Status of SuperB Detector

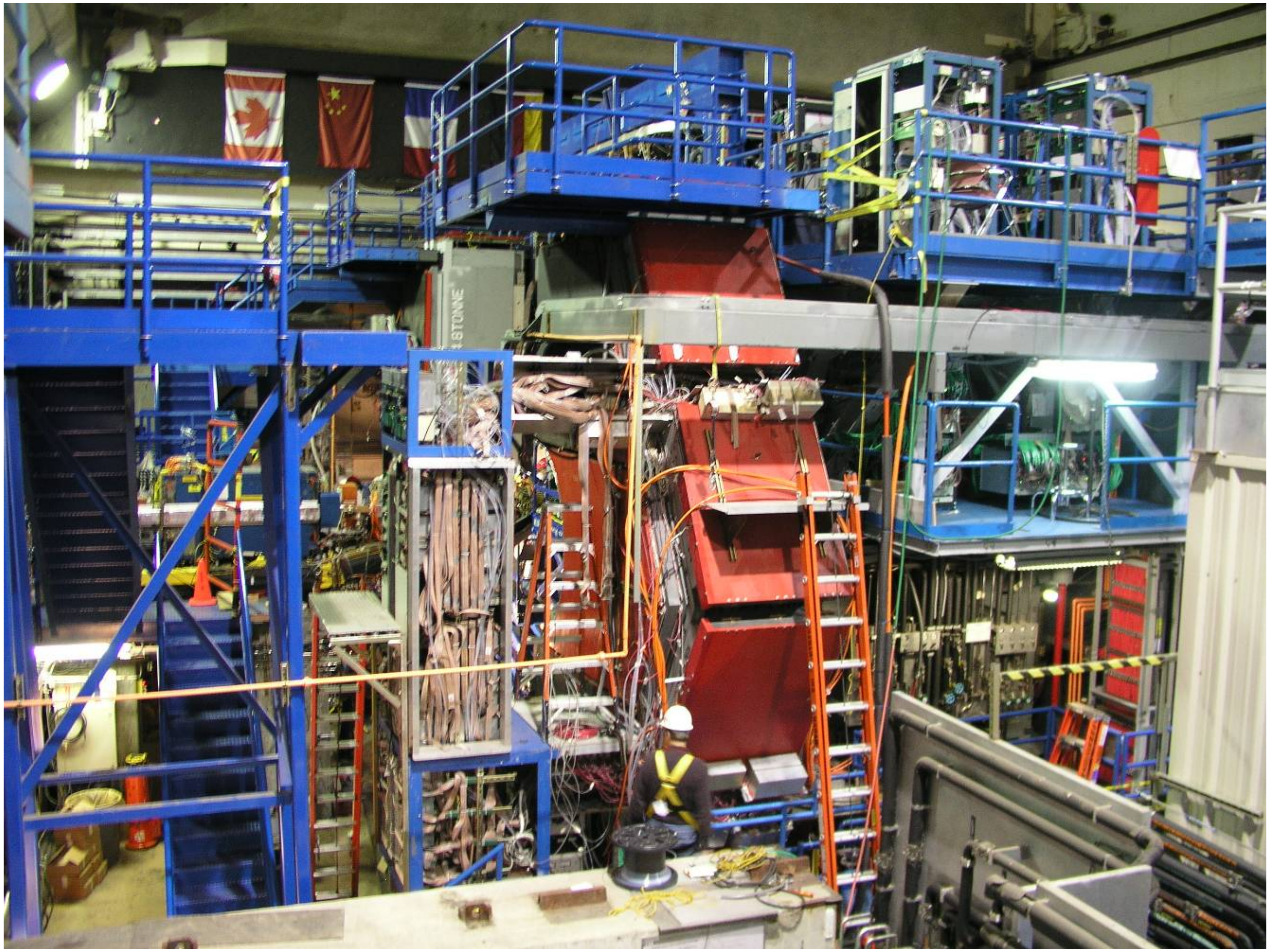
February 9, 2012
Joint Belle-II and SuperB Background Workshop
Vienna, Austria, 9-10 February, 2012

Francesco Forti
INFN and University, Pisa

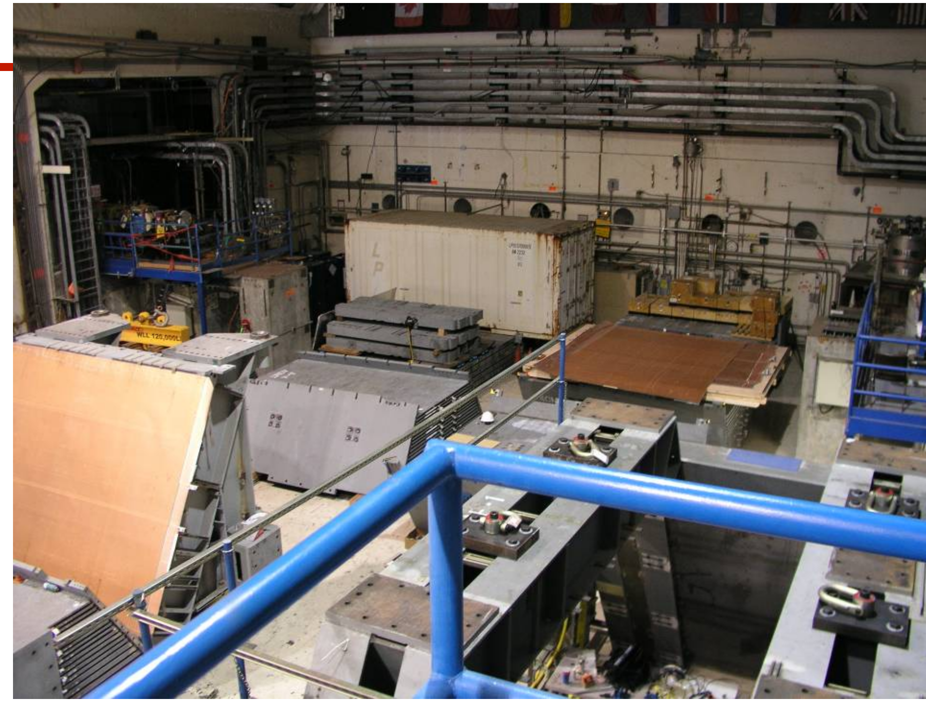
Detector Topics

- Babar decomissioning
- Overall description
- Subsystems
  - MDI
  - SVT
  - DCH
  - PID
  - EMC
  - IFR
  - ETD

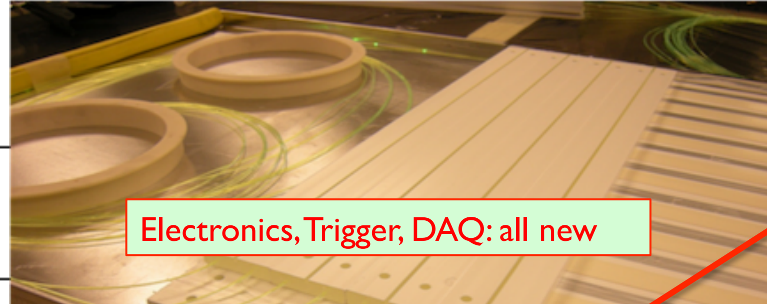
BABAR - March 2009



Deconstructed Onion Storage_ CEH, IR2



Detector … tions)



Electronics, Trigger, DAQ: all new

IFR: Replace LSST with scintillator + WLS Fibers + SiPM

Solenoid

PID: Focu
Reuse qu
New Ligh

EMC: Opt
Pb / Scinti

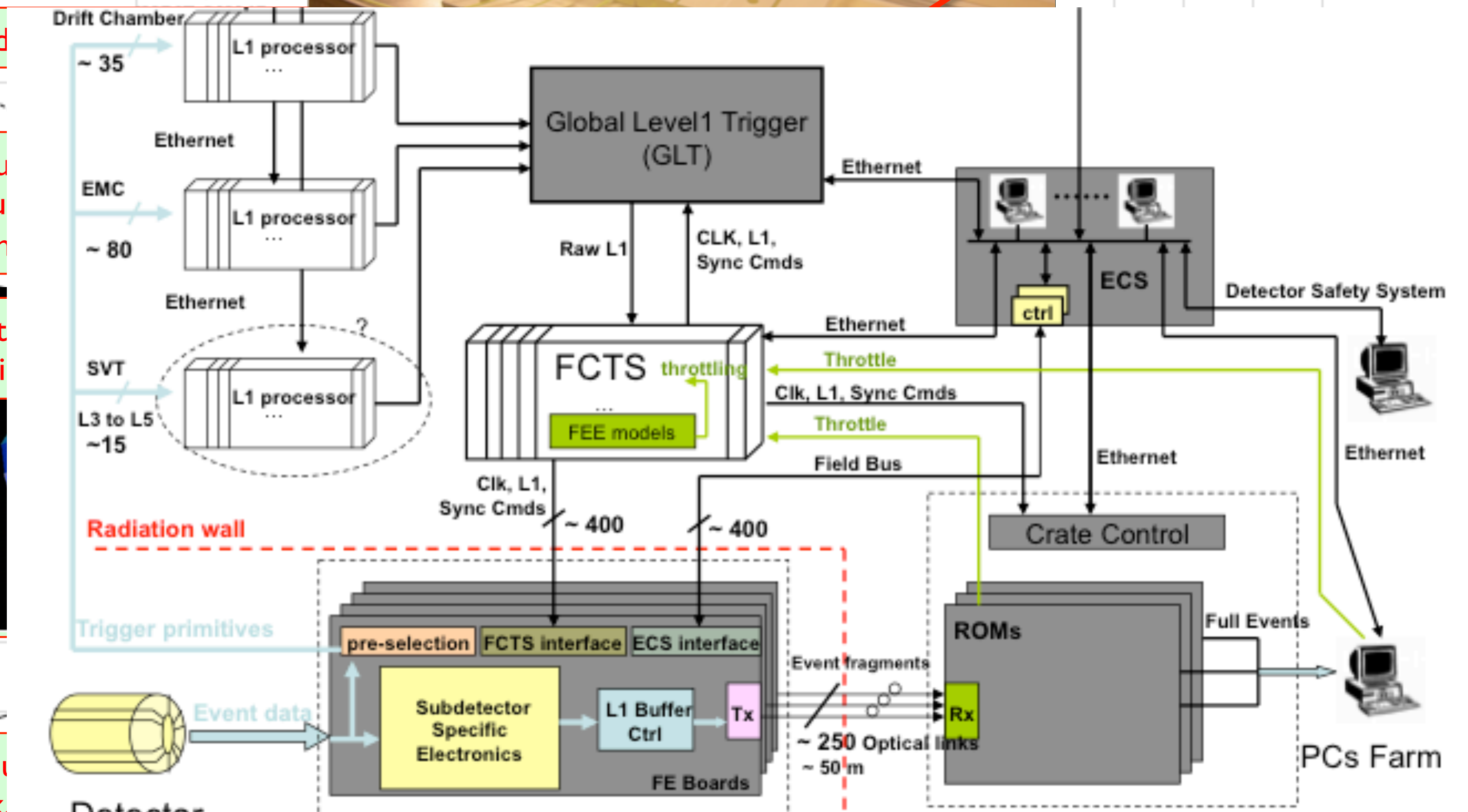
SVT: Fiv
strips +

Backgrou
Toushek

TI)barrel wit

rd, faster

20)



Collaboration

System	Institutions
SVT	Bologna, Milano, Pavia, Pisa, Rome3, Torino, Trieste, Trento, LBNL, Queen Mary, RAL, Strasbourg, Bari
DCH	LNF, McGill, Montreal, TRIUMF, UBC, Victoria, Lecce
PID	SLAC, BINP, Cincinnati, Bari, Padova, Maryland, LAL, LPNHE, UC Riverside
EMC	Bergen, Caltech, Perugia, Rome1, Napoli
IFR	Ferrara, Padova, Krakow, Bologna
ETD	SLAC, Caltech, Napoli, Bologna, LAL, Padova, Rome3
Computing	Padova, Ferrara, Torino, Bari, Bologna, Rome2, Pisa, Perugia, LNF, LBNL, Napoli, SLAC
Magnet/ Integration	SLAC, LNF, Pisa, Genova
Backgrounds/MDI	SLAC, Pisa, LNF, LNS, Cagliari, Ohio State
TBD	(Valencia, Barcelona, Annecy, Tel Aviv, Liverpool, Kiev, ITEP, Kansas, Livermore, Louisville, Notre Dame,Ohio State, Princeton, Southern Methodist, South Carolina, Austin, Utah)

+ Mexico
+ China

12 Nations
52 Institutions
252 Collaborators

…and growing. Will be formalized soon.

