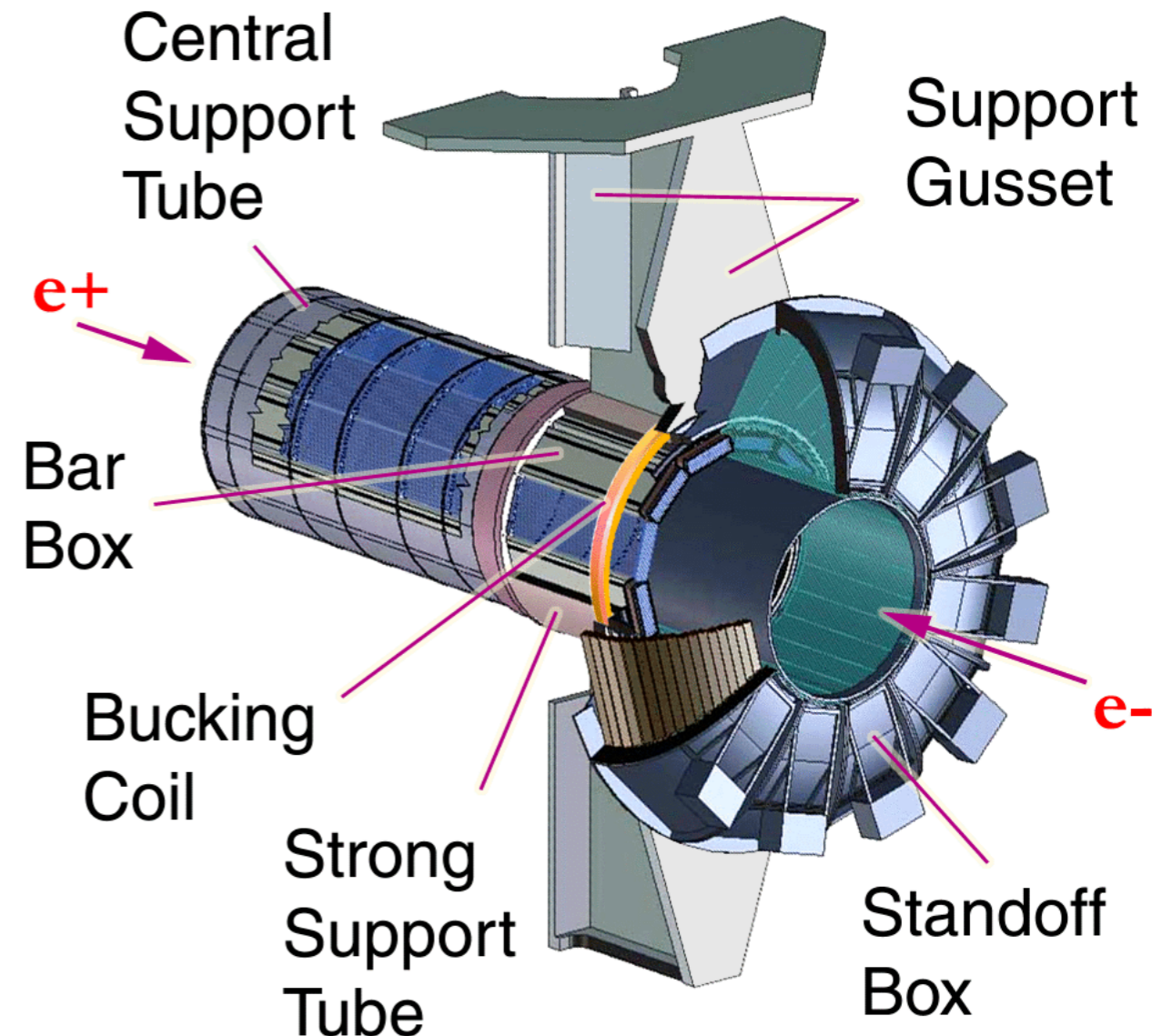
# DRIFT CHAMBER



- Basic technology adequate.
- Cannot reuse BaBar DCH because of aging
- Baseline:
  - Same gas, same cell shape
  - Carbon fiber endplates instead of Al to reduce thickness
- Options/Issues to be studied:
  - Miniaturization and relocation of readout electronics
    - Critical for backward calorimetric coverage
  - Conical endplate
  - Further optimization of cell size/gas

# PARTICLE ID I: DIRC

- DIRC is essential for Kaon-Pion discrimination above 0.7 GeV
- Barrel DIRC baseline
  - Quartz bars are OK and can be reused
    - Almost irreplaceable
    - PMTs are aging and need to be replaced
  - Keep mechanical support
- Barrel Options
  - Faster PMTs
  - Focusing readout
  - Different radiator

