Super*B*: An Overview

U. Wienands, SLAC

Outline

- Introduction: Beyond PEP-II/BaBar
- Requirements and Parameters
- Machine Optics & layout
- Polarized e–
- Site Layout
- Luminosity Projections
- Conclusion

Introduction

- PEP-II: 1.2 10^{34}/cm^2/s, about 0.5 ab^{-1}
- PEP-II/BaBar together with KEKB-Belle:
  - Definitive measurement of sin(2ß)
  - Exceeded their physics goals
  - Proved that multi-ampere beam currents can be handled
    - up to 3.2 A @ 3.1 GeV; 2 A @ 9 GeV in PEP-II
  - Proved that background is manageable
    - s.r. background as well as lost-particle background
  - Proved that high overall efficiency can be maintained
    - PEP-II/BaBar reached >85% up time
    - KEKB-Belle likely to be just as well

M. Giorgi

SuperB Physics Goals

- Increase by O(10) the precision of BaBar &Belle (*)
- Challenge CKM at the level of 1% (*)
- τ LFV sensitivity improvement by a factor between 10 and 100.
- Explore T-violation in τ .
- Search for magnetic structure of τ .
- Explore CPV in Charm.
- Great new Spectroscopy exploration.

Beam Polarization option and possibility to run at charm threshold

This can be achieved with 75 ab^{-1} at Y(4s) (10.58 GeV), corresponding to a peak luminosity of $10^{36}/cm^2/s$ plus a few months at the charm threshold with peak luminosity of 10^{35} cm^2 s^{-1}.

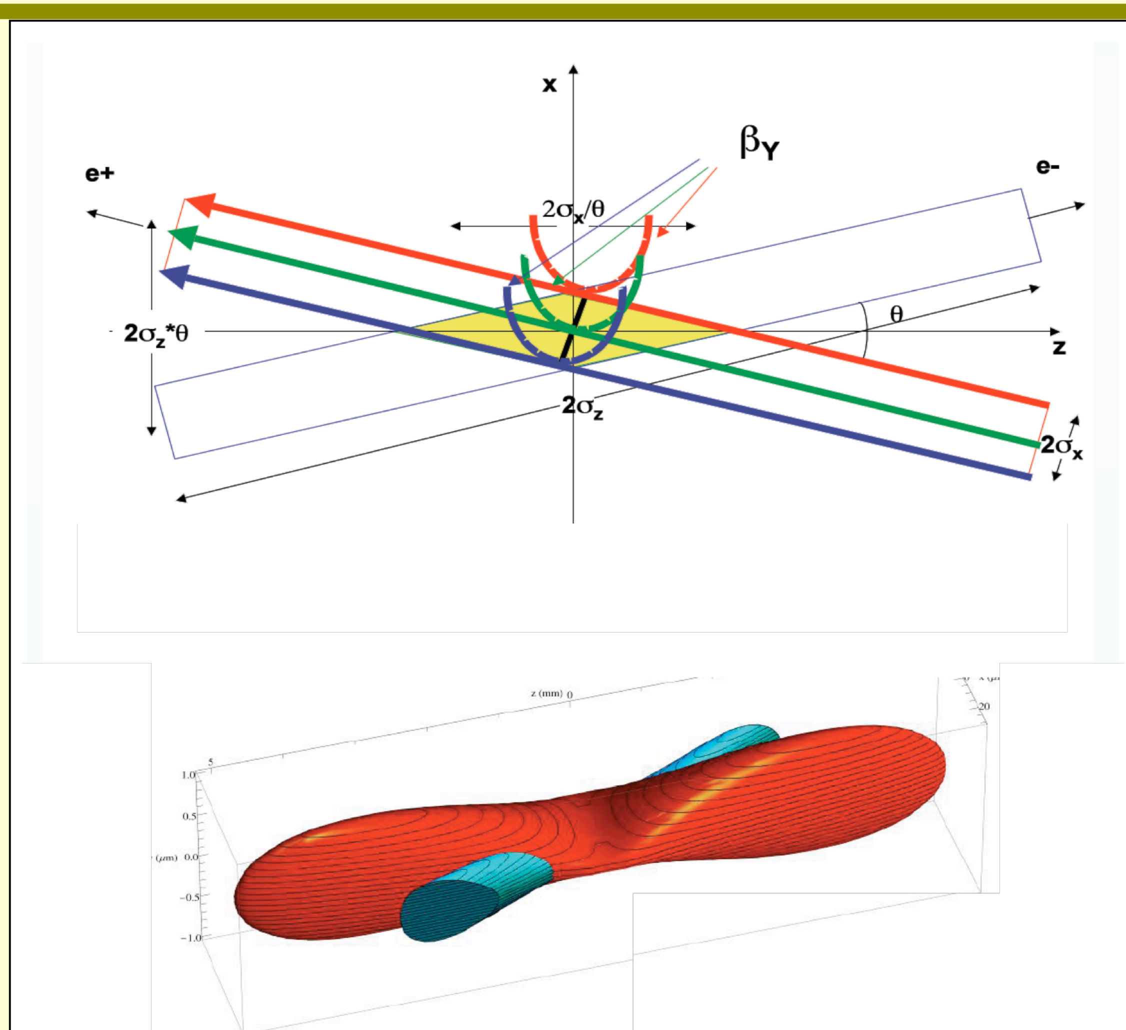
Beyond Present-day B-Factories

- Increase beam current
  - for 10^{36}, would require O(10 A)
  - tough, expensive
- Reduce beam size
  - know how to build low-emittance machines (lightsources)
  - need to focus tighter (lower β^*)
    - but short bunches become an issue
- Crossing angle
  - foreshortens IP => can use longer bunches
  - avoid excessive beam-beam on tails => crab waist

