SuperB: Physics, Accelerator and Detector

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Outline

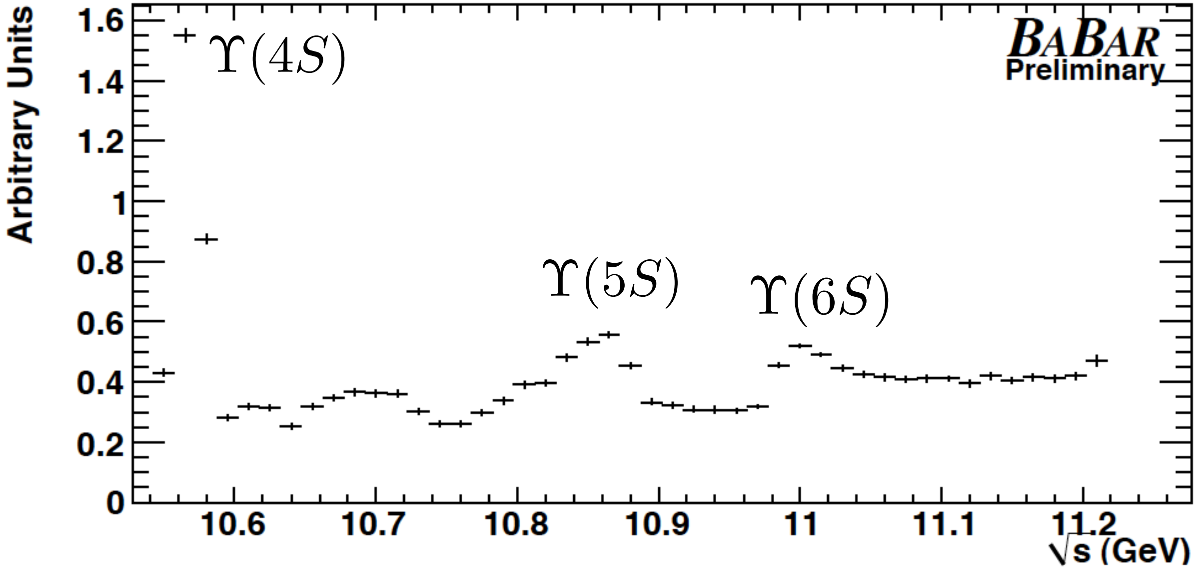
- Physics:
  - discovery potential of a SuperB factory.
- Accelerator:
  - the innovative scheme of SuperB.
- Detector:
  - general overview of the detector;
  - vertex detector specifications.
- Status of the project:
  - project approved and funded. Plans for organization, construction and running.

Physics

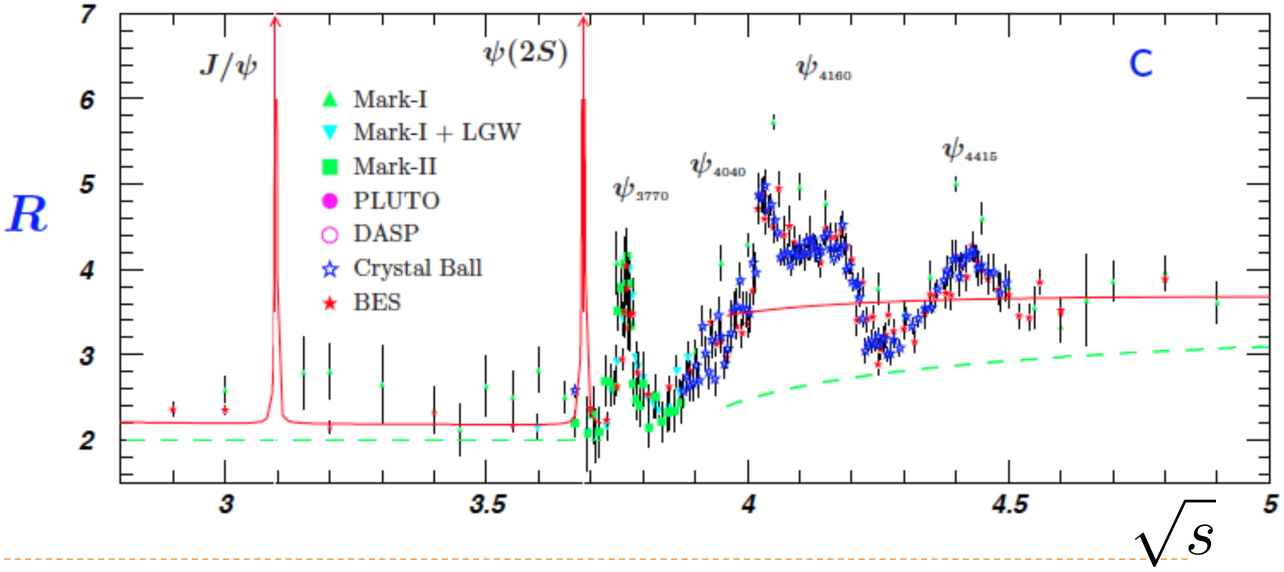
Physics Progress Report [arXiv:1008.1541]

Data sample

- Υ(4S) region:
  - 75 ab^{-1} at the Υ(4S)
  - Also run above / below the Υ(4S)
  - ~75 x10^{9} B, D and τ pairs



- ψ(3770) region:
  - 500 fb^{-1} at threshold
  - Also run at nearby resonances
  - ~2 x 10^{9} D pairs

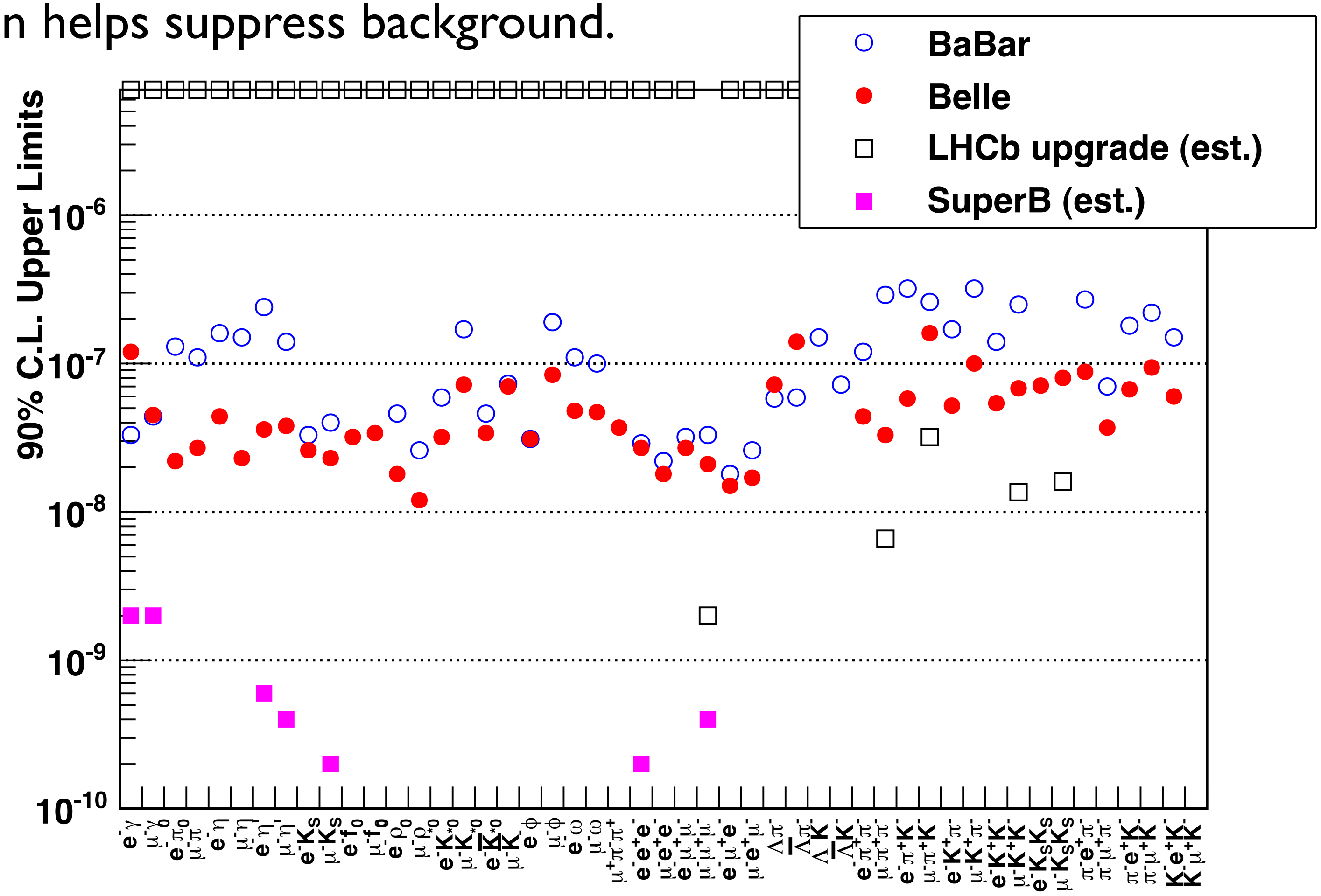


τ Lepton Flavor Violation (LFV)

- ν mixing leads to a low level of charged LFV ($B \sim 10^{-54}$).
  - Enhancements to observable levels are possible with new physics.
- e^- beam polarization helps suppress background.

Two orders of magnitude improvement at SuperB over current limits.

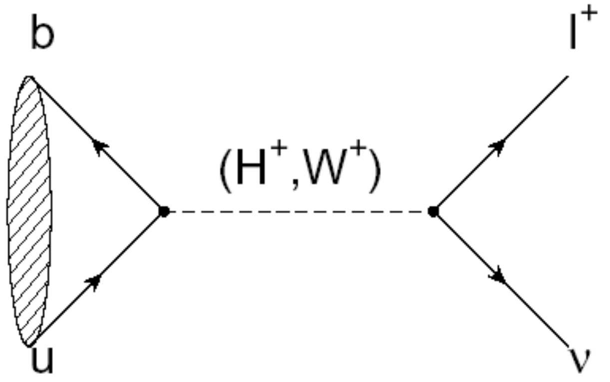
Hadron machines are not competitive with e^+e^- machines for these measurements.

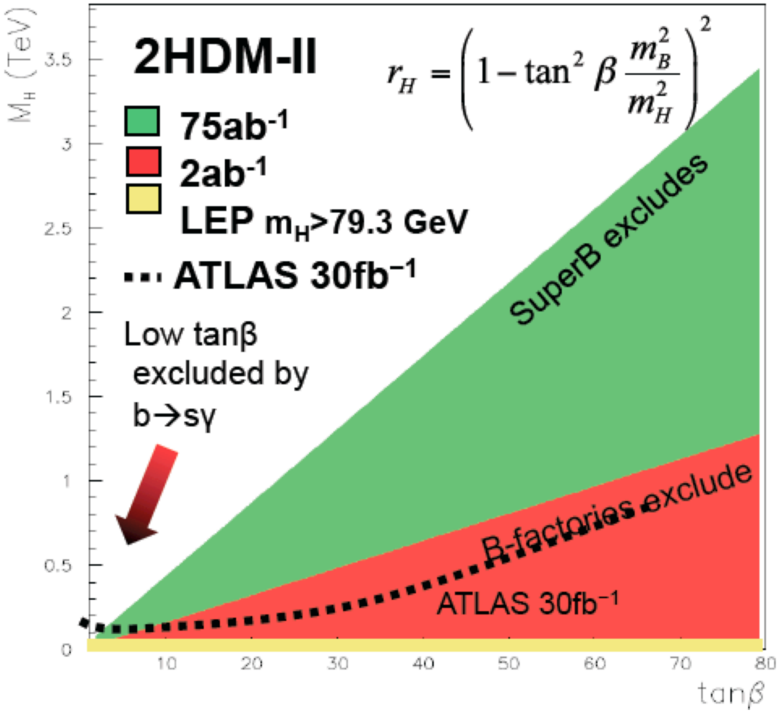


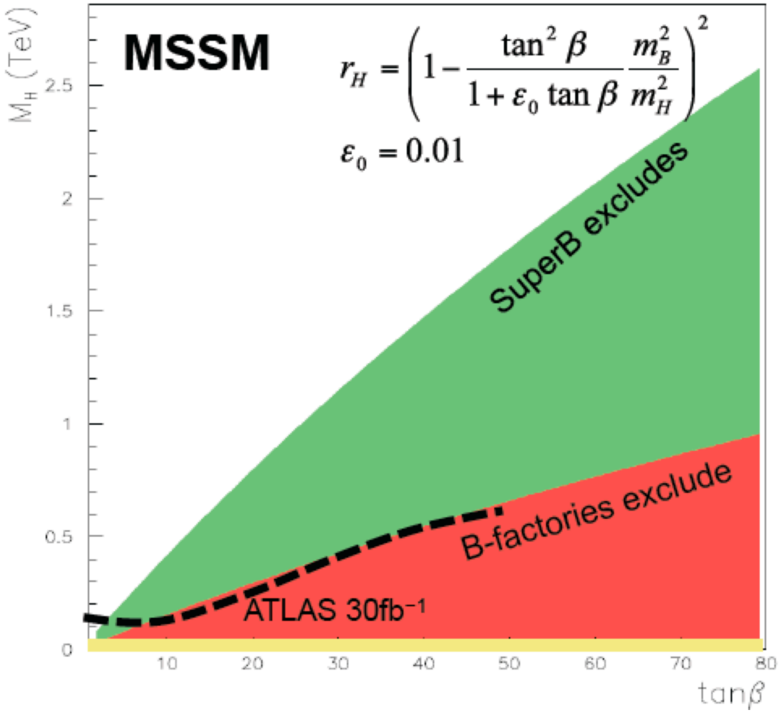
$B_{u,d}$ physics: Rare Decays

- Example: $B^{\pm} \to \tau^{\pm} \nu$
  - Rate modified by presence of H^+

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$







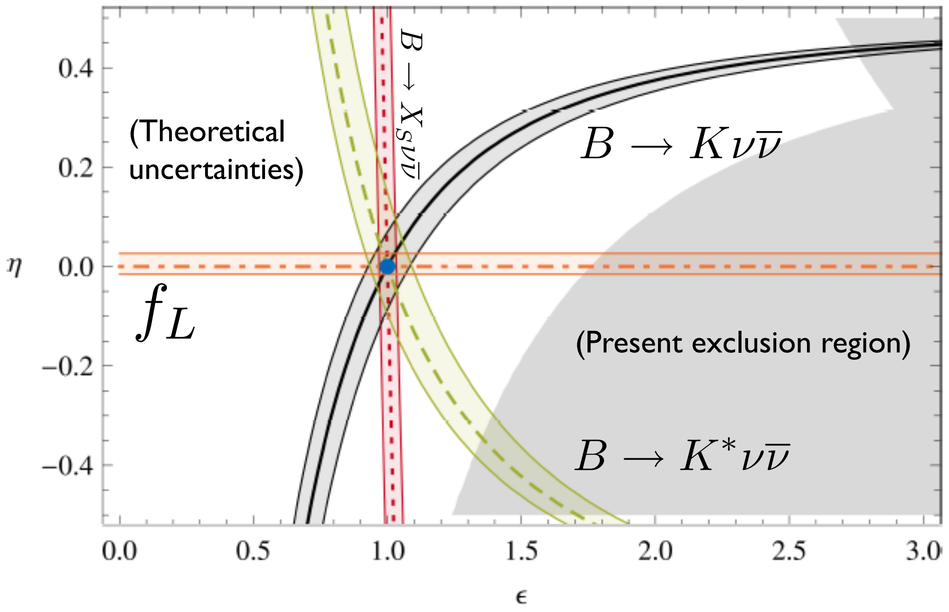
$B_{u,d}$ physics: Rare Decays

- Example: $B \to K^{(*)}\nu\bar{\nu}$
  - Need 75ab^{-1} to observe this mode.
  - With more than 75ab^{-1} we could measure polarization.