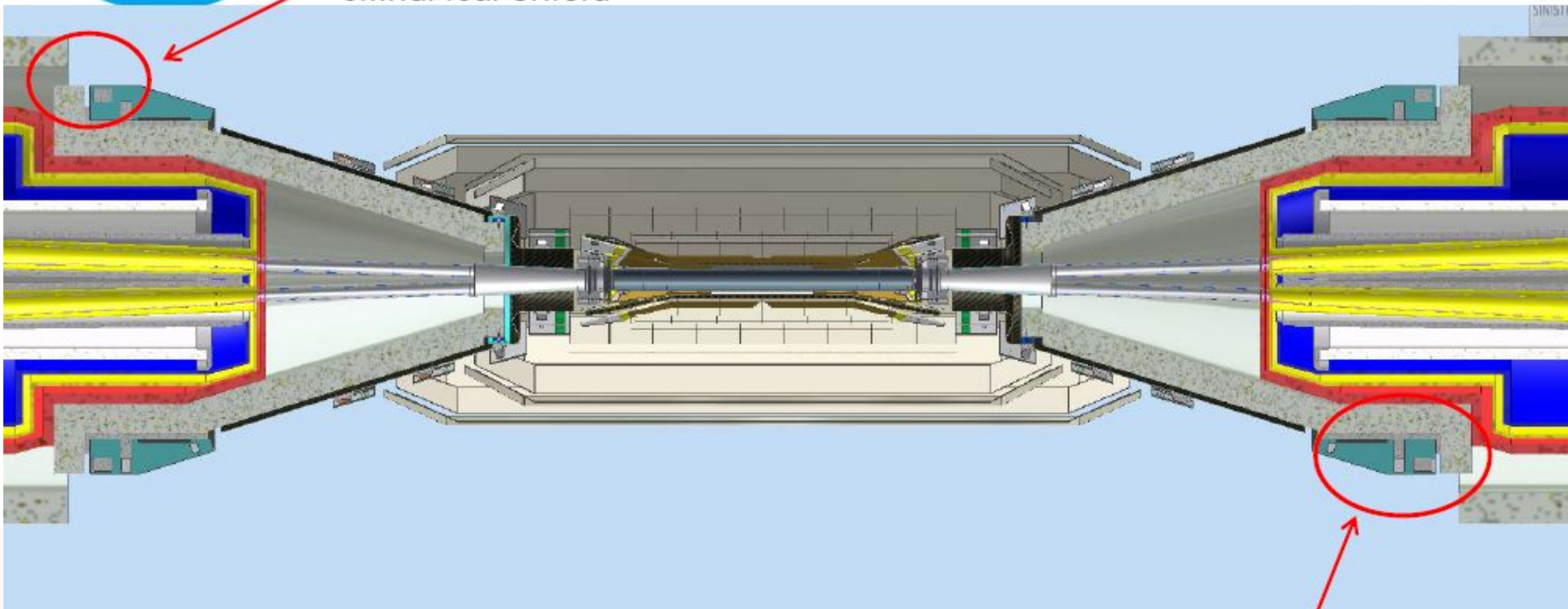

The Bancroft Building

MDI

Eugenio Paoloni

I.R. Layout

W conical shield
indipendent from
cilindrical shield



Transition card with radial dimension useful
to remain below ext diam W conical shield to
allow movement respect to cilindrical shield

Background sources

	Cross section	Evt/crossing	Scattering Rate	
Beam Strahlung	~340 mbarn ($E\gamma/E_{beam} > 1\%$)	~1400	0.34 THz	Luminosity lifetime driving term
Beam Strahlung	~150 mbarn ($E\gamma/E_{beam} > 10\%$)	~630	0.15 THz	Losses "near" the IP
e^+e^- production	~7.3 mbarn	~31	7.3 GHz	
e^+e^- production (seen by L0 @ 1.4 cm coverage 300 mRad)	~ 80 μbarn	~0.34	80 MHz	Main SVT L0 Background
Elastic Bhabha	$O(10^{-4})$ mbarn (Det. acceptance)	~420/Million	100 KHz	~L1 Trigger rate
$\Upsilon(4S)$	$O(10^{-6})$ mbarn	~4.2/Million	1 KHz	Physics

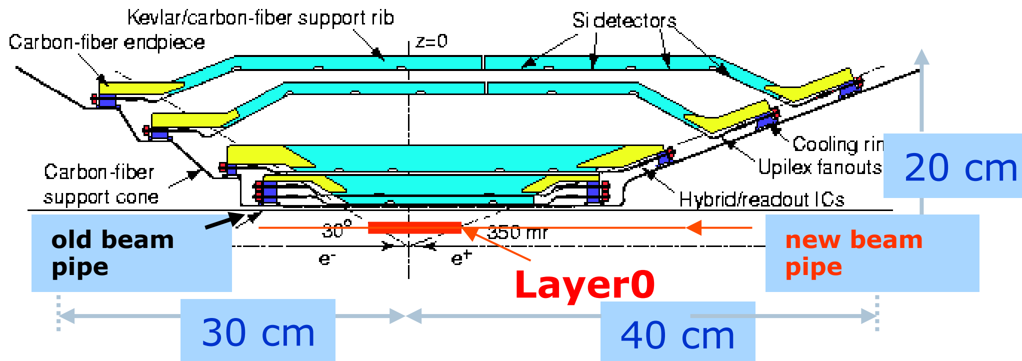
SVT

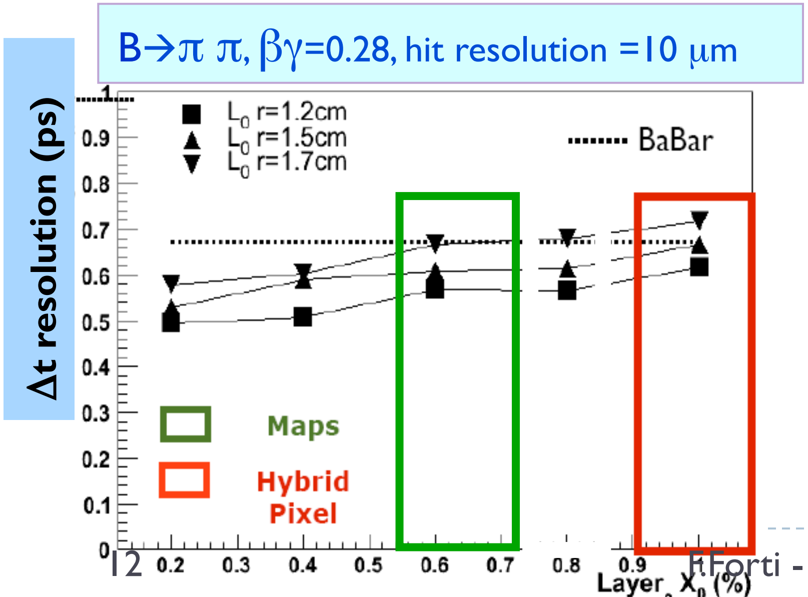
Giuliana Rizzo

The SuperB Silicon Vertex Tracker

- 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



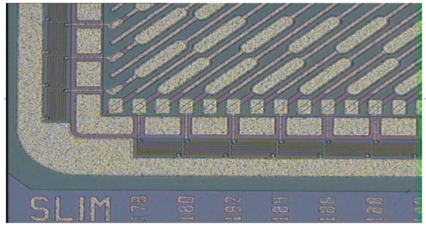


- Physycs performance and back. levels set stringent requirements on Layer0:
  - R~1.5 cm, material budget < 1% X_0,, ,
  - hit resolution 10-15 um in both coordinates
  - Track rate > 5MHz/cm^2 (with large cluster too!), TID > 3MRad/yr
- Several options under study for Layer0

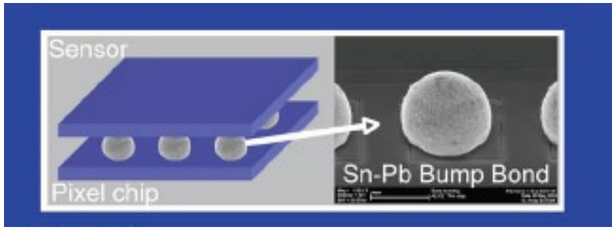
SuperB SVT Layer 0 technology options

Complexity

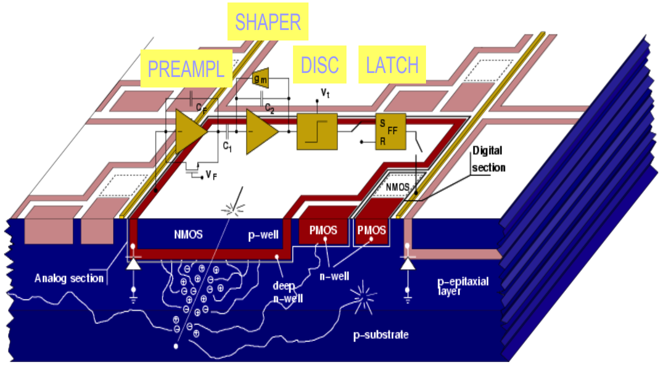
- **Striplets option: mature technology, not so robust against background occupancy.**
  - Marginal with back. track rate higher than ~ 5 MHz/cm^2
  - FE chip development & engineering of module design needed



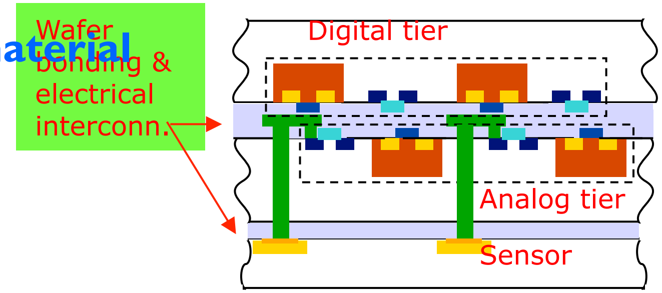
- **Hybrid Pixel option: viable, although marginal.**
  - Reduction of total material needed!
  - FE chip with 50x50 μm^2 pitch & fast readout (hit rate 100MHz/cm2) under development → FE prototype chip (4k pixel, ST 130 nm) successfully tested with pixel sensor matrix connected.



