SuperB Developments and Canadian Involvement

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IPP Annual General Meeting
St. John's Newfoundland
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Flavour sector gives experimental basis for much of SM parameters that can be:

- determined experimentally with precision
- compared with reliable theoretical predictions

established major pillars of the Standard Model:

- the particle content
- the weak couplings
- the suppression of flavour-changing neutral current

and constrains Beyond-SM theories

e.g. Minimal Flavour Violation (?)

when new physics is found at the LHC the flavour sector will continue to provide **unique information on the nature of that new physics**

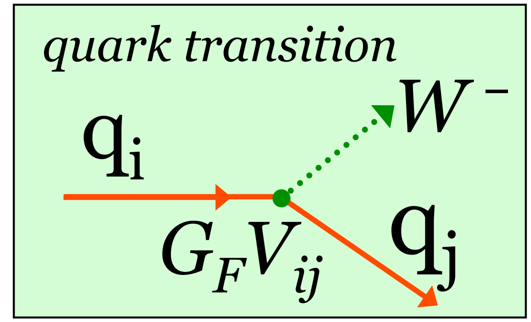
SuperB Project Overview

- Next generation Flavour-physics facility. Primarily will operate at the Y(4S) ($\rightarrow B\bar{B}$), but with ability to run on Y(1, 2, or 3S) and above the Y(4s) or at charm threshold.
- Asymmetry e^+e^- collider with luminosity ~100× PEP-II, 10^{36}, but with comparable beam currents and power.
  - somewhat lower asymmetry, $\beta\gamma = 0.28$ vs 0.56
- One beam will be longitudinally polarized ~80%

SuperB Physics Program

- Use a broad set of measurements to observe physics beyond the Standard Model and to elucidate its nature.
- Precision measurements involving loops.
  - new physics will enter such loops
  - interference ⇒ asymmetries
- Rare/Forbidden (in SM) decays
- Precision NC EW measurements with polarised beam via A_{LR} - unprecedented precision on NC vector couplings
- Complementary to LHC program

CKM Matrix



In SM weak charged transitions mix quarks of different generations

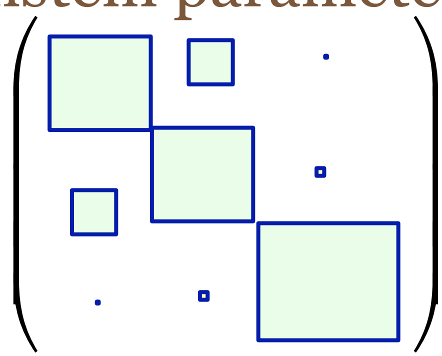
Encoded in unitary CKM matrix

$$\begin{pmatrix} d' & s' & b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Unitarity ➔ 4 independent parameters, one of which is the complex phase and sole source of CP violation in SM

Wolfenstein parameterisation:

$\mathbf{V}_{CKM} =$



$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

CKM Unitarity Triangle

Physics beyond the SM signaled by breakdown of unitarity of CKM matrix

$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

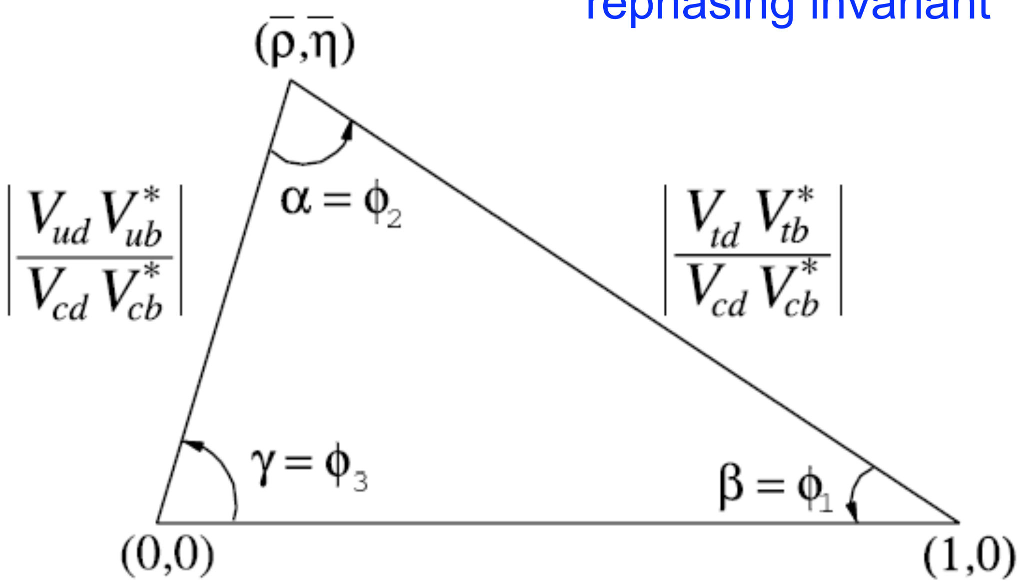
Wolfenstein parameterisation defined to hold to all orders in $\lambda \sim 0.2$ and rephasing invariant

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) \quad \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$

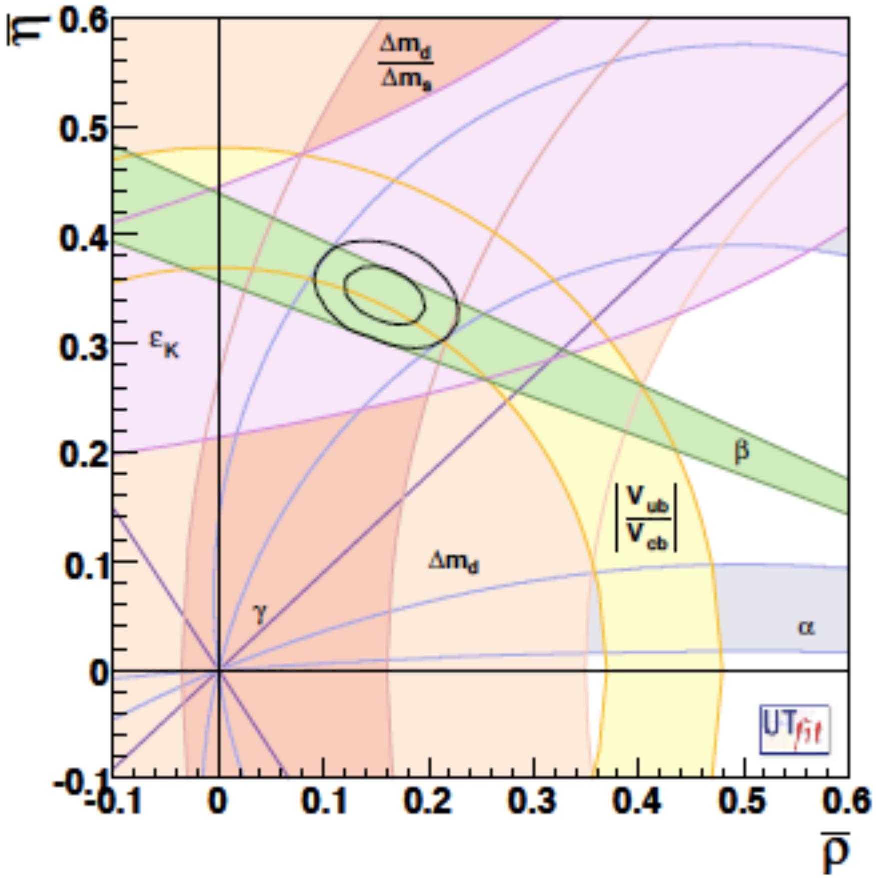
$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \quad \beta_s = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