$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\mathrm{SM}}|}\ , \qquad \eta = \frac{-\mathrm{Re}\left(C_L^\nu C_R^{\nu *}\right)}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

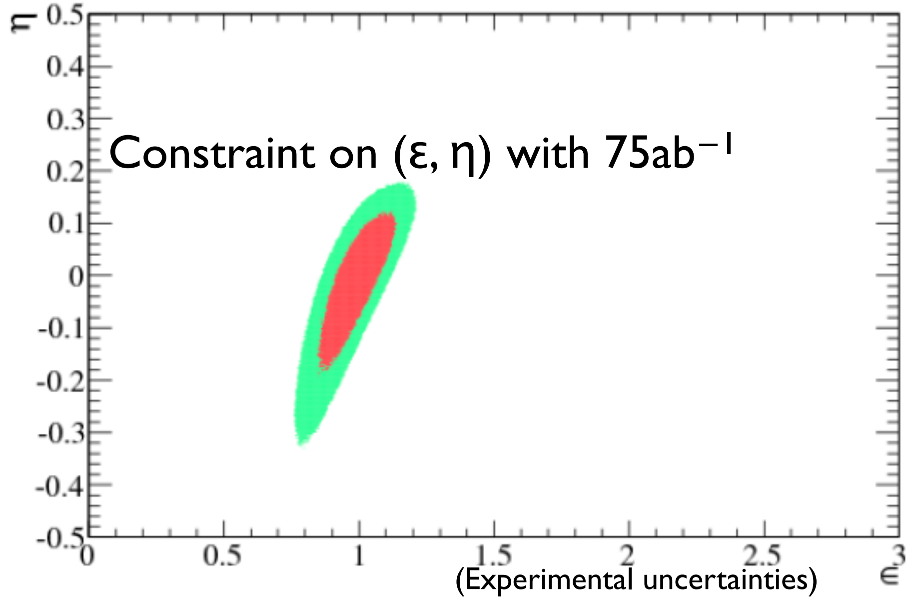
Sensitive to models with Z penguins and RH currents.

e.g. see Altmannshofer, Buras, & Straub *JHEP04(2009)022*



(Theoretical uncertainties)

(Present exclusion region)



Constraint on (ε, η) with 75ab^{-1}

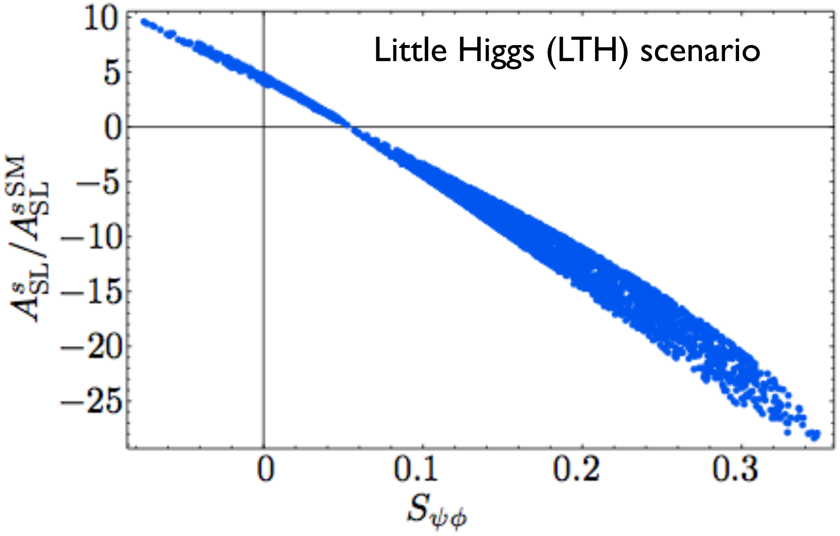
(Experimental uncertainties)

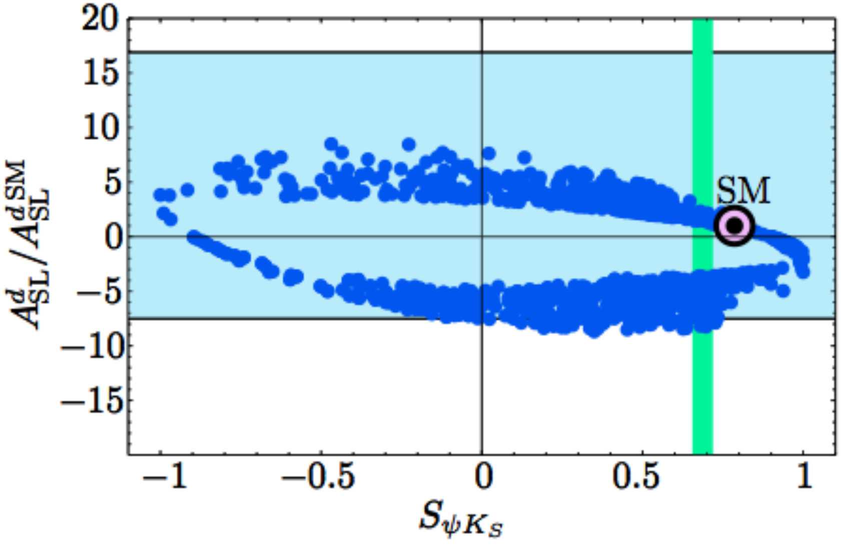
B_s physics

- Can cleanly measure A^s_{SL} using $\Upsilon(5S)$ data

$$A^s_{SL} = \frac{\mathcal{B}(B_s \to \overline{B}_s \to X^-\ell^+\nu_\ell) - \mathcal{B}(\overline{B}_s \to B_s \to X^-\ell^+\nu_\ell)}{\mathcal{B}(B_s \to \overline{B}_s \to X^-\ell^+\nu_\ell) + \mathcal{B}(\overline{B}_s \to B_s \to X^-\ell^+\nu_\ell)} = \frac{1-|q/p|^4}{1+|q/p|^4}$$

$$\sigma(A^s_{SL}) \sim 0.004 \text{ with a few } ab^{-1}$$

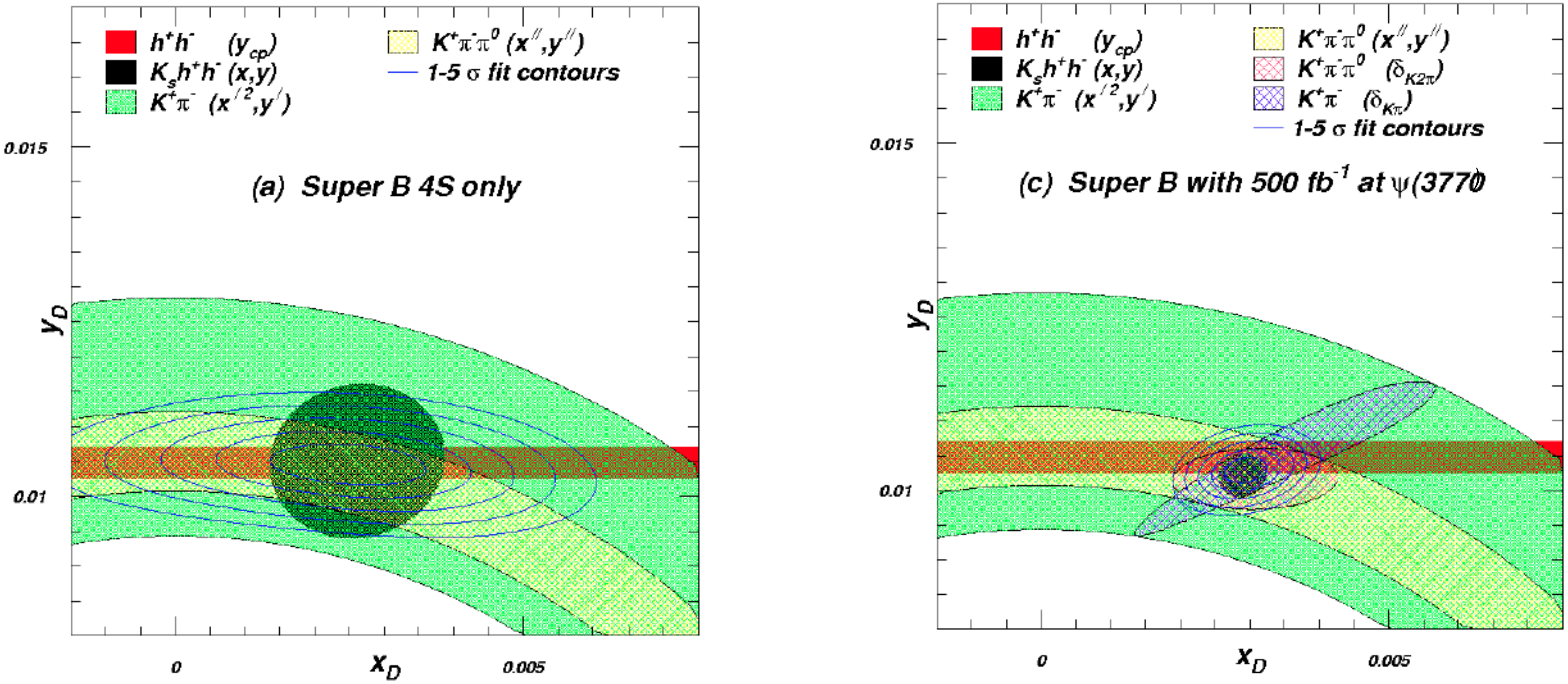




- SuperB can also study rare decays with many neutral particles, such as $B_s \to \gamma\gamma$, which can be enhanced by SUSY.

Charm

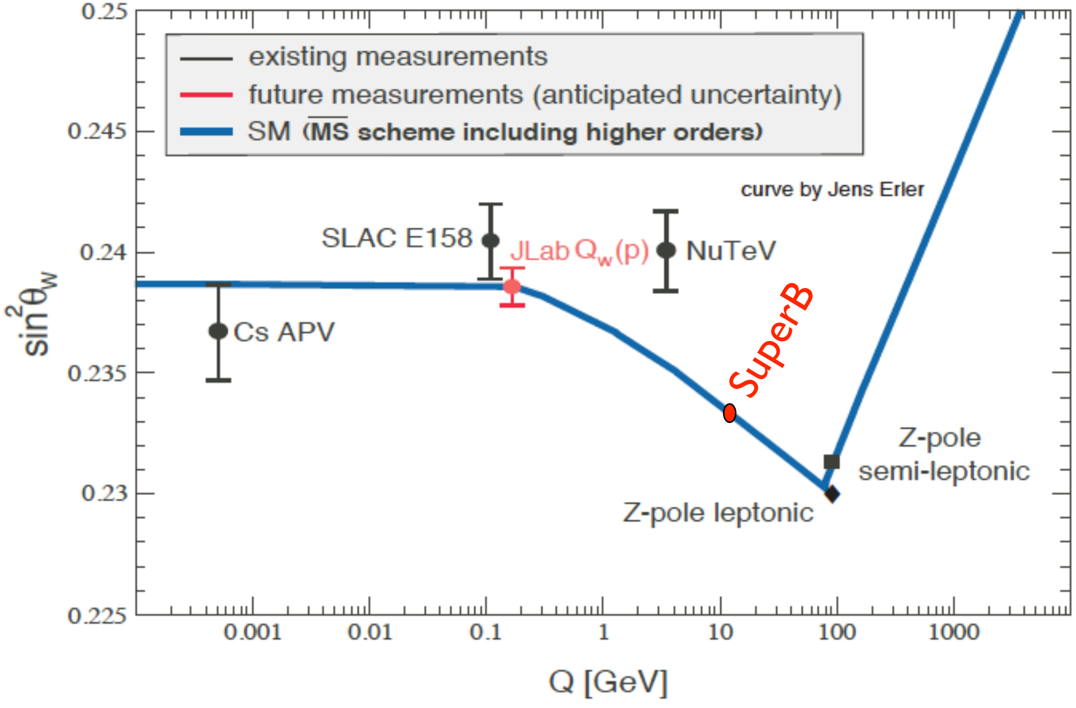
- Collect data at threshold and at the Υ(4S).
  - Benefit charm mixing and CPV measurements.



  - Also useful for measuring the Unitarity Triangle angle γ (strong phase in D→Kππ Dalitz plot).

Precision Electroweak

- $\sin^2\theta_W$ can be measured with polarized e^- beam
  - differential cross-section in $e^+e^- \to f^+f^-$ events
  - $\sqrt{s} = \Upsilon(4S)$ is theoretically clean, c.f. b-fragmentation at Z pole



$$A_{LR} = \frac{\sigma(P)-\sigma(-P)}{\sigma(P)+\sigma(-P)} = \frac{16}{\sqrt{2}}\left(\frac{G_F q^2}{4\pi\alpha}\right)\left(\frac{g_A^e\, g_V^b}{Q_b}\right) P$$

(P= e^- beam polarization)

- Measurable for all $B^0\ \bar{B}^0$ and $B^+\ B^-$ final states, both resonant and continuum.
- **All** QCD corrections included in the **single** form factor that cancels in the asymmetry.
- Very clean measurement, no **large** theoretical corrections (in progress…)

⇒ Excellent opportunity to measure g_V & $\sin^2\theta_W$ at SuperB with polarized beams!!

Perform the measurement also at the Ψ(3770) peak, with polarized beams.

Plot adapted from QWeak proposal (JLAB E02-020)

Interplay

- Combine measurements to elucidate structure of new physics.