- **CMOS MAPS option: new & challenging technology.**
  - Sensor & readout in 50 μm thick chip!
  - Extensive R&D (SLIM5-Collaboration) on
    - Deep N-well devices 50x50 μm^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.

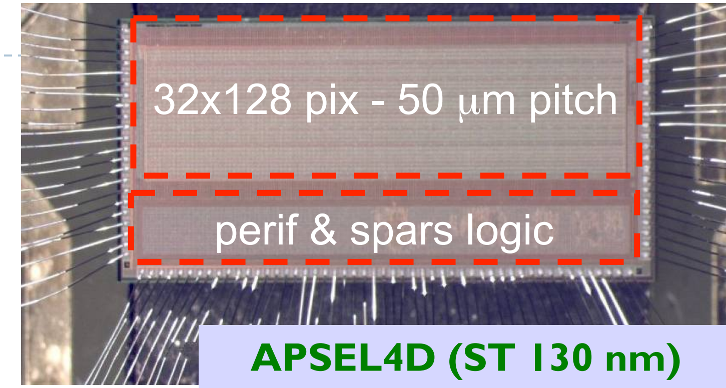


- **Thin pixels with Vertical Integration: reduction of material and improved performance.**
  - Two options are being pursued (VIPIX-Collaboration)
    - DNW MAPS with 2 tiers
    - Hybrid Pixel: FE chip with 2 tiers + high resistivity sensor



Recent results on pixel R&D for Layer0

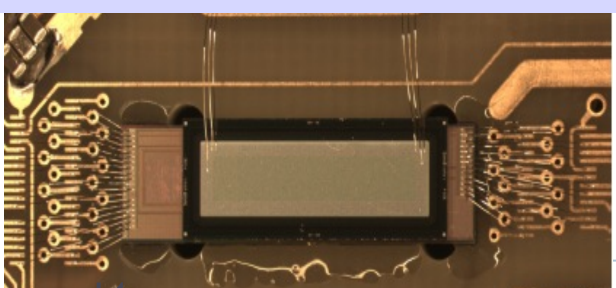
- CMOS DNW MAPS with data push sparsified readout + timestamp tested with beams:
  - resolution of 14 μm (digital output)
  - hit efficiency up to 92 %



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

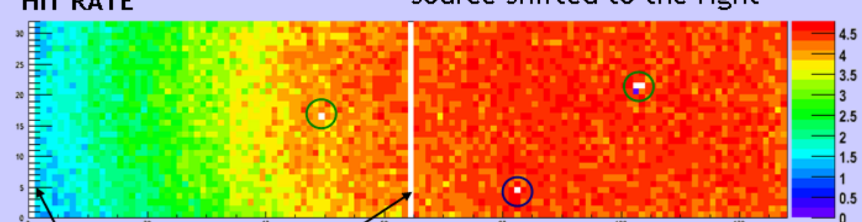
- HYBRID PIXEL: front-end chip with 50x50 μm pitch & fast readout architecture tested with sensor matrix
  - Optimized for hit rate 100MHz/cm2 on full chip size (~1.3 cm2)
  - VHDL simulation: Effi > 98% @ 60 MHz RDclock
  - Timestamp granularity 0.2-5.0 μs

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 μm² pitch & working sensor!!



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

DCH

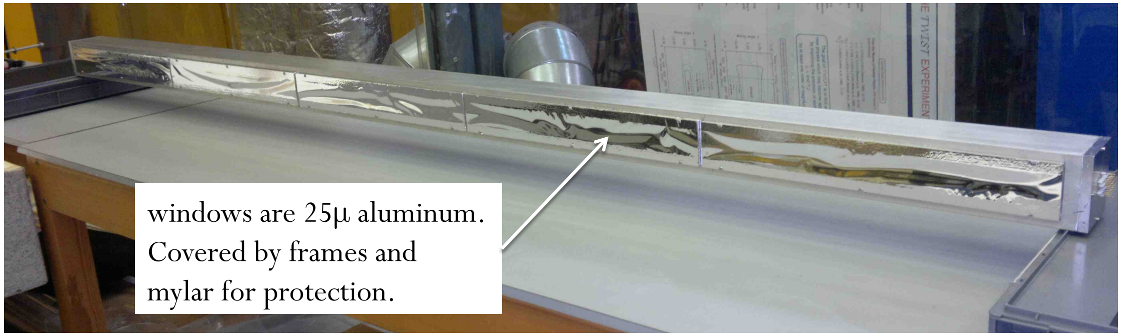
Giuseppe Finocchiaro and Mike Roney

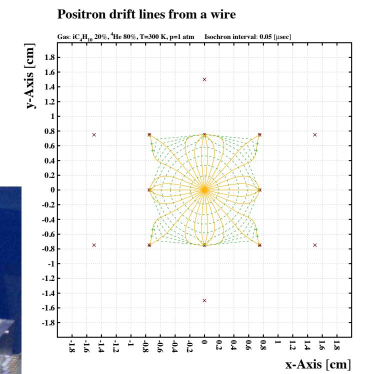
The SuperB Drift Chamber (DCH)

- Large volume gas tracking system for SuperB providing measurements of charged particle momentum and ionization energy loss used for particle identification.
- Primary device in SuperB to measure velocities of particles having momenta below ~700MeV/c
- About 40 layers of centimetre-sized cells strung approximately parallel to the beamline with subset of layers are strung at a small stereo angle in order to provide measurements along z, the beam axis
- Provide momentum measurements with precision of ~0.4% for tracks with p_t =1 GeV/c
- The DCH outer radius is constrained to 809mm by the DIRC quartz bars
- the nominal BABAR DCH inner radius of 236mm currently used until final focus cooling system constraints finalized
- chamber length of 2764mm at the outer radius: depends on forward PID and backward EMC

Prototype Chambers

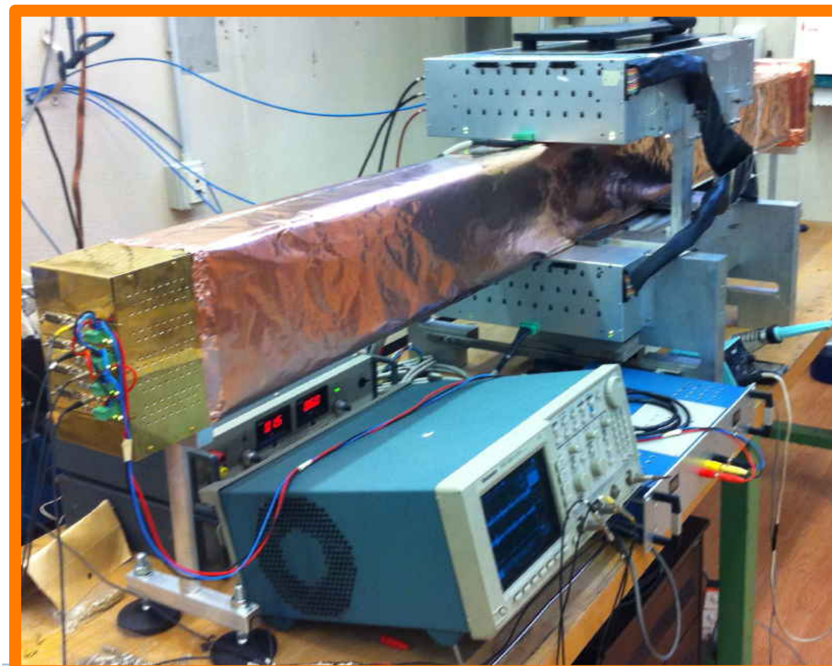
- 2.7m long single-cell chamber



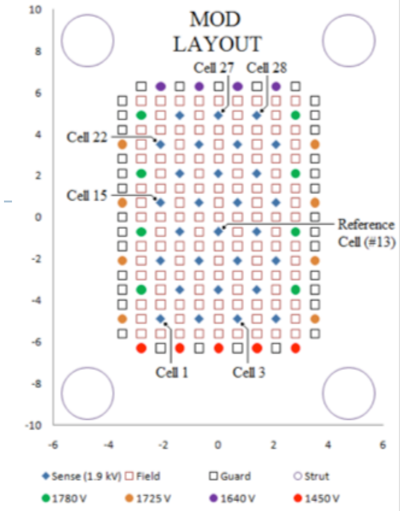


- Prototype preamp by U. Montreal group

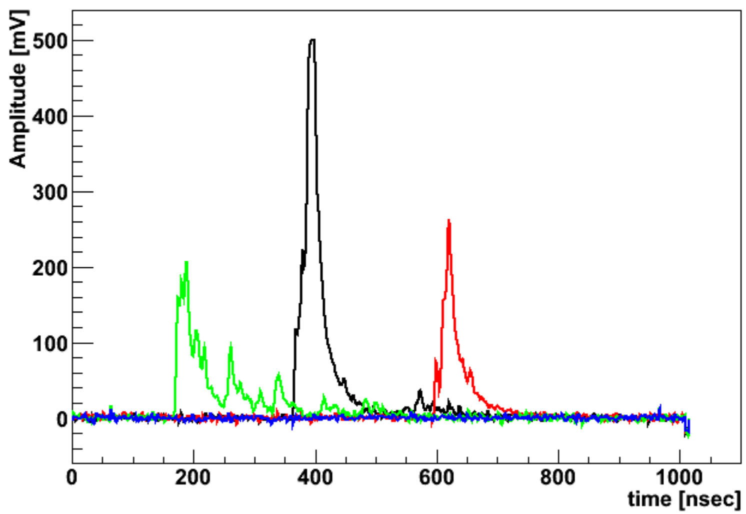
- *2.5m* long prototype with 28 sense wires arranged in 8 layers
  - Goal: study DCH response from single clusters in a realistic environment, and serve as a test bench for the final FEE and for test of DCH trigger implementation
  - Prototype 2 is currently integrated in the tracking telescope system at LNF



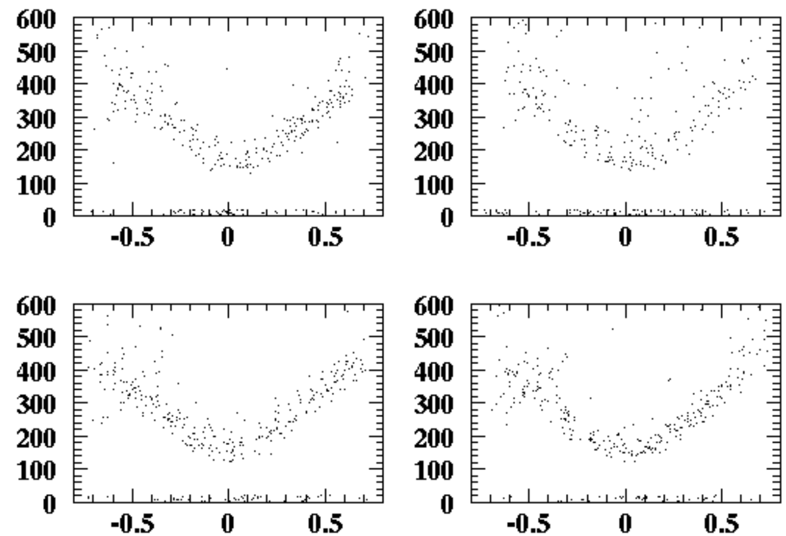
Prototype 2 (cont.)