Area of Δ~CP violation

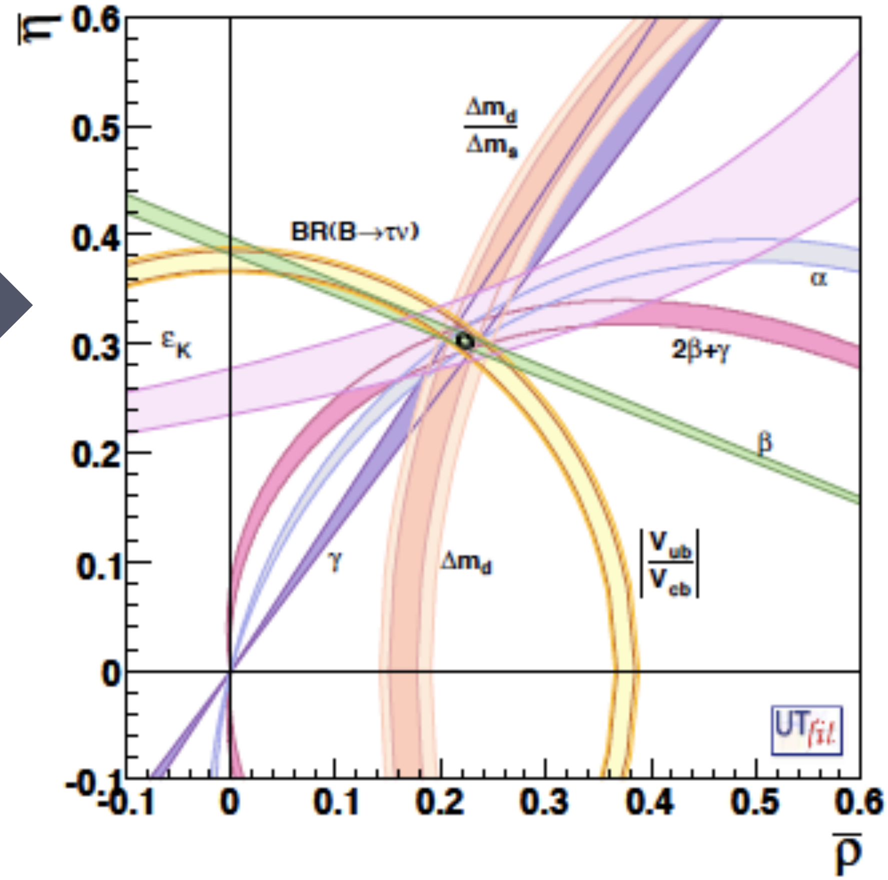


CKM Matrix

ρ = 0.163 ± 0.028
η = 0.344± 0.016

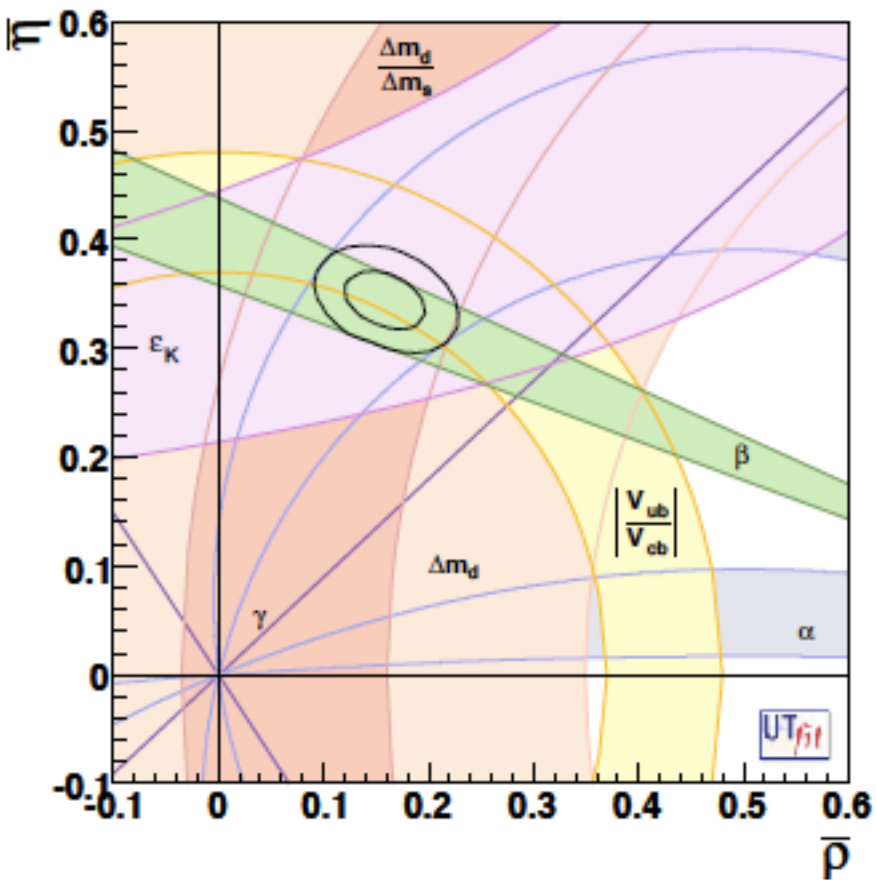


ρ = ± 0.0028
η = ± 0.0024

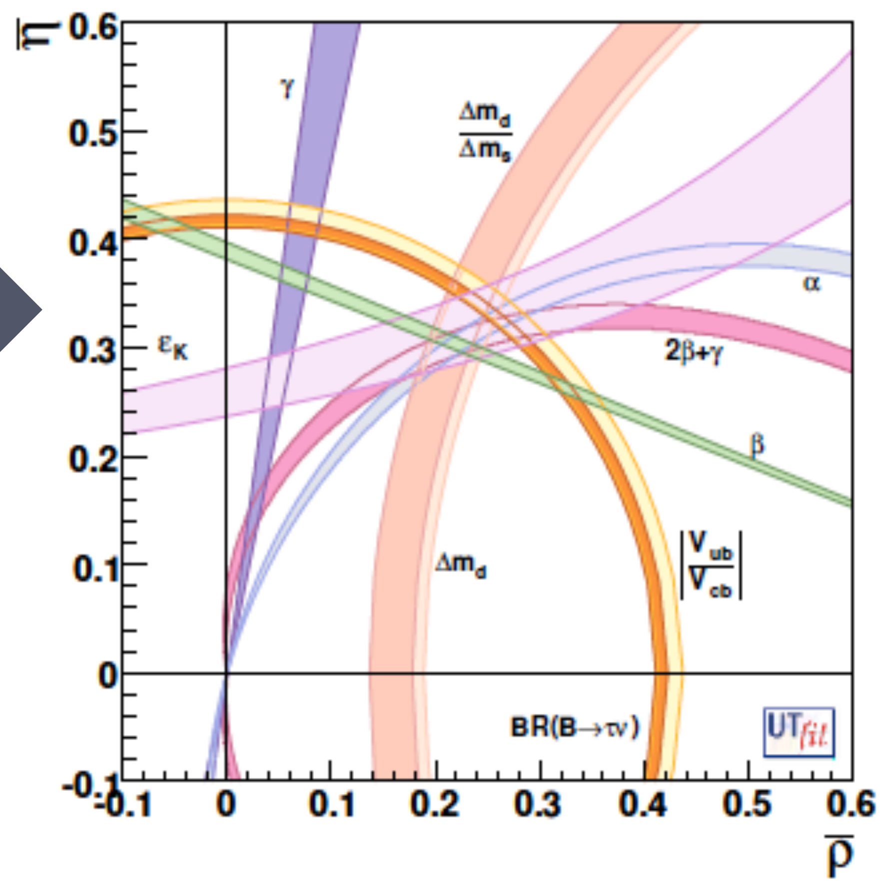


CKM Matrix

$\rho = 0.163 \pm 0.028$
$\eta\ = 0.344 \pm 0.016$



More interesting when SM fails – putting in ρ & η central values c 2008



Physics at Super Flavour Factories

- Test CKM at 1% level
  - CPV in B decays from new physics (non-CKM)
- B-recoil technique for B->K(*)ll, B->τν, B->D*τν
- τ physics: lepton flavour violations, g-2, EDM, CPV
- With polarised beam: Precision EW physics
- Many other topics:
  - ϒ(5S) physics, CPV in Charm, ISR radiative return, spectroscopy…
- Physics motivation is independent of LHC
  - If LHC finds NP, precision flavour input essential
  - If LHC finds no NP, high statistics B and τ decays are unique way of probing >TeV scale physics

Super Flavour Factory Physics Program Summary

B Physics at the $\Upsilon(4S)$

A. New Physics in CP violation
   1. ΔS measurements
B. Theoretical aspects of rare decays
   1. New physics in $B \to K^{(*)}\nu\bar{\nu}$ decays
   2. $\bar{B} \to X_s\gamma$ and $\bar{B} \to X_s\ell^+\ell^-$
   3. Angular analysis of $B \to K^*l^+l^-$
   4. $\bar{B} \to X_d\gamma$ and $\bar{B} \to X_d\ell^+\ell^-$
C. Experimental aspects of rare decays
   1. $B \to K^{(*)}\nu\bar{\nu}$
   2. $B \to \ell\nu$ and $B \to \ell\nu\gamma$
   3. Experimental aspects of $\bar{B} \to X_s\gamma$
   4. Inclusive and exclusive $b \to s\ell^+\ell^-$
   5. More on $B \to X_{s/d}\ell^+\ell^-$ with a hadron tag
D. Determination of $|V_{ub}|$ and $|V_{cb}|$
   1. Inclusive Determination of $|V_{ub}|$
   2. Inclusive Determination of $|V_{cb}|$
E. Studies in Mixing and CP Violation in Mixing
   1. Measurements of the mixing frequency and CP asymmetries
   2. New Physics in mixing
   3. Tests of CPT
F. Why measure γ precisely (and how)?
G. Charmless hadronic B decays
H. Precision CKM

B Physics at the $\Upsilon(5S)$

1. Measurement of B_s Mixing Parameters
2. Time Dependent CP Asymmetries at the $\Upsilon(5S)$
3. Rare Radiative B_s Decays
4. Measurement of $B_s \to \gamma\gamma$
5. Phenomenological Implications

Super Flavour Factory Physics Program Summary

Electroweak neutral current measurements

Spectroscopy
A. Introduction
B. Light Mesons
C. Charmonium
D. Bottomonium
  1. Regular bottomonium
  2. Exotic bottomonium
E. Interplay with other experiments

Direct Searches
A. Light Higgs
B. Invisible decays and Dark Matter
C. Dark Forces

τ physics
A. Lepton Flavor Violation in τ decay
  Predictions from New Physics models
    LFV in the MSSM
    LFV in other scenarios
  Super$B$ experimental reach
B. *CP* Violation in τ decay
C. Measurement of the τ electric dipole moment
D. Measurement of the τ $g-2$
E. Search for second-class currents

Super Flavour Factory Physics Program Summary

Charm Physics

A. On the Uniqueness of Charm
B. $D^0 - \bar{D}^0$ Oscillations
   1. Experimental Status
   2. Combination of measurements and CPV
   3. Measurements of strong phases
   4. Theoretical Interpretation
   5. Measuring x_D and y_D at Super$B$
   6. Projections for mixing measurements at Super$B$
   7. Estimated sensitivity to CPV from mixing measurements
C. CP Violation
   1. Generalities
   2. SM Expectations
   3. Experimental Landscape
   4. Littlest Higgs Models with T Parity – A Viable Non-ad-hoc Scenario
D. Rare Decays
   1. $D^0 \to \mu^+\mu^-, \gamma\gamma$
   2. $D \to l^+l^-X$
E. Experimental possibilities for rare decay searches at Super$B$
   1. $D \to l^+l^-X$
F. A case for Running at the $D\bar{D}$ threshold?

For discussion of the physics program at SuperB see Steve Robertson's opening talk in the Precision Frontier session Thursday @15:45

One physics example: Polarized Beam provide an impressive Precision EW Program at SuperB

- Measure the difference between cross sections with left-handed beam electrons and right-handed beam electrons

$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \propto g_V^f = T_3^f - Q_f \sin^2\theta_W$$

Driven by $\gamma - Z$ interference at $\sqrt{s} = 10.58$ GeV

- same type of measurement as performed by SLD at the Z

$e^+e^- \rightarrow \mu^+\mu^-$ @ $\sqrt{s}$=10.58GeV

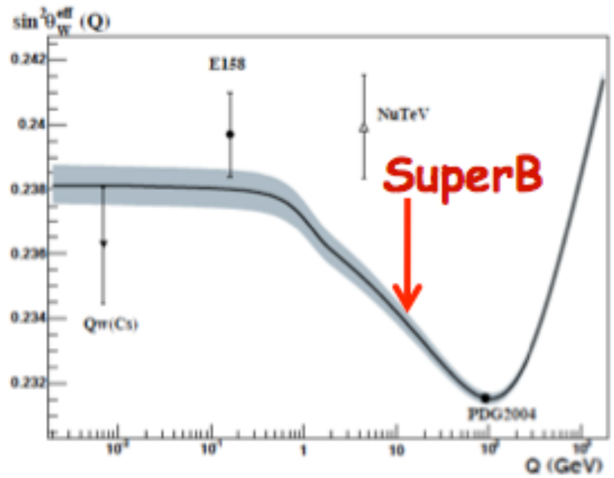
Diagrams	Cross Section (nb)	A_{FB}	A_{LR} (Pol = 100%)
$\|Z+\gamma\|^2$	1.01	0.0028	-0.00051