	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY				
								AC	RVV2	AKM	δLL	FBMSSM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★
✓	$\tau \to \ell\ell\ell$						★★★					
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)										
✓	$B \to K^{(*)+}\nu\bar{\nu}$			★	★★★			★	★	★	★	★
✓	S in $B \to K^0_S\pi^0\gamma$					★★★						
✓	S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★
✓	$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★
✓	$BR(B \to X_s\gamma)$		★★★	★		★						
✓	$BR(B \to X_s\ell\ell)$			★	★	★						
✓	$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★
	$B_s \to \mu\mu$							★★★	★★★	★★★	★★★	★★★
	β_s from $B_s \to J/\psi\phi$							★★★	★★★	★★★	★	★
✓	a_{sl}						★★★					
✓	Charm mixing							★★★	★	★	★	★
✓	CPV in Charm	★★									★★★	

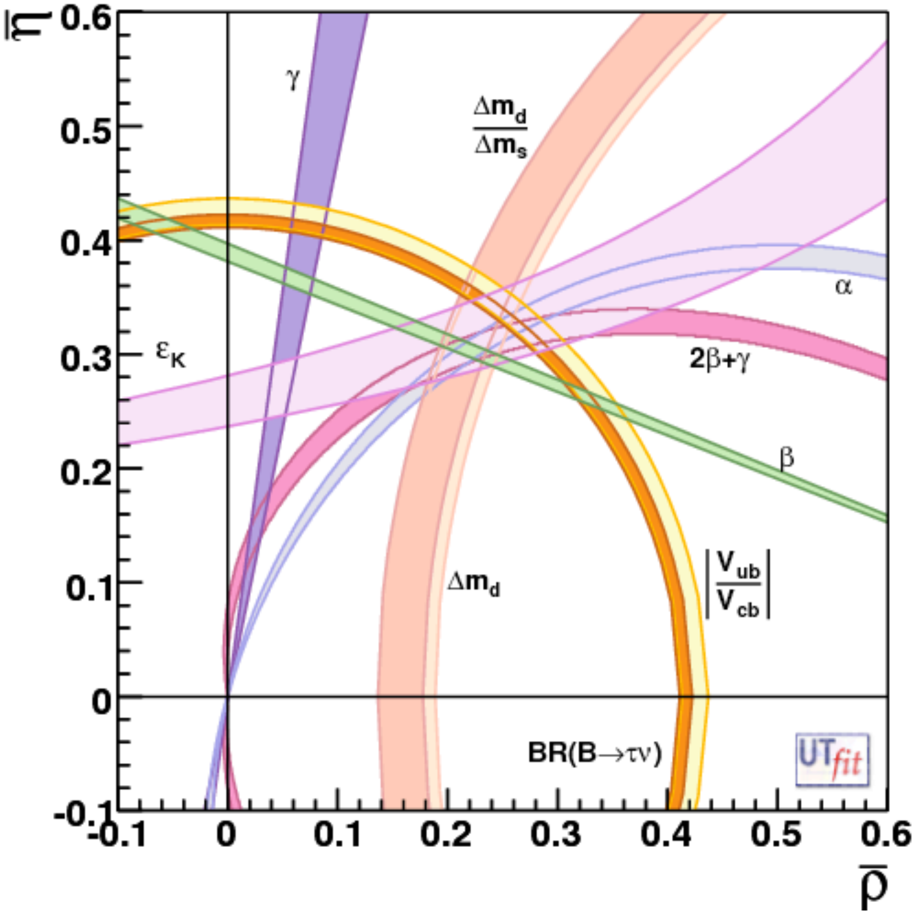
✓= SuperB can measure this

★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

Precision CKM constraints

- Unitarity Triangle Angles
  - $\sigma(\alpha) = 1-2^\circ$
  - $\sigma(\beta) = 0.1^\circ$
  - $\sigma(\gamma) = 1-2^\circ$
- CKM Matrix Elements
  - $|V_{ub}|$
    - Inclusive $\sigma = 2\%$
    - Exclusive $\sigma = 3\%$
  - $|V_{cb}|$
    - Inclusive $\sigma = 1\%$
    - Exclusive $\sigma = 1\%$
  - $|V_{us}|$
    - Can be measured precisely using τ decays
  - $|V_{cd}|$ and $|V_{cs}|$
    - can be measured at/near charm threshold.

The "dream" scenario with $75 ab^{-1}$

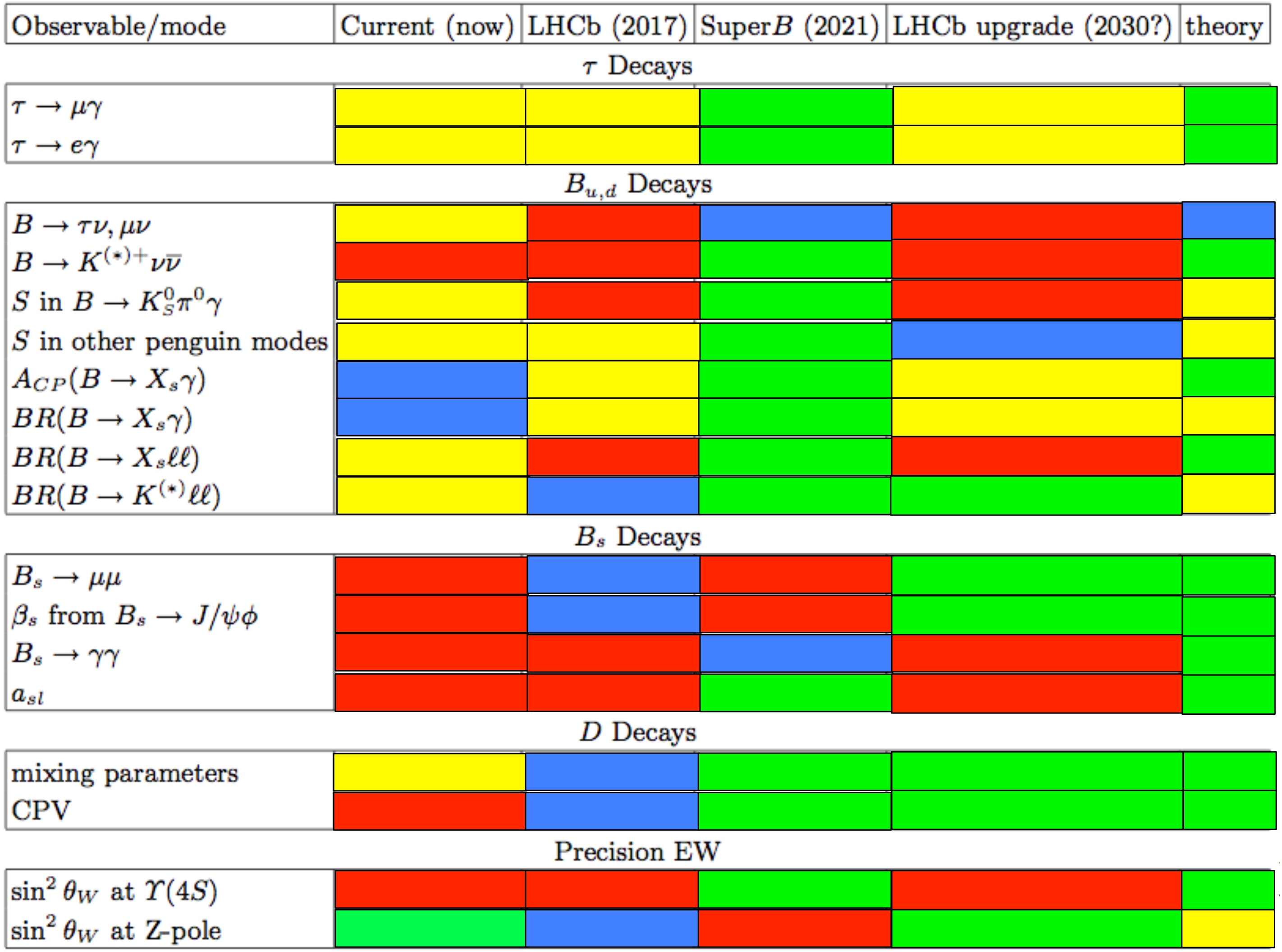


- SuperB Measures the sides and angles of the Unitarity Triangle

Golden Measurements: General

Experiment: 🟥 No Result 🟨 Moderate Precision 🟦 Precise 🟩 Very Precise

Theory: 🟨 Moderately clean 🟦 Clean Need lattice 🟩 Clean



Observable/mode	Current (now)	LHCb (2017)	Super$B$ (2021)	LHCb upgrade (2030?)	theory	
τ Decays						
$\tau \to \mu\gamma$	🟨	🟨	🟩	🟨	🟩	Benefit from polarized e⁻ beam
$\tau \to e\gamma$	🟨	🟨	🟩	🟨	🟩	
$B_{u,d}$ Decays						
$B \to \tau\nu, \mu\nu$	🟨	🟥	🟦	🟥	🟦	very precise with improved detector
$B \to K^{(*)+}\nu\overline{\nu}$	🟥	🟥	🟩	🟥	🟩	Statistically limited: Angular analysis with >75ab^{-1}
S in $B \to K^0_S\pi^0\gamma$	🟨	🟥	🟩	🟥	🟨	Right handed currents
S in other penguin modes	🟨	🟨	🟩	🟦	🟨	SuperB measures many more modes
$A_{CP}(B \to X_s\gamma)$	🟦	🟨	🟩	🟨	🟩	systematic error is main challenge
$BR(B \to X_s\gamma)$	🟦	🟨	🟩	🟨	🟨	control systematic error with data
$BR(B \to X_s\ell\ell)$	🟨	🟥	🟩	🟥	🟩	
$BR(B \to K^{(*)}\ell\ell)$	🟨	🟦	🟩	🟩	🟨	SuperB measures e mode well, LHCb does μ
B_s Decays						
$B_s \to \mu\mu$	🟥	🟦	🟥	🟩	🟩	
β_s from $B_s \to J/\psi\phi$	🟥	🟦	🟥	🟩	🟩	
$B_s \to \gamma\gamma$	🟥	🟥	🟦	🟥	🟩	
a_{sl}	🟥	🟥	🟩	🟥	🟩	
D Decays						
mixing parameters	🟨	🟦	🟩	🟩	🟩	
CPV	🟥	🟦	🟩	🟩	🟩	Clean NP search
Precision EW						
$\sin^2\theta_W$ at $\Upsilon(4S)$	🟥	🟥	🟩	🟥	🟩	Theoretically clean
$\sin^2\theta_W$ at Z-pole	🟩	🟦	🟥	🟩	🟨	b fragmentation limits interpretation

Physics program in a nutshell

- Versatile flavor physics experiment
  - Probe new physics observables in wide range of decays.
    - Pattern of deviation from Standard Model can be used to identify structure of new physics.
    - Clean experimental environment means clean signals in many modes.
    - Polarized e^- beam benefit for precision electroweak measurements and for τ LFV searches.
  - Best capability for precision CKM constraints of any existing/ proposed experiment.
    - Measure angles and sides of the Unitarity triangle
    - Measure other CKM matrix elements at threshold and using τ data.

Accelerator

Accelerator Progress Report [arXiv:1009.6178]

A new generation collider

- SuperB is a second generation flavor factory aiming for a luminosity of 10^{36} cm^{-2}s^{-1} =1 kHz/nb
- The two orders of magnitudes luminosity gain with respect to the first generation B factories is obtained increasing the density of the bunches at the interaction point (IP) by demagnifying their vertical size to ~30 nm
- To reach this goal the amplitude of the betatron oscillations must be kept at minimum
  - optimal ring lattice design to minimize the radial emittance
  - precise magnets alignment and machine tuning to minimize the emittance coupling
  - large Piwinsky angle, $\phi = \frac{\sigma_z}{\sigma_x} \tan \frac{\theta}{2}$ and crab waist collision scheme to overcome the beam-beam luminosity limit

Path to hight luminosity

$$\mathcal{L} \sim f_{\text{coll}} \frac{N^{+} N^{-}}{4\pi\,\sigma_x\,\sigma_y} = 10^{36}\,\text{cm}^{-2}\,\text{s}^{-1}$$

A. Numerator ⤴ (Currents) 1÷2 A ⤴10÷20 A

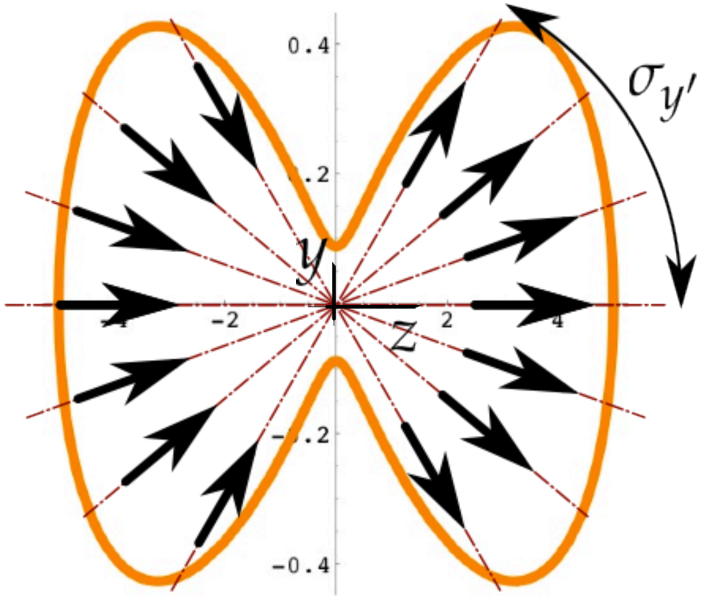
- Wall plug power (Electric monthly bill)~ proportional to current, Longitudinal Fast Instability: limit ~ 5 $10^{35}/\text{cm}^2\text{s}$

B. Denominator ⤵ (bunch size)

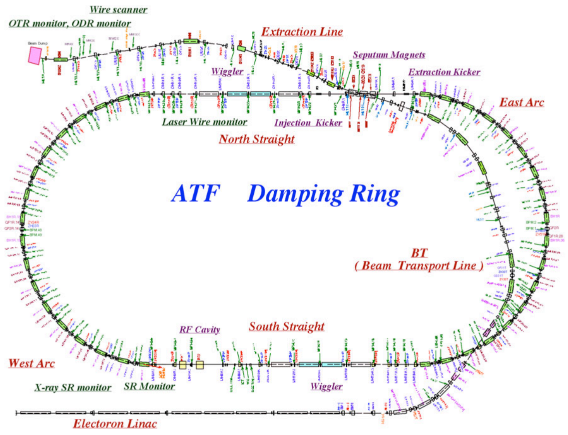
PEP-II 100 x 3 μm^2 ⤵ SuperB 100 μm x 30 nm

- How to squeeze the vertical bunch size to 30 nm ?

Hour glass shaped bunch @ σ_y=30 nm



Bunch shape at the IP



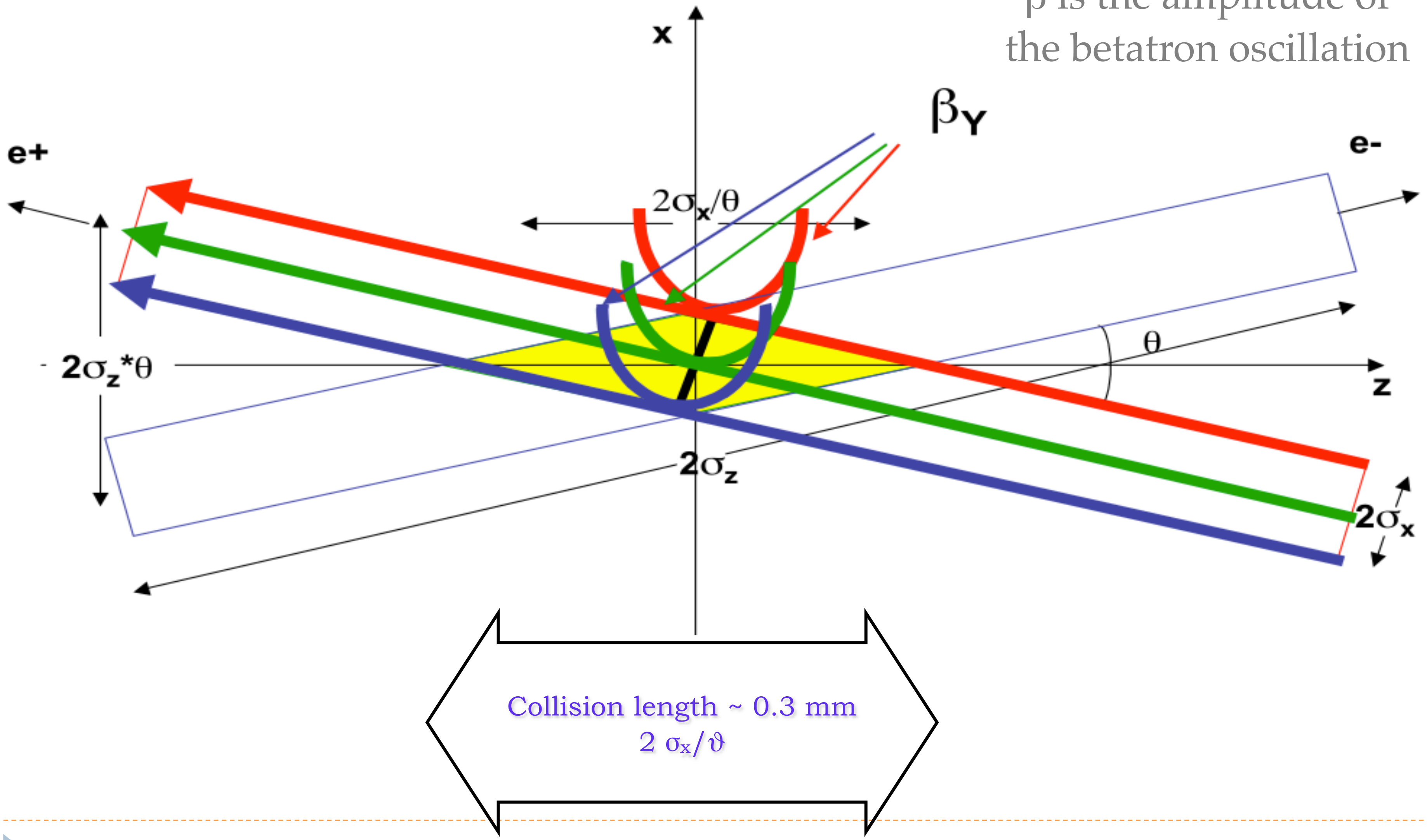
$$\sigma_y \times \sigma_{y'} = \epsilon_y$$