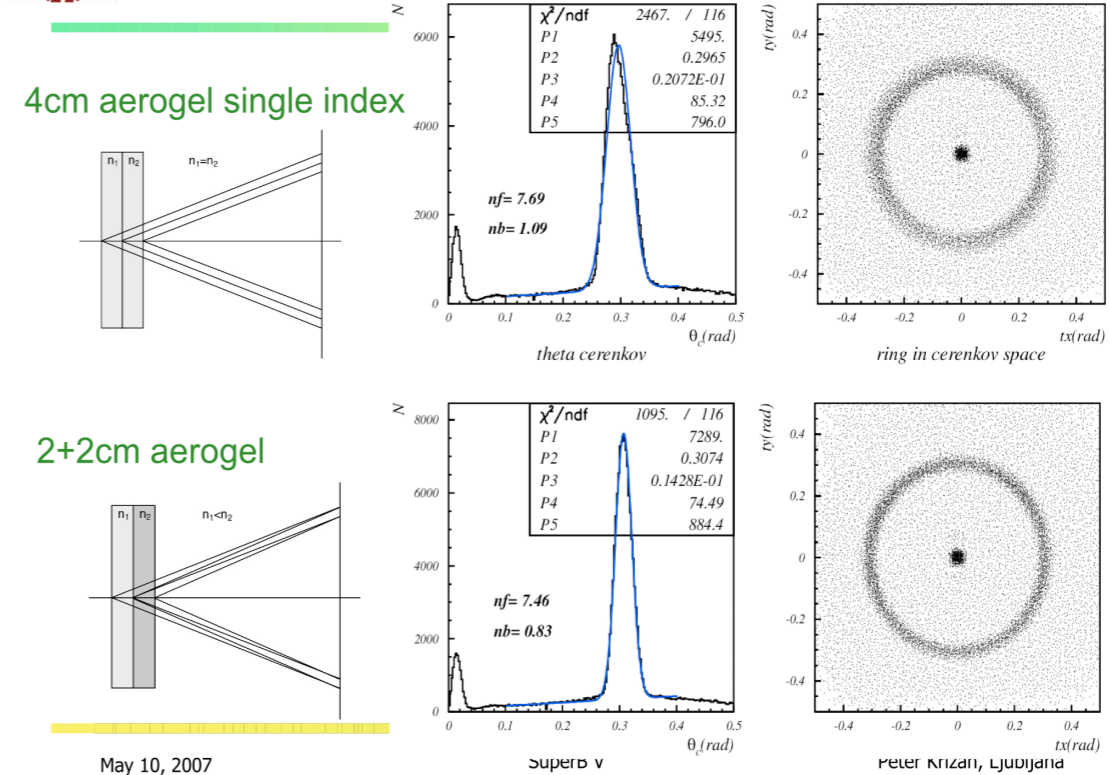


# OPTION: ENDCAPS PID

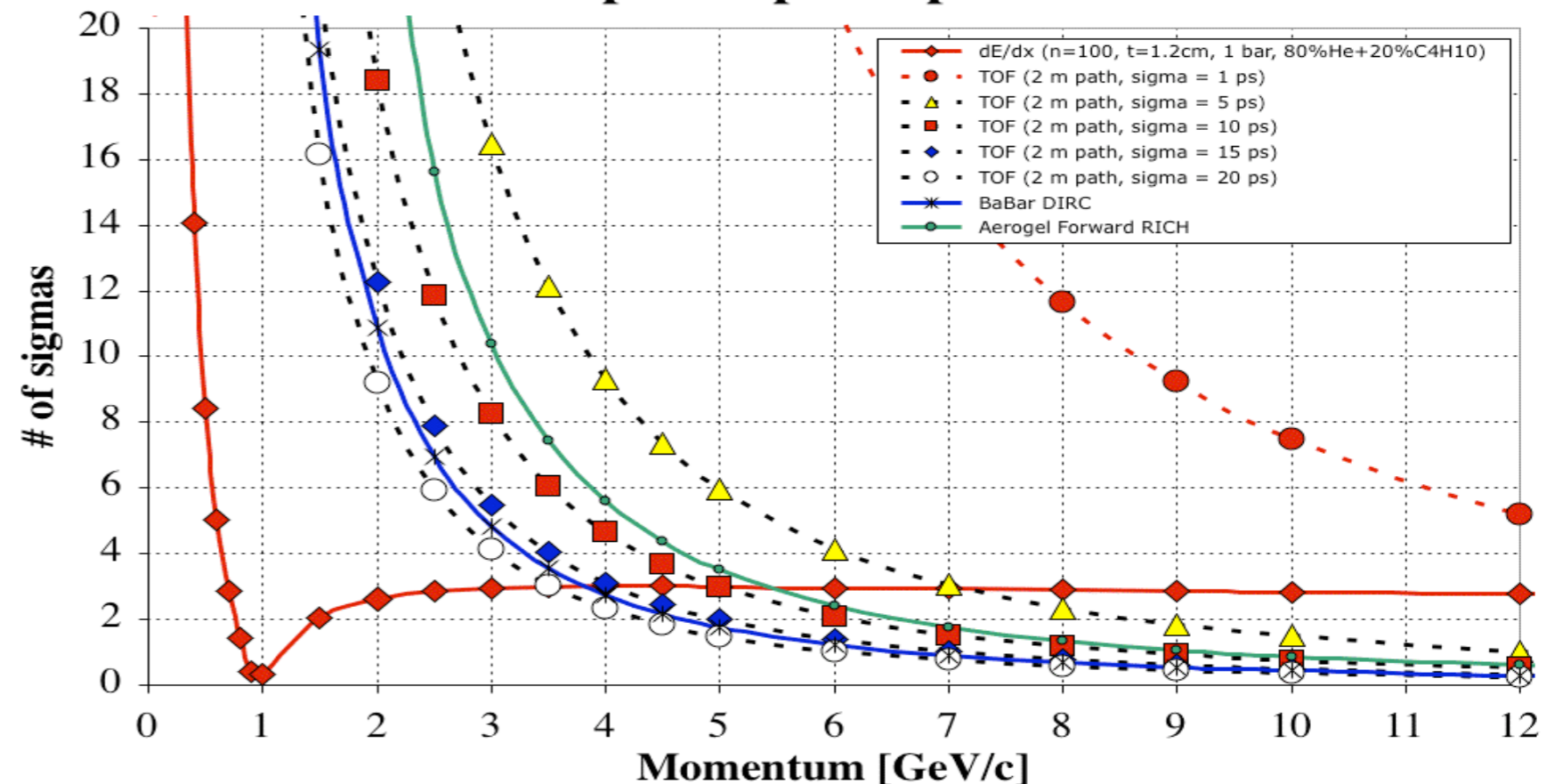


## Focusing configuration – data

- Extending PID coverage to the forward and backward considered
- Possibly useful, physics case needs to be established quantitatively
- Serious interference with other systems
  - Material in front of the EMC
  - Needs space
    - cause displacement of front face of EMC
    - require miniaturization and displacement of DCH electronics
  - TOF seems the only viable option



## Expected p/K separation



## Technologies

- Aerogel-based focusing RICH
  - Working device
  - Requires significant space (>25 cm)
- Time of flight
  - Need about 10ps resolution to be competitive with focusing RICH
  - 15-20ps OK. 10ps seems to be achievable, although not easy

# CALORIMETER

## ■ Barrel CsI(Tl) crystals

- Still OK and can be reused (the most expensive detector in BaBar)
- Baseline is to transport barrel as one device
  - Various other transportation options

## ■ Forward Endcap EMC

- BaBar crystal are damaged by radiation and need to be replaced
- Occupancy at low angle makes CsI(Tl) too slow
  - Pure CsI, LSO

## ■ Backward EMC option

- Because of material in front will have a degraded performance