$\sigma_{ALR} = 5\times10^{-6} \rightarrow \sigma_{(\sin2\theta eff)} = 0.00018$

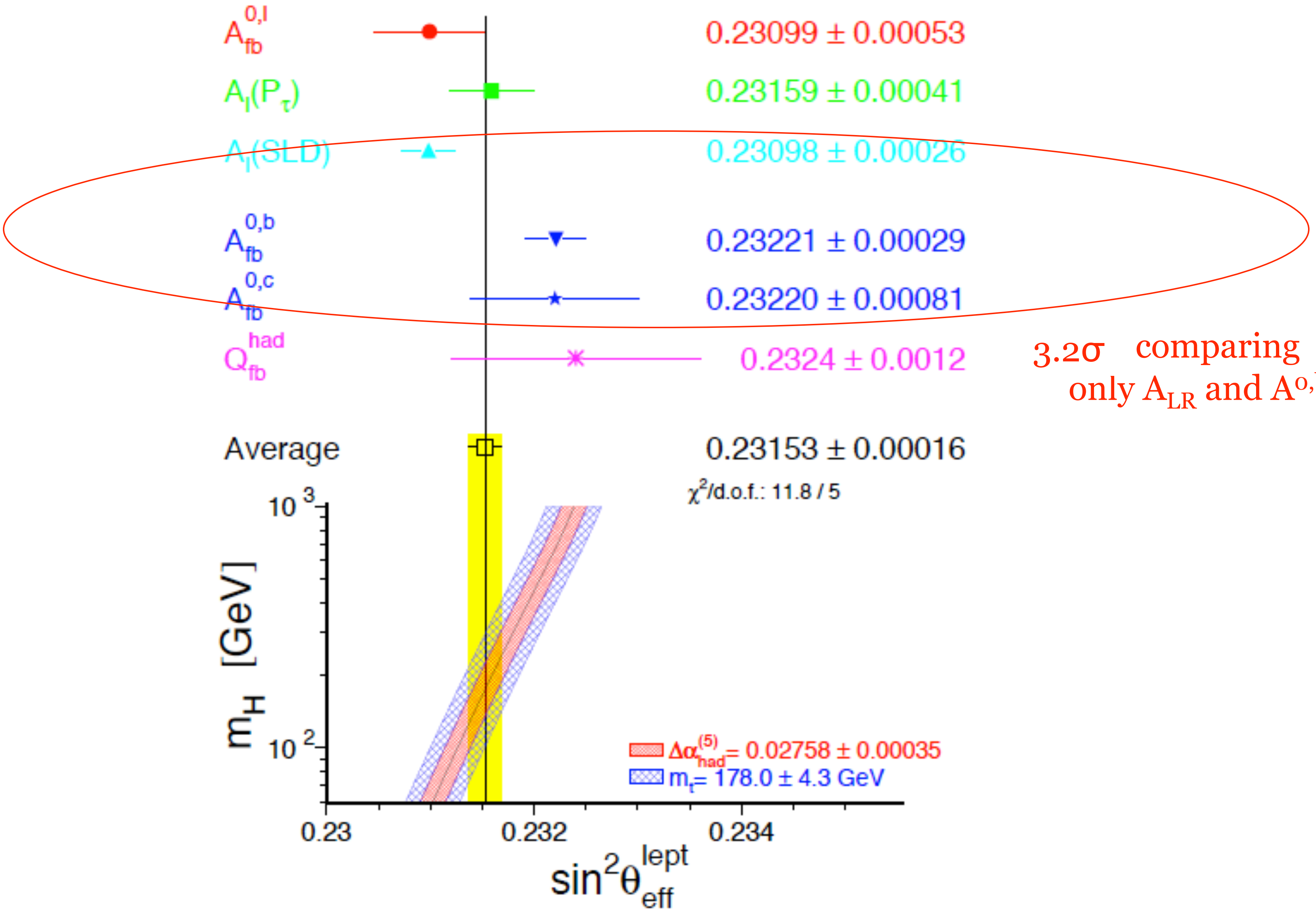
cf SLC A_{LR} $\sigma_{(\sin2\theta eff)} = 0.00026$

relative stat. error of 1.1% (pol=80%)
require <~0.5% systematic error on beam polarisation

- polarized beam provide measurement of $\sin^2\Theta_W(\mathrm{eff})$ of using muon pairs of comparable precision to that obtained by SLD, except at 10.58GeV.



- Similar measurement can be made with taus and charm
- Test neutral current universality at high precision
- Because it depends on gamma-Z interference it is sensitive to Z'
- Measure NC Z-b-bbar vector coupling with higher precision and different systematic errors than determined at LEP with A_{FB}^{b} and at high precision

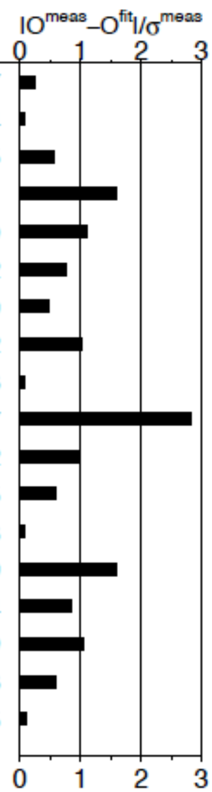


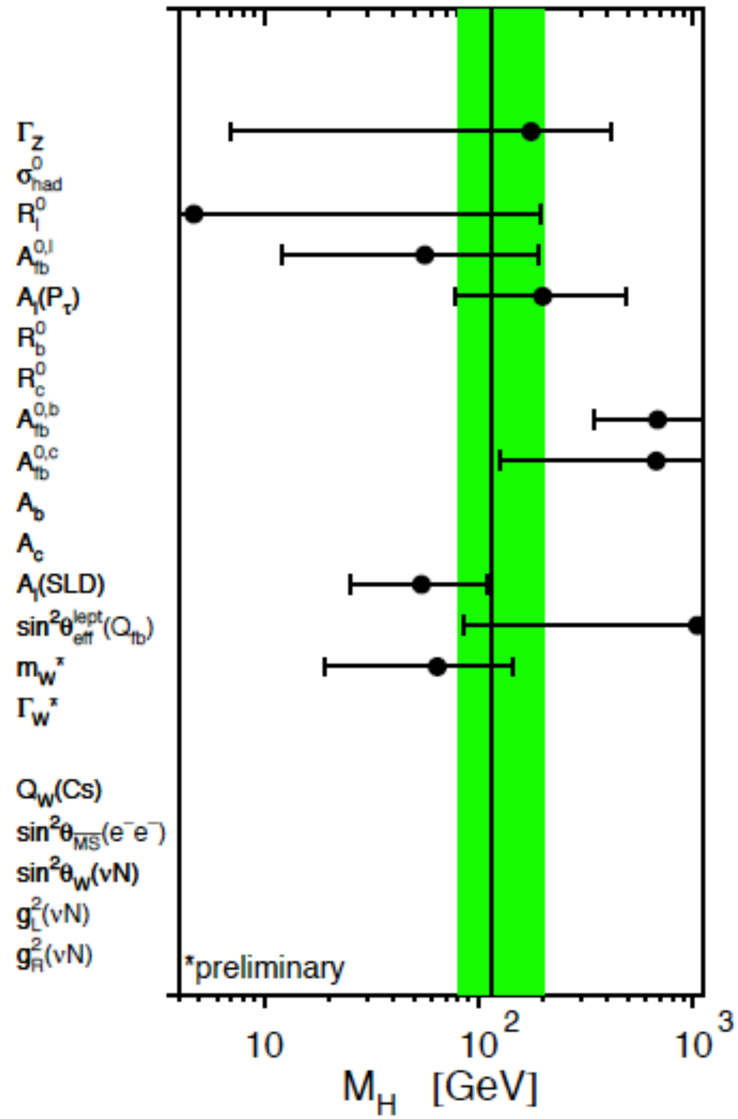
3.2σ comparing only A_{LR} and $A^{0,b}_{fb}$

Z-b-bar

- note: if A_{FB}^{b} is omitted from the SM fit $M_{Higgs}=76\pm^{54}_{33}$GeV low mass Higgs is strongly preferred

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5





$$A_{LR} = -\frac{6}{\sqrt{2}}\left(\frac{G_F M^2_{Y(4S)}}{4\pi\alpha}\right) g^e_A g^b_V \langle Pol \rangle$$

In SM Q_b=-1/3; g^e_A= -0.5

$$\langle Pol \rangle = 80\%; A_{LR} \sim -0.01$$

1 billion reconstructed Y(4S) decays gives A_{LR} to 0.3% stat.
Currently value:

$$g^b_V = -0.3220 \pm 0.0077 (2.4\%)$$

- 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...)

Very Recent realization: Tau Polarization as Beam Polarimeter

$$P_{z'}^{(\tau-)}(\theta,P_e) = -\frac{8G_F s}{4\sqrt{2}\pi\alpha}\mathrm{Re}\left\{\frac{g_V^l - Q_b g_V^b \Upsilon_{1S,2S,3S}(s)}{1+Q_b^2\Upsilon_{1S,2S,3S}(s)}\right\}\left(g_A^\tau \frac{|\vec{p}|}{p^0} + 2g_A^e \frac{\cos\theta}{1+\cos^2\theta}\right)$$

$$+ P_e \frac{\cos\theta}{1+\cos^2\theta}$$

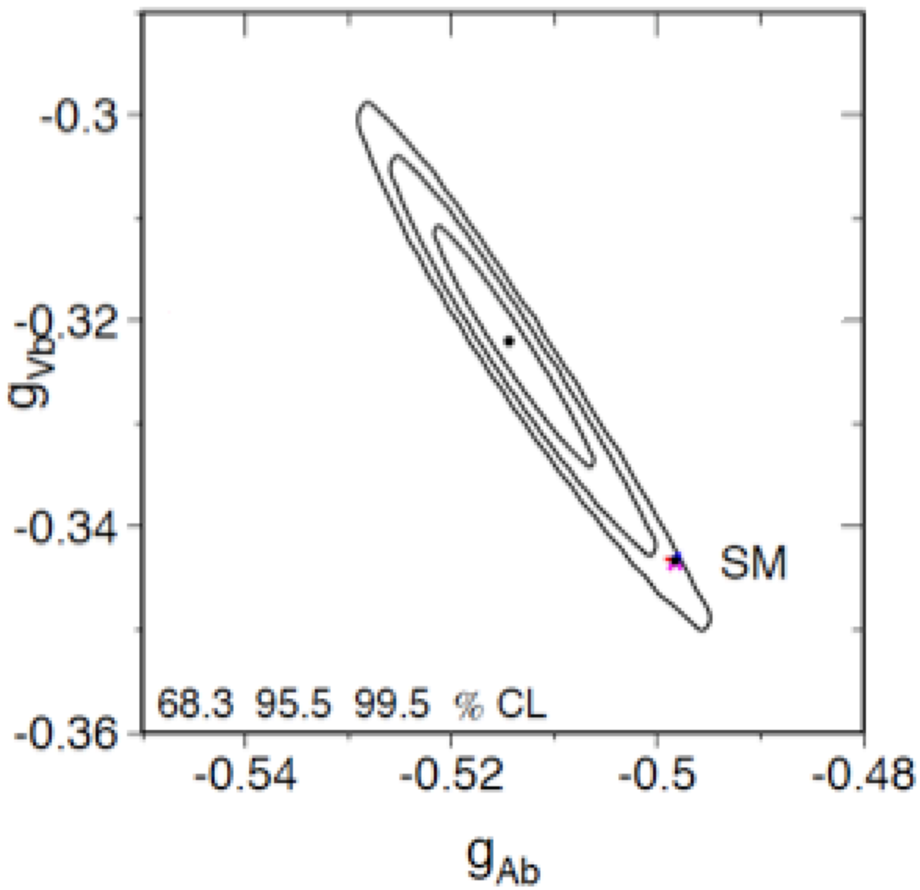
- Dominant term is the polarization forward-backward asymmetry whose coefficient is the beam polarization
- Measure tau polarization as a function of θ for the separately tagged beam polarization states
- Because it's a forward-backward asymmetry it doesn't use information we'd want to use for new physics studies