Crab Waist

Raimondi

Graphics by
E. Paoloni



Crab Waist

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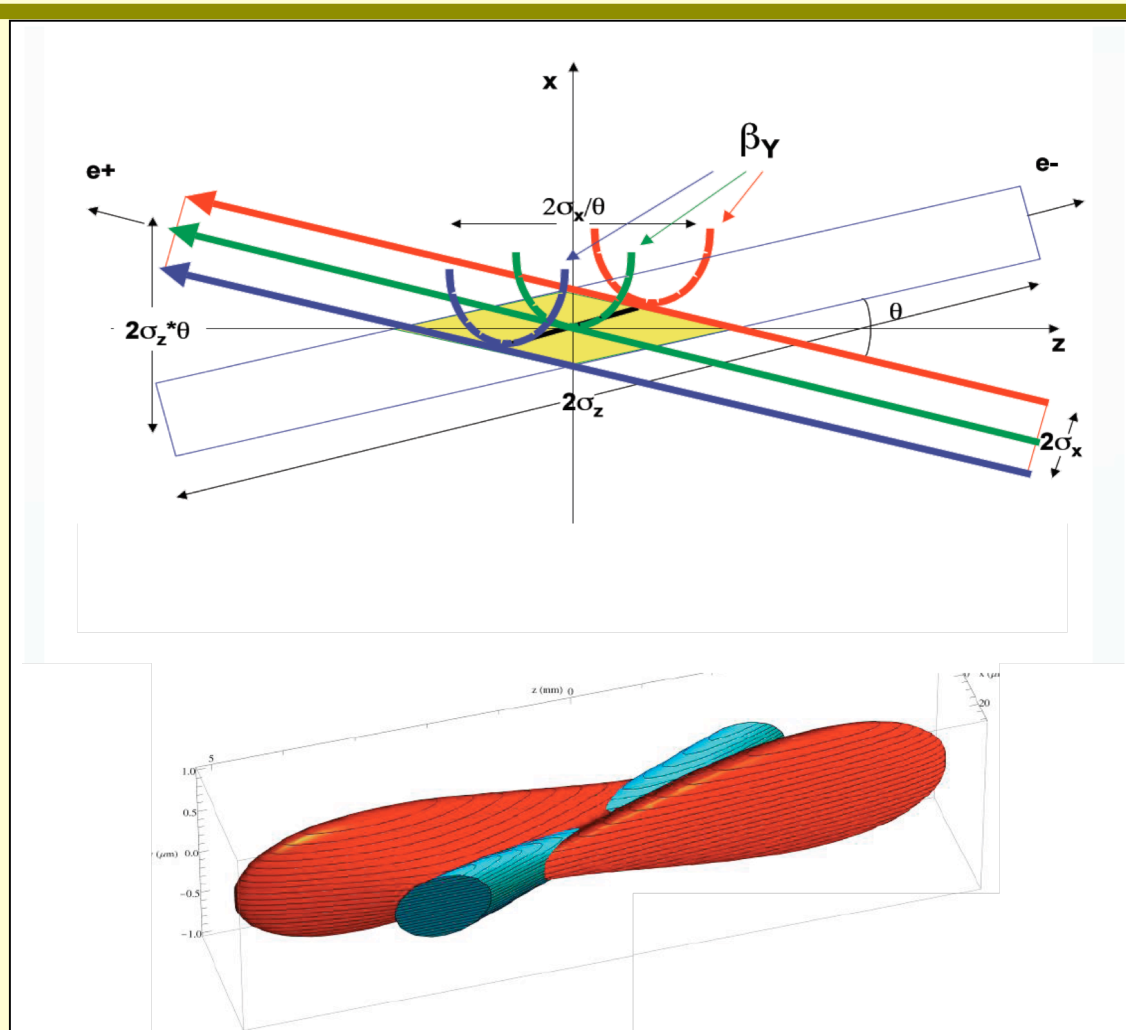
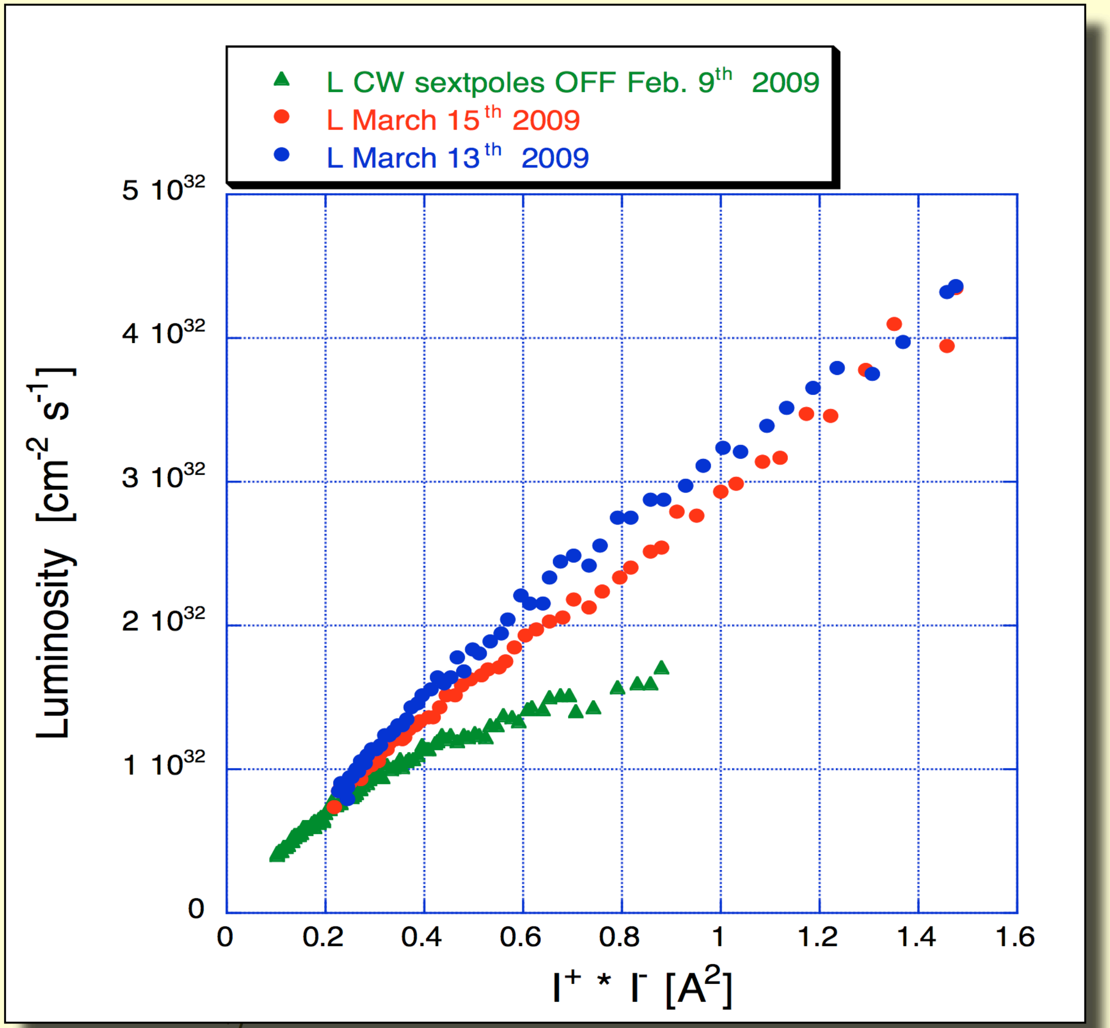


Crab-Waist operation at DAΦNE

Milardi et al.



PARAMETER REQUIREMENTS FROM PHYSICS

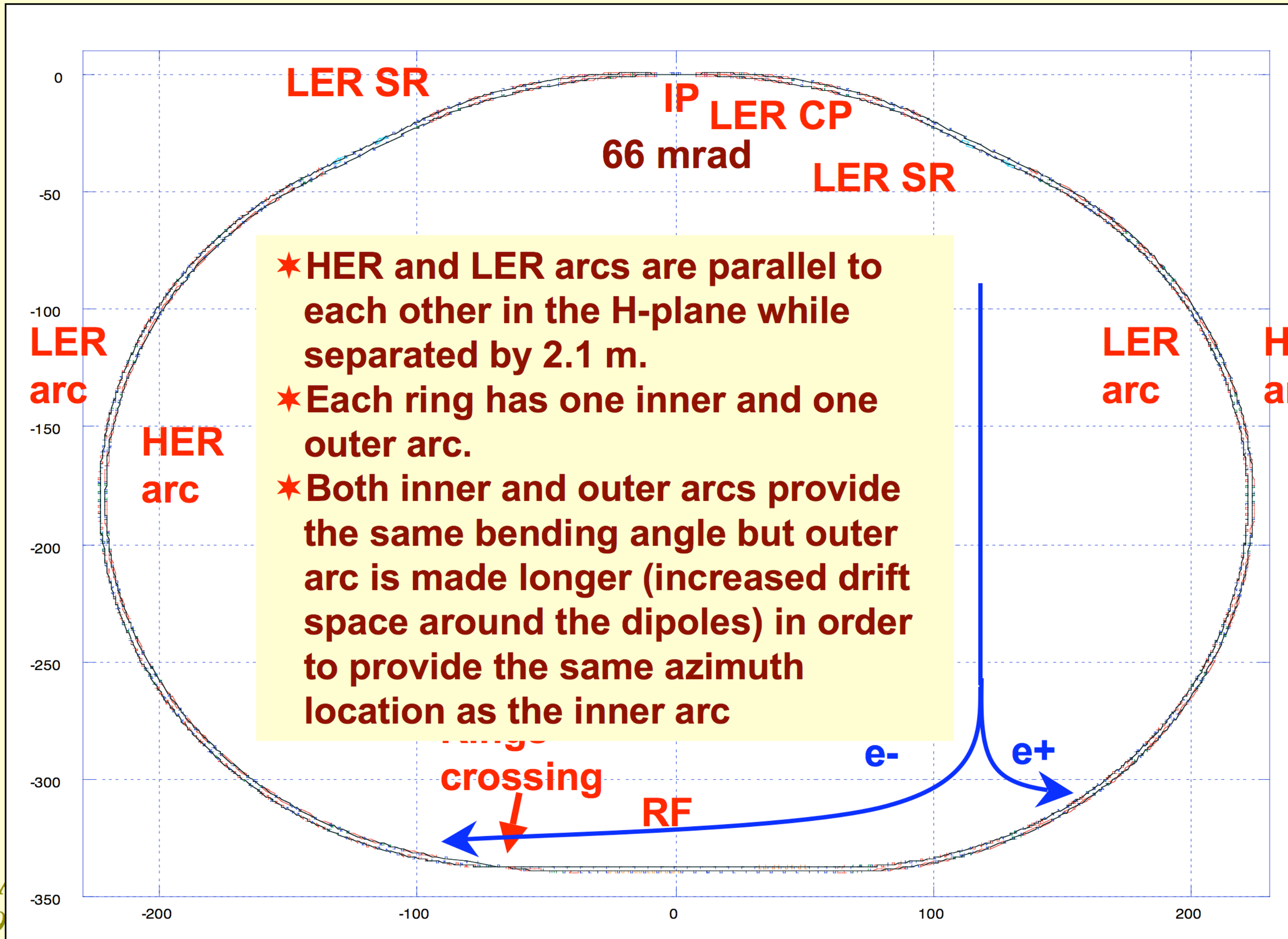
Parameter	Requirement	Comment
Luminosity (top-up mode)	10^{36} cm^{-2}s^{-1} @ $\Upsilon(4S)$	
Integrated luminosity	75 ab^{-1}	Based on a "New Snowmass Year" of 1.5 x 10^7 seconds (PEP-II experience-based)
CM energy range	From just below charm ≈τ threshold to $\Upsilon(5S)$	For a better study of CP violation in Charm and for B_s measurements.
Minimum boost	$\beta\gamma = 0.28$ (4x7 GeV) (under discussion)	1 cm beampipe radius. First measurement at 1.5 cm
e^- Polarization	60-85%	Enables τ *CP* and *T* violation studies, measurement of τ *g*-2 and improves sensitivity to lepton flavor-violating decays. Detailed simulation, needed to ascertain a more precise requirement, are in progress.