- Full commissioning and debugging is ongoing using cosmic ray data and on the BTF beam at LNF

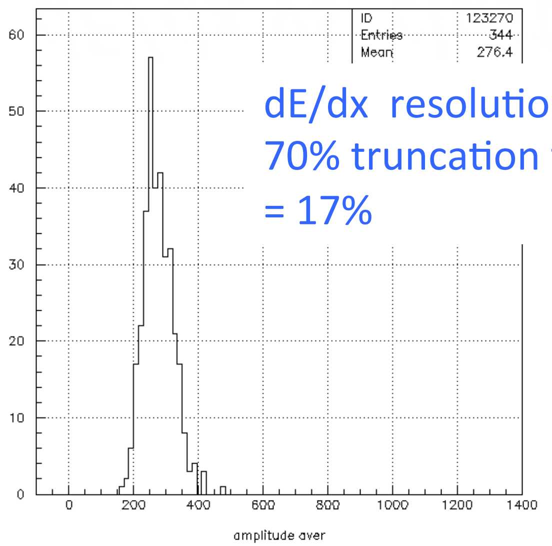


Digitized waveforms from 4 of the cells in a sample event

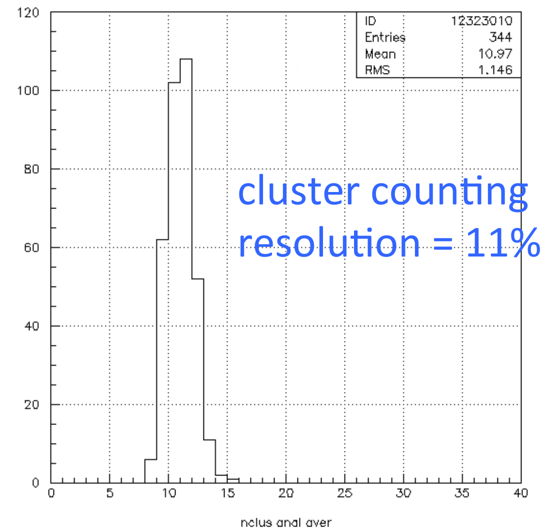


(Preliminary) space-time relations in the same 4 cells

dE/dx vs. cluster counting resolution on 10 samples



dE/dx resolution with 70% truncation fraction = 17%



cluster counting resolution = 11%

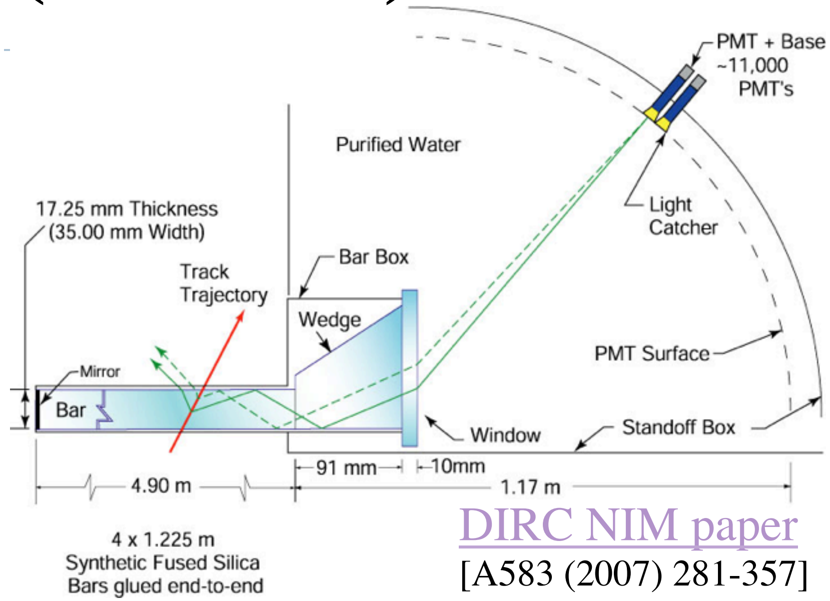
PID

N. Arnaud and J. Va'vra

The Focusing DIRC (FDIRC)

Based on the successful BaBar DIRC:

- Detector of Internally Reflected Cherenkov light [SLAC-PUB-5946]



DIRC NIM paper [A583 (2007) 281-357]

Main PID detector for the SuperB barrel

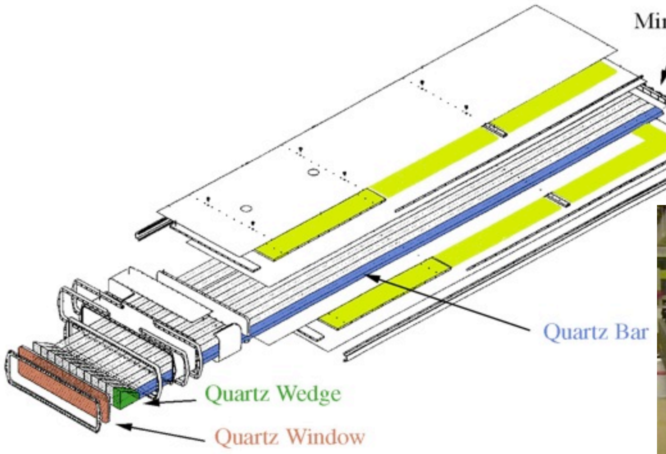
- K/π separation up to 3-4 GeV/c
- Performance close to that of the BaBar DIRC

To cope with high luminosity (10^{36} cm^{-2}s^{-1}) & high background:

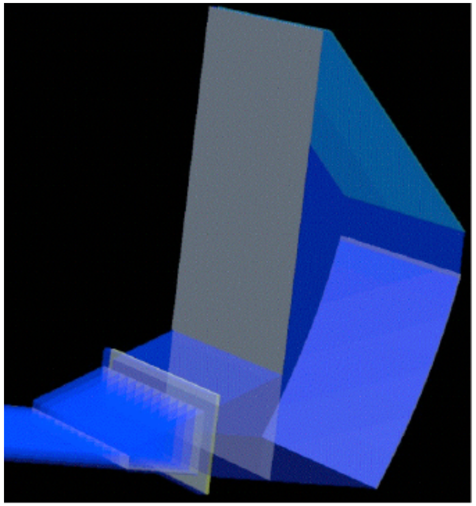
- Complete redesign of the photon camera (SLAC-PUB-14282)
- A true 3D imaging using:
  - 25× smaller volume of the photon camera
  - 10× better timing resolution to detect single photons
  - Optical design is based entirely on Fused Silica glass → avoid water or oil as optical media

FDIRC concept

Re-use BaBar DIRC quartz bar radiators

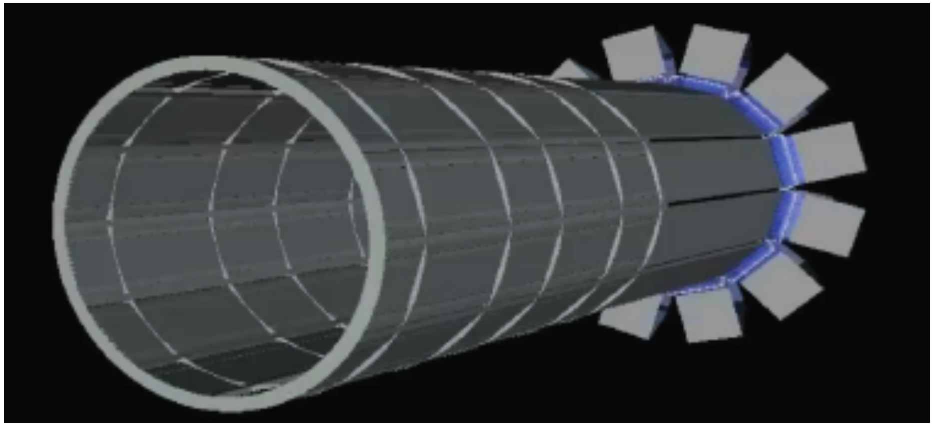


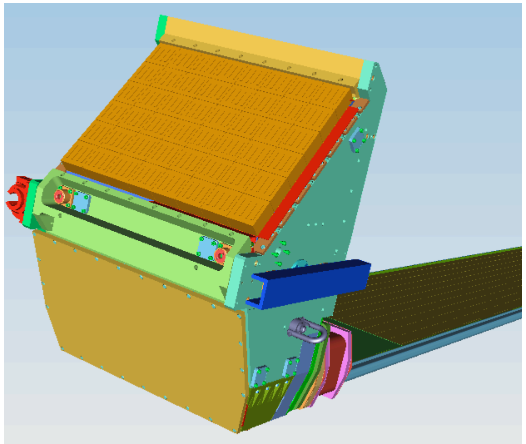
New photon camera



Geant4 simulation

Photon cameras at the end of bar boxes



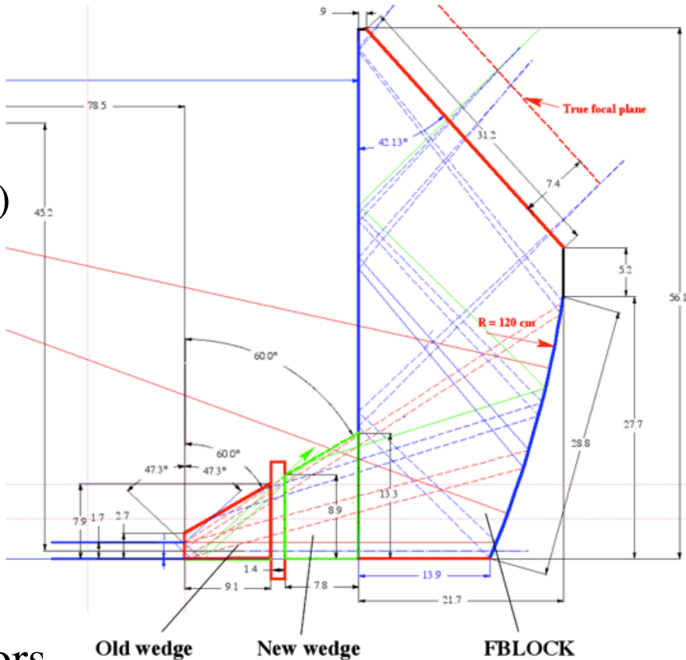


Current mechanical design

FDIRC photon camera (12/system)

Photon camera design (FBLOCK):