  - Maybe just a VETO device for rare leptonic B decays as  $B \rightarrow \tau \nu$ .
- Physics impact needs to be quantitatively assessed
- DIRC bars are necessarily in the middle
- DCH electronics relocation is critical for the performance

# FORWARD E.M. CALORIMETER

- Both pure CsI and LSO could be used in the forward EMC
- LSO more expensive, but more light, more compact, and more radiation hard
  - Now LSO is available industrially
  - Cost difference still significant, but not overwhelming.
- Use LSO as baseline
  - Gives better performance
  - Leaves PID option open
- CsI option still open
  - in case of cost/availability issues

SIPAT LSO

Quoted Price: 15 USD/cc

Crystal	CsI(Tl)	CsI	LSO
$\tau$ decay(ns)	680, 3340	16	47
$\chi_0$ (cm)	1.86	1.86	1.14
$R_{\text{molier}}(\text{cm})$	3.8	3.8	2.3
$\lambda_{\text{nuclear}}(\text{cm})$	37	37	
LY ( $\gamma/\text{MeV}$ )	56000, 64:36%	2500	27000
$\lambda_{\text{peak}}(\text{nm})$	550	315	420
Rad Hard (Mrad)	.01	.01-.1	100
$\rho$ (g/cm <sup>3</sup> )	4.51	4.51	7.40
$n_0$	1.79	1.95	1.82

## Bakward calorimeter

- Keep as an option
  - Backward endcap
  - Barrel extension
- Could be less performant
  - Lead – scintillator ?
- Benchmark physics gain