Super*B* Performance Parameters

- Luminosity: 10^{36} $cm^{-2}s^{-1}$
- Polarized electron beam (≈70% @ high lumi)
- Moderate beam requirements
  - 1.9/2.5 A beam current
  - 5 mm bunch length
  - 2 nm/5 pm emittance (x/y)
  - moderate rf power (17 MW)
  - continuous injection (“trickle charge”)
  - All of these have been done at other facilities
- Tight focus at the IP
  - 8 by 0.036 μm
  - smaller than done so far.

Super*B* Layout

M. Biagini



- HER and LER arcs are parallel to each other in the H-plane while separated by 2.1 m.
- Each ring has one inner and one outer arc.
- Both inner and outer arcs provide the same bending angle but outer arc is made longer (increased drift space around the dipoles) in order to provide the same azimuth location as the inner arc

SuperB Parameters

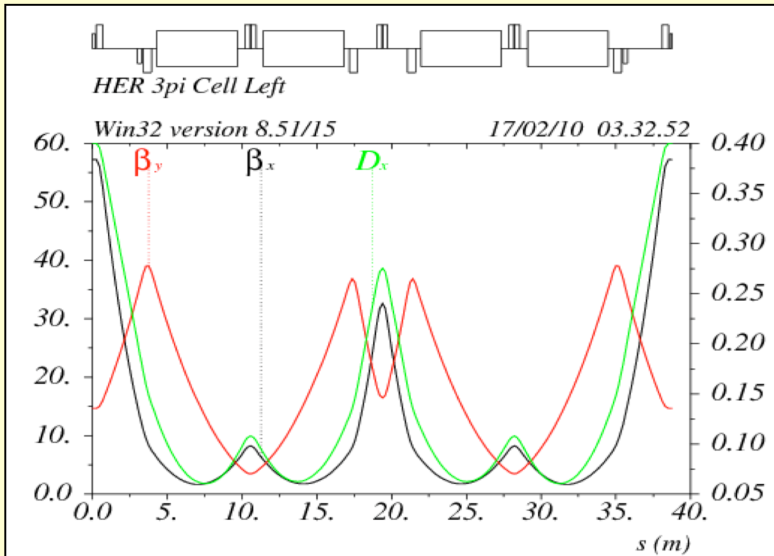
Parameter	Units	Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
		HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2} s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
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
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (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	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. 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	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

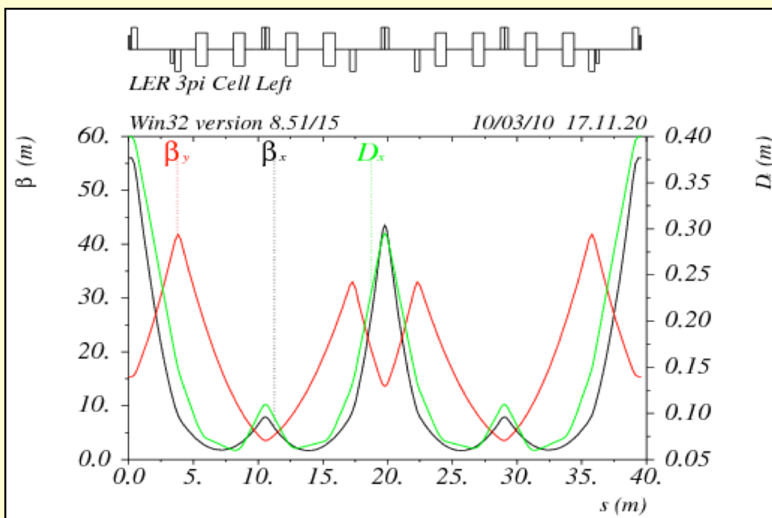
Parameter Flexibility

- The horizontal emittance can be decreased by about a factor 2 in both rings
  - change the partition number (change RF frequency)
  - readjust the lattice functions.
- The IP optics has built-in capability of about a factor 2 in decreasing the IP beta functions.
- The RF system will be able to support higher beam currents (up to a factor x1.6) over the baseline, when all the available PEP RF units are installed.

Arc Magnet Lattice

P. Raimondi





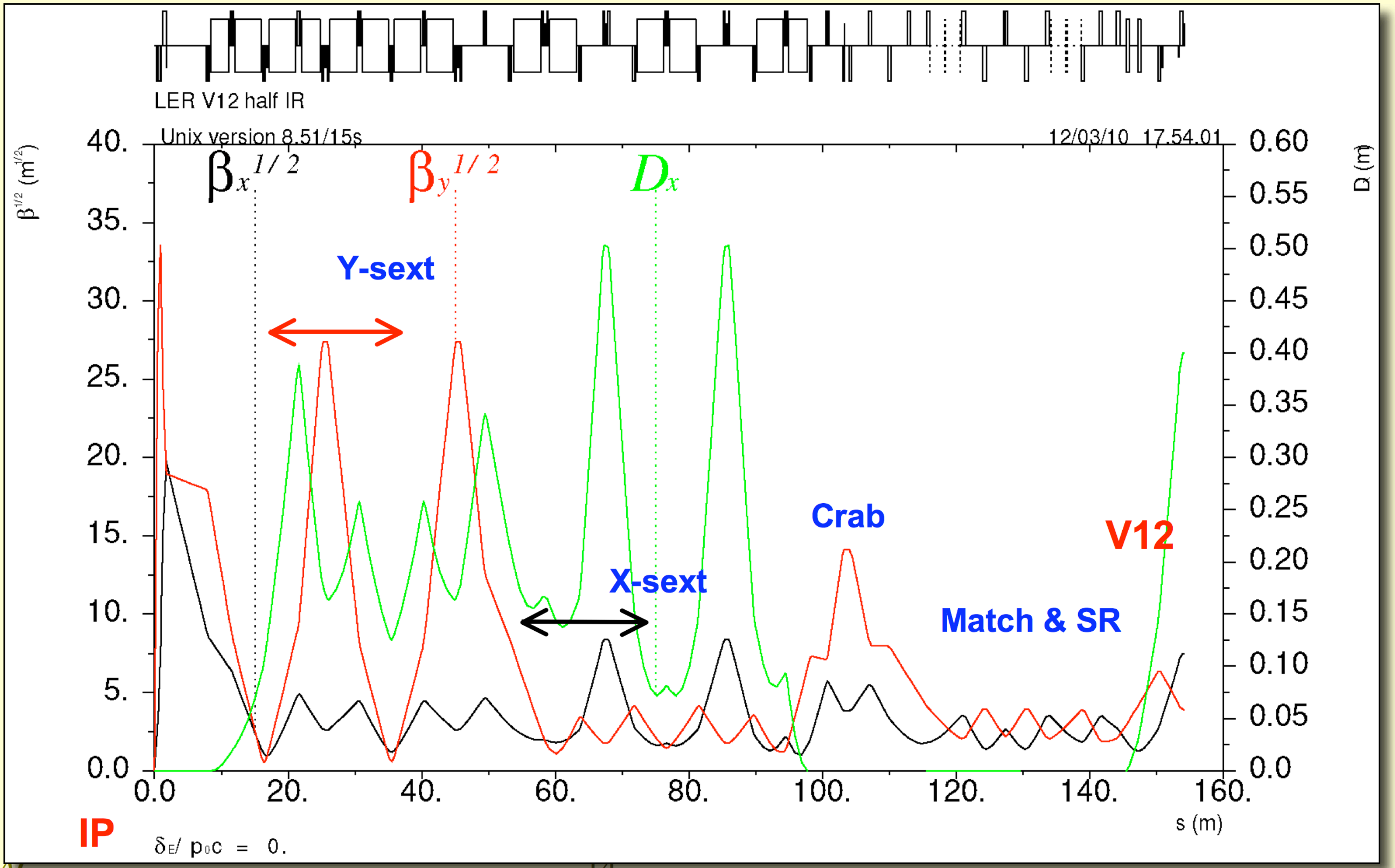
$\mu_x = 3\pi$, $\mu_y = \pi$
Cell in HER