- Initial design by ray-tracing (SLAC-PUB-13763)
- Experience from the 1st FDIRC prototype (SLAC-PUB-12236)
- Geant4 model now (SLAC-PUB-14282)



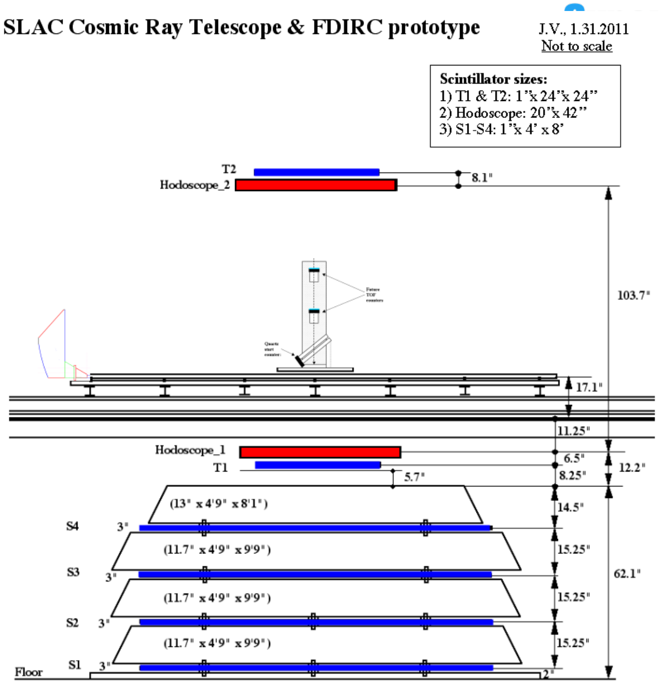
Main optical components

- New wedge (old bar box wedge was not long enough)
- Cylindrical mirror to remove bar thickness
- Double-folded mirror optics to provide access to detectors

Photon detectors: highly pixilated H-8500 MaPMTs

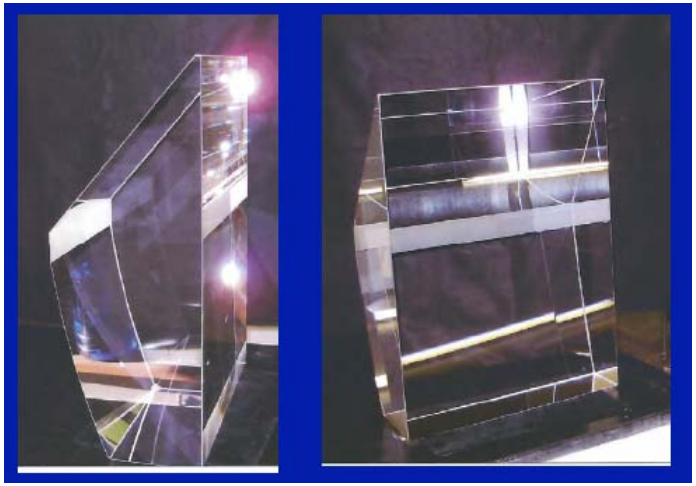
- Total number of detectors per FBLOCK: 48
- Total number of detectors: 576 [12 FBLOCKs]
- Total number of pixels: 576 × 32 = 18,432

FDIRC Status



- FDIRC prototype to be tested in the SLAC Cosmic Ray Telescope
- Activities
  - Validation of the optics design
  - Mechanical design & integration
  - Front-end electronics

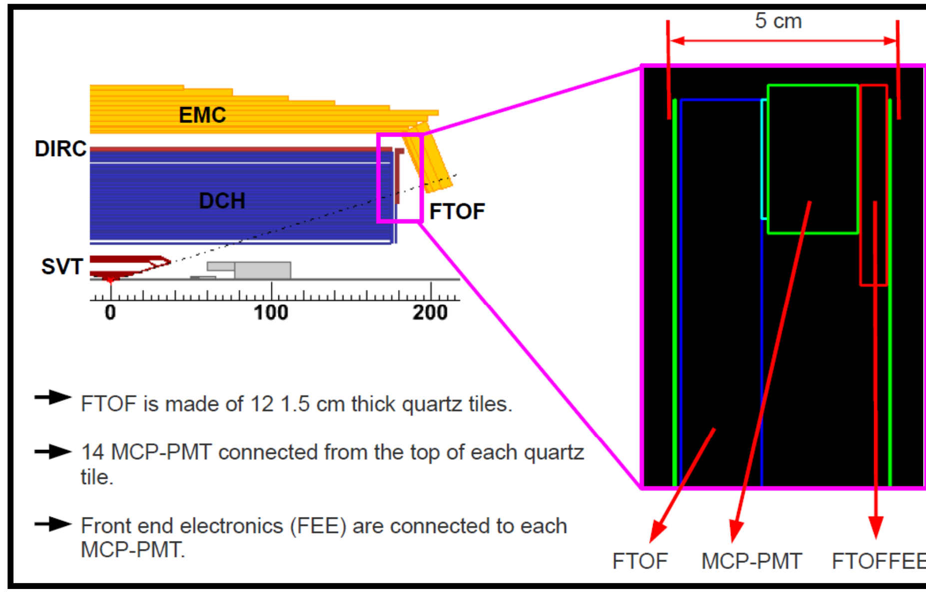
    TDC: 70 ps resolution; rate: a few MHz/ pixel
  - Simulation: background, reconstruction…
- Design to be frozen for the TDR
- Main future challenge
  - Move from R&D to construction phase!



R&D on a forward PID detector

- Goal: to improve charged particle identification in the SuperB forward region
  - In BaBar: only dE/dx information from drift chamber
- Challenges
  - Limited space available
  - Any additional detector should have a small X_0
  - Gain limited by the small solid angle [θ_{polar}~15÷25 degrees]
    → The new detector must be efficient
- Different technologies being studied
  - Time-Of-flight: ~100ps resolution needed
  - RICH: great performances but thick and expensive

• FTOF geometry



- Decision by the TDR time
  - Task force set inside SuperB to review proposals:
  - There is merit to leave some space (5cm) but more would damage the DCH performance.
  - Building an innovative forward PID detector would require additional manpower & abilities

EMC

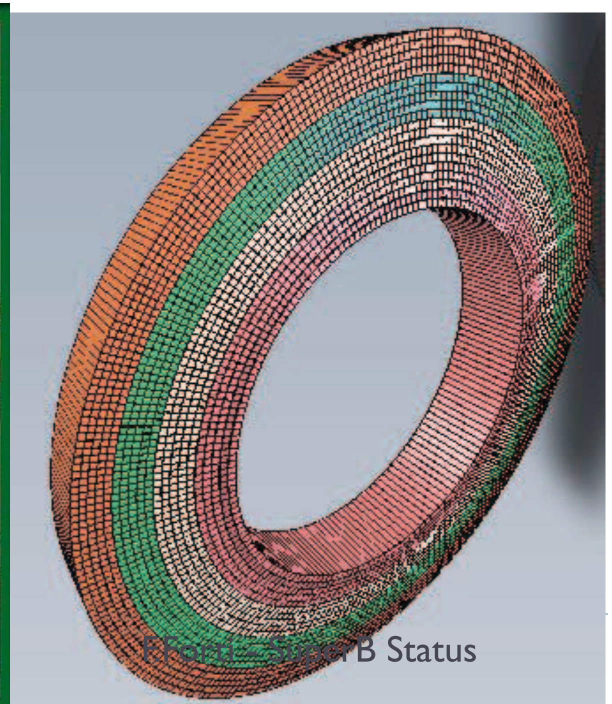
Claudia Cecchi and Frank Porter

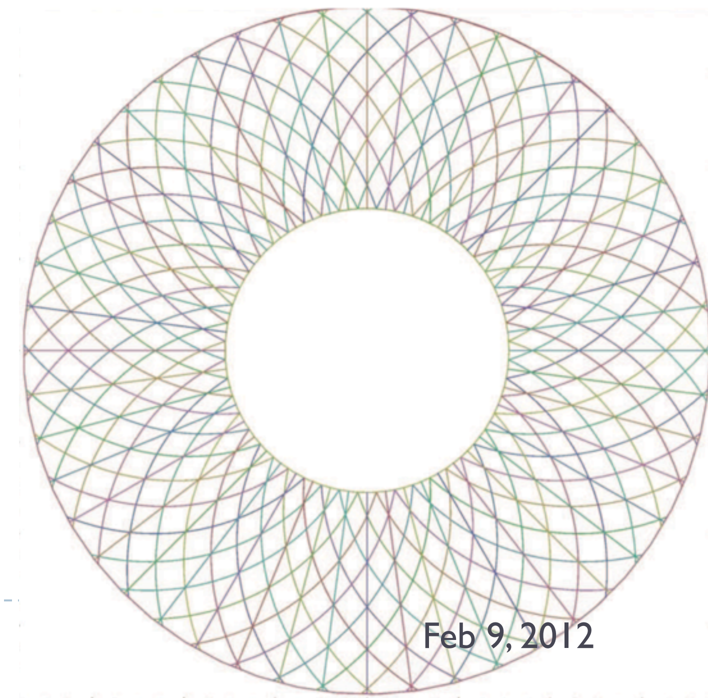
Electromagnetic calorimeter (EMC)

System to measure electrons and photons, assist in particle identification

Three components

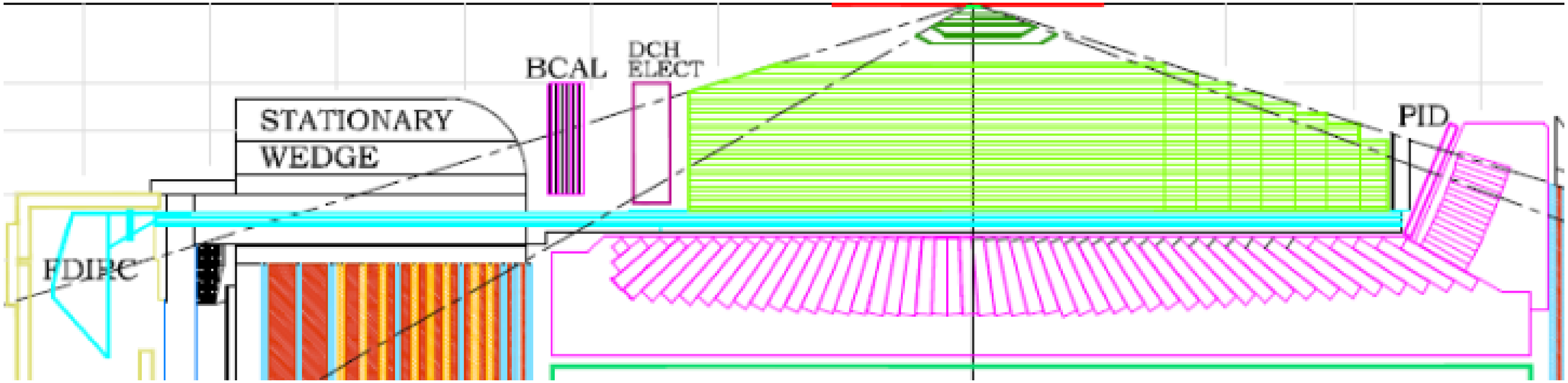
1. Barrel EMC: CsI(Tl) crystals with PiN diode readout
   - Reuse Babar Crystals with new electronics
2. Forward EMC: LYSO(Ce) ? crystals with APD readout
   - Different crystal options
3. Backward EMC: Pb scintillator with WLS fiber to SiPM/MPPC readout
   - Space available, but no final decision yet