CROSS SECTION
X
ANGULAR DIVERGENCE @ IP
=
EMITTANCE (CHARACTERISTIC OF THE RING)

- PEP-II emittance = 1.5nm x Rad
  Angular divergence ~ 50 mRad = 50 micron / mm
  Bunch collision length should be ~ 2 μm
- ATF state of the art emittance = 2pm x Rad
  Angular divergence ~ 67 microRad =67 nm / mm
- SuperB emittance ~ 5pm x Rad
  Angular divergence ~ 166 microRad =166 nm / mm
  Bunch collision length ~ 0.6 mm

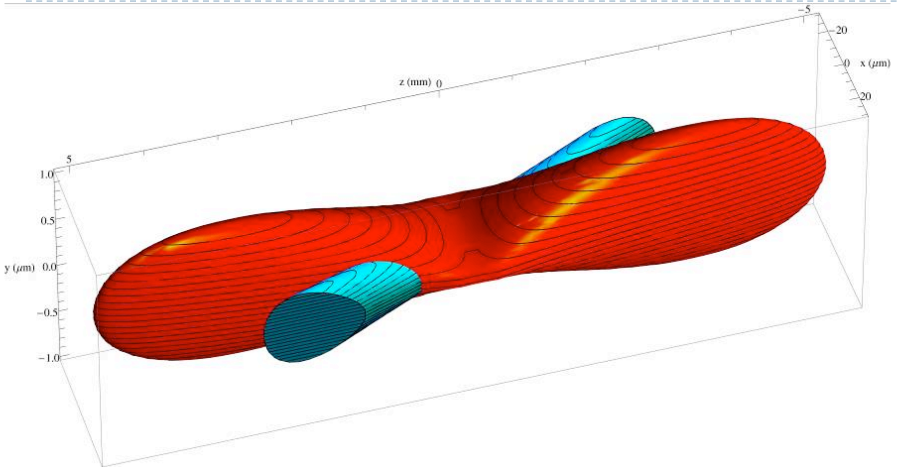
Large crossing angle collision scheme

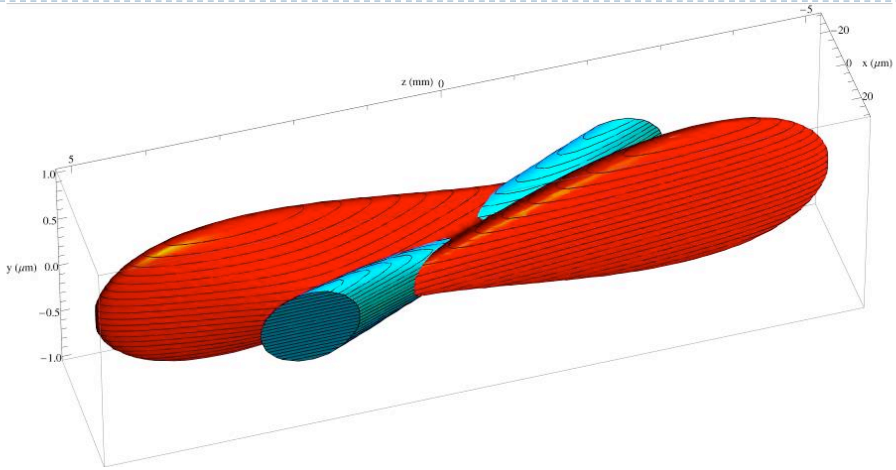
β is the amplitude of the betatron oscillation

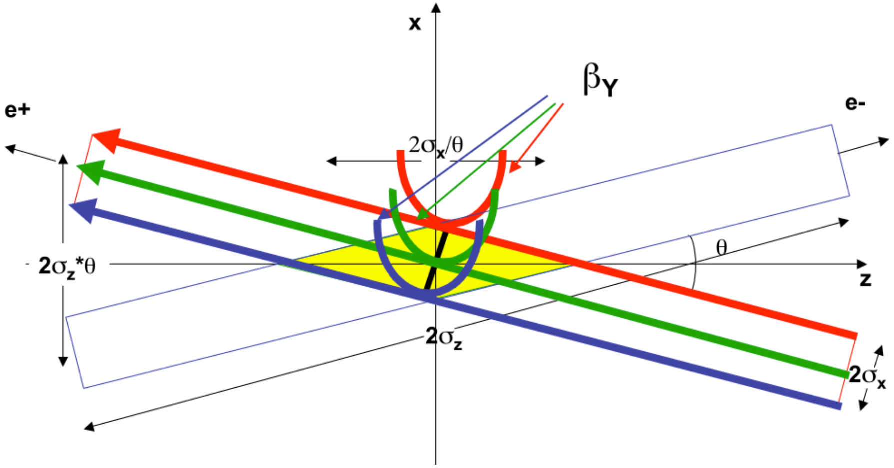


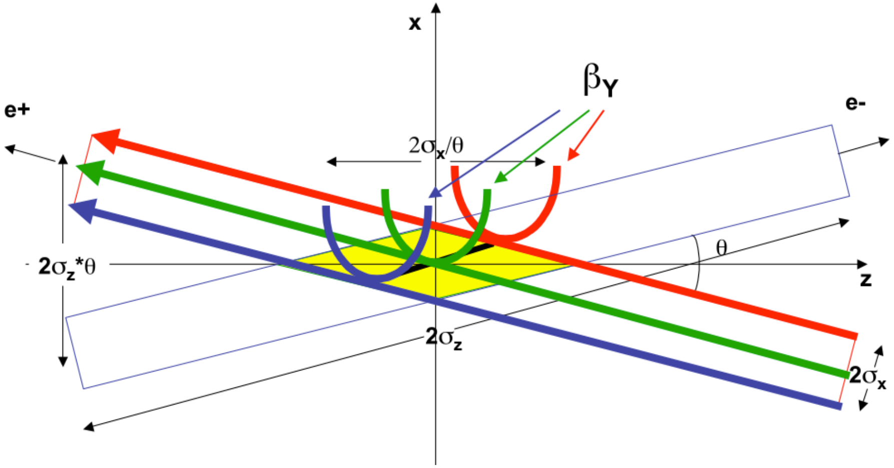
Collision length ~ 0.3 mm
$2\ \sigma_x/\vartheta$

Crab Waist Transform









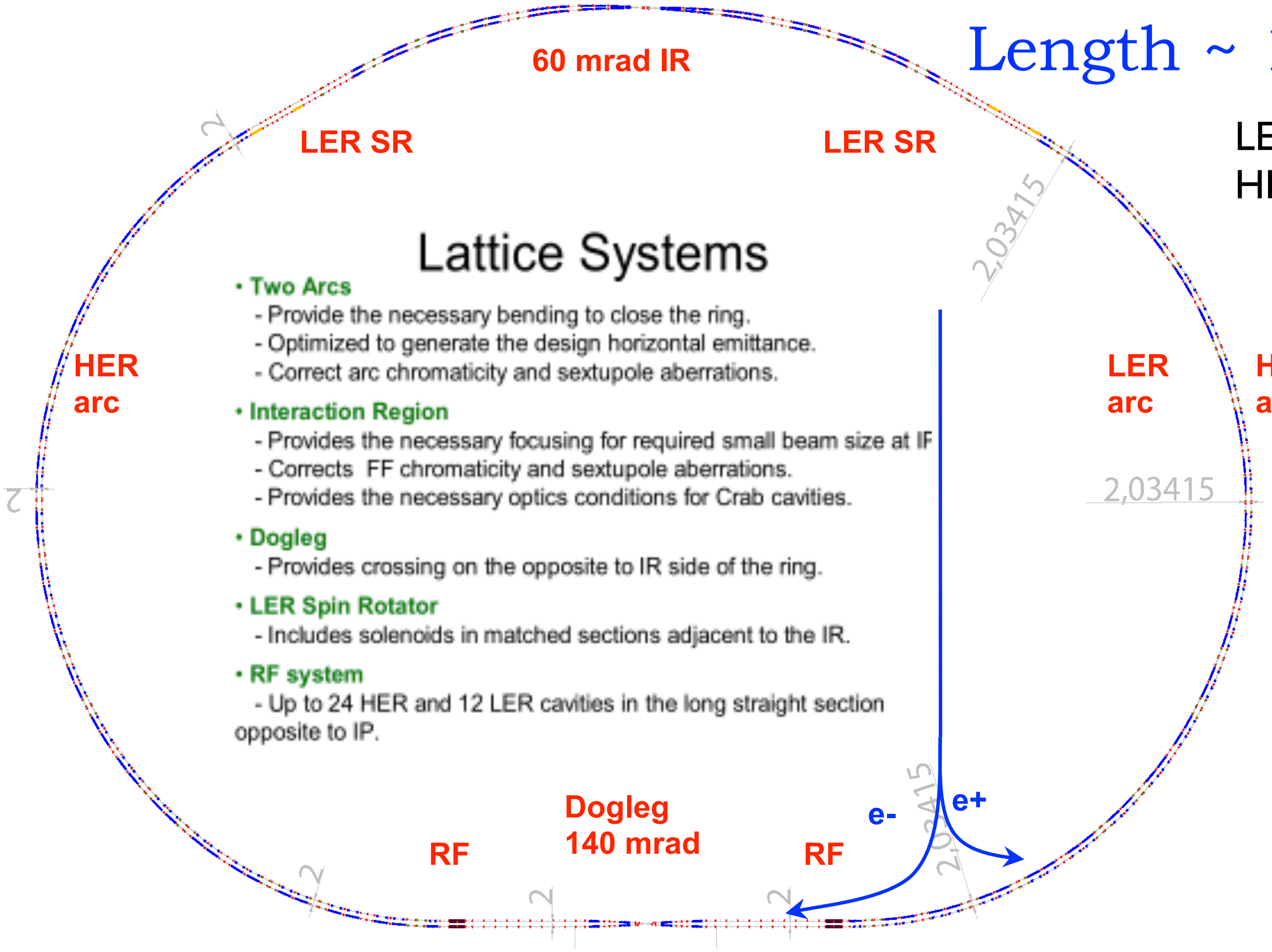
Crab Waist technique benefits:

- maximize geometrical overlap of beams;
- reduction of vertical tune shift;
- suppression of vertical synchrobetatron resonances.

Machine parameters

	Units	HER	LER	HER	LER	HER	LER
Machine		Super B		PEP II		Super KEKB	
Circumference	*m*	*1258.4*		*2200*		*3016.3*	
Frequency turn	Hz	2.38E+05		1.36E+05		9.95E+04	
# bunch		978		1732		2500	
Frequency collision	MHz	233		236		249	
Full crossing angle	Rad	0.066		0.000		0.083	
Energy	GeV	6.7	4.18	9.0	3.1	7	4
Energy ratio		1.60		2.90		1.75	
βx	cm	2.6	3.2	35	40	2.4	3.2
βy	*μm*	*253*	*205*	*9000*	*10800*	*410*	*270*
coupling	%	0.25	0.25	0.24	0.45	0.35	0.40
Radial emittance εx	nm	2.07	2.37	55	33	2.4	3.1
Vertical emittance εy	pm	5.18	5.93	1300	1500	8.4	12.4
Bunch length	cm	0.5	0.5	1.15	1.25	0.5	0.6
Current	A	1.89	2.44	2.07	3.21	2.6	3.62
# particles/bunch	10^{10}	5.08	6.56	5.49	8.52	6.55	9.13
Hor. size @ IP σx	μm	7.34	8.71	43.87	36.33	7.75	10.62
Ver. size @ IP σy	*nm*	*36.2*	*34.9*	*3421*	*4025*	*59.0*	*59.0*
Piwinsky angle		22.50	18.95	0.00	0.00	26.79	23.46
Horizontal tune shift	%	0.21	0.33	5		0.28	0.28
Vertical tune shift	%	9.89	9.55	5		8.75	9.00
Luminosity	*10^{36} Hz/cm^2*	*1.02*		*0.012*		*0.80*	

Machine layout



Lattice Systems

- **Two Arcs**
  - Provide the necessary bending to close the ring.
  - Optimized to generate the design horizontal emittance.
  - Correct arc chromaticity and sextupole aberrations.
- **Interaction Region**
  - Provides the necessary focusing for required small beam size at IP
  - Corrects FF chromaticity and sextupole aberrations.
  - Provides the necessary optics conditions for Crab cavities.
- **Dogleg**
  - Provides crossing on the opposite to IR side of the ring.
- **LER Spin Rotator**
  - Includes solenoids in matched sections adjacent to the IR.
- **RF system**
  - Up to 24 HER and 12 LER cavities in the long straight section opposite to IP.

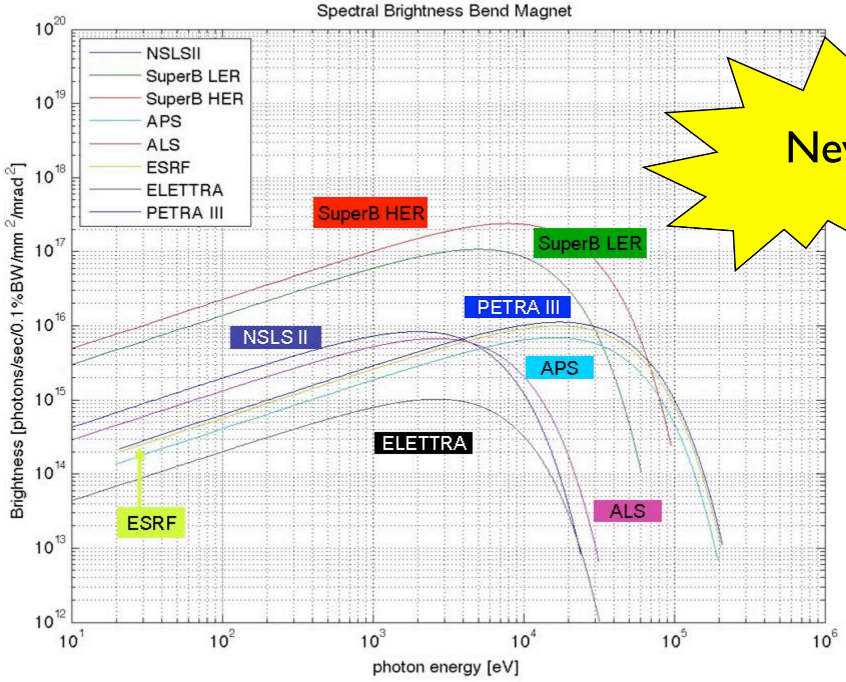
Length ~ 1258 m

LER = electrons

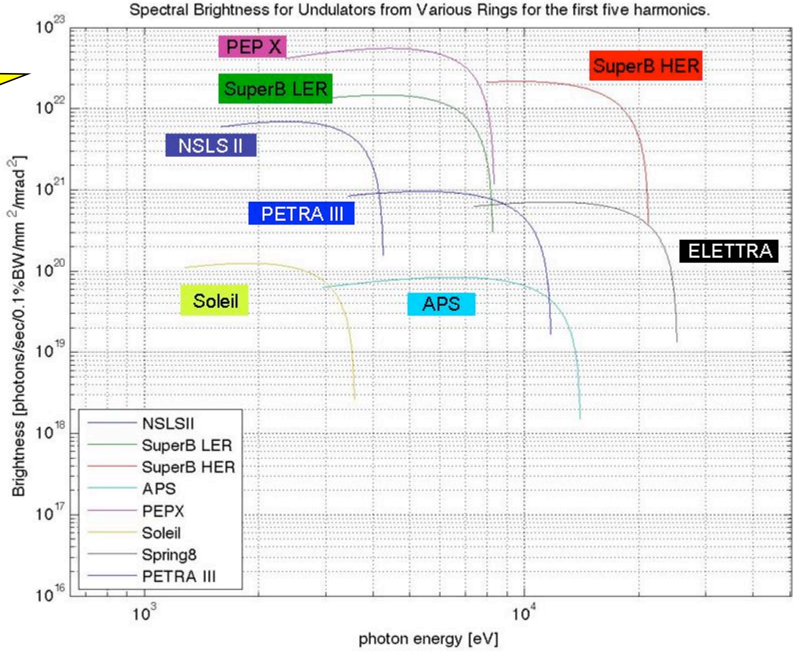
HER = positrons

Synchrotron light properties @ SuperB

- Comparison of brightness and flux from bending magnets and undulators for different energies dedicated SL sources & SuperB HER and LER
- Synchrotron light properties from dipoles are competitive
- Assumed undulators characteristics as NSLS-II
- Light properties from undulators still better than most LS, slightly worst than PEP-X (last generation project)


Spectral Brightness Bend Magnet

New


Spectral Brightness for Undulators from Various Rings for the first five harmonics.