Φ80 x 70

Φ80 x 120

Large size LSO (Ce:Lu<sub>2</sub>SiO<sub>6</sub>) crystals are in production



# IFR: STEEL THICKNESS

- BaBar configuration has too little iron for  $\mu$  ID

- $> 6.5 \lambda_1$  required; 4-5 available in barrel

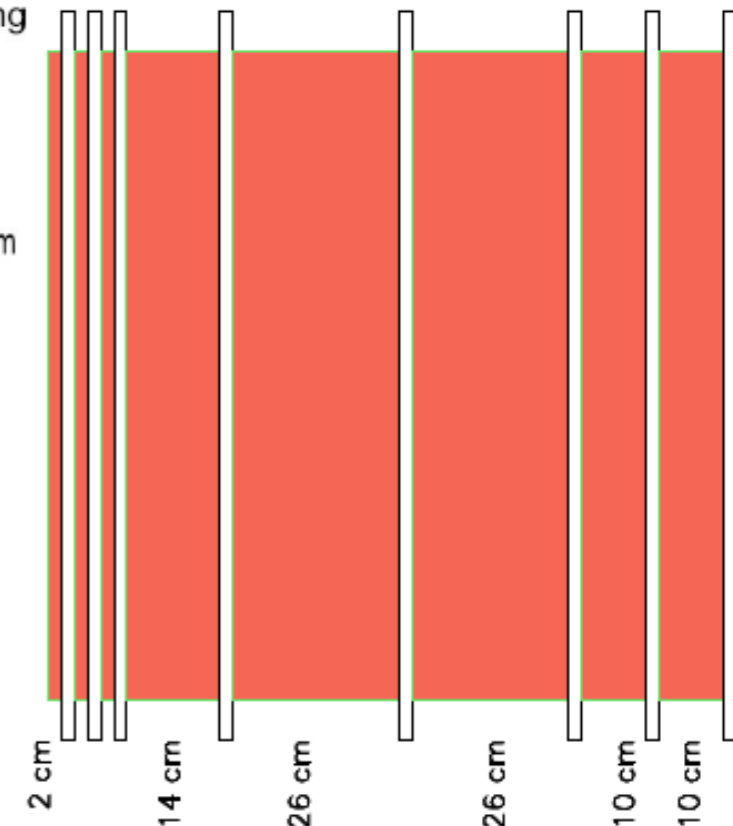
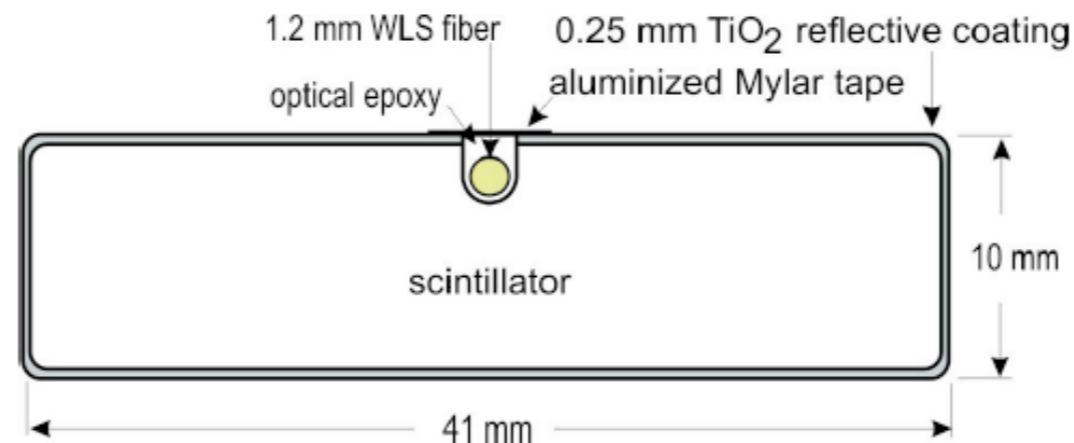
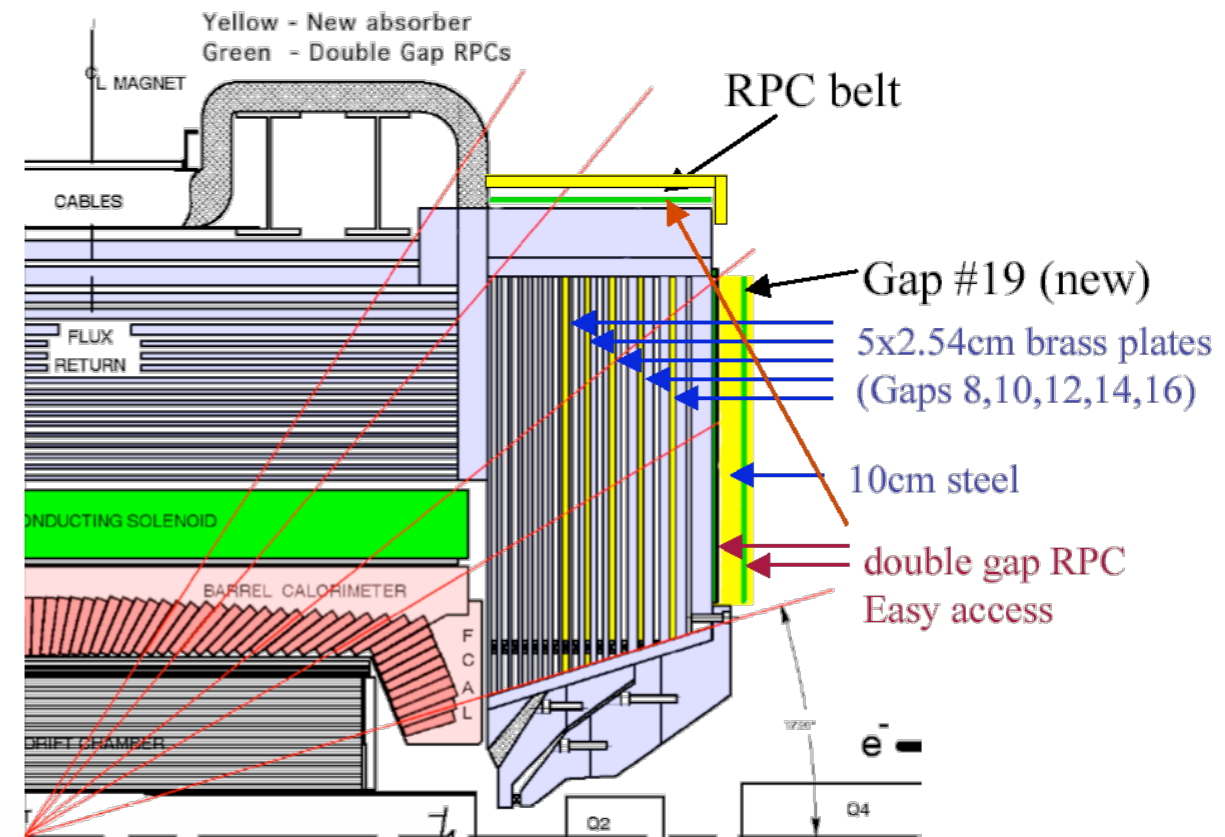
- Fine segmentation overdid  $K_L$  efficiency optimization

- Focus on  $\mu$  ID : fewer layers and more iron

- Baseline:

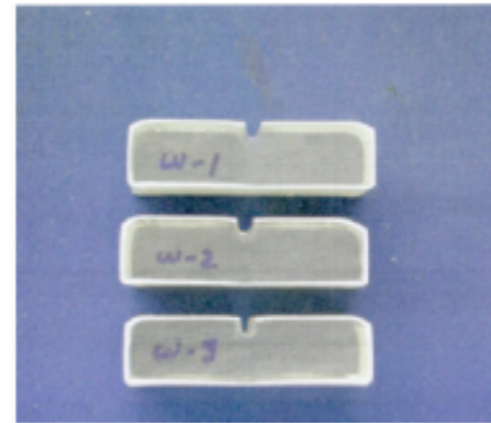
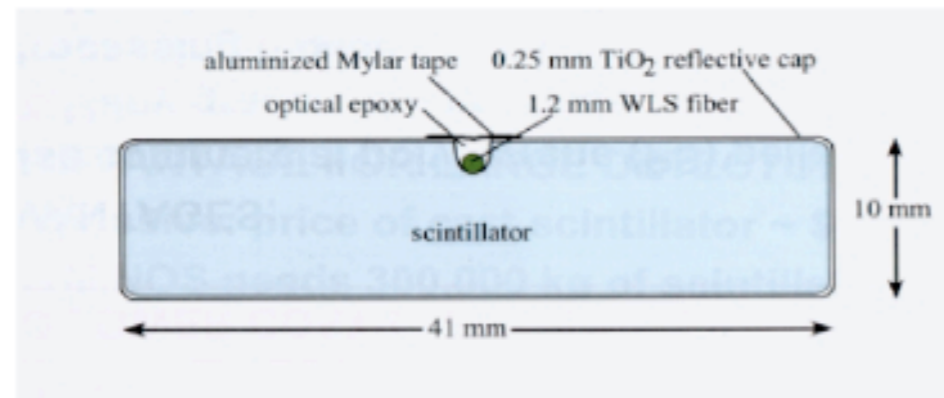
- Fill gaps in Babar IFR with more iron
  - Leave 7-8 detection layers
  - Need to verify structural issues
  - Scintillator bars à la MINOS because rates in the 100Hz/cm<sup>2</sup> range

- Cost effectiveness of steel reuse needs to be fully assessed



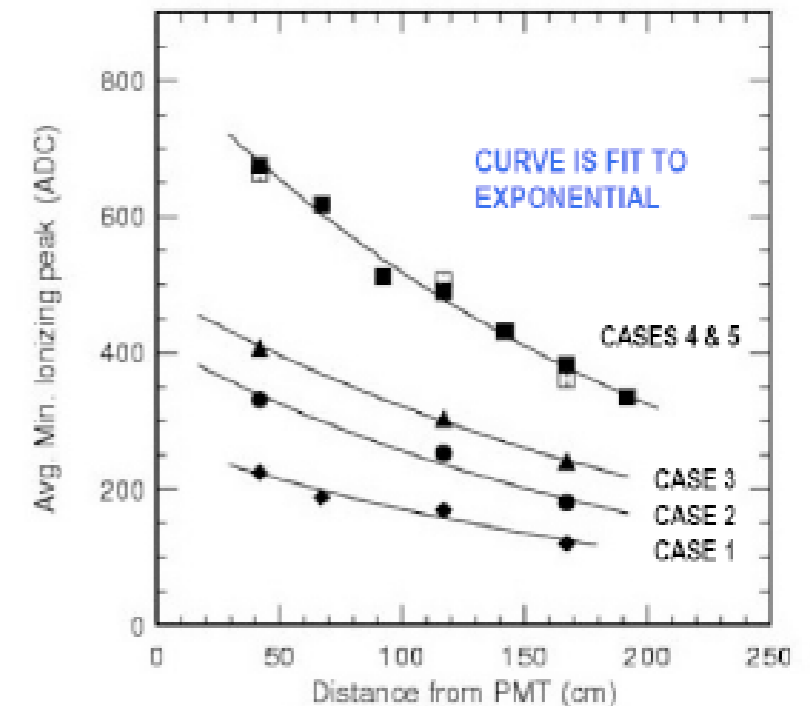
# EXTRUDED SCINTILLATORS

MINOS USES A LARGE VOLUME OF CHEAP CO-EXTRUDED SCINTILLATOR BARS (8m x 4cm x 1cm) WITH SINGLE 1.2mmØ Y11-175 multiclad WLS FIBER EPOXIED IN EXTRUDED GROOVE



MINOS PRODUCTION BARS SHOWING 4 x 1 cm<sup>2</sup> CROSS SECTION WITH CO-EXTRUDED TiO<sub>2</sub> AND GROOVE FOR WLS FIBER