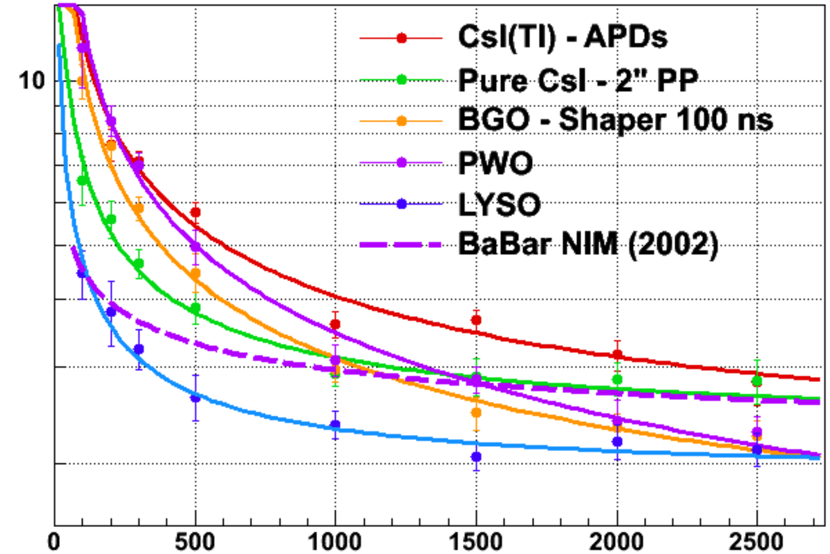
EMC Barrel

- Reuse Babar CsI(Tl) Crystals and mechanical structure
- Replace preamplifier with faster shaping
- Studies ongoing on signal processing and waveform digitizing to optimize performance



LYSO + possible alternatives

• LYSO -> finalizing results from Beam Test at BTF, roughening of crystals is ongoing, readout with 2 APD's per crystals is ready….but….
….beam lines not available until beginning of 2012 (we are in contact with people for BTF, Mainz, SLAC) more news soon



1) CsI pure, readout VPT and Photopentode
   Measurements in LAB have started

2) PWO-II (second generation of crystals L.O. increased by 85%) + LAAPD

3) BGO readout PMT
   already some studies have been carried out → PMT readout + APD (to be done)

4) BGO and PWO measurments of LY with radiation damage at Caltech

• FULL MATRIX TEST with ONE of the alternatives (1-2-3) in 2012 after measurements in LAB and simulation studies

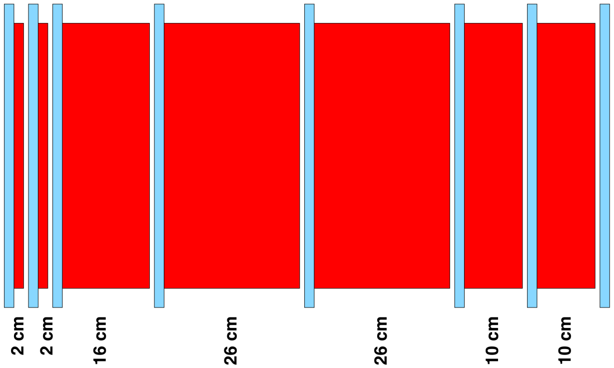
IFR

Roberto Calabrese

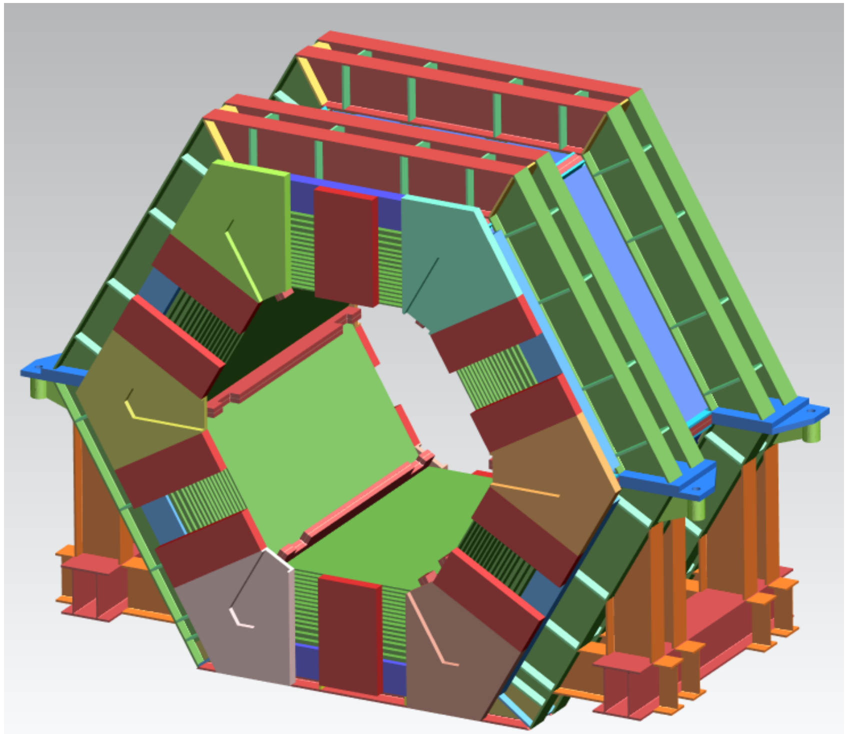
Instrumented Flux Return

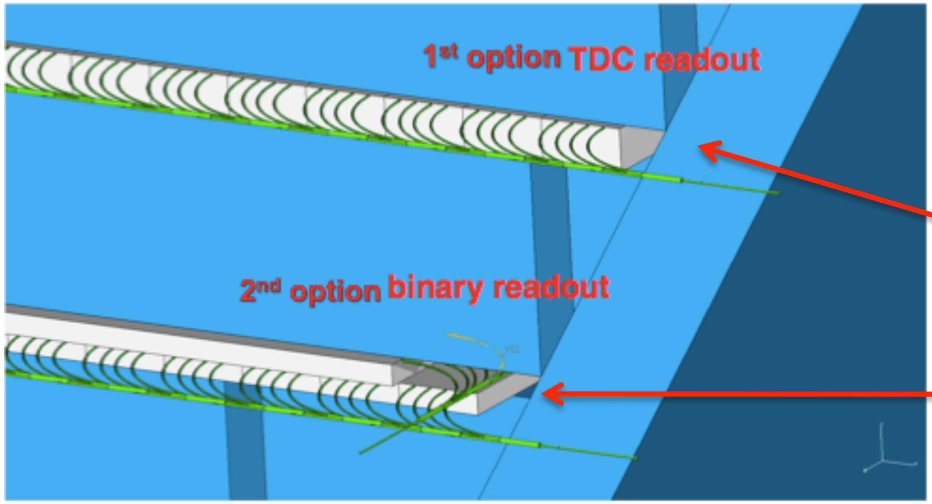
The muon an KL detector will be built in the magnet flux return reusing the Babar iron structure with some modification.

Modeling and FEA calculation in progress.



Keep longitudinal segmentation in front of the stack to retain KL capability





Two readout option are under study:

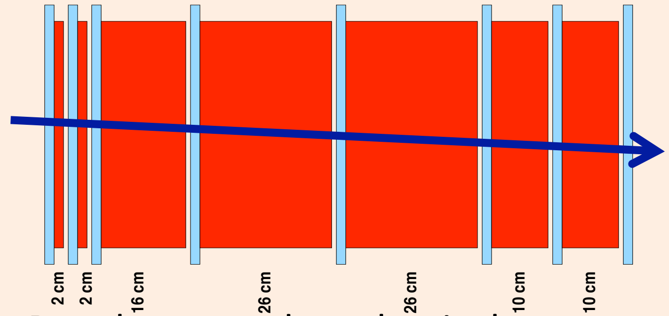
1. read one coordinate with the bar position and the other with the arrival time of the signal
2. "double coordinate layout": orthogonal scintillator bars. (BiRO readout)

Path toward the TDR

IFR

- Few core technical decisions need to be made for the TDR
  - Amount of iron (and its segmentation)
  - Number of active layers (8 vs 9)
  - Position of the SiPM in the barrel

Driven by cost and performance.



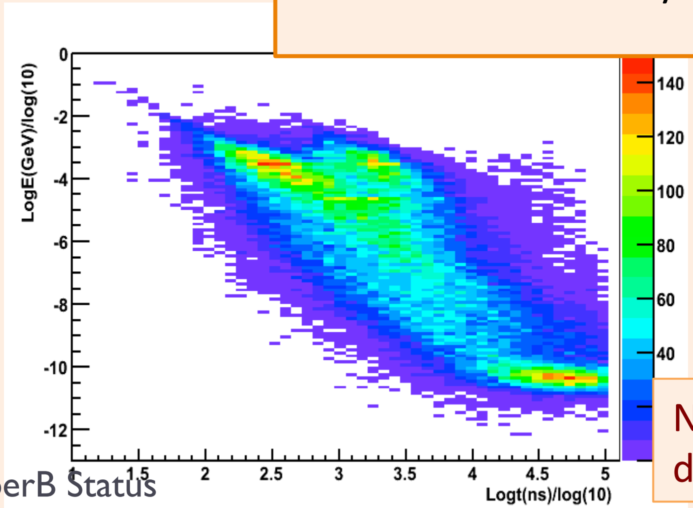
Rough cost and mechanical evaluation of different possibilities ready.

Beam test data analysis ongoing.

Mainly driven by machine background.

Simulation studies are in progress to find the best place and for shielding development.

New SiPM irradiation tests with and without shielding to be done.