Detector

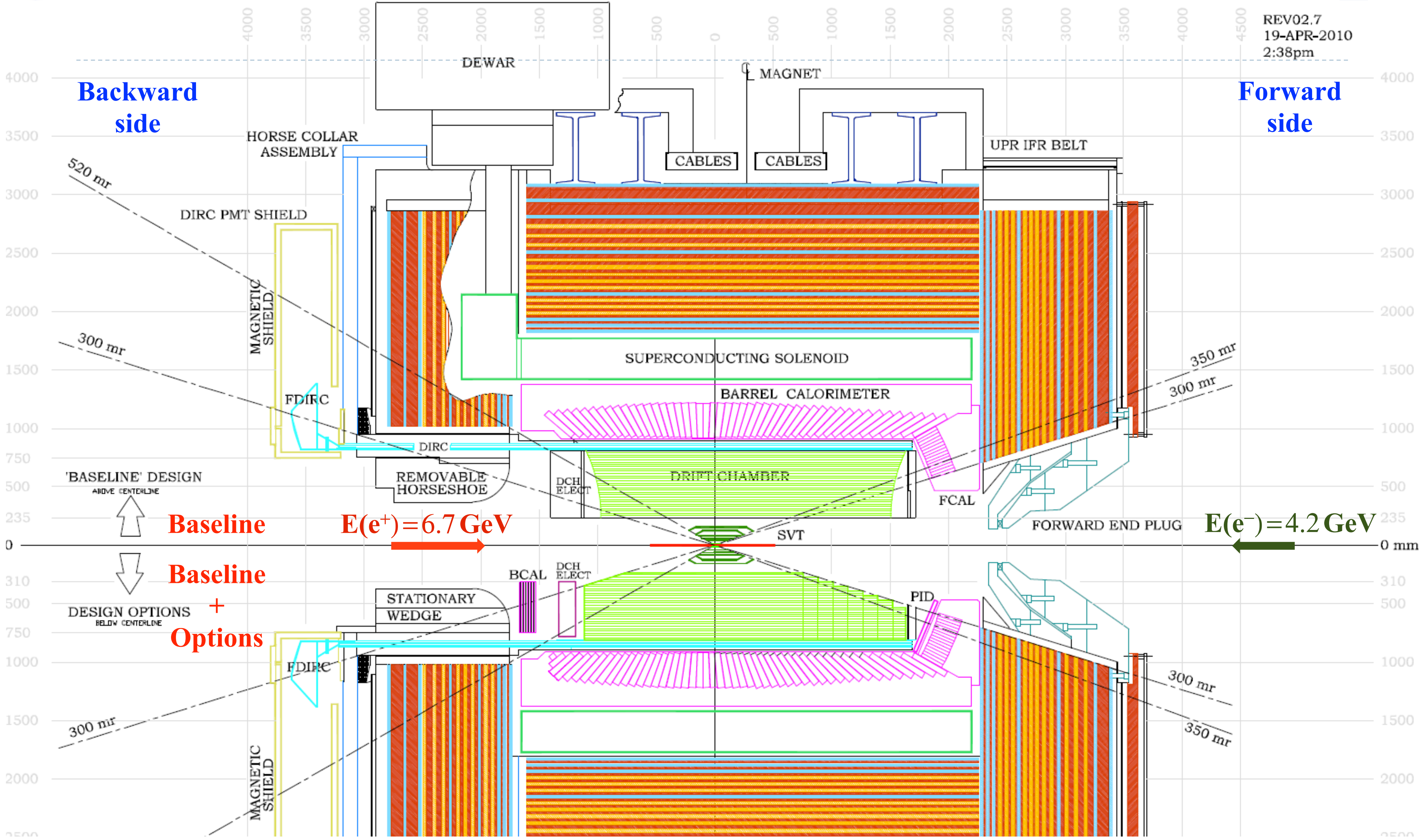
Detector Progress Report [arXiv:1007.4241]

from Blair Ratcliff talk at FPCP2011

Detector evolution: BaBar → SuperB

- SuperB based on “BaBar prototype”. It reuses:
  - Fused Silica bars and barboxes of the DIRC
  - DIRC and DCH support
  - Barrel EMC CsI(Tl) crystals and mechanical structure
  - Superconducting coil and flux return (some redesign)
- Require moderate design improvement and R&D to cope with new machine IR, high luminosity, smaller boost (4.2x6.7 GeV) and the high DAQ rates:
  - Small beam pipe technology
  - New 6 layer SVT with of a thin silicon sensor for the inner layer
  - New DCH with CF mechanical structure, modified gas and cell size
  - New photon camera for DIRC fused silica bars
  - New Forward calorimeter crystal (possibly LYSO). Backward veto option.
  - Minos-style extruded scintillators for instrumented flux return (muon and K_L detection)
  - Electronics and trigger - x100 real event rate
  - Computing - to handle massive data volume

SuperB Detector (with options)



Detector issues for design and R&D

Sys	Baseline	Issues (technical OR manpower; R&D)
MDI	Initial IR designed	Magnetic elements and radiation masks. Design of tungsten shields. Background simulations: discrepancy with Belle-II results for QED bkg ("pairs") about factor 15.
SVT	6-layer silicon detector. Layer0 striplets detector.	Technology for Layer0 upgrade: hybrid pixel or MAPS. Readout architecture. Mechanical design.
DCH	Stereo-Axial. He-based gas mixture.	CF mechanical structure Gas speed, cell size. Cluster counting option.
PID	Photon detection for quartz bars with focusing blocks	FBLOCK design: photon detection, mechanical structure.
EMC	Barrel: CsI(Tl) from BaBar. Forward: LYSO.	Readout electronics and trigger. Mechanical structure. Forward EMC technology: LYSO/ LYSO+CsI(Tl); Pure CsI. Backward EMC
IFR	Scintillators + fibers	SiPM radiation damage and location. Optimized configuration: absorber thickness definition and number of active layers.
ETD	Synchronous constant latency	Fast link radiation hardness. L1Trigger (jitter and rate). ROM design. Link to computing for HLT. Headroom.

Detector options

6 Layer SVT	LO Striplets @ ~1.5 cm if background is acceptable as default. MAPS Option. Retain 5 Layer outer detector.
SVT – DCH transition radius	~> than 20 cm determined by beam element cryostats to allow easy installation
Backward EMC	Inexpensive Veto device bringing 8-10% sensitivity improvements for B→τν. Proposed solution is based on lead/scintillator layers read out with WLS fibers and coupled to photosensors (MPPC, SiPM, …).
Forward PID	Physics gains about 5% in B→K$^{(*)}$νν. Somewhat larger gains for higher multiplicities Focusing TOF, with ~90 ps/hit resolution, is the appropriate technology.
Absorber in IFR	Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.

Geometry Selection Task Force

Decisions taken in 2011:

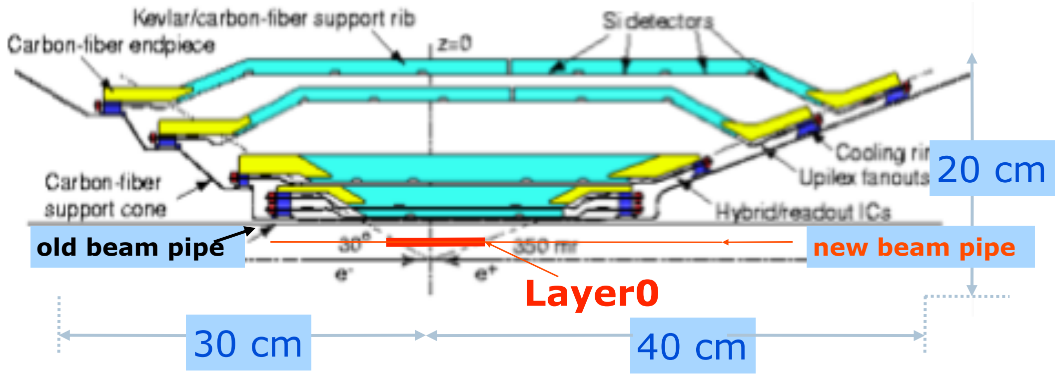
To be considered for baseline design.

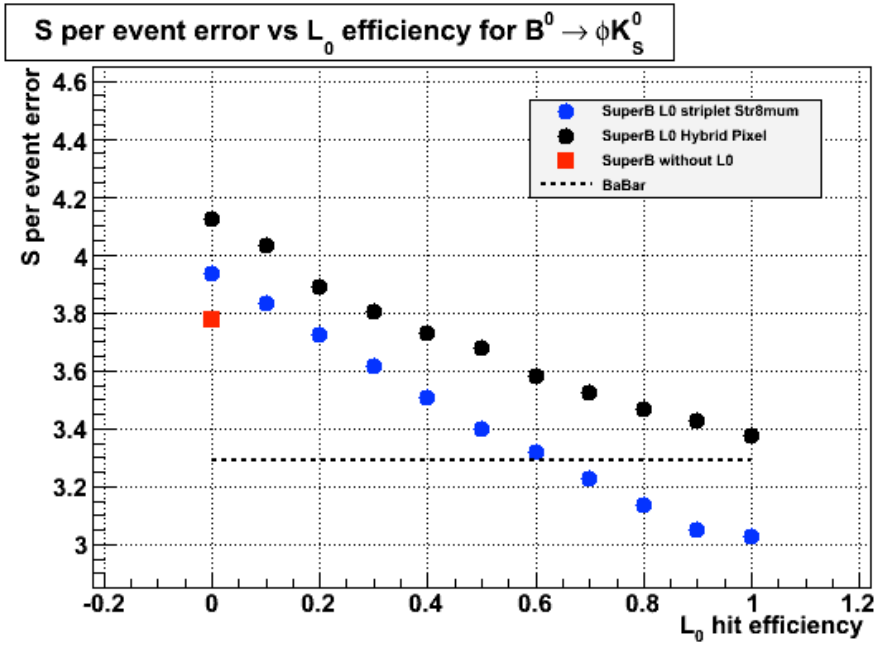
To be considered as an upgrade option.

The SuperB Silicon Vertex Tracker (SVT)

- SVT provide precise tracking and vertex reconstruction, crucial for time dependent measurements, and perform stand-alone tracking for low p_t particles.

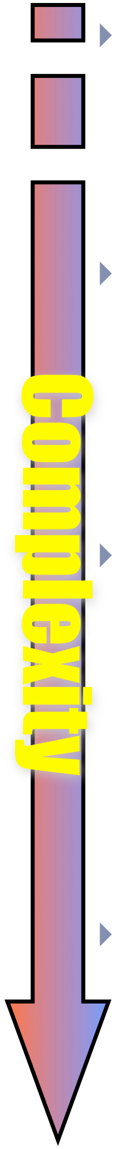
- Based on BaBar SVT: 5 layers silicon strip modules + Layer0 at small radius to improve vertex resolution and compensate the reduced SuperB boost w.r.t PEPII



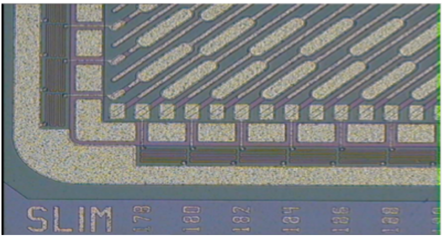


- Physics performance and back. levels set stringent requirements on Layer0:
  - R~1.5 cm, material budget < 1% X_0
  - hit resolution 10-15 μm in both coordinates
  - Track rate > 5MHz/cm^2 (with large cluster too!), Total Integrated Dose > 3MRad/yr

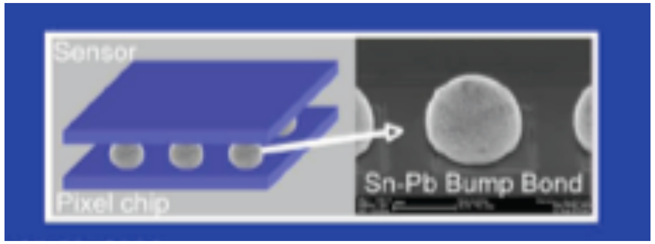
SuperB SVT Layer 0 technology options



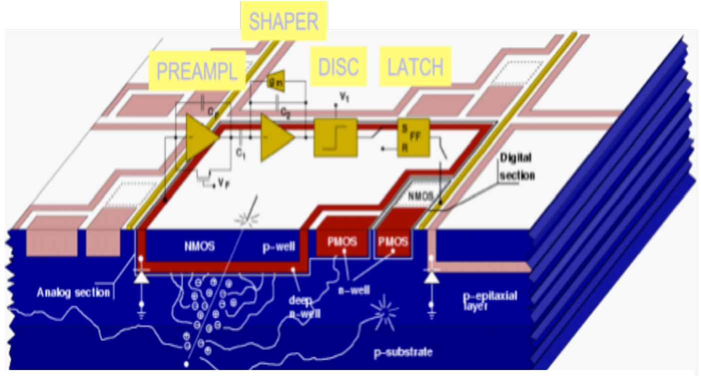
- **Striplets option:** **mature technology, not so robust against background occupancy.**
  - Marginal with back. track rate higher than ~ 5 MHz/cm^2
  - FE chip development & engineering of module design needed



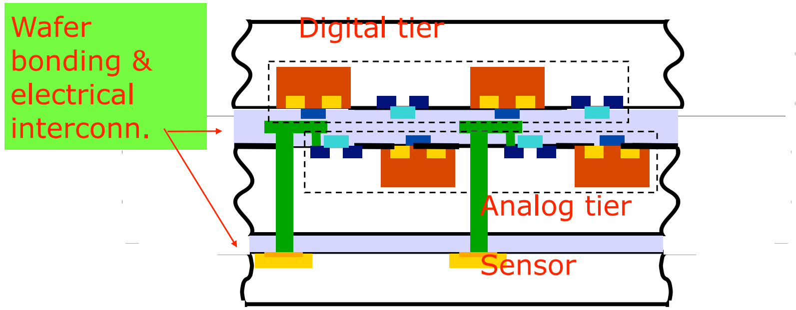
- **Hybrid Pixel option:** **viable, although marginal.**
  - Reduction of total material needed!
  - FE chip with 50x50 μm^2, pitch & fast readout (hit rate 100MHz/cm2) under development → FE prototype chip (4k pixel, ST 130 nm) successfully tested with pixel sensor matrix connected.