Tau Polarization as Beam Polarimeter

- Advantages:
  - Measures beam polarization at the IP: biggest uncertainty in Compton polarimeter measurement is likely the uncertainty in the transport of the polarization from the polarimeter to the IP.
  - It automatically incorporates a luminosity-weighted polarization measurement
  - If positron beam has stray polarization, it's effect is automatically included
- How well can we do? Use experience at LEP (in this case, use OPAL) and BaBar to guide us:
  - with a few ab^{-1} statistics not the issue; can expect systematic error of at least as small as 0.005

SM expectation & LEP Measurement of g_V^b

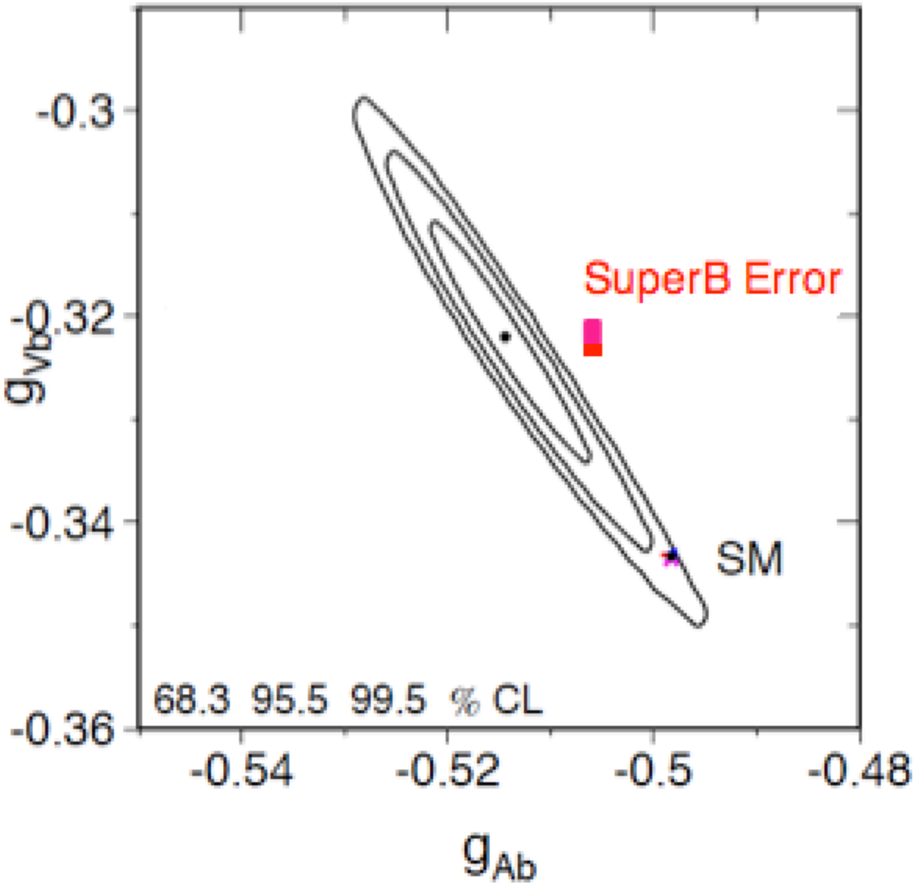
- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077



SM expectation & LEP Measurement of g_V^b

- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077

- with 1.0% polarization systematic error and 0.3% statistical error gives SuperB error of ±0.0032



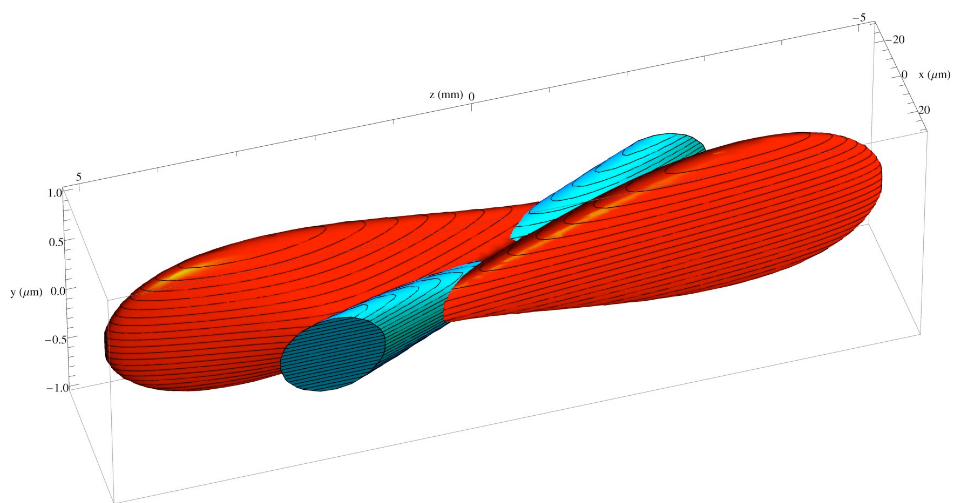
At SuperB no QCD corrections

- At LEP QCD corrections were required – hadronization effects, hard gluons, etc
- We think it was done properly at LEP with correctly assessed systematic uncertainties, but…
- An advantage at SuperB over a high energy machine, e.g. Z-factory, is that these corrections do not exist: we are coupling to pseudoscalars with no hadronization

Key Technologies

- Crossing angle IR with large Piwinski angle (DAFNE,KEKB)
- Crab waist scheme (Frascati, DAFNE)
- Very low IR vertical and horizontal beta functions (ILC)
- Low horizontal and vertical emittances (Light sources)
- Ampere beam currents (PEP-II, KEKB)

J. Seeman, HEPAP, May 2009



crab waist idea (Raimondi)

Italian Government Approval late 2010

- SuperB has been approved as the first in a list of 14 “flagship” projects within the new Italian national research plan.
- The national research plan has been endorsed by “CIPE” (the institution responsible for infrastructure long term plans)
- A financial allocation of 250 Million Euros in about five years has been approved for the “Superb flavour factory”
- INFN will contact agencies for MOUs on construction
- U.S. DOE contributing much of PEP-II and BaBar: negotiating details

Funds start to flow

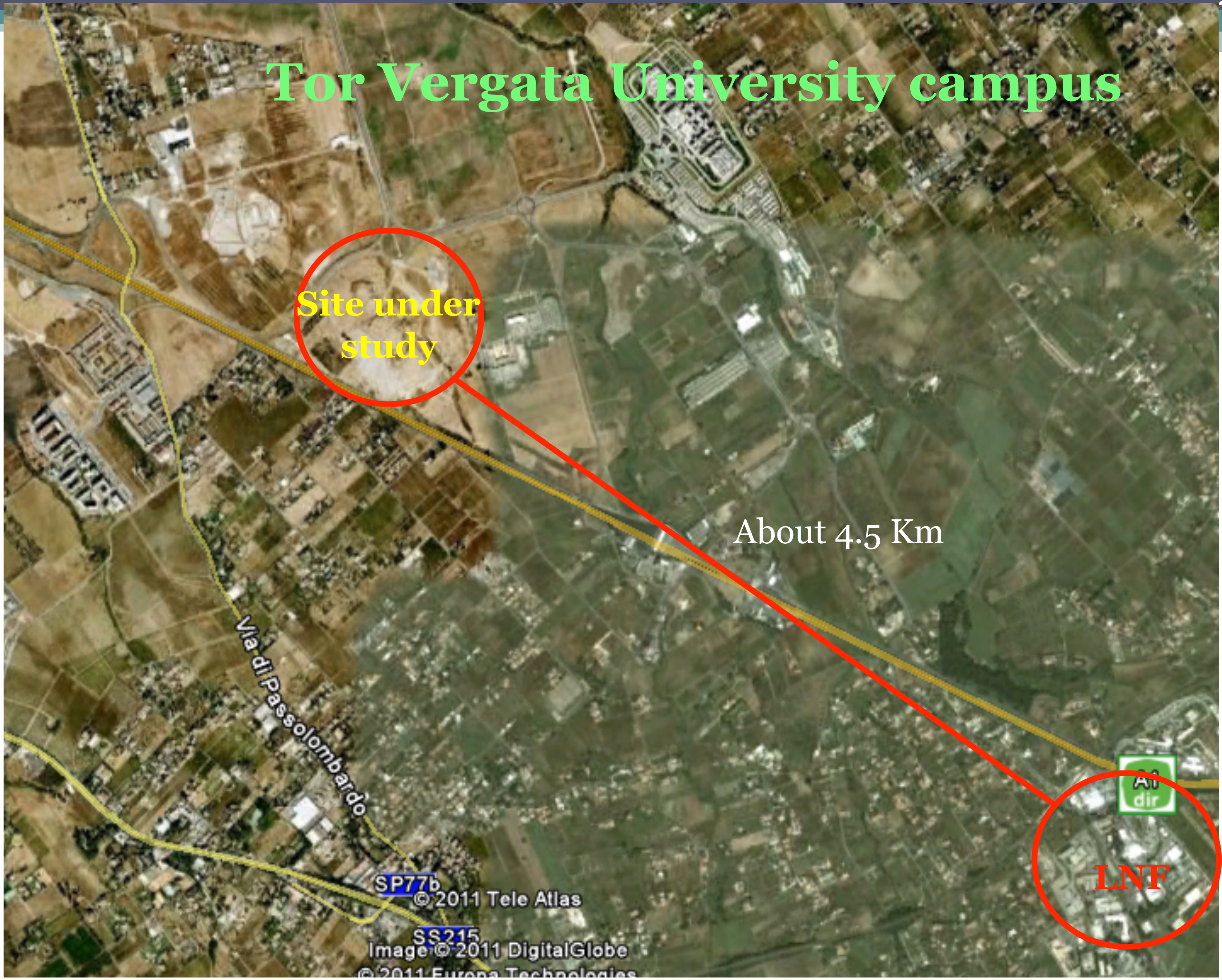
- At the end of 2010 an initial sum of 19 MEuros has been allocated
- A sum of the order of 50 is expected for 2011 budget
- An early allocation of part of the 2011 budget is foreseeable before summer