Low dispersion in dipoles
=> low emittance

$\mu_x = 3\pi$, $\mu_y = \pi$
Cell in LER

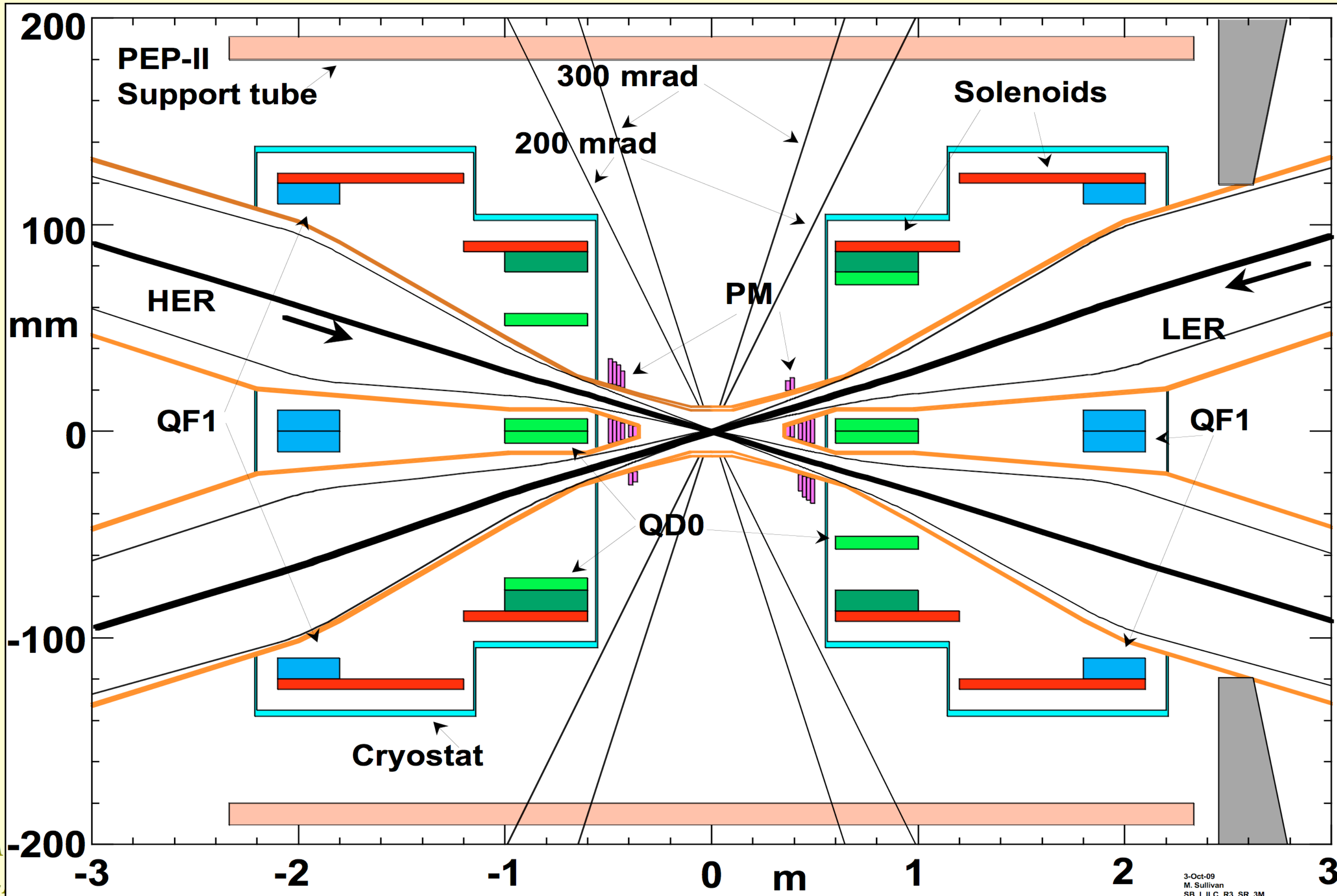
LER IR Optics

Raimondi, Nosochkov



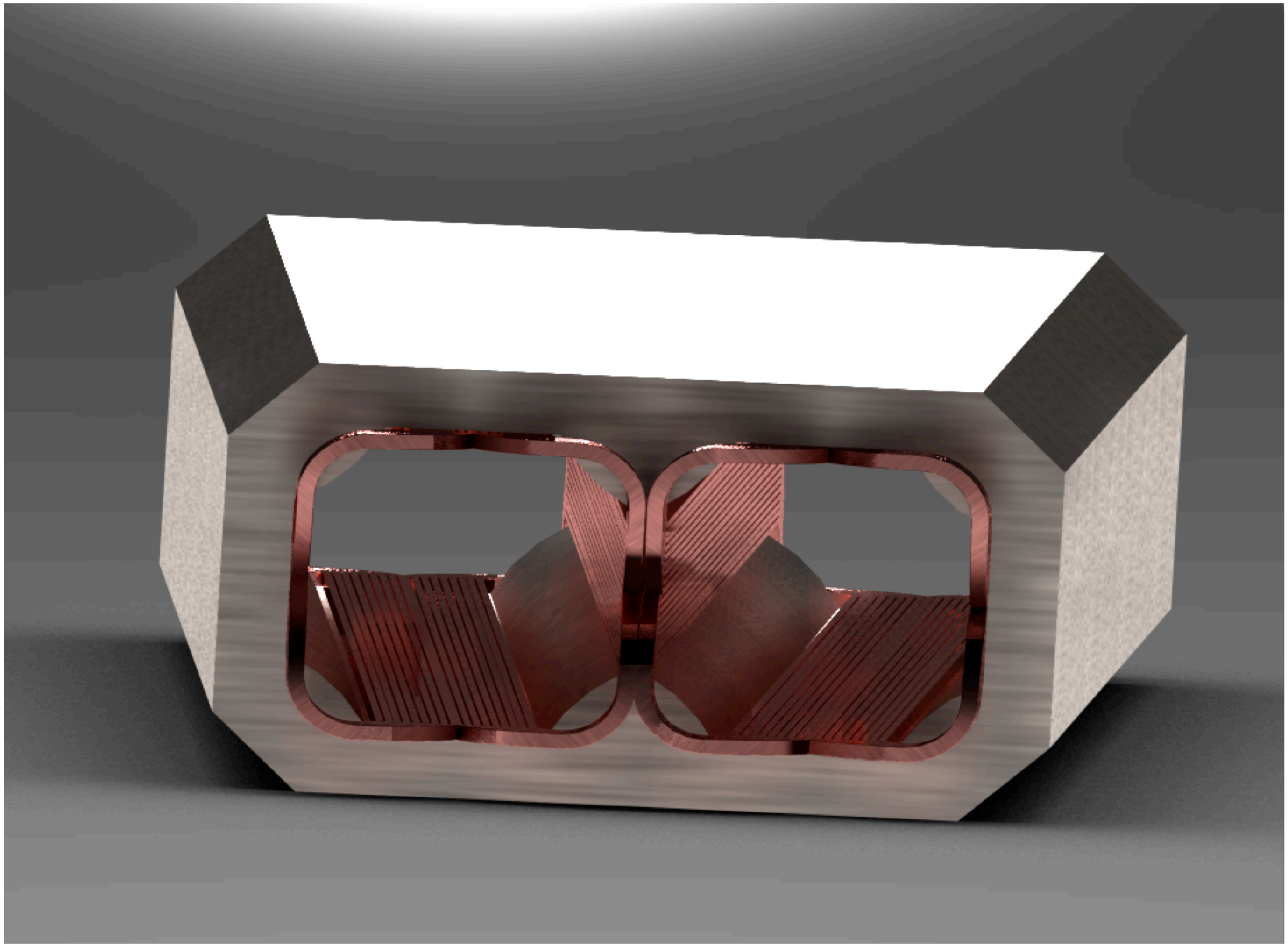
Super*B* IR Layout

M. Sullivan



Superferric QD0

P. Vobly



Energy Range

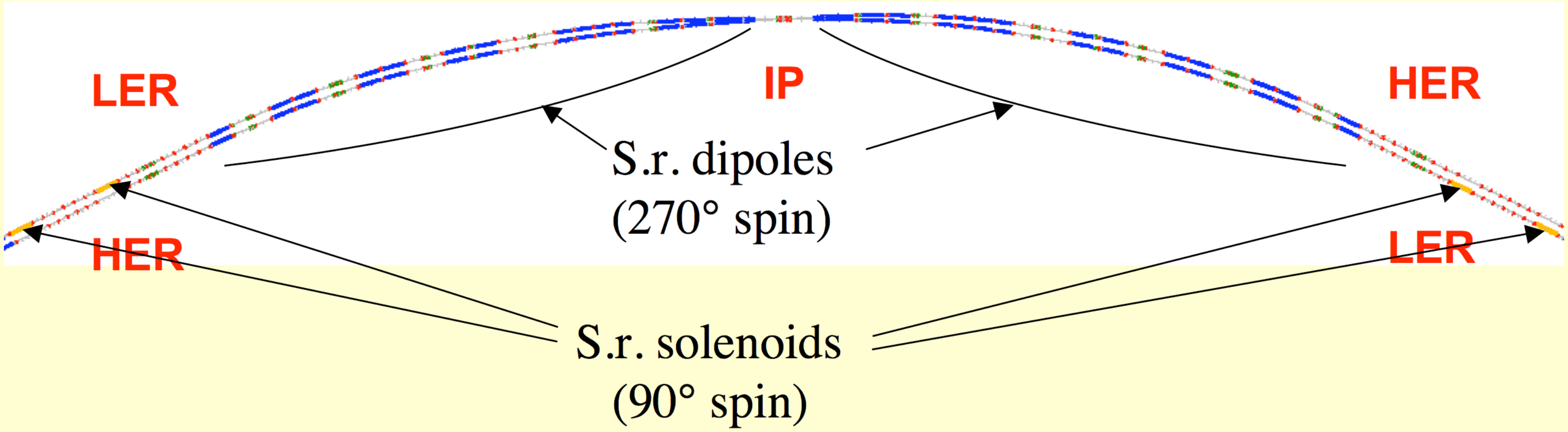
- Change center of-mass energy while maintaining the same magnetic field strength ratio for QD0 and QF1
- Can get to all of the Upsilon resonances $\Upsilon(1S)\ldots\Upsilon(5S)$
- Can scan the center-of-mass energy above the $\Upsilon(4S)$
  - without removing or changing any of the permanent magnets
- Have to remove most if not all of the permanent magnets for Tau-charm energy region