- **CMOS MAPS option:** **new & challenging technology.**
  - Sensor & readout in 50 μm thick chip!
  - Extensive R&D (SLIM5-Collaboration) on
    - Deep N-well devices 50x50μm^2 with in-pixel sparsification.
    - Fast readout architecture with target hit rate 100MHz/cm2 & 100 ns timestamping developed..
  - CMOS MAPS (4k pixels) successfully tested with beams.



- **Thin pixels with Vertical Integration:** **reduction of material and improved performance.**
  - Two options are being pursued (VIPIX-Collaboration)
    - DNW MAPS with 2 tiers
    - Hybrid Pixel: FE chip with 2 tiers + high resistivity sensor



SuperB SVT Layer 0 technology options

- **Striplets option: mature technology, not so robust against background occupancy.**
  - Marginal with back. track rate higher than ~ 5 MHz/cm^2
  - FE chip development & engineering of module design needed

Baseline solution

- **Hybrid Pixel option: viable, although marginal.**
  - Reduction of total material needed!
  - FE chip with 50x50 μm^2, pitch & fast readout (hit rate 100MHz/cm2) under development → FE prototype chip (4k pixel, ST 130 nm) successfully tested with pixel sensor matrix connected.
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- **Thin pixels with Vertical Integration: reduction of material and improved performance.**
  - Two options are being pursued (VIPIX-Collaboration)
    - DNW MAPS with 2 tiers
    - Hybrid Pixel: FE chip with 2 tiers + high resistivity sensor

Possible upgrades

Status of the Project

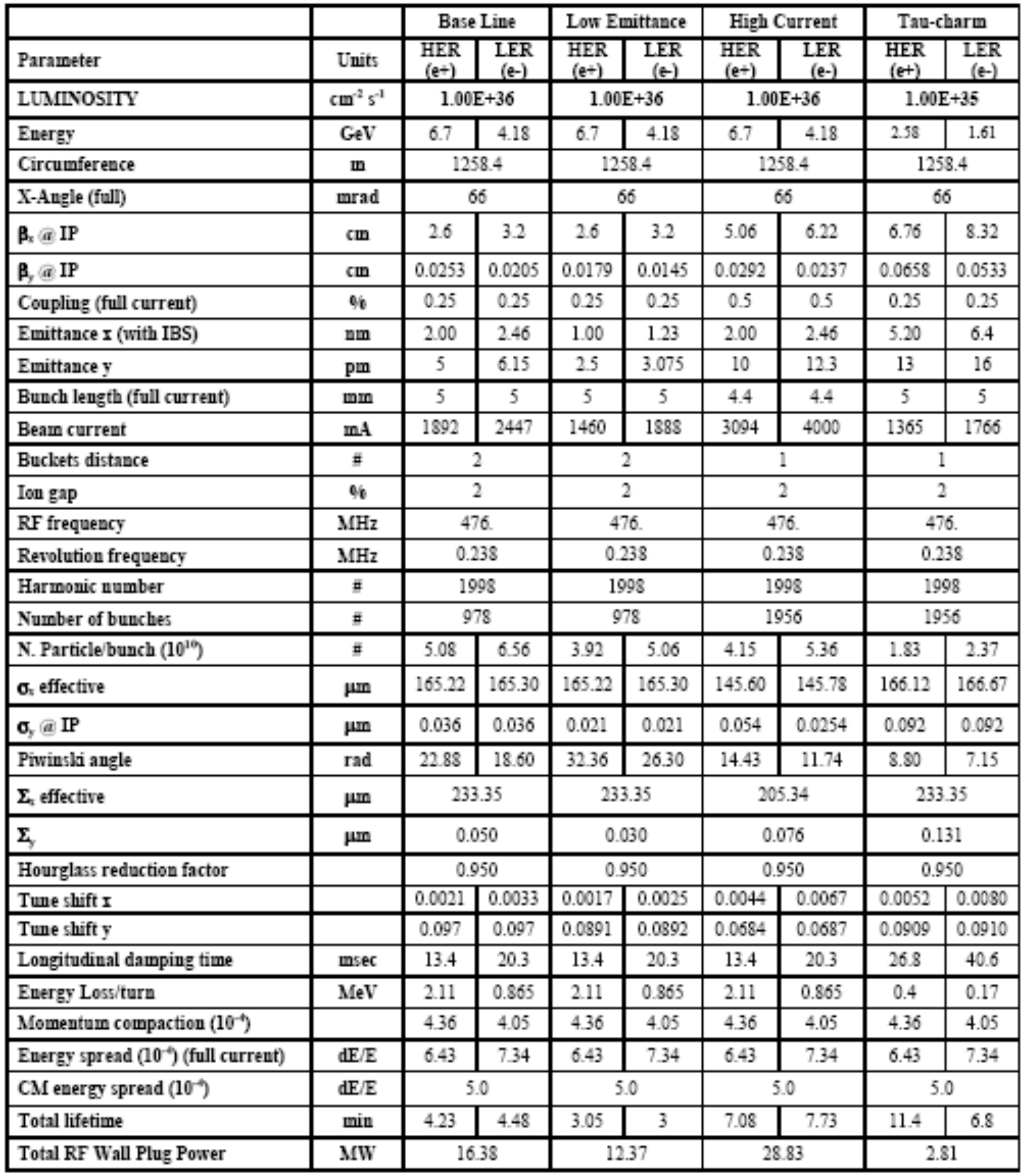
SuperB Status

- SuperB inserted in April 2010 among the Italian National Research Program(PNR) Flagship Projects
  - Cooperation of INFN and IIT (Italian Institute of Technology): HEP experiment and light source
- In december 2010 first funding of 19M€ as first part of a pluriennal funding plan
  - Internal to Ministry of Research
- In april 2011 approval of the PNR, including 250M€ for SuperB.
  - Press release at: http://www.istruzione.it/web/ministero/cs190411
  - PNR at: http://www.istruzione.it/web/ricerca/pnr
- In may 2011 decision on the site: in Rome close to LNF
  - at the University of Rome "Tor Vergata".

Funding and Management

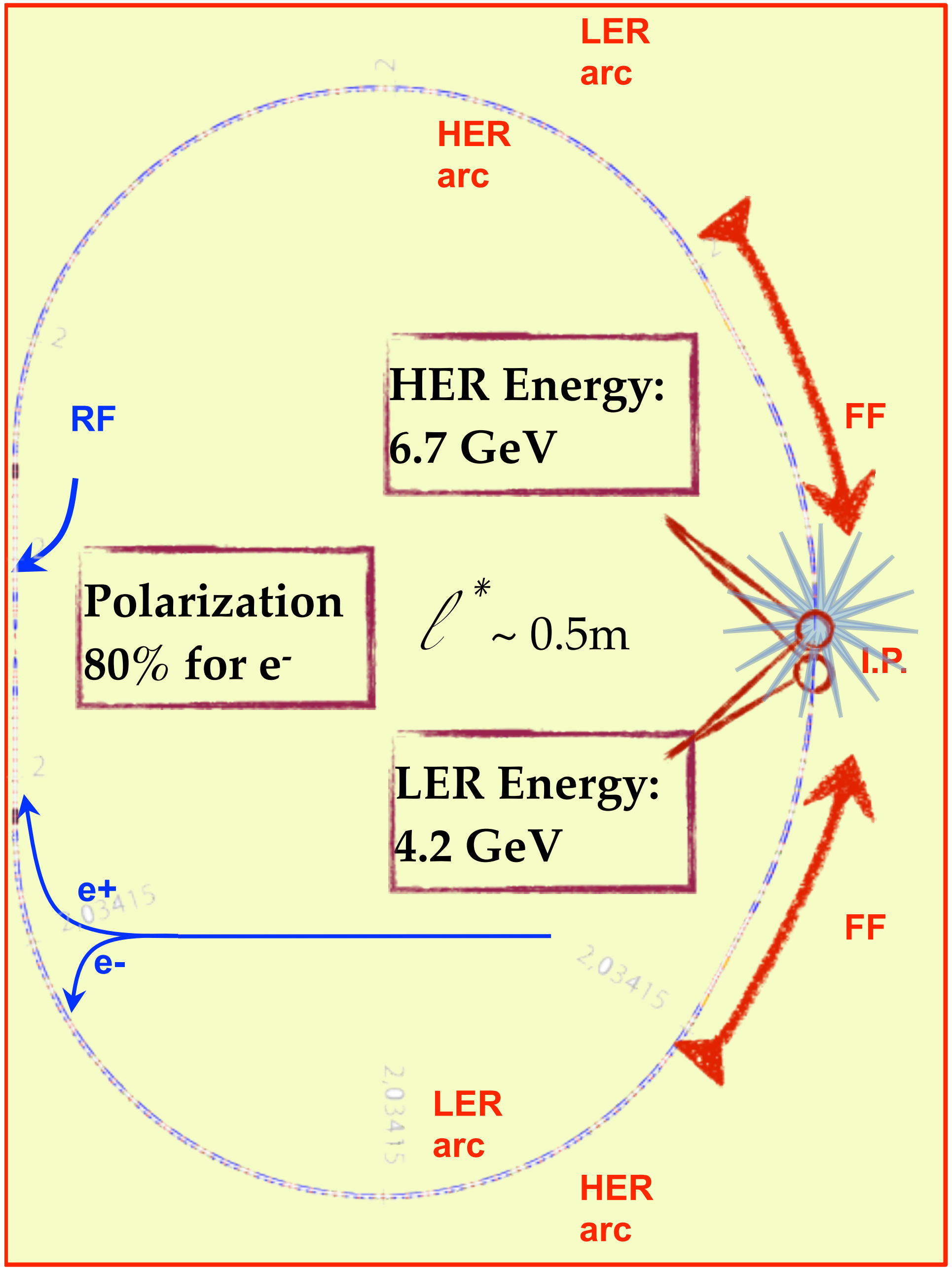
- MoUs for TDR work in place with Canada, France, UK, Russia and SLAC.
- Negotiation with partner countries for construction MoUs started
- Expect that
  - Important in-kind contribute by the re-use of parts of PEP-II and Babar, for a value of about 135M€
  - For the accelerator and infrastructure most funding will be Italian
  - For the detector only half of the needed funding will come from Italy (about 25M€)
- The project will be managed through a European Research Infrastructure Consortium (ERIC)

SuperB Parameters



		Base Line		Low Emittance		High Current		Tau-charm	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2} s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
Emittance x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
Emittance y	pm	5	6.15	2.5	3.075	10	12.3	13	16
Bunch length (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	MHz	476.		476.		476.		476.	
Revolution frequency	MHz	0.238		0.238		0.238		0.238	
Harmonic number	#	1998		1998		1998		1998	
Number of bunches	#	978		978		1956		1956	
N. Particle/bunch (10^{10})	#	5.08	6.56	3.92	5.06	4.15	5.36	1.83	2.37
σ_x effective	μm	165.22	165.30	165.22	165.30	145.60	145.78	166.12	166.67
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.0254	0.092	0.092
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
Σ_x effective	μm	233.35		233.35		205.34		233.35	
Σ_y	μm	0.050		0.030		0.076		0.131	
Hourglass reduction factor		0.950		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.097	0.097	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Longitudinal damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.17
Momentum compaction (10^{-4})		4.36	4.05	4.36	4.05	4.36	4.05	4.36	4.05
Energy spread (10^{-4}) (full current)	dE/E	6.43	7.34	6.43	7.34	6.43	7.34	6.43	7.34
CM energy spread (10^{-4})	dE/E	5.0		5.0		5.0		5.0	
Total lifetime	min	4.23	4.48	3.05	3	7.08	7.73	11.4	6.8
Total RF Wall Plug Power	MW	16.38		12.37		28.83		2.81	