First expenses

- Integrating the team: enrolment of new people
- Civil engineering projects
- Preliminary site related works

Site

- Requirements:
  - Extension
  - Electric power supply
  - Cooling
  - Vibrations
- preferred: at Frascati or nearby


Tor Vergata University campus
Site under study
About 4.5 Km
LNF
Via di Passolombardo
SP77b
SS215
A1 dir
© 2011 Tele Atlas
Image © 2011 DigitalGlobe
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Tor Vergata option

- Autonomous interest from a wide community of the University (not only physicists)
- First contacts for a feasibility evaluation
  - Space
  - Electricity
  - Water
  - permits

Site requirements satisfied

- Extension of the order of 300000 square meters
- 2 x 150 kilovolt electric supplies nearby
- Water supply adequate and the possibility of additional supply from a number of pits
- Vibration measurements: the good surprise
- Site archaeology free

Official steps

- On May 24 a presentation to the academic community
- A letter from the Rector on may 28 making the site available
- The decision to move with this solution was taken by the May 29 by INFN board of directors
- The site has been decided

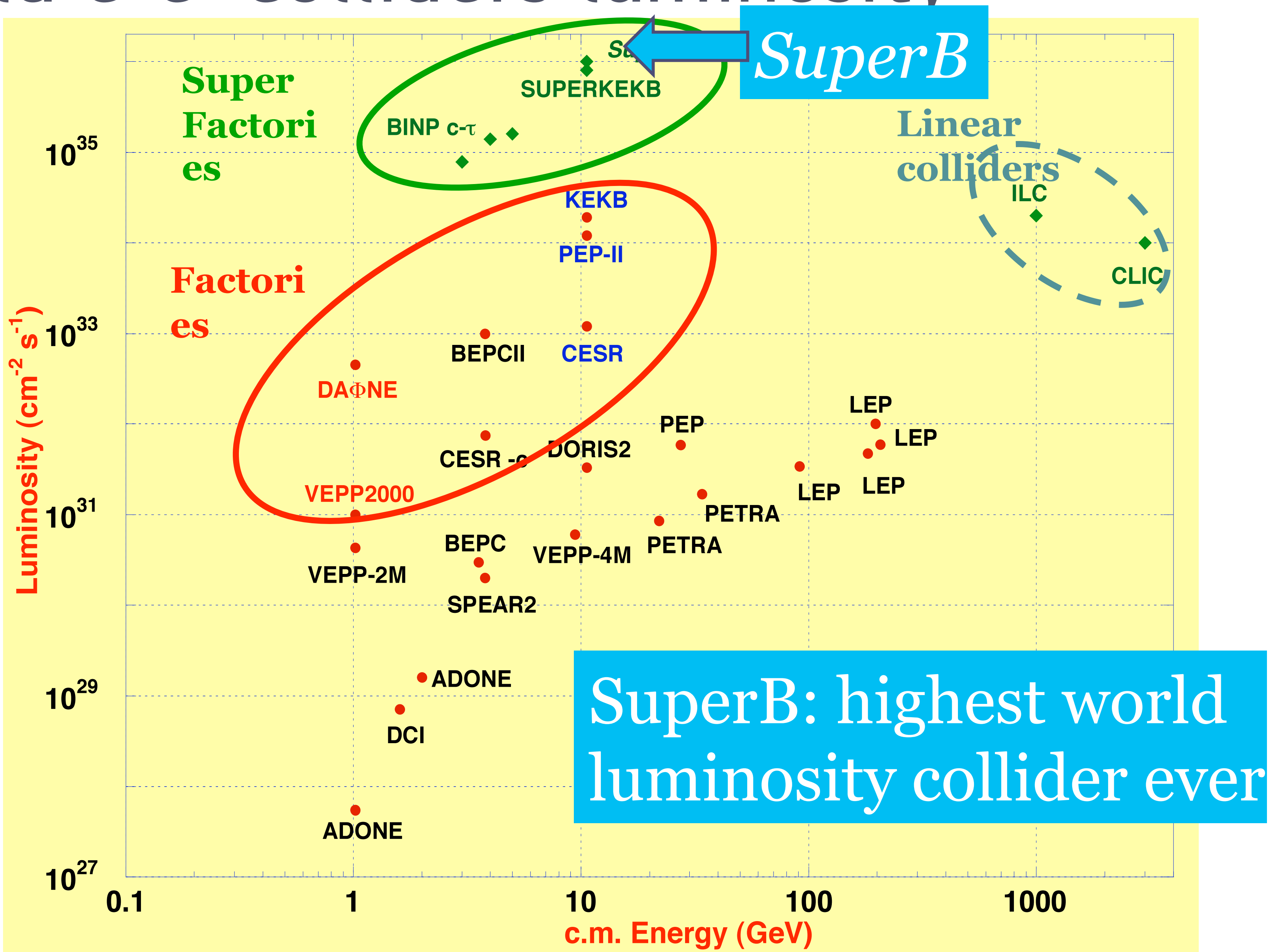
governance

- Three phases
  - INFN: the past and present starting phase
  - Consortium: as soon as possible (less than a year) as an independent legal entity
    - Following main European infrastructures
    - More flexibility in the organisation
    - Can directly associate foreign partners (EGO like)
    - An “intermediate solution”
  - European consortium (ERIC): the final structure

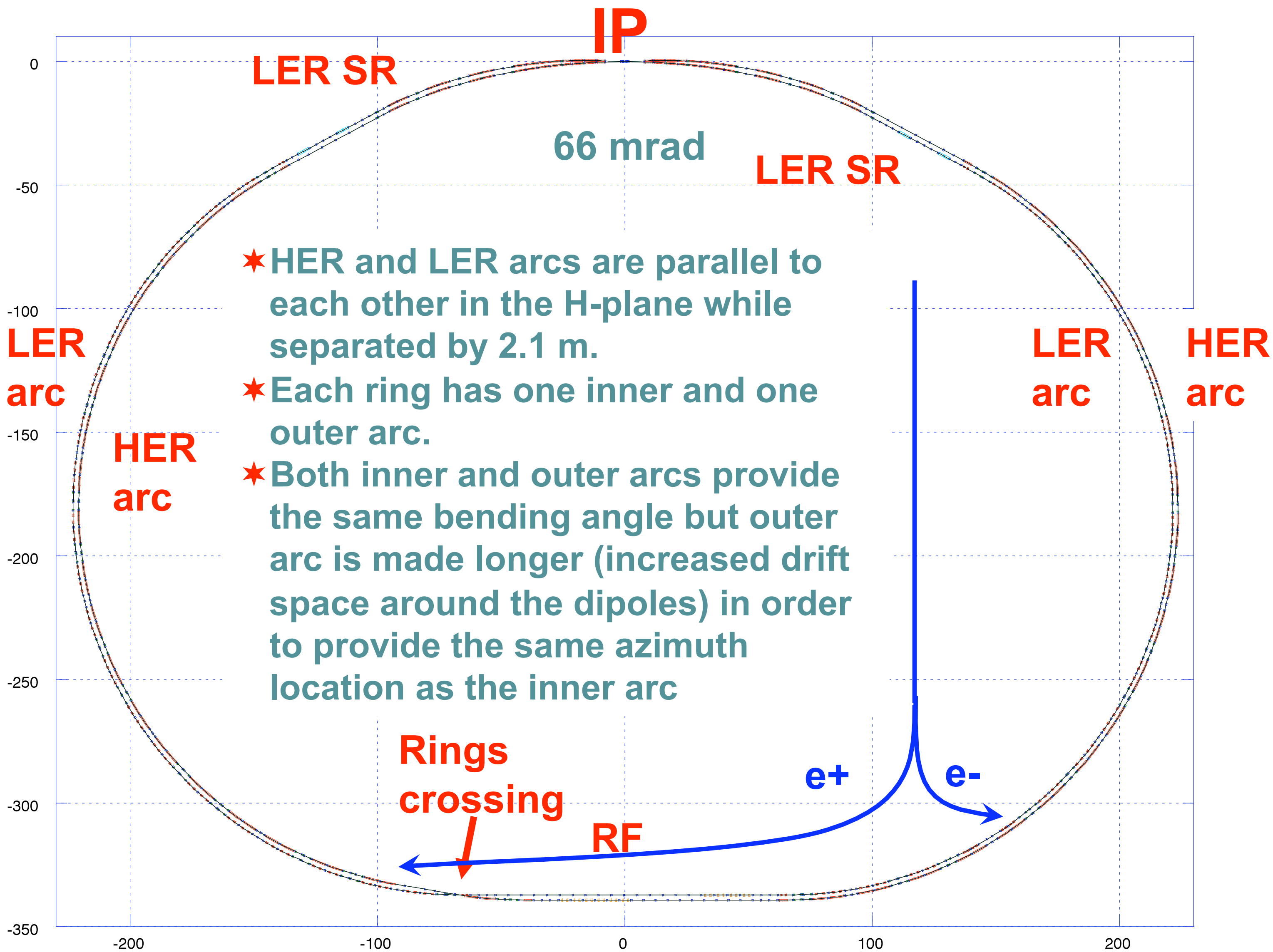
governance

- A CERN-like organisation
  - A director general and a directorate
    - Departments under director's supervision
  - A scientific evaluation committee
    - Science
    - Machine
  - A finance evaluation committee
- A known and working scheme
- proposed name for the Consortium:
  - Cabibbo Lab