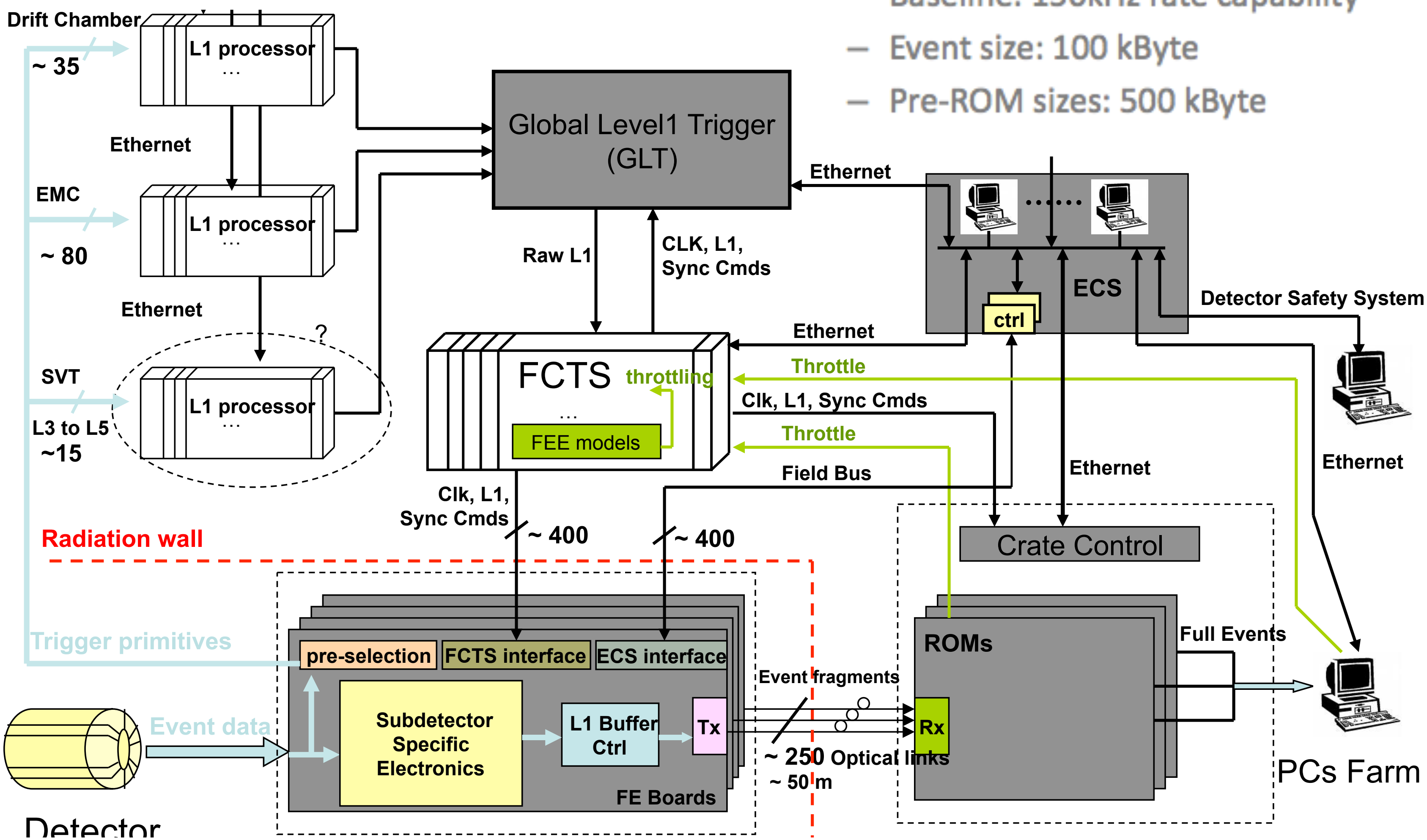
Neutron energy degradation

ETD/Online

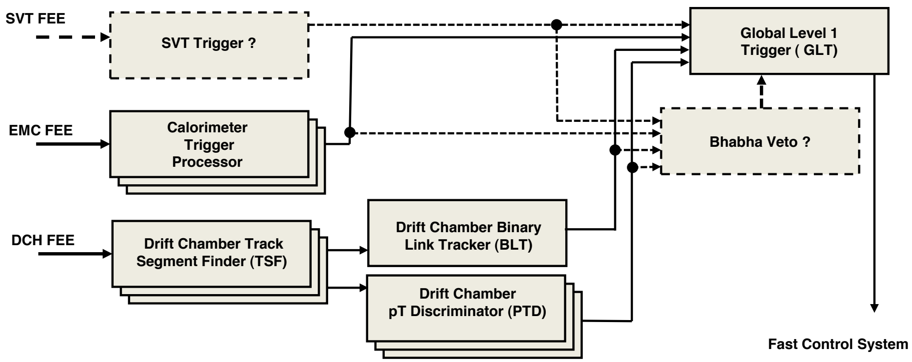
Dominique Breton, Umberto Marconi, Steffen Luitz

SuperB ETD System Overview

- Level-0 trigger rates at L=10^{36} $cm^{-2}s^{-1}$:
  - 50kHz Bhabha, 25kHz beam backgrounds, 25kHz physics+backgrounds
  - 50% headroom desirable
- Baseline: 150kHz rate capability
- Event size: 100 kByte
- Pre-ROM sizes: 500 kByte



Level-1 Trigger



- Fully pipelined
- Input running at 7(?) MHz
  - Continuous reduced-data streams from sub-detectors over fixed latency links
    - DCH hit patterns (1 bit / wire / sample)
    - EMC crystal sums, appropriately encoded
- Total latency goal: 6 us
    - Includes detectors, trigger readout, FCTS, propagation
  - Leaves 3-4us for the trigger logic
- Trigger jitter goal: <=50ns to accommodate short sub-detector readout windows

- Baseline: "BaBar-like L1 Trigger" with some improvements
  - Calorimeter trigger
    - Cluster counts and energy thresholds
  - Drift chamber trigger
    - Track counts, p_T, z-origin of tracks
  - Highly efficient, orthogonal
  - To be validated for high-lumi environment
  - Challenges: time resolution, trigger jitter and pile-up
- To be studied
  - SVT in trigger (# tracks, # tracks from/not from IP, # of back-to-back tracks in Phi)
    - Tight interaction with SVT and SVT FEE design
  - Bhabha veto
    - Baseline: Best done in HLT

The SuperB Project: Brief summary

- In 2010 SuperB has been selected as the first project of the Flagship Projects of the National Research Plan
- In Dec SuperB has been approved and funded
  - 250 M for infrastructure (Apr 2011)
  - Strong ministerial support, at least so far.
- Site
  - Tor Vergata has been chosen as the site for SuperB.
  - Strong support of the University, in particular for all civil engineering.
  - Closeness to LNF allows important synergies.
- Kick-off day on May 30, 2011
  - Officially began the project construction phase

SuperB Funding in INFN 3-year plan

Componenti Super B	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Sviluppo Acceleratore (130 M€) Costruzione infrastrutture, Sviluppo damping rings, Sviluppo transfer lines, Messa in funzione linac, Damping lines transfer lines, Costruzione facility end-user	20	50	60							
Sviluppo Centri Calcolo (43 M€) Sviluppo progettazione costruzione centro di calcolo per analisi dati	5	15	23							
Completamento Acceleratore (126 M€) Installazione componenti negli archi acceleratore, Installazione zona di interazione, Messa in funzione acceleratore				42	42	42				
Utilizzo installazione (80 M€) Costi operazione e manutenzione acceleratore							20	20	20	20
Totale Infrastrutture tecniche (379 M€)	25	65	83	42	42	42	20	20	20	20
Overheads INFN (34.3 M€ equivalente al 9%)	2.3	5.9	7.5	3.8	3.8	3.8	1.8	1.8	1.8	1.8
Cofinanziamento INFN (150 M€)	15	15	15	15	15	15	15	15	15	15
Costo Totale del progetto (563.3 M€)	42.3	85.9	105.5	60.8	60.8	60.8	36.8	36.8	36.8	36.8

256M

Funding for accelerator and infrastructure only

Computing funding from special funds for south development (43M)

Detector funding inside ordinary funding agency budget – not on this table

In addition, we re-use parts of PEP-II and Babar, for a value of about 135M€

IIT contribution (100M?) in addition, mainly for synchrotron light lines construction. To be defined during next month

CabibboLab

- In July 2011 INFN approved:
  - MoU between INFN and UTorVergata
  - Statute of the CabibboLab.
    - Purpose: construction and operation of a high-luminosity electron-positron collider, as described in the National Research Program 2011
- In Sep 2011:
  - Minister signed the authorization for the CabibboLab
  - An initial 19M was transfered to the consortium
  - The General Director has been appointed: R.Petronzio
- Phases of the consortium
  - Initially an italian consortium (IIT will join soon)
  - Foreseen the evolution in an ERIC (European Research Infrastructure Consortium)

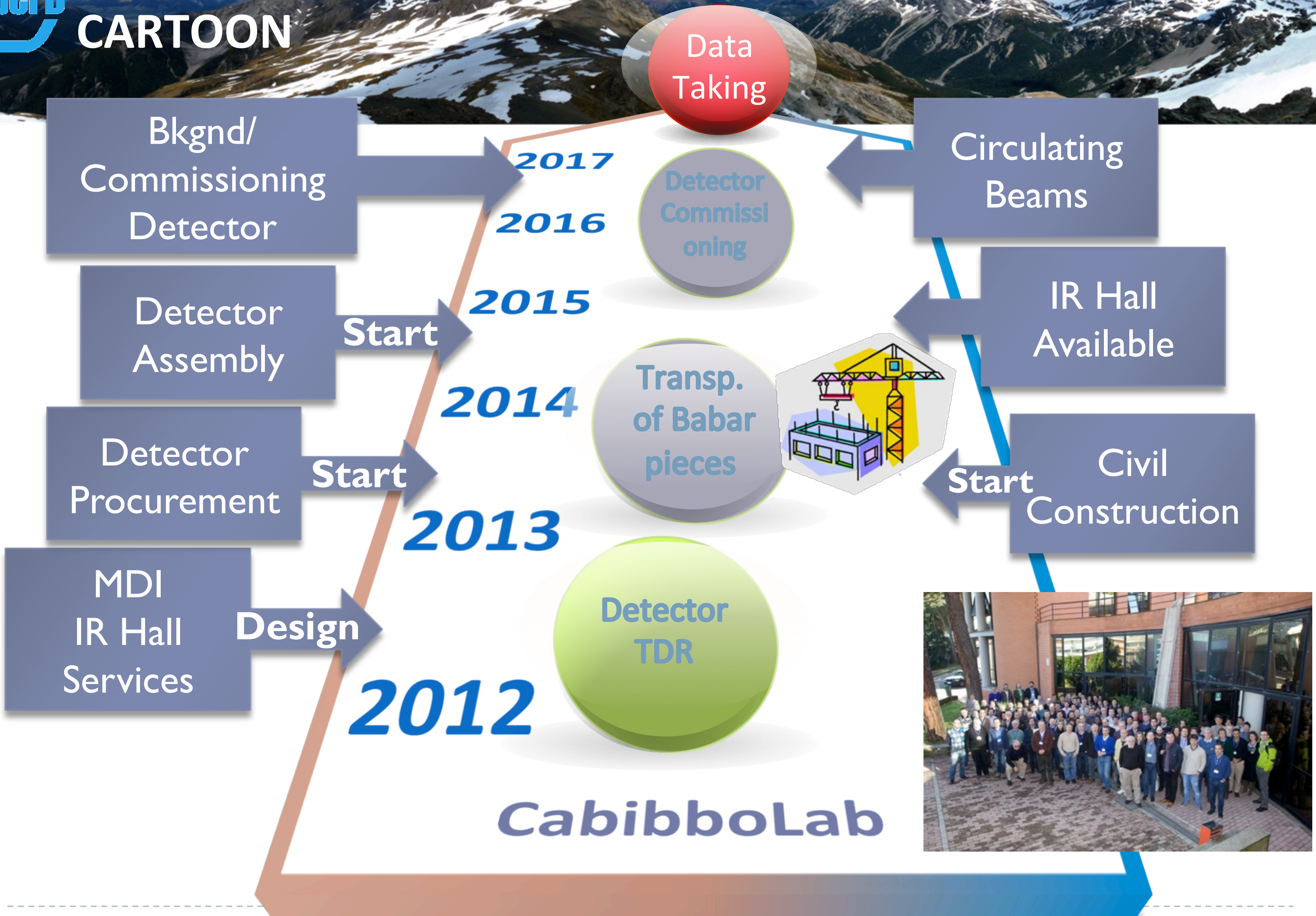
Documents

- The Discovery Potential of a Super B Factory Slac-R-709
- Physics at Super B Factory: hep-ex/0406071
- SuperB report: hep-ex/0512235
- SuperB Conceptual Design Report arxiv.org/abs/0709.0451
- New Physics at the Super Flavor Factory arxiv.org/abs/0810.1312
- Detector Progress Report: arxiv.org/abs/1007.4241
- Physics Progress Report: arxiv.org/abs/1008.1541
- Accelerator Progress Report: arxiv.org/abs/1009.6178
- The Impact of SuperB on Flavour physics: arxiv.org/abs/1109.5028
- See http://superb.infn.it