Polarization in Super*B*

- Polarized e^- is a 1st-level requirement for Super*B*
  - primarily driven by τ physics
- Sokolov-Ternov self polarization too slow
  - > polarized injector for electrons
  - (SLC gun provides ≥ 90% polarized e^-)
- Beam lifetime at high luminosity is short
  - > overcomes depolarization
  - > prevents polarization from adding difficult-to-fulfill spin-matching requirements
- Longitudinal polarization => spin rotators

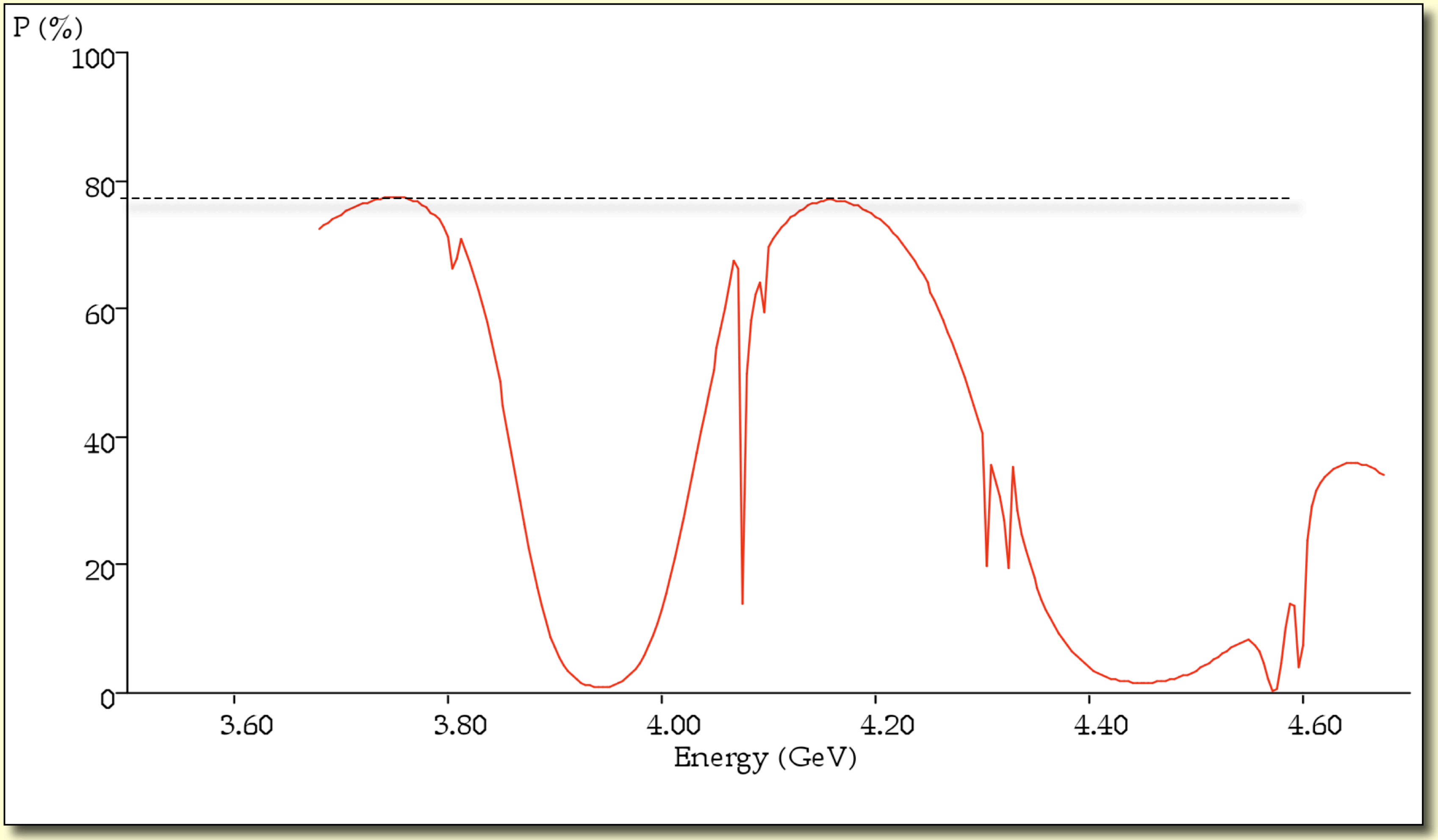
Spin Rotation

- 90° spin rotation about x axis
  - 90° about z followed by 90° about y
- "flat" geometry => no vertical emittance growth
- Solenoid scales with energy => LER more economical
- Solenoids are split & decoupling optics added.