World e⁺e⁻ colliders luminosity

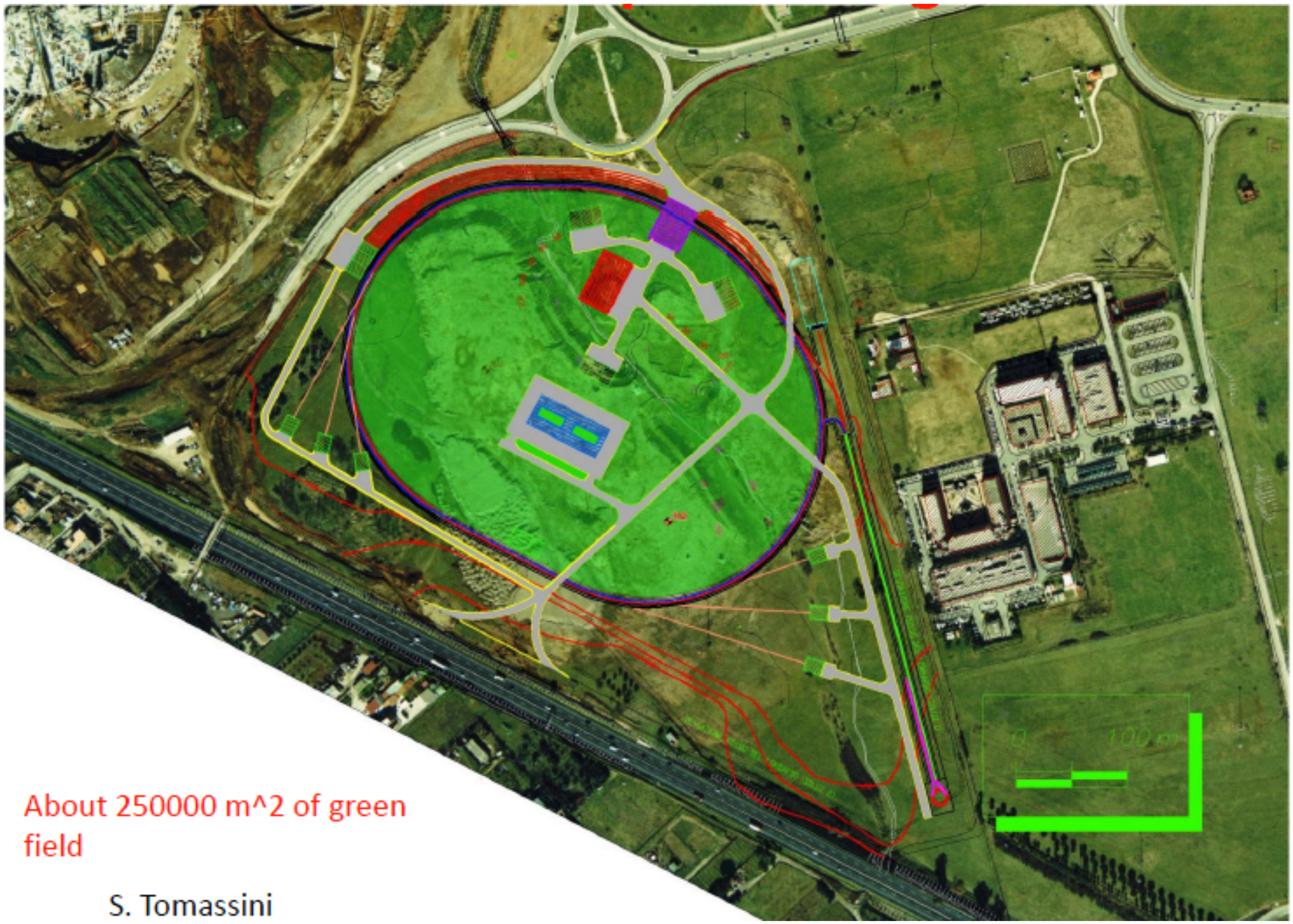


Present layout: 2 rings, 1 tunnel



- 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

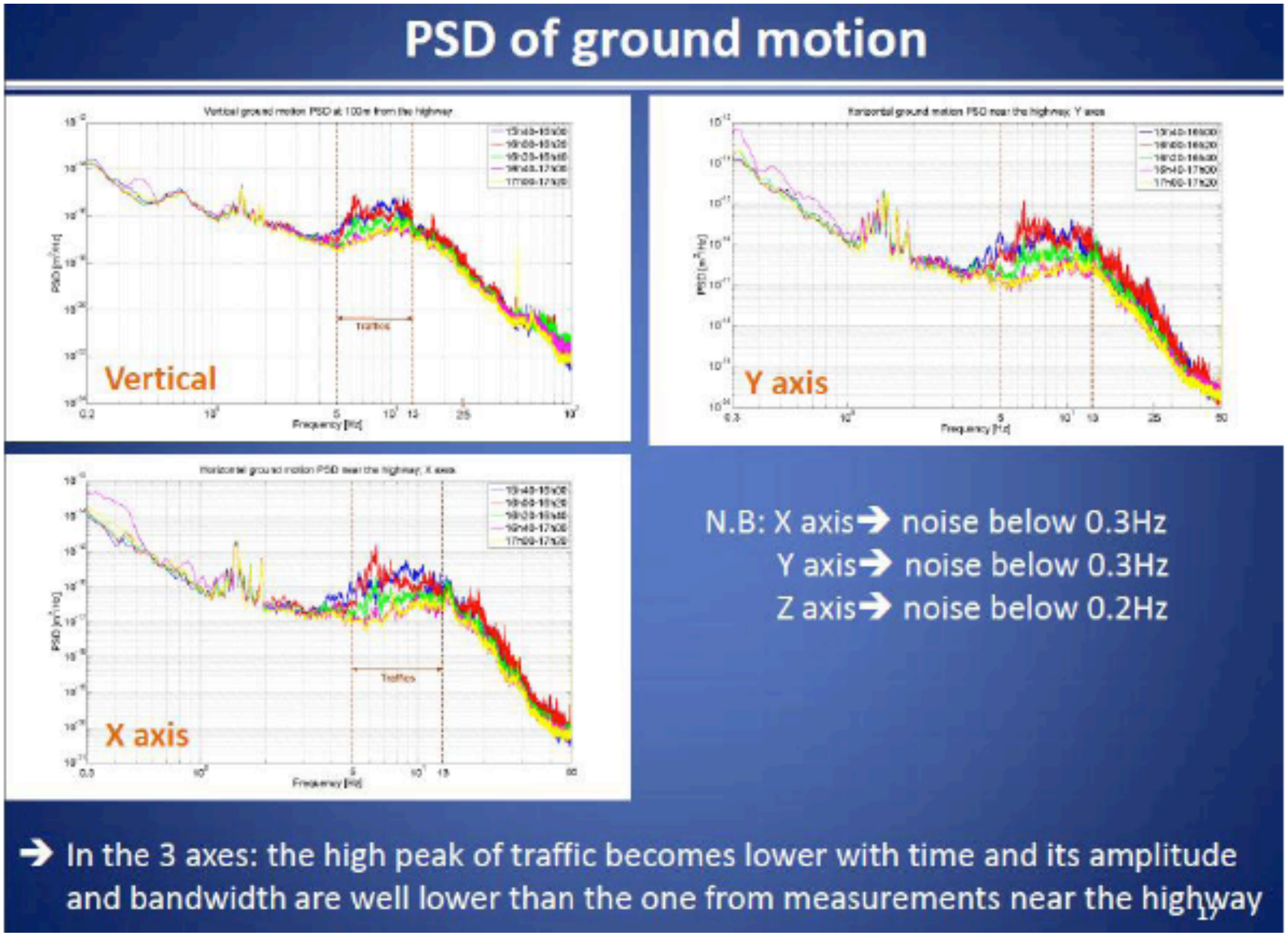
Tor Vergata site



About 250000 m^2 of green field

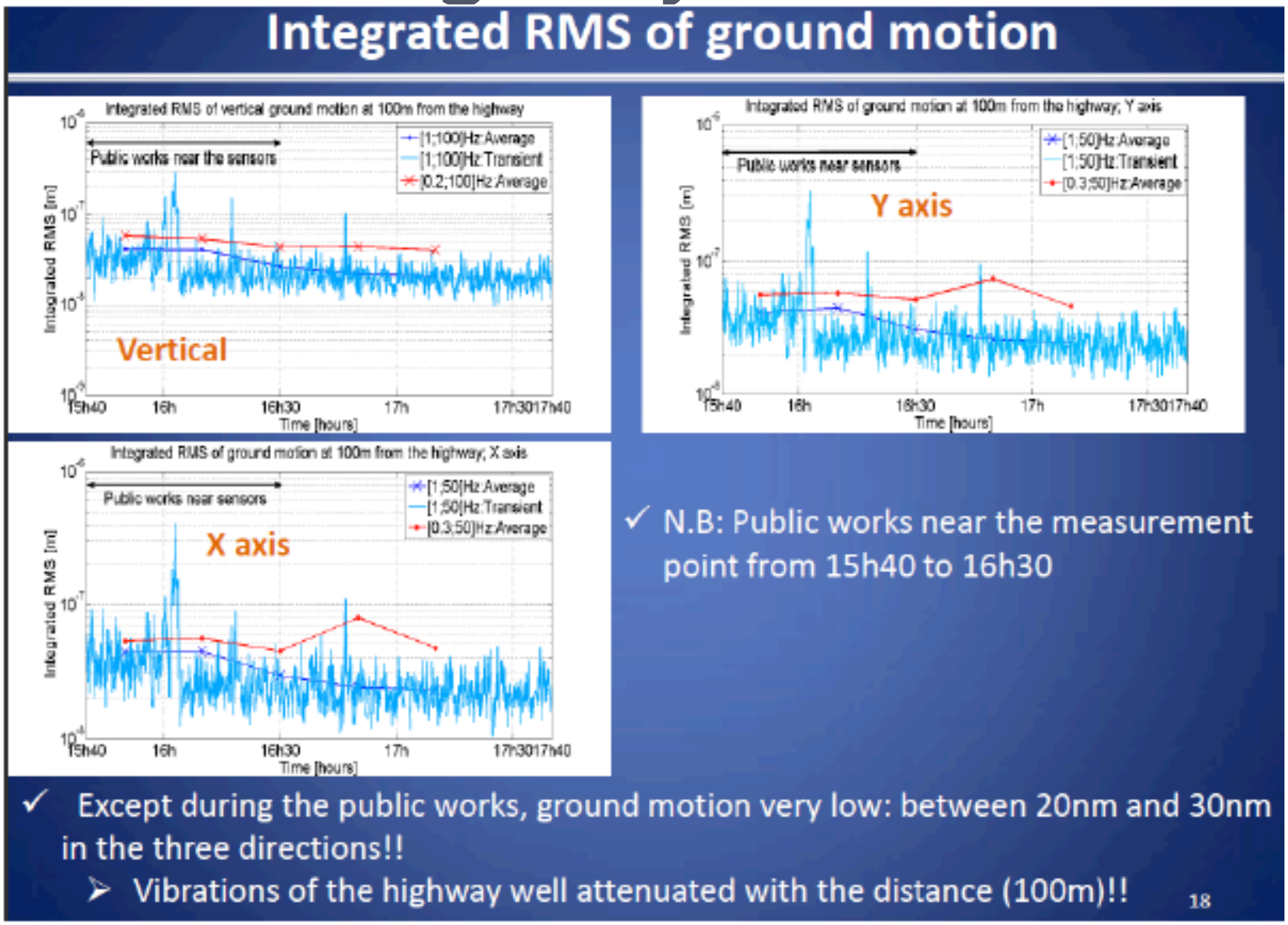
S. Tomassini

Vibration studies



Bolzon et al, presented by John Seeman

Vibration studies 100m from highway



Bolzon et al, presented by John Seeman

Vibration Budget

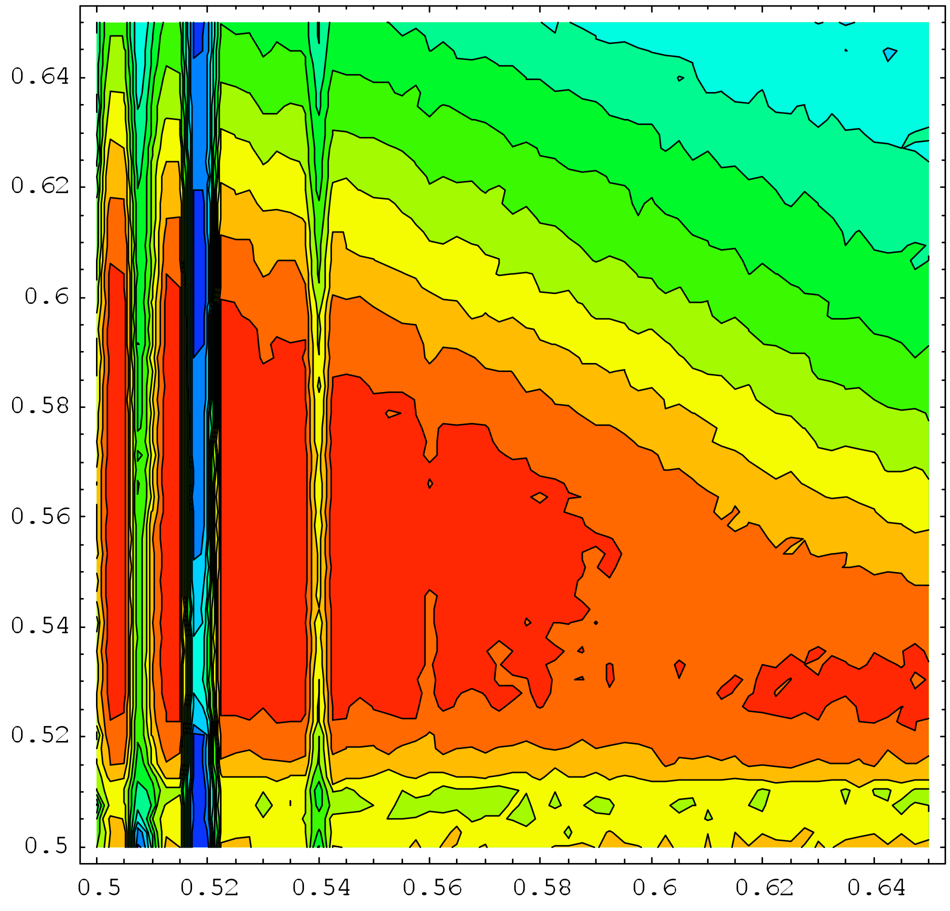
	Request (vertical displacement)	Measured (vertical displacement)
IP	300 nm	20-40 nm
Final Focus	300 nm	20-30 nm
Arcs	500 nm	20-30 nm

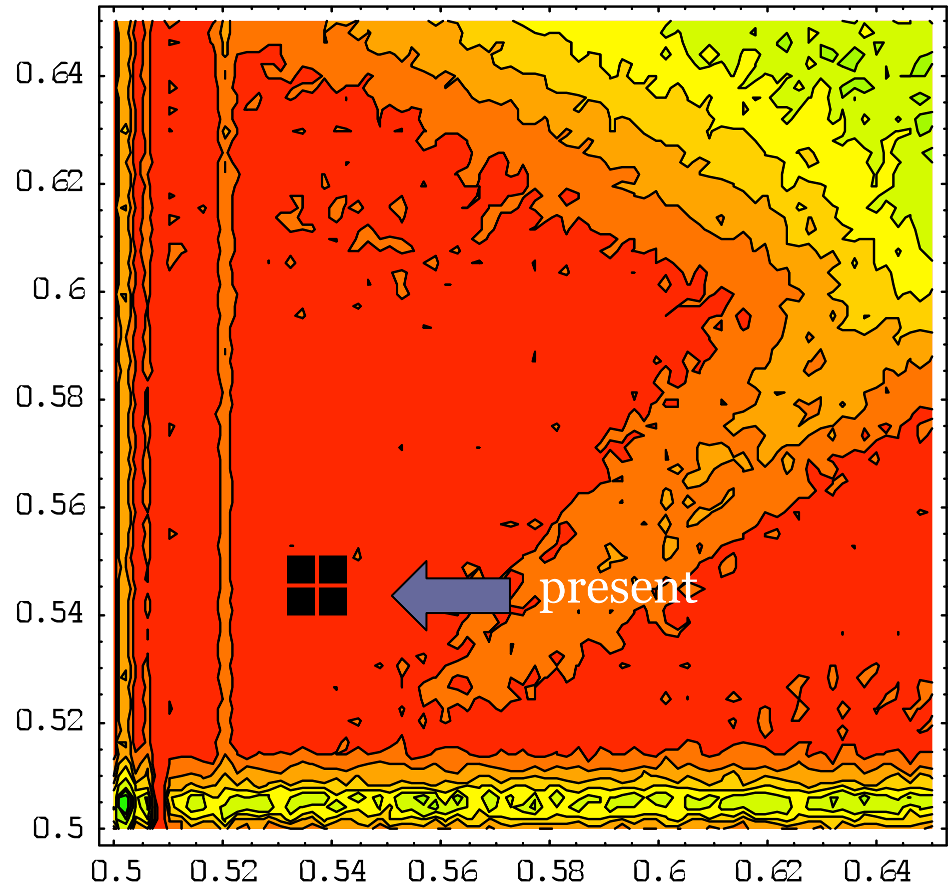
S. Tomassini, presented by John Seeman

The success phase space is increasing…

D.Shatilov

CDR, $\xi_y = 0.17$ CDR2, $\xi_y = 0.097$



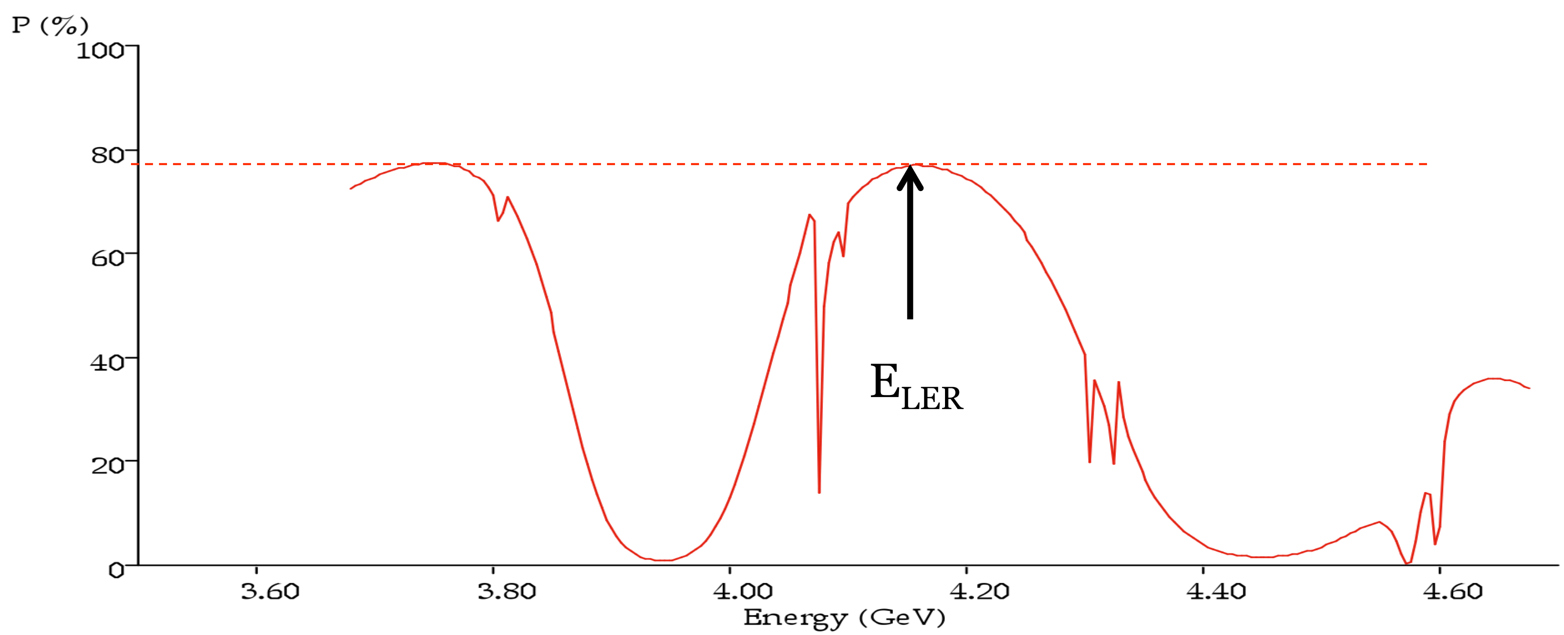


Beam-beam tune scan

L (red) = 1. ·10^{36}

Polarization resonances

- Beam polarization resonances do constrain beam energy choice
- Plot shows the resonances in the energy range of LER
- Beam polarization computed assuming
  - 90% beam polarization at injection
  - 3.5 minutes of beam lifetime (beam-beam limited)
- From this plot is clear that the best energy for LER should be 4.18 GeV → HER must be 6.7 GeV



SuperB Canada

Current Canadian Group:

- UBC: C. Hearty, R. So, J.-F. Caron
- McGill: P. Patel, S. Robertson, D. Swersky, D. Lindemann, R. Cheaib
- Montreal: J.-P. Martin, P. Taras
- Victoria: M. Roney, S. Dejong

PhD Graduate students split their time with BaBar

Project Grant submitted requests for support of 4x 50% PhD students, 4x 100% MSc students and one Postdoc ramping to 100% in 2012 – enables completion of TDR