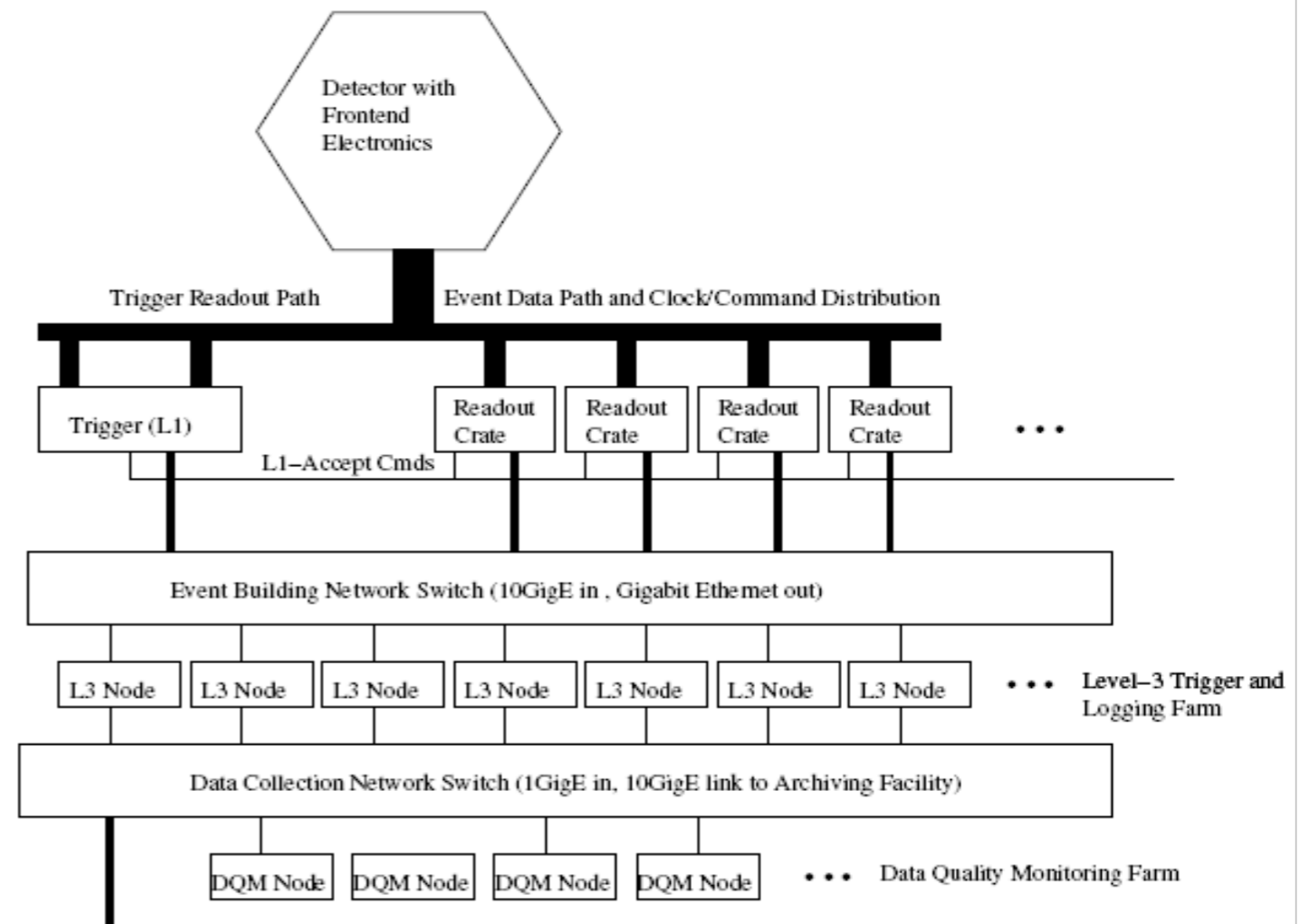
ATTENUATION LENGTH MEASUREMENTS FOR 5 CASES



- R&D going on
  - Studies on Wavelength Shifter (WLS) optical fiber
  - Matching of WLS fiber witht the scintillator bars
- First measurements from a cosmic test stand
  - Light yield, efficiency, spatial/temporal resolution