SUPER*B* COLLIDER PROGRESS REPORT



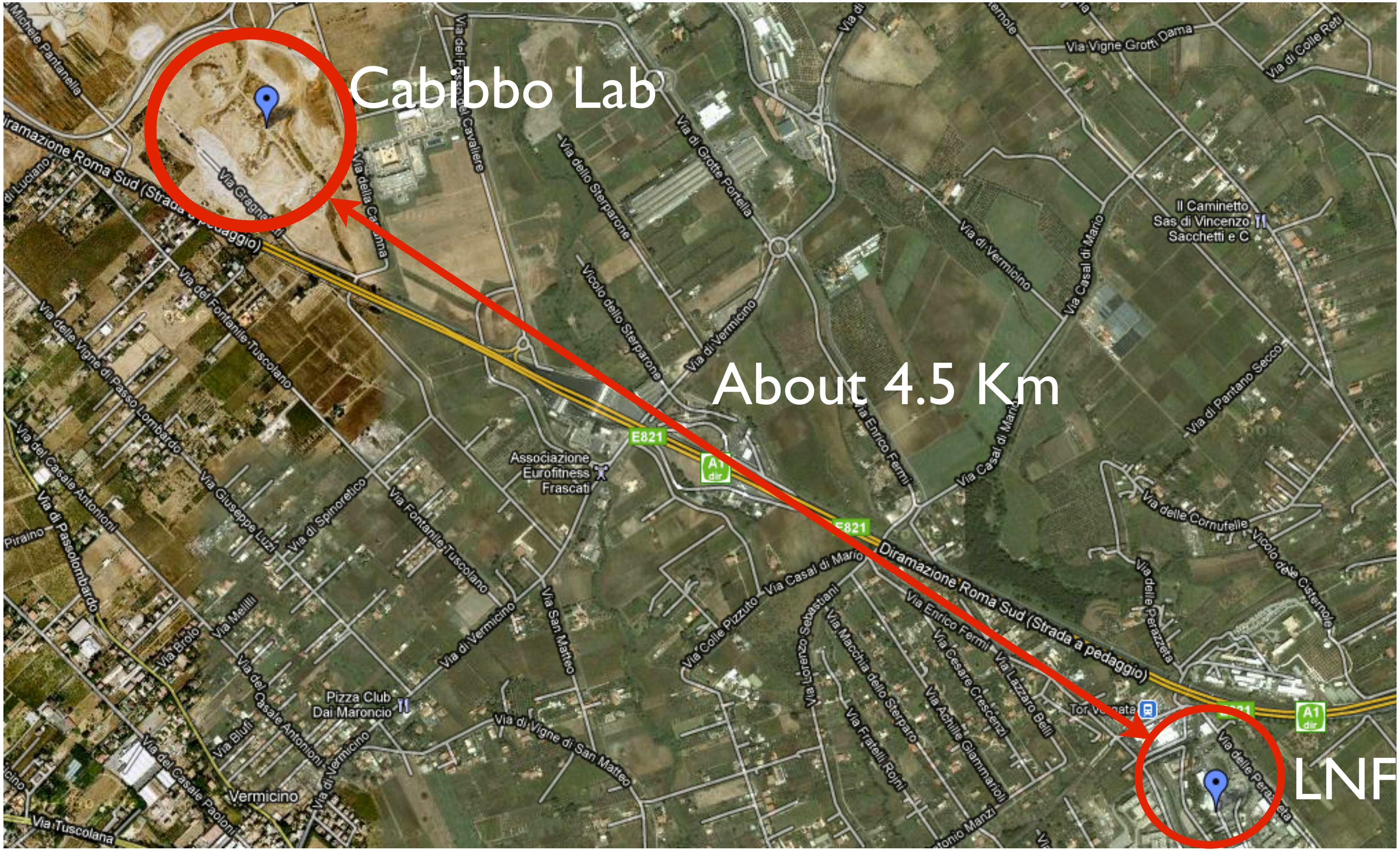
HER Energy:
6.7 GeV

Polarization
80% for e$^-$

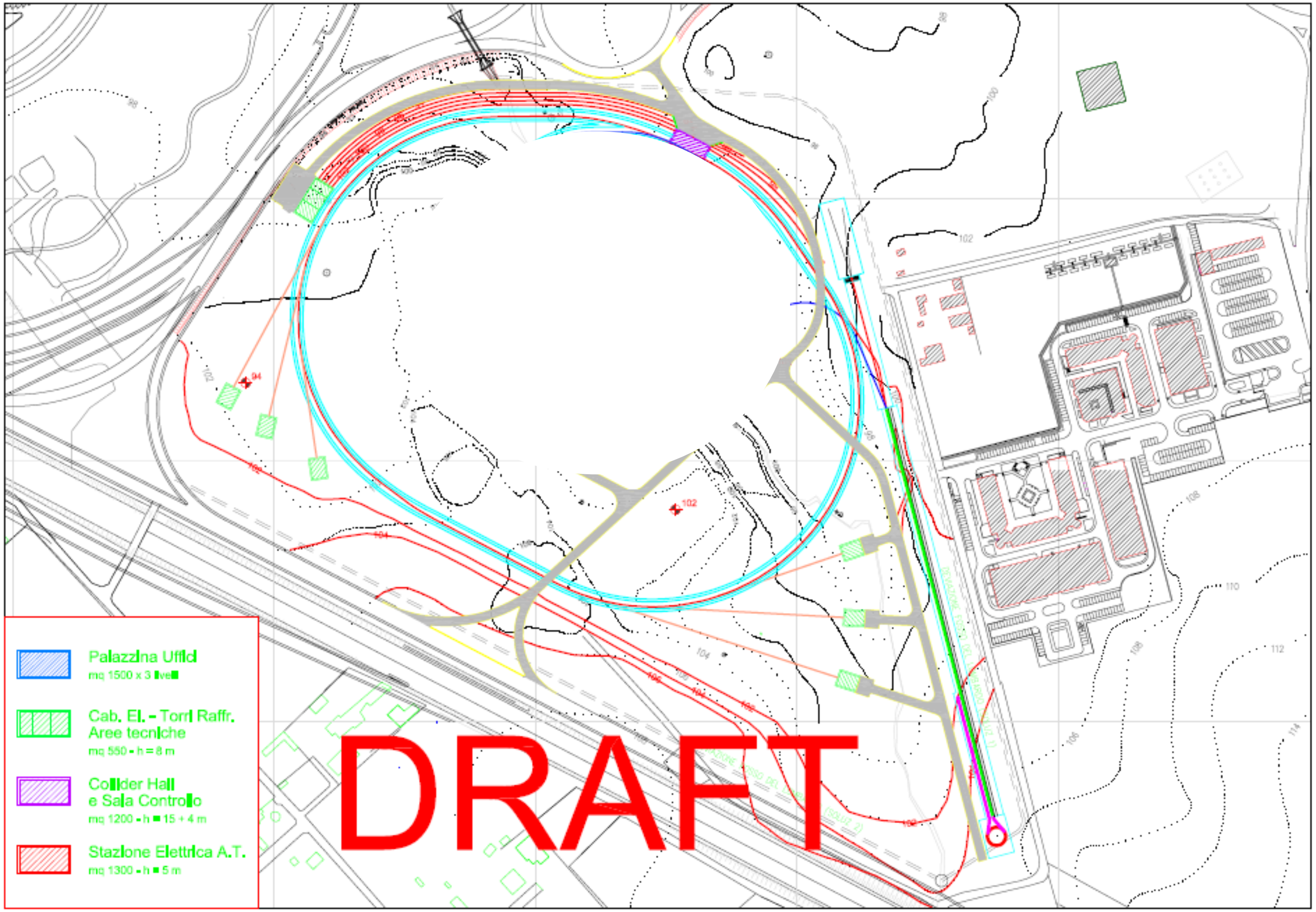
$\ell^* \sim 0.5\text{m}$

LER Energy:
4.2 GeV

The SuperB Factory will be built at the University of Rome “Tor Vergata”



Possible layout



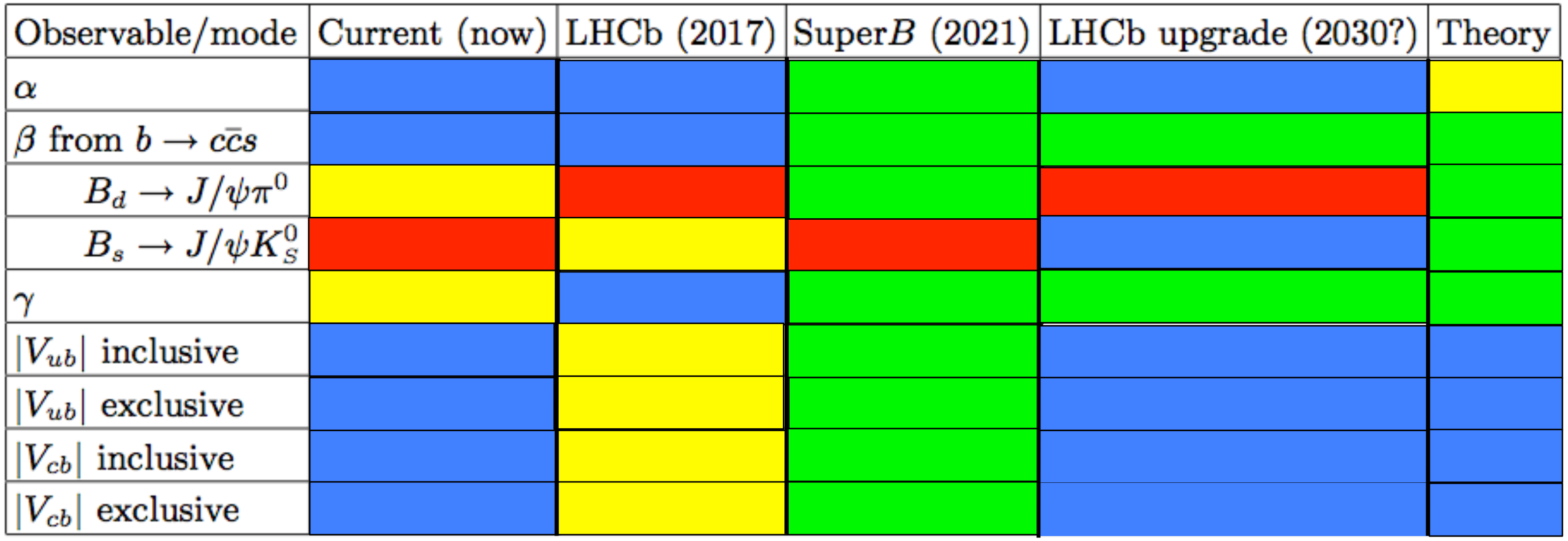
Next steps and timeline

- Complete the Technical Design Report
  - End of 2011/Mid 2012
- Prepare the transition from TDR Phase to Construction
  - Collaboration started formally forming in Elba meeting, May 2011
- Start recruitment for the construction: mainly Accelerator Physicists and Engineers
- Completion of construction foreseen end of 2015
  - First collisions mid 2016

Backup slides

Golden Measurements: CKM

- Comparison of relative benefits of SuperB (75 ab^{-1}) vs. existing measurements and LHCb (5 fb^{-1}) and the LHCb upgrade (50 fb^{-1}).



Observable/mode	Current (now)	LHCb (2017)	Super$B$ (2021)	LHCb upgrade (2030?)	Theory
α	🟦	🟦	🟩	🟦	🟨
β from $b \to c\bar{c}s$	🟦	🟦	🟩	🟩	🟩
$B_d \to J/\psi\pi^0$	🟨	🟥	🟩	🟥	🟩
$B_s \to J/\psi K_S^0$	🟥	🟨	🟥	🟦	🟩
γ	🟨	🟦	🟩	🟩	🟩
$\lvert V_{ub}\rvert$ inclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{ub}\rvert$ exclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{cb}\rvert$ inclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{cb}\rvert$ exclusive	🟦	🟨	🟩	🟦	🟦

LHCb can only use ρπ

β theory error B_d

β theory error B_s

Need an e^+e^- environment to do a precision measurement using semi-leptonic B decays.

Experiment: 🟥 No Result 🟨 Moderate Precision 🟦 Precise 🟩 Very Precise

Theory: 🟨 Moderately clean 🟦 Clean Need lattice 🟩 Clean

SuperB is designed with 80% longitudinal polarization for e^-

- Polarization allows:
  - Precision Measurement in ElectroWeak sector
  - EDM and g-2 in τ .
  - BKG reduction for LFV in τ .

- Polarized beams provide measurements of $\sin^2\theta_W(\mathrm{eff})$ with comparable precision to SLD but at much lower energies.
- Polarization allows for NC Z-bb coupling measurement with better precision and different systematic w.r.t. LEP measurement of A_{FB}^b .

Differential Cross sections in $e^+e^- \rightarrow f^+f^-$

Diagrams	σ (nb)	A_{FB}	A_{LR} (Pol = 100%)
$\lvert Z+\gamma \rvert^2$	1.01	0.0028	-0.00051
$\lvert Z \rvert^2+\lvert \gamma \rvert^2$ No interference	1.01	0.0088	-0.00002

Interference term is $\sim g_A^e g_V^f$

Asymmetries at Z-pole for measured σ

$$
\begin{aligned}
A_{FB} &= \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \\
A_{LR} &= \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \frac{1}{\langle |\mathcal{P}_e| \rangle} \\
A_{LRFB} &= \frac{(\sigma_F - \sigma_B)_L - (\sigma_F - \sigma_B)_R}{(\sigma_F + \sigma_B)_L + (\sigma_F + \sigma_B)_R} \frac{1}{\langle |\mathcal{P}_e| \rangle} .
\end{aligned}
$$

at LEP: 15M hadronic Z decays, unpolarized

at SLC: 0.5M hadronic Z decays, polarized e^-

at SuperB: Z-term ~30M, polarized e^-

Expected stat. error: $\sigma(A_{LR}) = 4.6 \times 10^{-6}$

relative stat. error 1.1% (80% polarization).

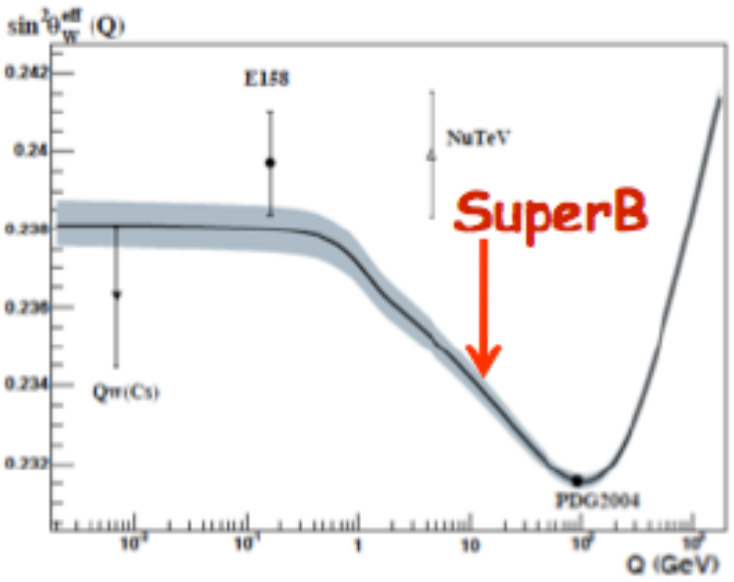
Systematics <0.5% on polarization needed

$$A_{LR} \propto g_V^f \propto (T_3^f - 2Q_f \sin^2\theta_{eff}^f)$$

$\sigma(\sin^2\theta_{eff}) = 1.8 \times 10^{-4}$

cfr SLC $\sigma(\sin^2\theta_{eff}) = 2.6 \times 10^{-4}$

Electroweak measurement @ SuperB

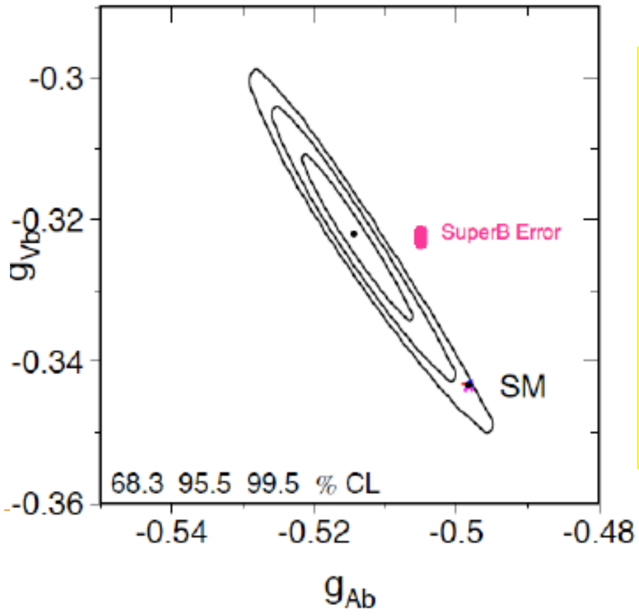


$$A_{LR} = \frac{\sigma(P)-\sigma(-P)}{\sigma(P)+\sigma(-P)} = \frac{16}{\sqrt{2}}\left(\frac{G_F q^2}{4\pi\alpha}\right)\left(\frac{g_A^e\, g_V^b}{Q_b}\right) P$$

- Measurable for all $B^0\,\bar{B}^0$ and $B^+\,B^-$ final states, both resonant and continuum.
- **All** QCD corrections included in the **single** form factor that cancels in the asymmetry.
- Very clean measurement, no **large** theoretical corrections (in progress...)

⇒ Excellent opportunity to measure g_V & $\sin^2\theta_W$ at SuperB with polarized beams!!

0.5% polarization syst.
0.3% stat. error
→ 0.0021



The L-R luminosity asymmetry has to be very well controlled.Possibly done using monitoring
using Bhabhas
Polarization should be measured better than . 05%
luminosity dependent polarization affects systematic uncertainties

Is this measurement also possible with Charm?

1. @Υ(4S) . But hadronization correction.
2. Operate at a ccbar vector resonance above open charm threshold Ψ(3770), use the same analysis method as for b.