Polarization (P_{inj} = 90%)

3.5 min
beam lifetime

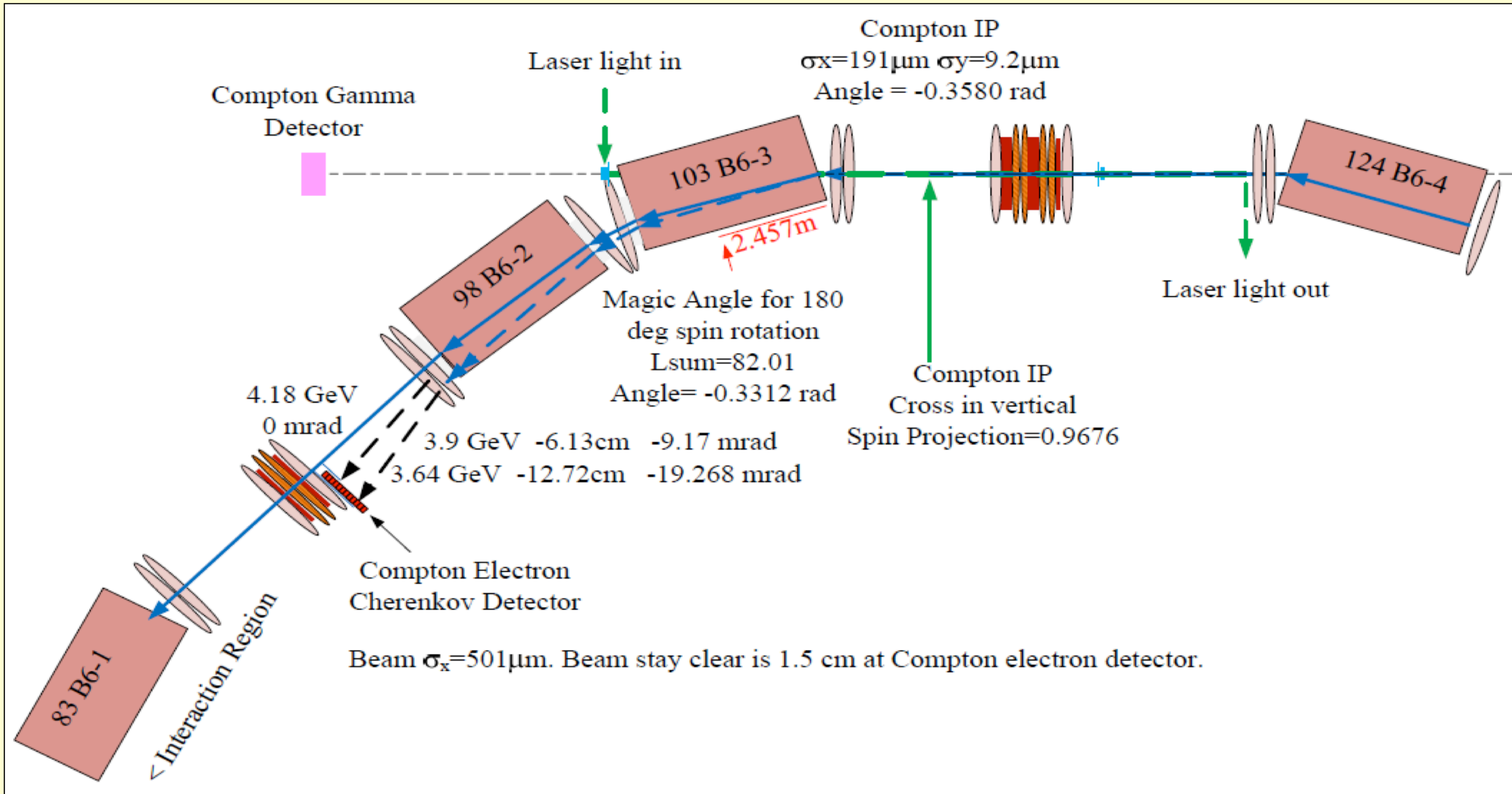


Polarimetry

- Compton polarimeter for long. polarization
- <1% *dP*/*P* specification, achievable given rates
- 1-watt mode locked Nd:YLF circularly polarized laser at 119 MHz
  - > bunch-by-bunch polarization measurement
- Polarimeter 180° in spin upstream of IP
  - avoid collision-induced background.