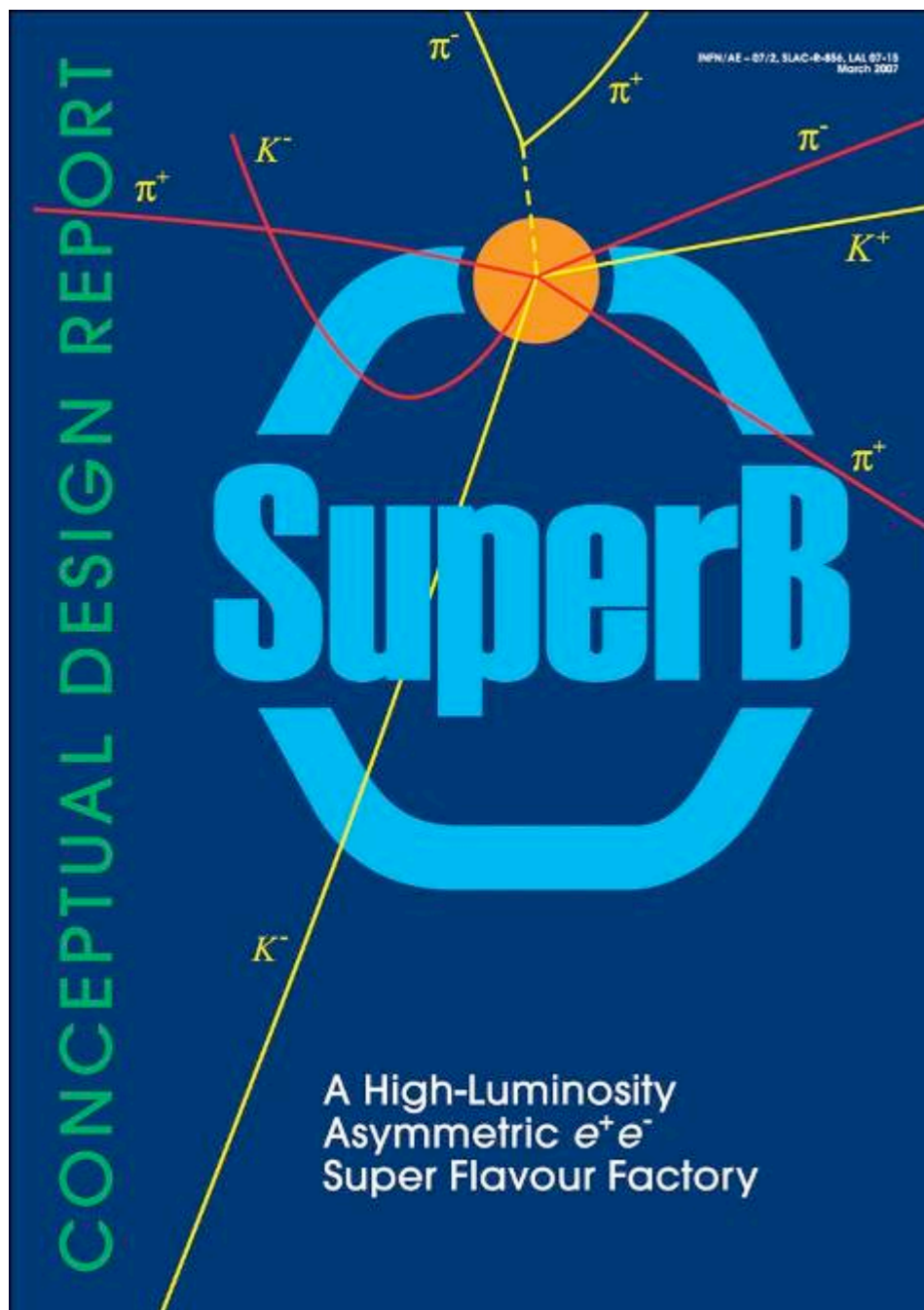
# DATA ACQUISITION

- L1 Trigger rate of 100-150KHz
  - Unless a hardware Bhabha rejector is developed
  - Up from 5KHz current Babar rate
- Event size
  - More readout channels
  - “Interesting Physics” rate
    - @ SuperB 5 KHz ( S/N = 20-30 )
    - @ BaBar 50Hz ( S/N = 100 )
  - Bigger mean event size
- Some electronics could be reusable
  - Especially front-end cards, maybe power supplies
- The bulk of the electronics is obsolete and unmaintainable
  - Should be remade with state-of-the-art technology
- Clearly a major cost driver
  - Costed using recent experiments experience (LHC)



Parameter	Year 1	Year 2	Year 3	Year 4	Year 5
Luminosity ( $\text{ab}^{-1}$ )	2	6	12	12	12
Storage (PB)					
Tape	3.1	10.2	22.0	26.2	27.8
Disk	0.83	3.35	7.55	10.2	10.2
CPU (MSpecInt2000)					
Data reconstruction	3.0	8.8	14.7	8.8	0.0
Skimming	2.7	9.4	16.1	12.1	0.0
Monte Carlo	9.5	28.0	46.6	28.0	0.0
Physics analysis	5.1	15.0	30.0	30.0	30.0
Total	20	61	107	79	30

# CONCLUSIONS



Lot more informations written into our  
Conceptual Design Report

(physics + machine + detector)

INFN/AE-07/02,  
SLAC-R-856,  
LAL 07-15

Available at:

[www.pi.infn.it/SuperB](http://www.pi.infn.it/SuperB)

[arxiv.org/abs/0709.0451](http://arxiv.org/abs/0709.0451)

476 pages

Printed and available

Copies can be requested from  
[Lucia.Lilli@pi.infn.it](mailto:Lucia.Lilli@pi.infn.it)

*Join you too the SuperB team!*

# BACKUP

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
<b>1</b>	<b>SuperB detector</b>	<b>3391</b>	<b>1873</b>	<b>40747</b>	<b>46471</b>
<b>1.0</b>	<b>Interaction region</b>	<b>10</b>	<b>4</b>	<b>210</b>	<b>0</b>
<b>1.1</b>	<b>Tracker (SVT + L0 MAPS)</b>	<b>248</b>	<b>348</b>	<b>5615</b>	<b>0</b>
<b>1.1.1</b>	<b>SVT</b>	<b>142</b>	<b>317</b>	<b>4380</b>	<b>0</b>
<b>1.1.2</b>	<b>L0 Triplet option</b>	<b>23</b>	<b>33</b>	<b>324</b>	<b>0</b>
<b>1.1.3</b>	<b>L0 MAPS option</b>	<b>106</b>	<b>32</b>	<b>1235</b>	<b>0</b>
<b>1.2</b>	<b>DCH</b>	<b>113</b>	<b>104</b>	<b>2862</b>	<b>0</b>
<b>1.3</b>	<b>PID (DIRC Pixilated PMTs + TOF)</b>	<b>110</b>	<b>222</b>	<b>7953</b>	<b>6728</b>
<b>1.3.1</b>	<b>DIRC barrel - Pixilated PMTs</b>	<b>78</b>	<b>152</b>	<b>4527</b>	<b>6728</b>
<b>1.3.1</b>	<b>DIRC barrel - Focusing DIRC</b>	<b>92</b>	<b>179</b>	<b>6959</b>	<b>6728</b>
<b>1.3.2</b>	<b>Forward TOF</b>	<b>32</b>	<b>70</b>	<b>3426</b>	<b>0</b>
<b>1.4</b>	<b>EMC</b>	<b>136</b>	<b>222</b>	<b>10095</b>	<b>30120</b>
<b>1.4.1</b>	<b>Barrel EMC</b>	<b>20</b>	<b>5</b>	<b>171</b>	<b>30120</b>
<b>1.4.2</b>	<b>Forward EMC</b>	<b>73</b>	<b>152</b>	<b>6828</b>	<b>0</b>
<b>1.4.3</b>	<b>Backward EMC</b>	<b>42</b>	<b>65</b>	<b>3096</b>	<b>0</b>
<b>1.5</b>	<b>IFR (scintillator)</b>	<b>56</b>	<b>54</b>	<b>1268</b>	<b>0</b>
<b>1.6</b>	<b>Magnet</b>	<b>87</b>	<b>47</b>	<b>1545</b>	<b>9623</b>
<b>1.7</b>	<b>Electronics</b>	<b>286</b>	<b>213</b>	<b>5565</b>	<b>0</b>
<b>1.8</b>	<b>Online computing</b>	<b>1272</b>	<b>34</b>	<b>1624</b>	<b>0</b>
<b>1.9</b>	<b>Installation and integration</b>	<b>353</b>	<b>624</b>	<b>3830</b>	<b>0</b>
<b>1.A</b>	<b>Project Management</b>	<b>720</b>	<b>0</b>	<b>180</b>	<b>0</b>