Polarization at low energies with high luminosity is needed

That is included in the SuperB design

Luminosity

$$\mathcal{L} = f_c \int d^3\mathbf{x}\, dt\, \rho_1(\mathbf{x},t)\cdot\rho_2(\mathbf{x},t) v_{\text{rel.}} = 10^{36}\text{cm}^{-2}\text{s}^{-1} = 1\text{kHz/nb}$$

- f_c is the bunch collision frequency
- $\rho_i(\mathbf{x},t)$ is the particle spatial density at time t and point $\mathbf{x}$ of the beam i
- $v_{\text{rel.}}$ is the relative speed of the two bunches

Under the assumption of gaussian rigid bunches each one having N_i particles:

$$\rho_i(\mathbf{x},t) = \rho_i(\mathbf{x} \mp \beta\hat{\mathbf{z}}t) = N_i \mathcal{G}(\mathbf{x}\,;\mu = \pm\beta\hat{\mathbf{z}}\mathbf{t}\,;\sigma_i)$$

The density superposition integral can be evaluated algebraically. For head on collisions:

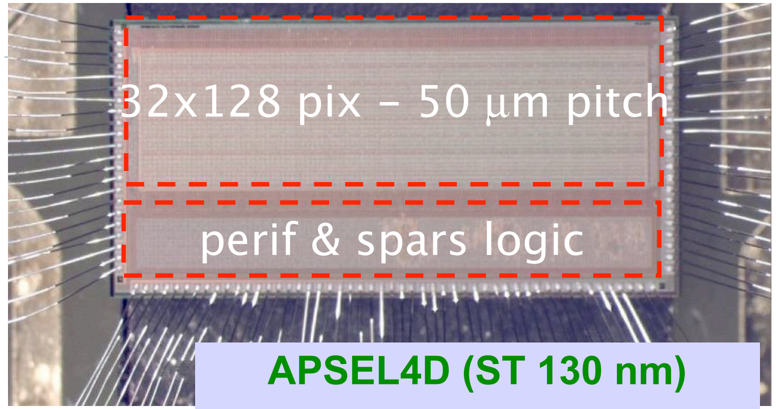
$$\mathcal{L} = f_c \frac{N_1 N_2}{2\pi\,\Sigma_x\,\Sigma_y}$$

$$\Sigma_{x,y} = \sigma_{1\,x,y} \oplus \sigma_{2\,x,y};$$

N.B.: in this assumption σ is constant (which is not the case in real life)

Recent results on pixel R&D for Layer0

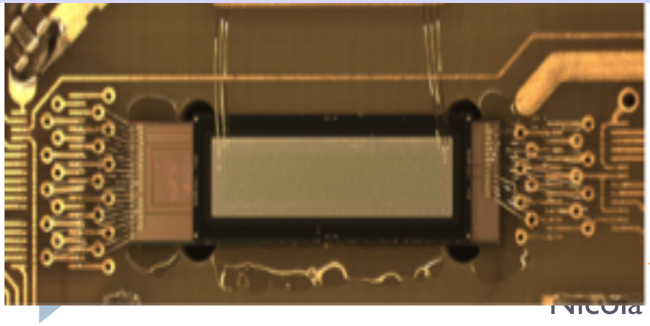
- CMOS DNW MAPS with data push sparsified readout + timestamp tested with beams:
  - resolution of 14 μm (digital output)
  - hit efficiency up to 92 %



APSEL4D (ST 130 nm)
S/N ~ 20, P ~ 30 μW/ch

- HYBRID PIXEL: front-end chip with 50x50 μm pitch & fast readout architecture tested with sensor matrix
  - Optimized for hit rate 100MHz/cm2 on full chip size (~1.3 cm2)
  - VHDL simulation: Effi > 98% @ 60 MHz RDclock
  - Timestamp granularity 0.2-5.0 μs

FE chip (ST 130 nm, 32x128 pix)
bump-bonded to sensor matrix
S/N ~ 200, P ~ 2.5 μW/ch

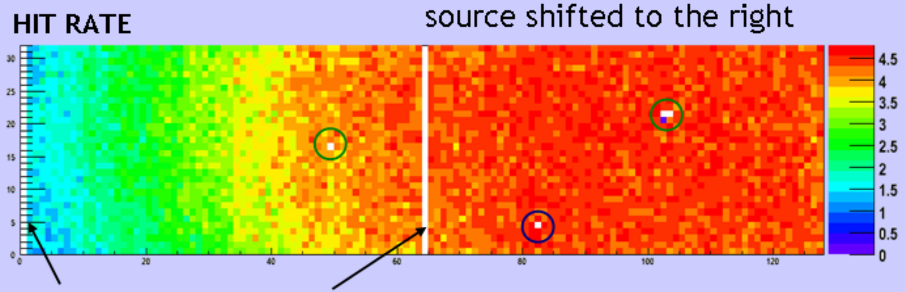


Response to a Sr90 source (e-) threshold@1/4 MIP (60σ noise)

→ good quality of the interconnection @ 50x50 μm^2 pitch & working sensor!!

pixels not working ○

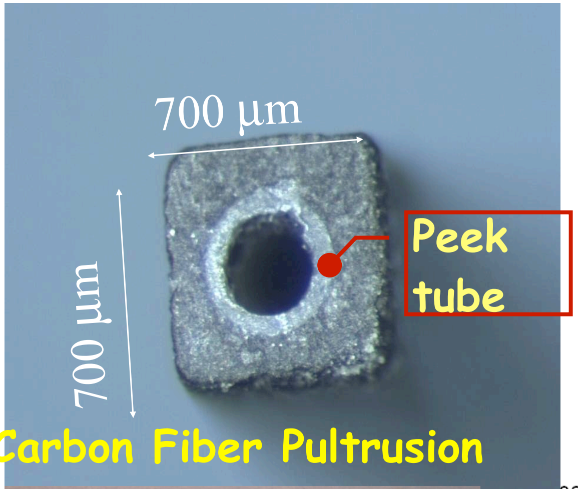
pixel not connected to the sensor ○



due to known problem on the FE chip

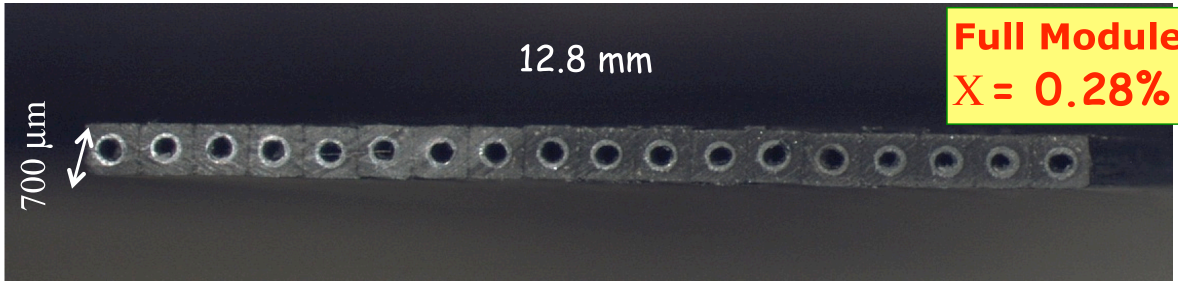
Light pixel module support & cooling

- Light support with integrated cooling needed for pixel module: P~2W/cm^2
- Carbon Fiber support with microchannel for coolant fluid developed in Pisa:
  - Total support/cooling material = 0.28 % X_0 full module, 0.15% X_0 net module
- Thermo-hydraulic measurements in TFD Lab: results within specs

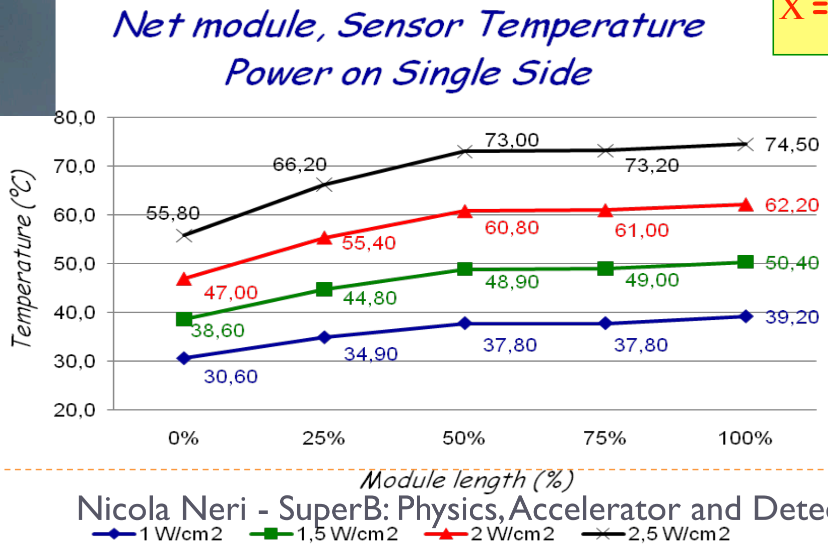


Carbon Fiber Pultrusion

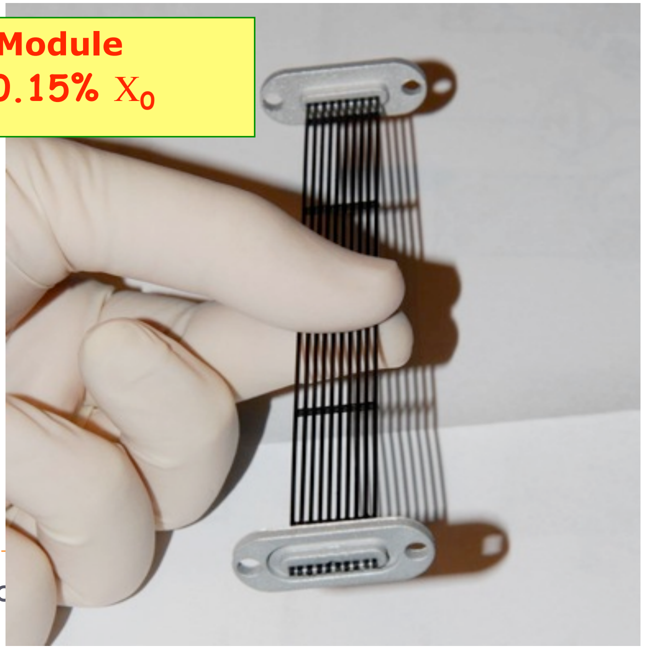
Full module supports with microchannels glued toghether



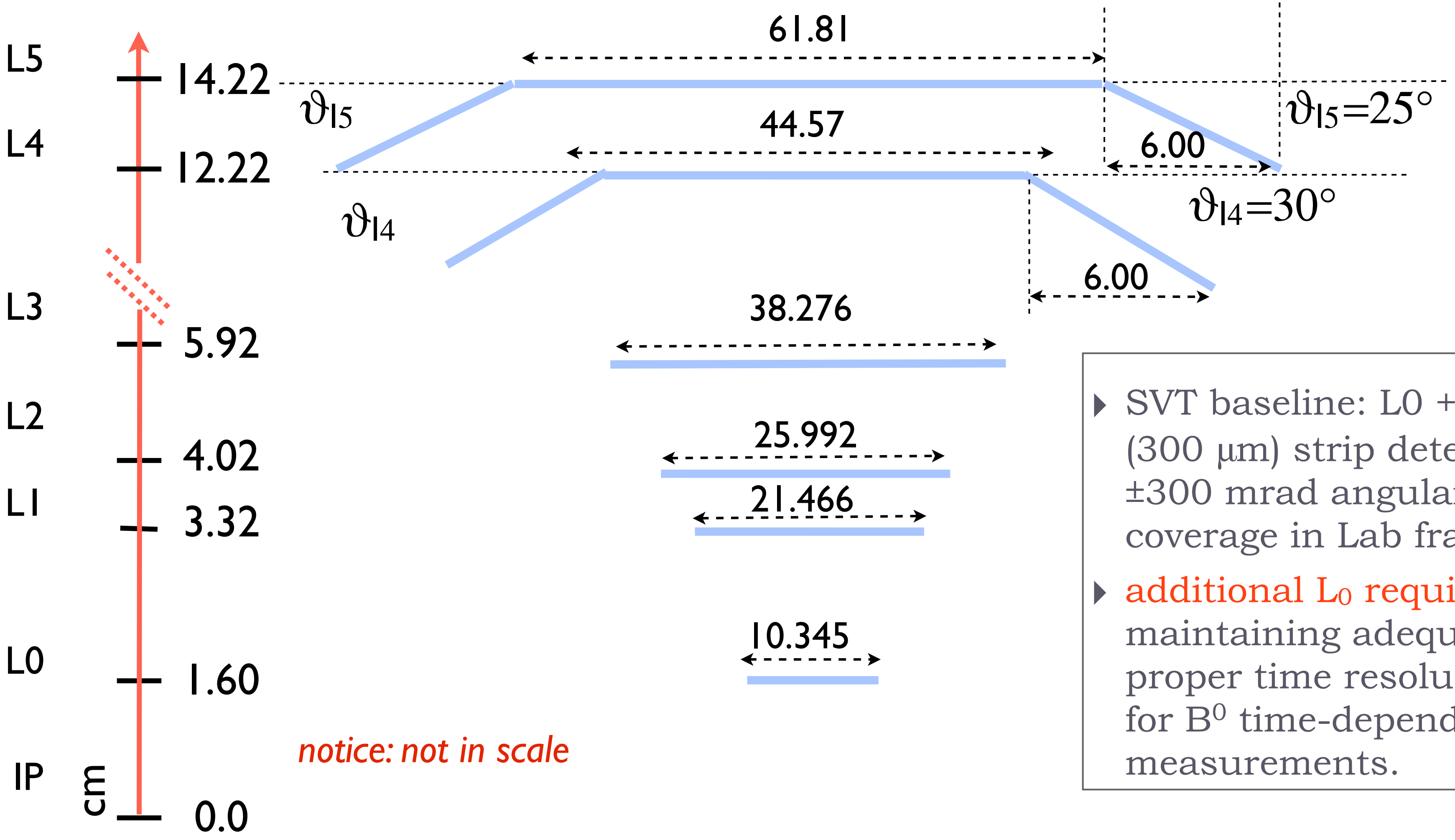
Full Module
X = 0.28% X_0



Net Module
X = 0.15% X_0



The SVT layout



notice: not in scale

- SVT baseline: L0 + L1-L5 (300 μm) strip detectors, ±300 mrad angular coverage in Lab frame;
- additional L_0 required for maintaining adequate proper time resolution for B^0 time-dependent measurements.

Symmetric coverage down to 300 mrad FW and BW

Readout chip for strip modules

- Design of new readout chip(s) for striplets/strip detector is needed since existent chips do not match all the requirements:
  - Analog info is needed for: dE/dx (with high dynamic range required for low p_T tracks >10 MIPs), position resolution, hit time resolution.
  - Very high rates in inner layers due to background:
    - L1-L3: 700-300 KHz/strip up to 2 MHz/striplet in Layer0 (safety factor x5 included)
    - Short shaping time needed to minimize inefficiency due to overlapping hits. L0: 25 ns, L1-L3: 50-100ns.
  - Long shaping time needed for long module in L4-L5 to reduce noise contribution: 0.5 – 1 μs give reasonable S/N with acceptable inefficiency (rates 25-50 KHz/strip)
- Probably need to develop 2 different chips: one for L0/L1-L2-L3 and one for L4-L5.

Readout chip general requirements

- Trigger
  - frequency: 150 kHz (1.5 Safety Factor) <-- several implication in readout chip design (number of output lines, fast ouput clock).
  - jitter: 100 ns (the goal is to go down to 30 ns)
  - latency: 10 µs (1.7 Safety Factor; Level 1 design is 6 µs)
- DAQ window: 100-300 ns
- Time stamping: 30 MHz (5-40 MHz)
- Chip readout clock: 50 MHz

- Within the SuperB – SVT group we started to evaluate if the readout architecture developed for Layer0 pixels could be adapted for strip readout, but contribution in this area is very welcome!

Next R&D on pixel for Layer0

- Improvements in MAPS performance being pursued with:
  - **INMAPS CMOS process** with quadruple well + high resistivity substrate: higher charge collection efficiency & rad hardness → **design of first prototypes ongoing**
  - **3D MAPS** with 2 CMOS tiers interconnected:: higher cce efficiency, more complex in-pixel logic, reduce cross-talk → **first chips under test, testbeam in Sep. 2011**

- Improved readout architecture developed for pixel with Vertical Integration
  - TimeStamp is latched in each pixel when fired & readout is time ordered.
    - Timestamp granularity 100 ns
  - Readout could work in data push mode & triggered mode
    - VHDL results for 100MHz/cm2 hit rate: Effi_triggered=98.2%, Effi_data_push=99.9%
  - **New submission of large 3D MAPS and FE chip for Hybrid pixel (2-tiers), with the improved readout architecture, in preparation for mid 2011**

- Vertical interconnection of FE chip (2-tiers) with high resistivity pixel matrix (best technology under investigation) will give the best performance: high S/N and radiation hardness, low power and material budget