Canadian Involvement

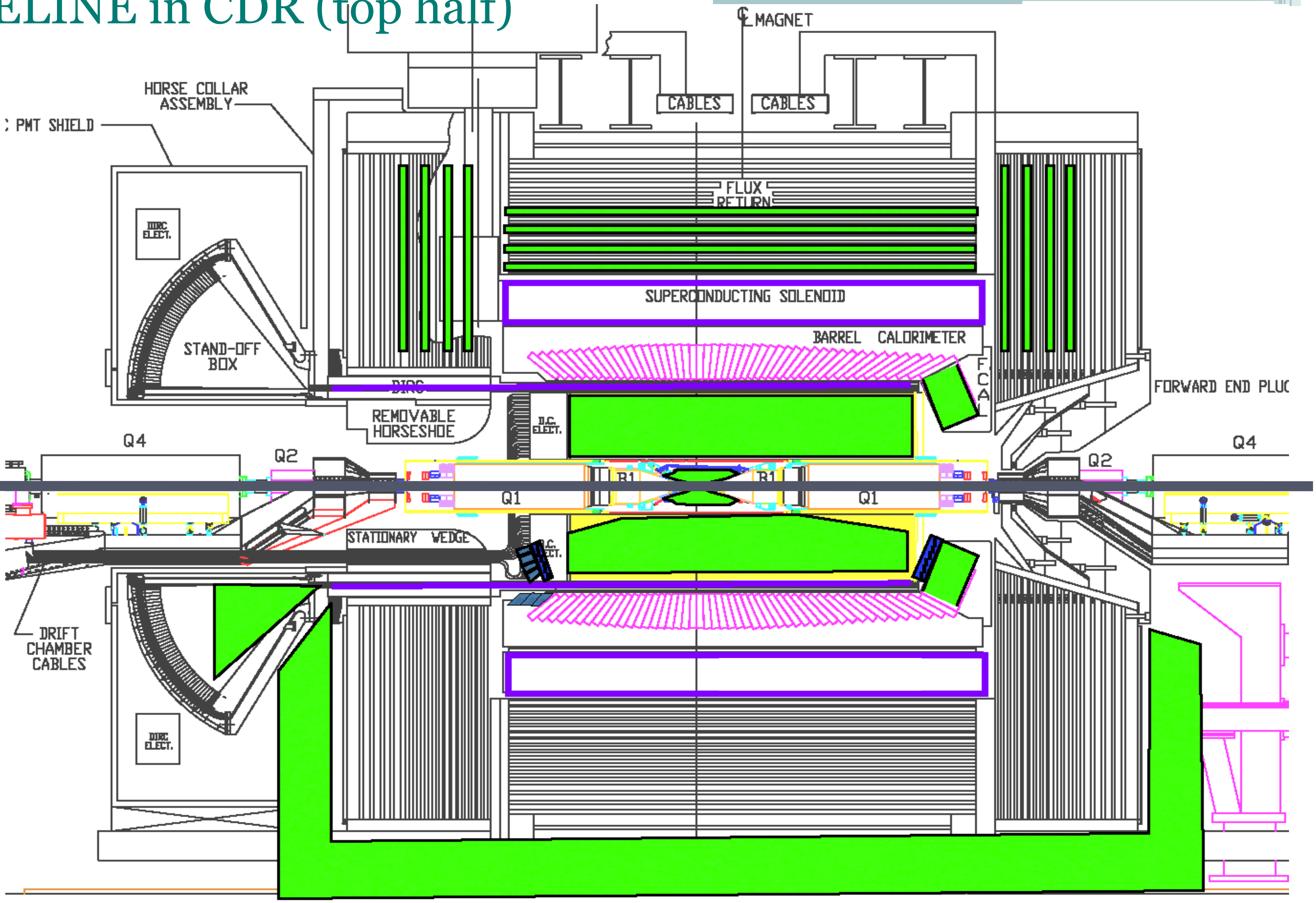
- Currently Frascati and Canada are the only DCH groups
- Discussions of moving forward on that project have started now that we have approval.

- Anticipate that more groups to join the project
- Expect Canada to contribute an appropriate share
- WE ARE NOW RECRUITING NEW CANADIAN COLLABORATORS

Reminder of Detector Overview

- Reuse BaBar components: magnet, DIRC bars, barrel CsI calorimeter.
- Some issues:
  - New silicon; add Layer 0 with smaller beam pipe
  - Need new way to read out DIRC
  - Need new technology for forward calorimeter
  - Possible forward PID
  - Likely backward EMC

BASELINE in CDR (top half)



OPTIONS (Bottom half)

Green items are new; others are reused from BaBar

Canadian Contributions to Drift Chamber

- Current focus is on TDR design for the drift chamber and expect to contribute to construction
- e.g. details of design; background studies; implementation of cluster counting option, etc
- Consider contributing up to 50% of the costs of the DCH, remainder provided by collaborators in Italy (LNF, Roma-2)

M&S Cost updates from Detector Whitepaper in $k CDN

Costs in $k CDN	
exchange	1.34
Costs in $k CDN	M&S
Endplates	737
Inner cylinder	211
Outer cylinder	134
Wire	324
Feedthroughs	462
Endplate systems	405
HV distribution and crates	166
Signal (from FEE to Opt links)	1,696
Assembly & stringing except robots	871
Stringing Robots	201
Gas System	268
Test	54
DCH part of Trigger (approx)	696
TOTAL	6,225
Total excluding gas system	5,957

50% DCH Canadian share would represent ~3M$CDN

foresee applying to combination of NSERC + CFI

Canadian DCH Contributions

- Scope for various levels of support
- Scope for different interests across Canada regarding types of contributions (e.g. crimp pin and feed through fabrication and testing; wire procurement and testing; development of stringing robotics; development of QC/ QA systems; etc …)
  - welcome additional Canadian groups – suitable matches for a variety of interests hardware or software

Canadian DCH Contributions

Discussions are underway regarding allocation of work-packages between Italian and Canadian institutions

- DCH will be strung at LNF
  - mechanical engineering will be done in Italy
- Target is to have Canadian sources fund ~half of DCH, looking at various combinations of construction only + project components requiring operational support
  - electronics contributions: UdM, started discussions with TRIUMF
  - gas system likely Canadian responsibility
  - …

Scope for HQP Training

- Currently, PhD students are on both BaBar and SuperB: expect this model to continue until data on SuperB available – BaBar preparing for long term reliable and stable access to data for analysis – excellent synergy with SuperB
- All BaBar PhD students have been the drivers of an analysis and principle author of at least one paper published in either PRL or PRD
- Opportunity for graduate students to work on SuperB hardware and publish BaBar physics paper
- New Canadian groups coming into SuperB would be welcomed into BaBar if they want their students to publish BaBar physics results

Summary

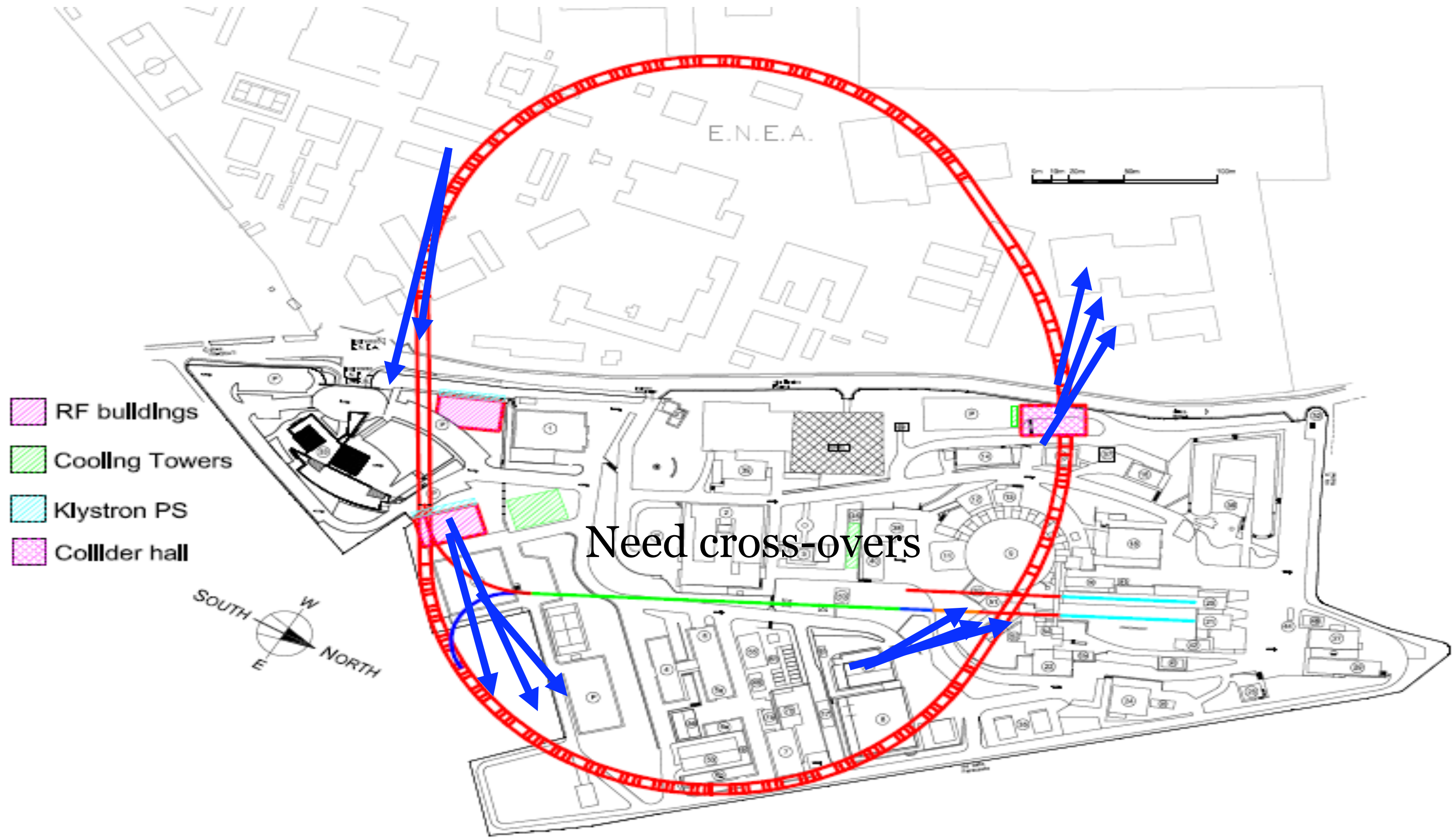
- SuperB is now approved and site is selected
- Extremely broad and exciting physics program with sensitivity to new physics that is complementary to the LHC and other EW precision measurements in Canadian program.
- Flexibility in ways that the machine can achieve 100× luminosity with beam currents and power comparable to current facilities.
- Canadian group is active in drift chamber design work, studies of backgrounds and physics potential
- EXCELLENT HQP training ground: construction+ physics
- Scope for different levels of support
- Scope for different interests
- Very Welcome to NEW COLLABORATORS

Additional slides

Why not AT Frascati itself?

- Need to go deep underground
- Surface space strongly constrained
- Half below the “Enea” lab
- Strong limitations on possible light source beamlines
- More difficult evolution into an international structure

Frascati Site



Other sites

- Solutions available at different far locations
  - Piemonte (near Torino)
  - Sardinia
  - Campania
  - Puglia
- Rome area
  - Private solutions
  - Tor Vergata (Roma-2)