Outlook

- The SuperB accelerator has been approved and funded
- The legal structure for its construction and operation has been defined, the CabibboLab
- A strong detector collaboration exists and we expect significant growth over the next months
- The international accelerator team exists, but need strengthening – Leadership almost defined.
- The accelerator workpackage structure is being defined
- Actual construction will start end 2012-2013

DETECTOR TIMELINE
CARTOON



BACKUP

Detector Design Issues

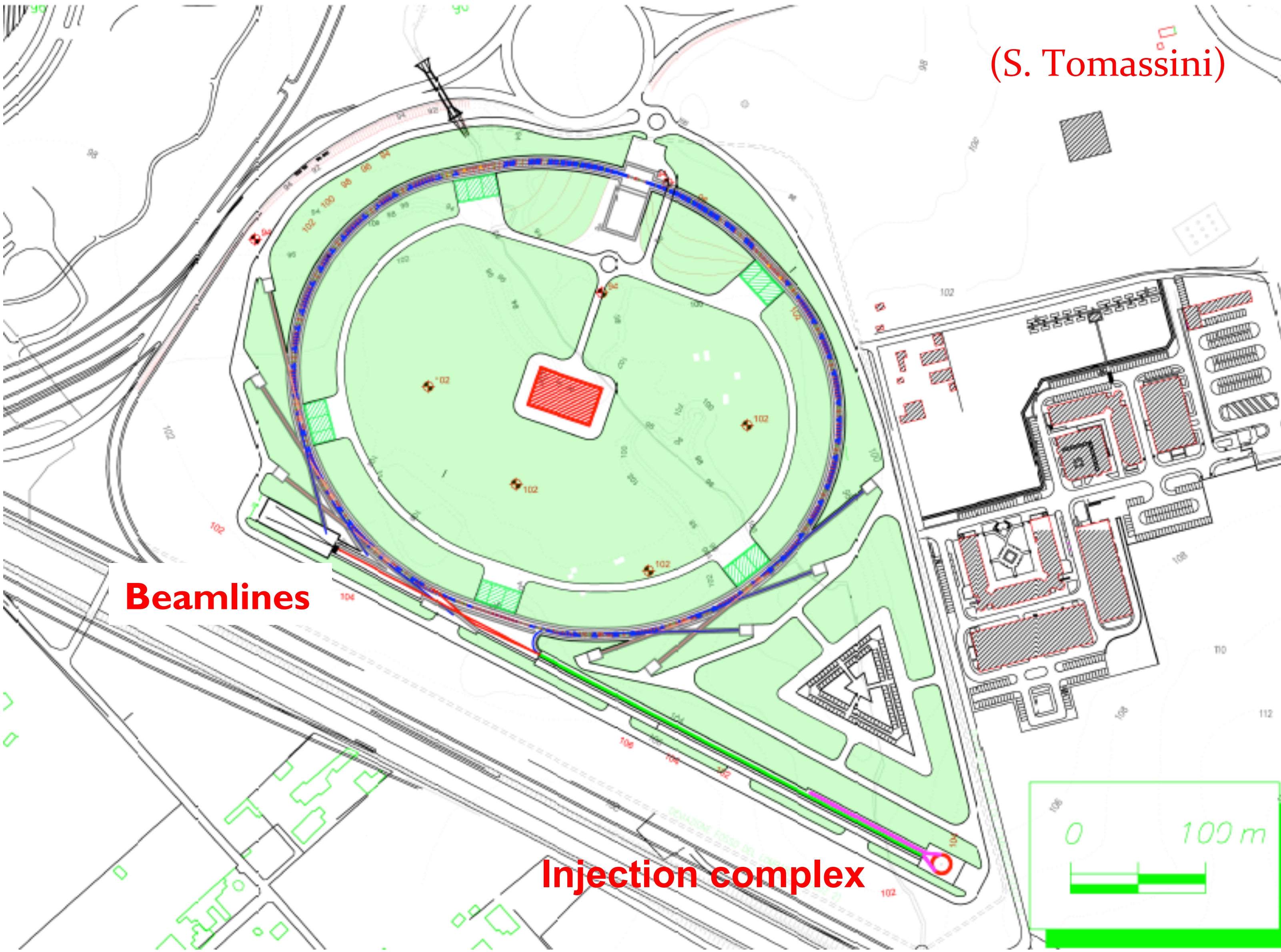
System	Baseline	Issues (technical OR manpower; R&D)
MDI	Initial IR designed	Magnetic elements and radiation masks. Design of tungsten shields. Background simulations: global map, detector occupancy
SVT	6-layer silicon	Technology for Layer 0: striplets or pixels. Thin pixels R&D. Readout chip for strips. Mechanical design.
DCH	Stereo-axial He-based	Dimensions (inner radius, length). Mechanical structure Cluster counting option.
EMC	Barrel: CsI(Tl) Forw: LYSO	Electronics and trigger. Mechanical structure Forward EMC technology: LYSO / LYSO+CsI(Tl); Pure CsI. Backward EMC: cost/benefit analysis
PID	DIRC w/ FBLOCK	FBLOCK design. Photon detection. Mechanical structure Forward PID: cost/benefit analysis. Different technologies.
IFR	Scintillator+ fibers	8 vs 9 layers. SiPM radiation damage and location. Extra 10cm iron. Mechanical design and yoke reuse.
ETD	Synchronous const. latency	Fast link rad hardness. L1Trigger (jitter and rate). ROM design. Link to computing for HLT.

Budget rivelatore

- Bugdet costruito bottoms-up, ma ancora molto approssimativo
  - Non solo per difetto.

WBS	Item	EDIA mm	Labor mm	M&S kEuro	Rep.Val. kEuro
1	**SuperB detector**	**4037**	**2422**	**52953**	**48922**
1.0	Interaction region	21	12	860	0
1.1	Tracker (SVT + Strip + MAPS)	408	442	6444	0
1.2	DCH	165	139	3421	0
1.3	PID	116	236	5820	7138
1.4	EMC	219	360	12147	31574
1.5	IFR	37	184	1374	0
1.6	Magnet	93	59	3767	10210
1.7	Electronics	994	342	9234	0
1.8	Online System	912	24	2074	0
1.9	Installation and integration	353	624	7596	0
1.A	Project Management	720	0	216	0

SuperB @ Tor Vergata




Site
About 4.5 Km
LNF
Via di Passolombardo
A1 dir
SP77b
© 2011 Tele Atlas
SS215
Image © 2011 DigitalGlobe
© 2011 Europa Technologies

Site

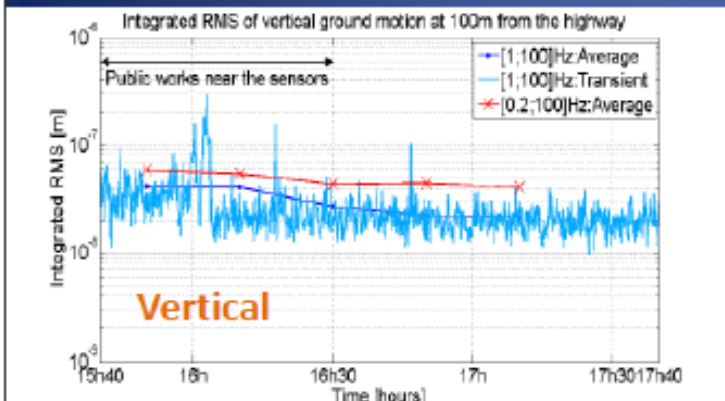
- Ground motion measurements performed on site in April (more to come) show very «solid» grounds in spite of the vicinity of the Rome-Naples Highway 100 m away
- The Highway is at higher level with respect to the site, and the traffic vibrations («cultural noise») are very well damped

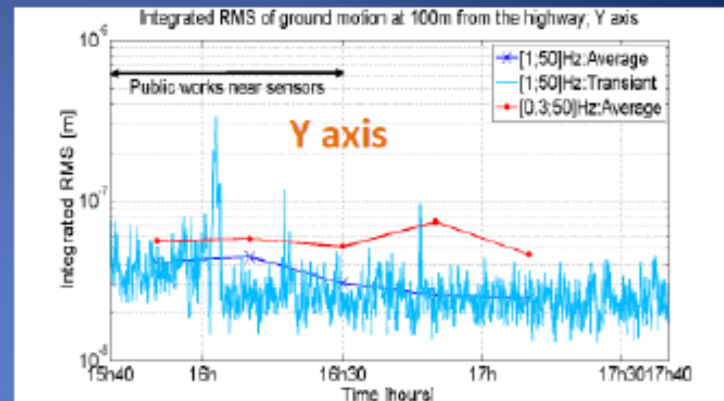
	Request (vertical displacement)	Measured (vertical displacement)
IP	300 nm	20-40 nm
Final Focus	300 nm	20-30 nm
Arcs	500 nm	20-30 nm

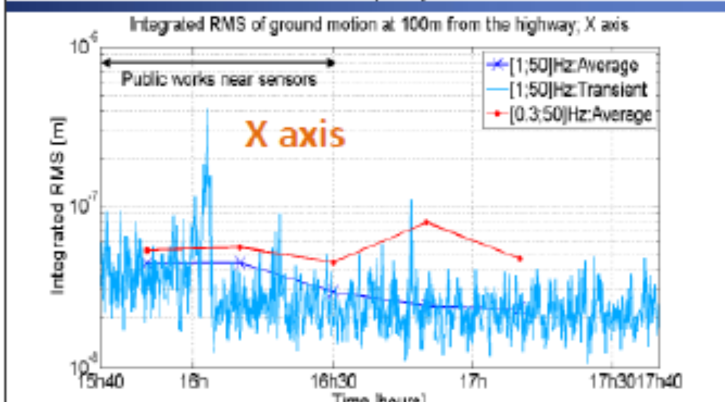
Vibrations measurements 100 m from highway

Integrated RMS of ground motion

(B. Bolzon et al)







✓ N.B: Public works near the measurement point from 15h40 to 16h30

✓ Except during the public works, ground motion very low: between 20nm and 30nm in the three directions!!

➢ Vibrations of the highway well attenuated with the distance (100m)!!

18