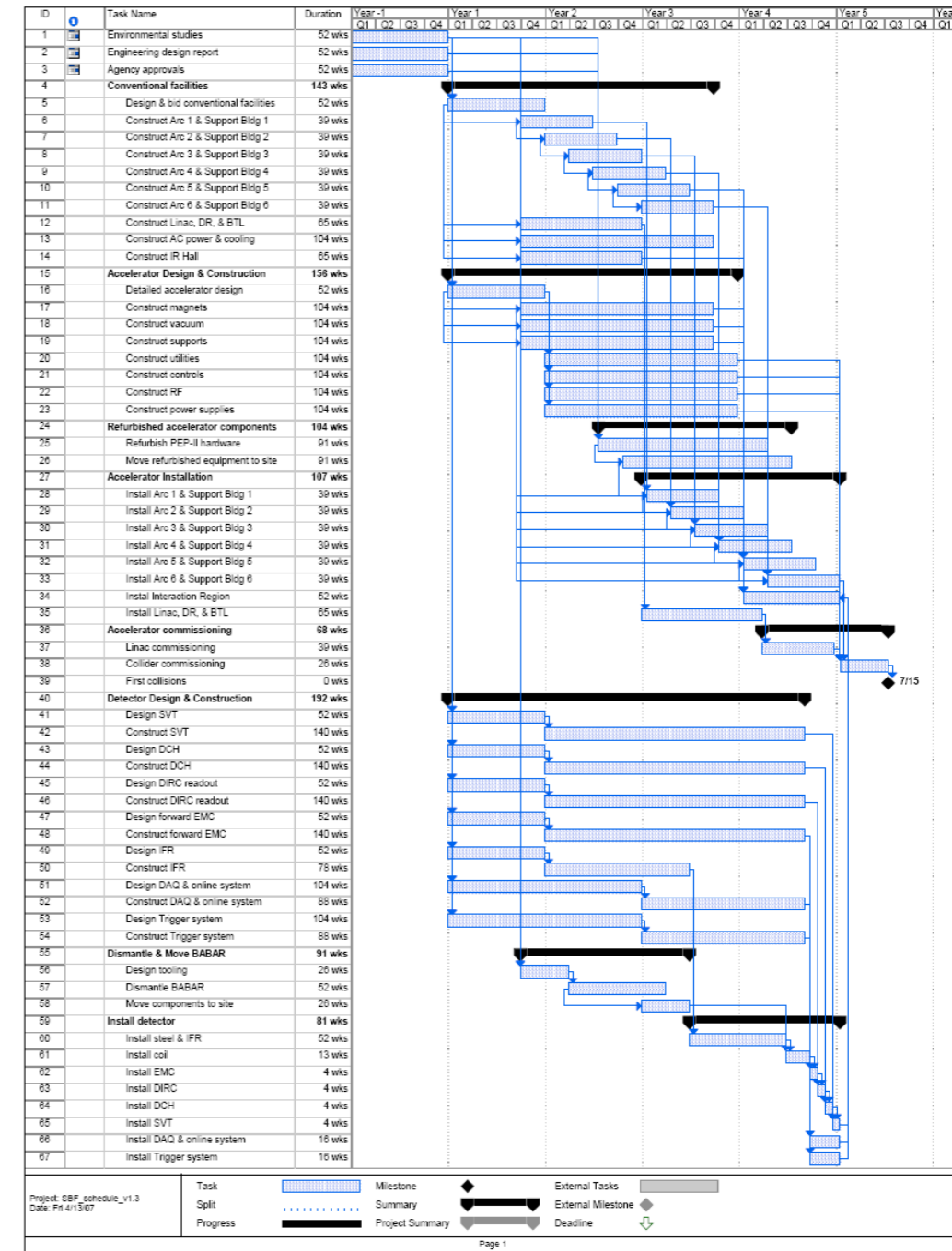


Figure 5-1. Overall schedule for the construction of the SuperB project.