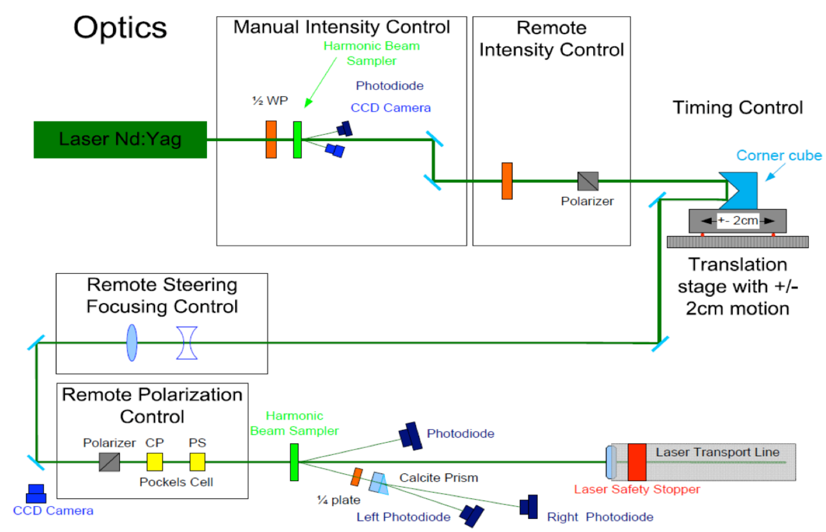
Compton Polarimeter

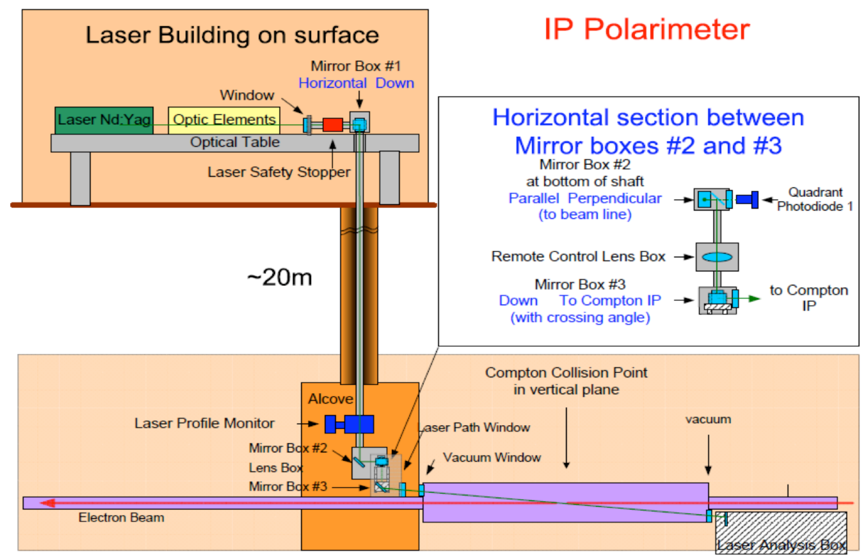
K. Moffeit



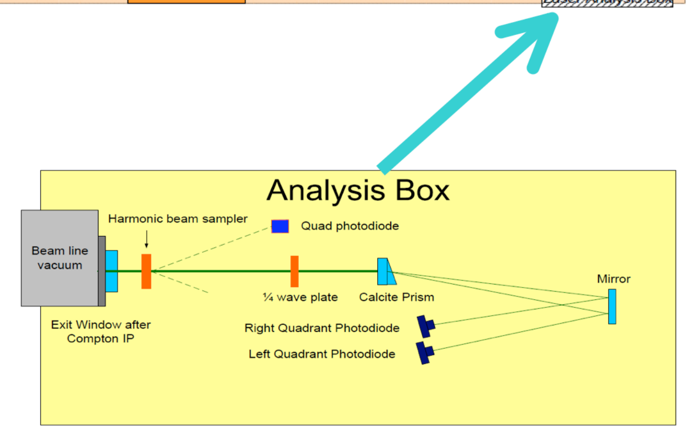
Polarimeter Layout

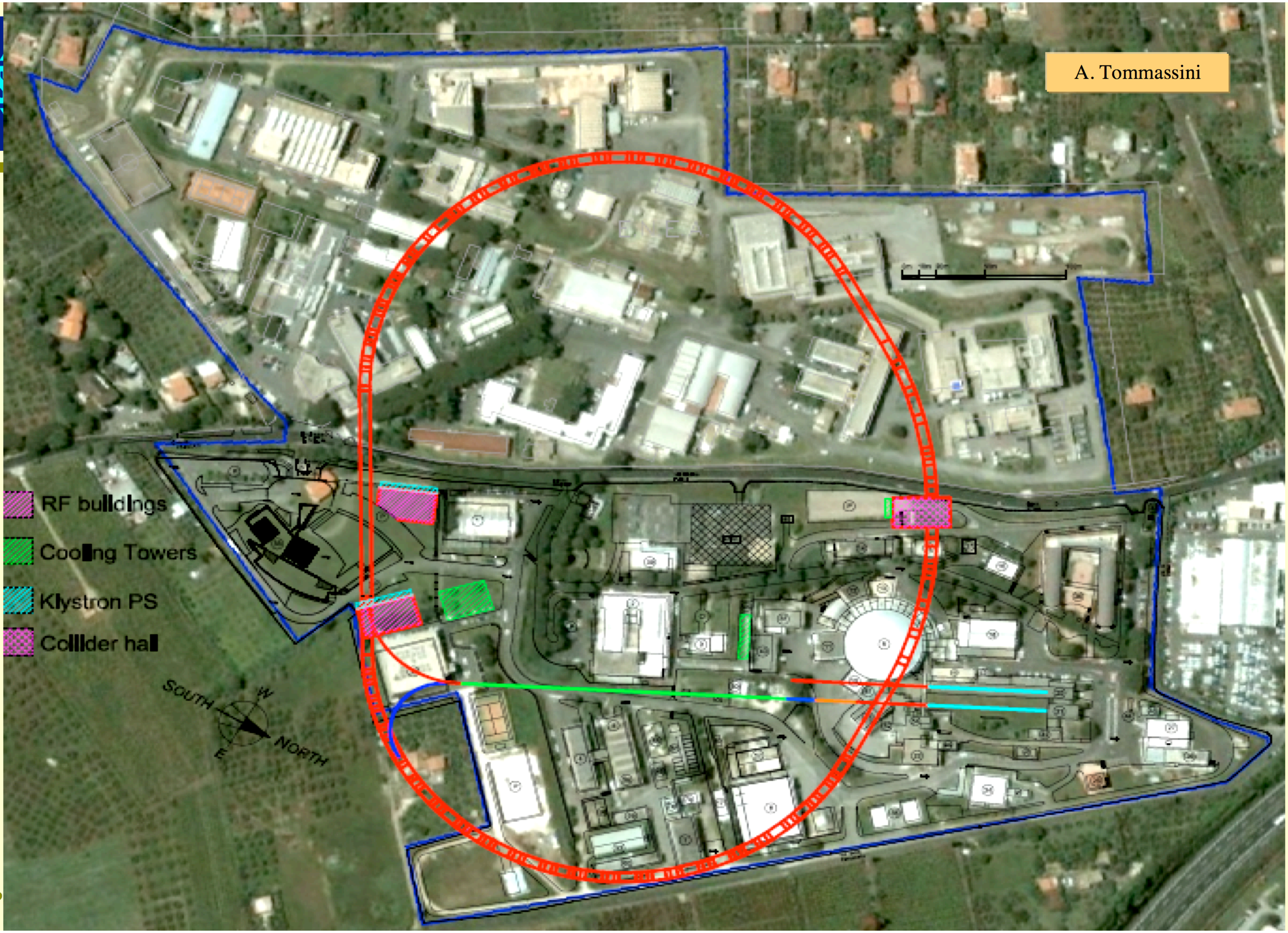
K. Moffeit



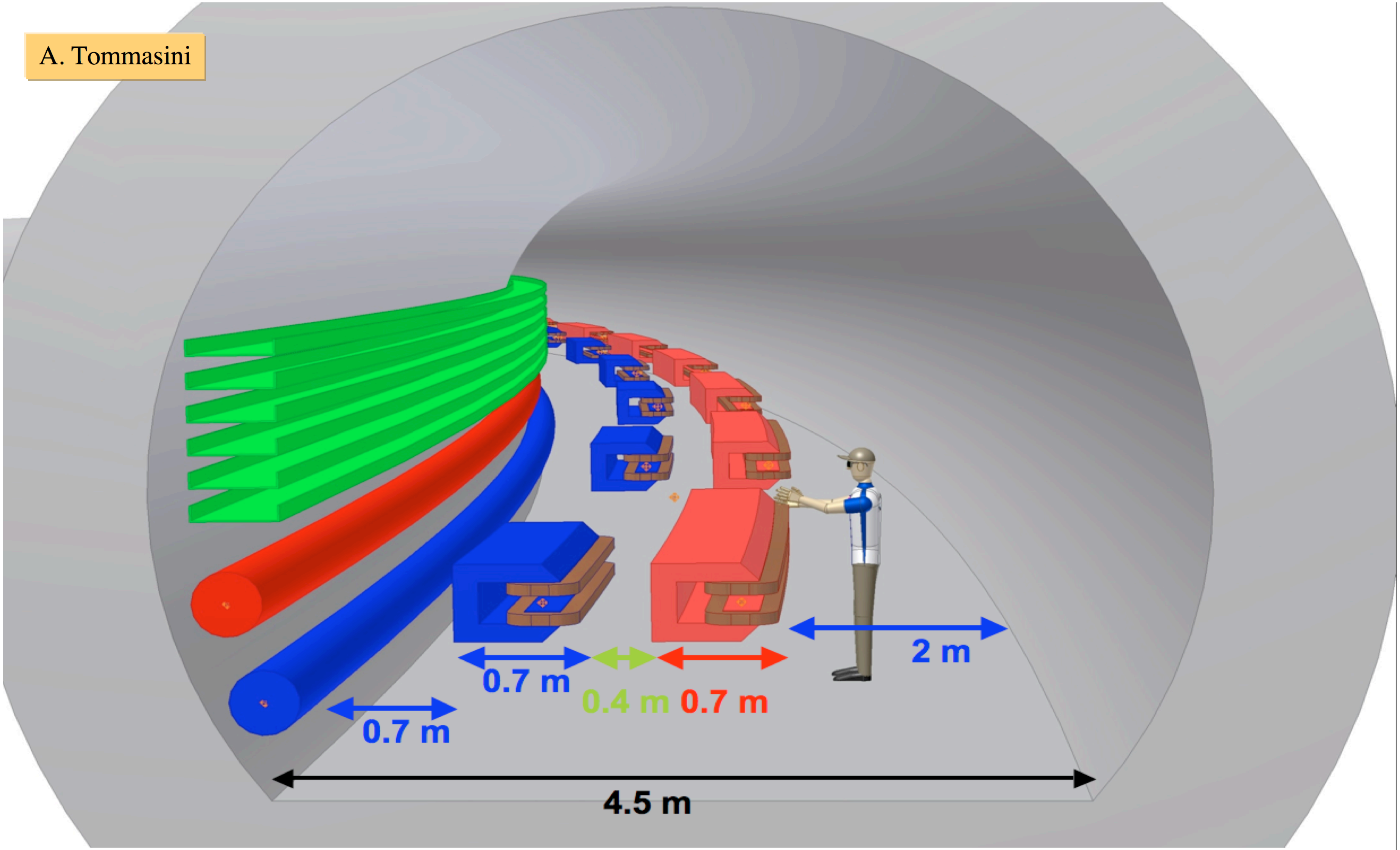


- Aim for ≤ 1% syst. error.
- Polarization bunch-by-bunch




A. Tommassini
RF buildings
Cooling Towers
Klystron PS
Collider hall
SOUTH
W
E
NORTH

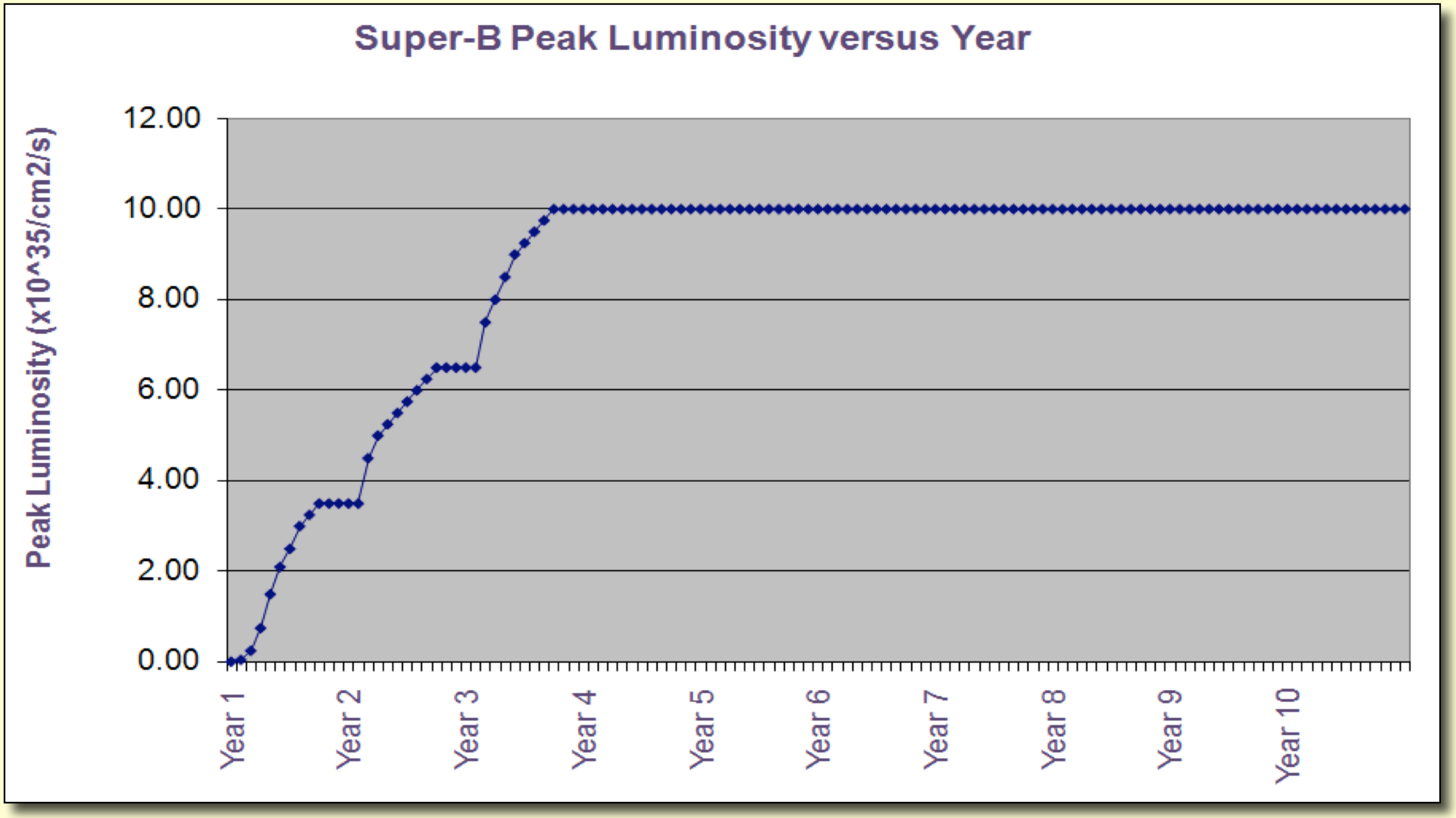
U.
FP



SuperB: Storage Ring Tunnel Occupancy

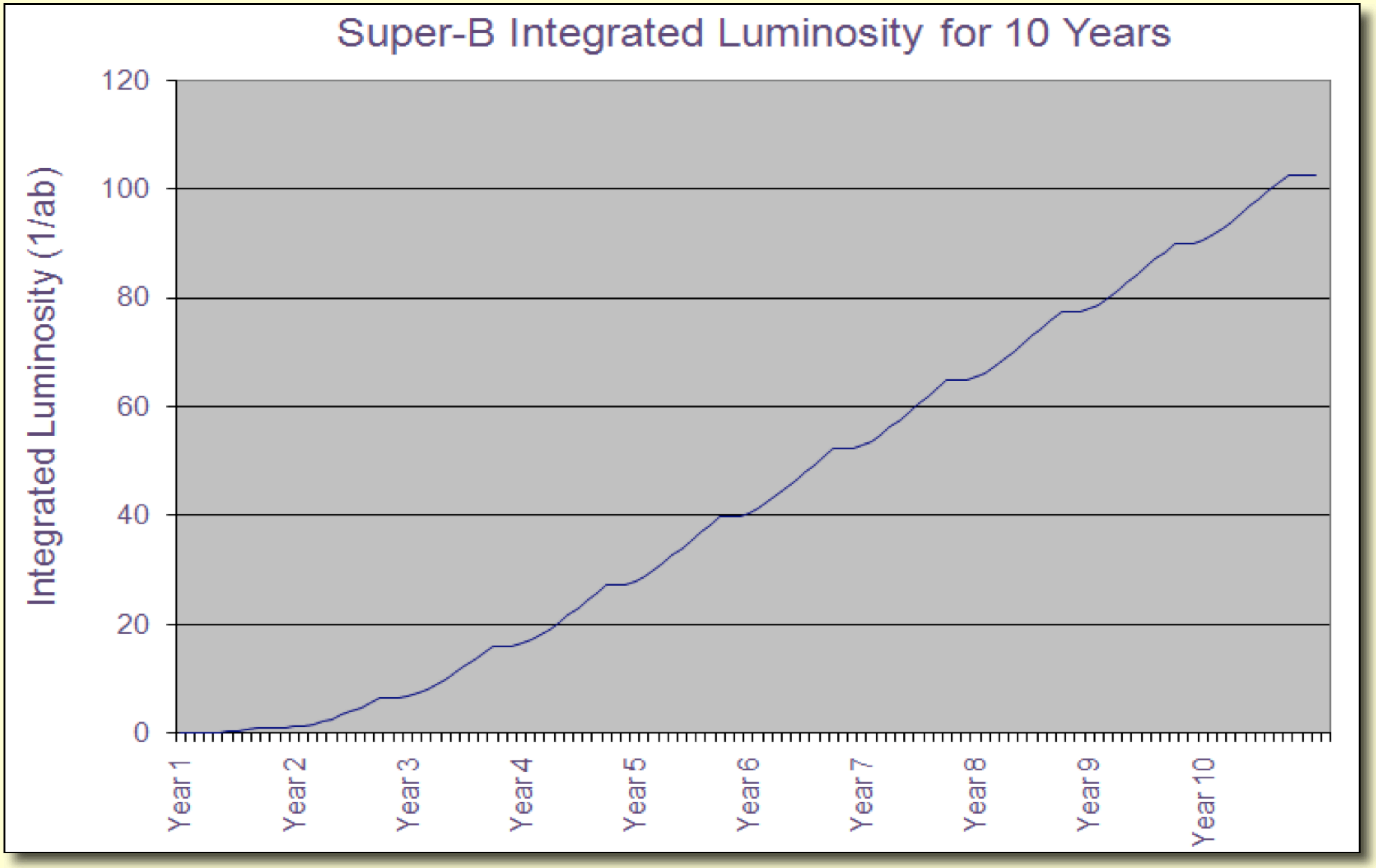
SuperB Luminosity Evolution

J. Seeman



SuperB ∫Ldt

J. Seeman



Super*B*: An International Project in Italy

- LNF-SLAC core design team
  - augmented by collaborators from BINP, Cockroft, Orsay, CEA, CNRS, LPSC, DESY, Pisa, et al.
- Significant contribution from the US in form of PEP-II hardware foreseen
  - Magnets, rf cavities, pol. e^- source, vacuum (??), …
  - Ongoing discussions with US DOE
- SLAC acc. physics and engineering contribution has been defined
  - consistent with Super*B* needs & other SLAC commitments
- Strong interest in France (IN2P3)

Super*B*: An International…

- International Management team
  - Giorgi(It); Hitlin, Leith(US); Wormser(Fr)
- MOUs for TDR phase being prepared
  - IN2P3 (Fr)…signed
  - DOE (US)
  - Canada
  - Russia
  - Spain, Poland, UK

Super*B* Contributors (excerpt)

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- F. Bosi, E. Paoloni (Pisa University, Italy)

€ Super*B* Cost $

- The total construction cost is presently estimated at roughly €700M
  - not “the official number”; TDR will contain a detailed estimate of project cost.
- PEP-II component valuated at about $250M
- SLAC labor (acc. phys., eng.) likely to be about $30M
- HERA Model (if followed):
  - Host provides buildings & civil construction & carries operating costs
  - Technical systems: All collaborating countries provide contributions in kind.
- Operating costs estimated near €70M p.a.

Conclusion

- Super*B* employs a novel design to provide extreme luminosity with reasonable beam parameters
  - The crab-waist has been implemented succesfully at DAΦNE in day-to-day operation.
- Super*B* is from the start designed for compatibility with polarized electron beams
  - polarized e^+ are not excluded but not in baseline
- International team with experience in building high-luminosity e^+e^- colliders.
- An updated Design Report is in the final stages of editing.
- Work toward detailed Technical Design Report is in progress.
- Italian Govt. is presently undergoing a planning exercise
  - Should indicate where SuperB fits in