Hadron2011, Munich, June 16, 2011

Future Experiments

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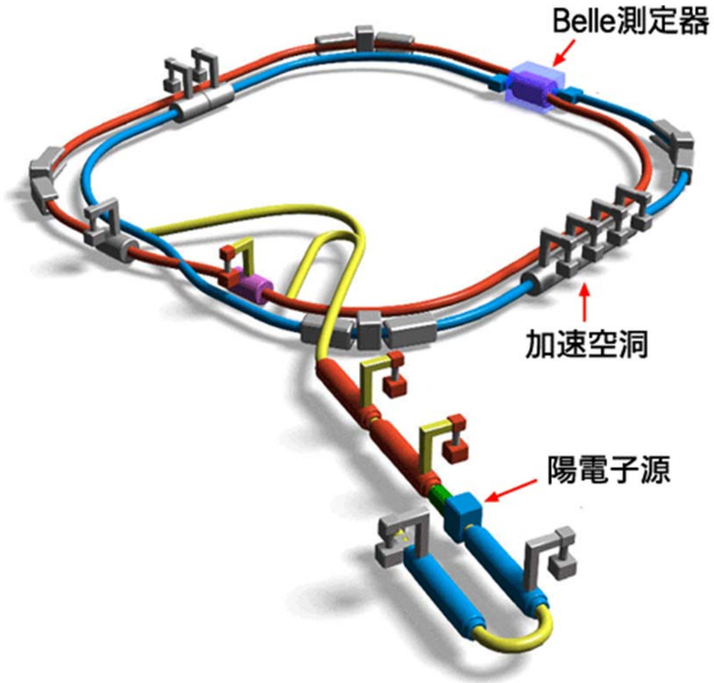
Contents

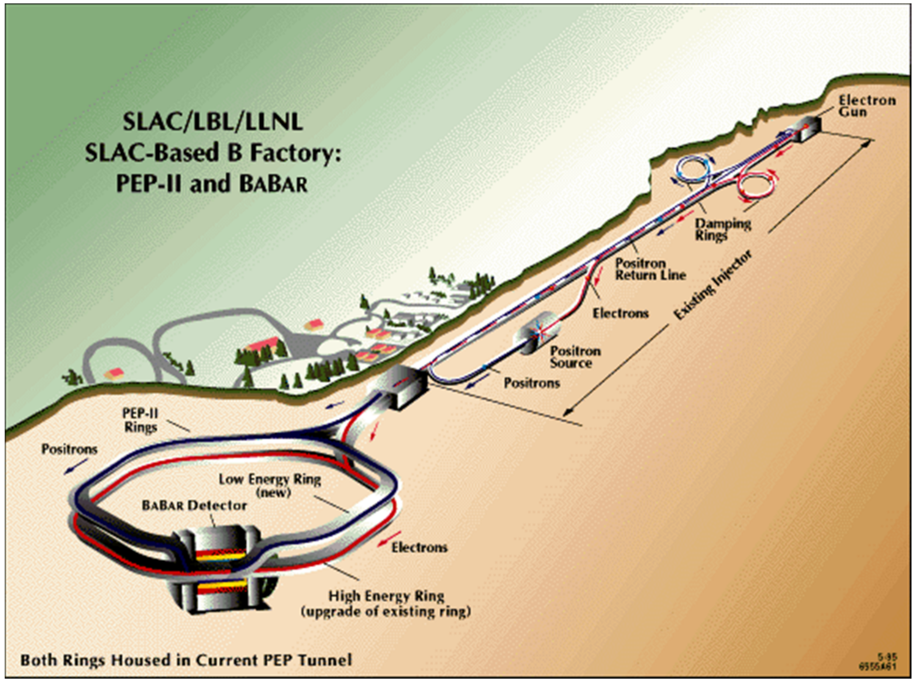
Status and prospects of the projects:

- Super B factories: Belle-II/SuperKEKB and SuperB
- PANDA at FAIR
- JLAB: CLAS12 and GlueX

CLAS12

Asymmetric B factories





$\sqrt{s}=10.58$ GeV

$e^{+} \longrightarrow \Upsilon(4s) \longleftarrow e^{-}$

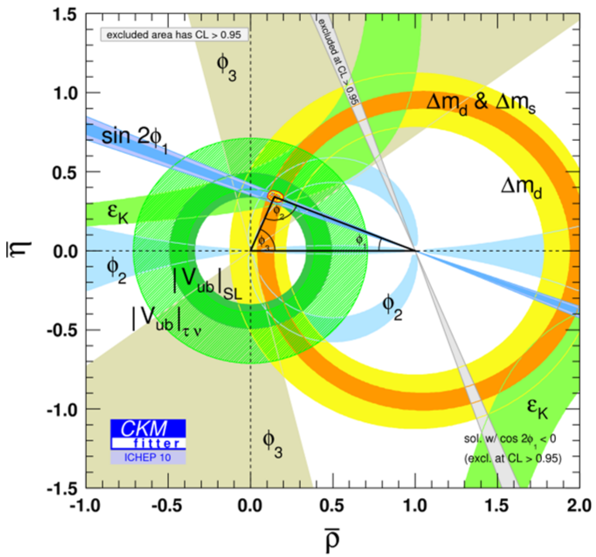
$\Upsilon(4s) \rightarrow B, \ \overline{B}$

$\Delta z \sim c\beta\gamma\tau_B \sim 200\mu m$

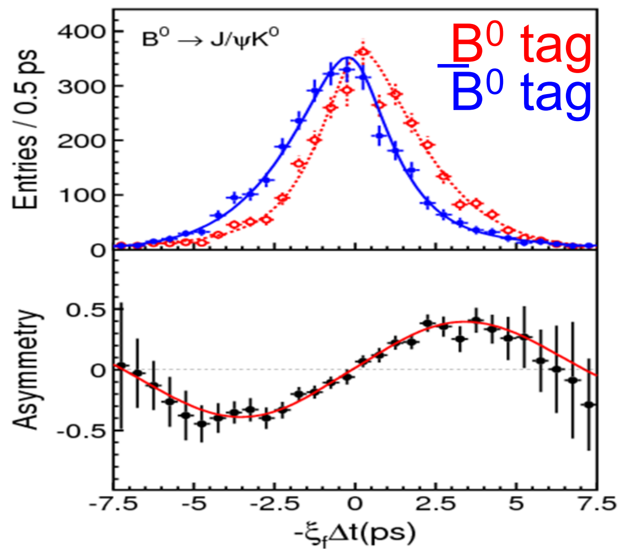
BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$

B-factories – a huge success!

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decays (e.g., $B \rightarrow \tau\nu$, $D\tau\nu$)
- $b \rightarrow s$ transitions: probe for new sources of CPV and constraints from the $b \rightarrow s\gamma$ branching fraction



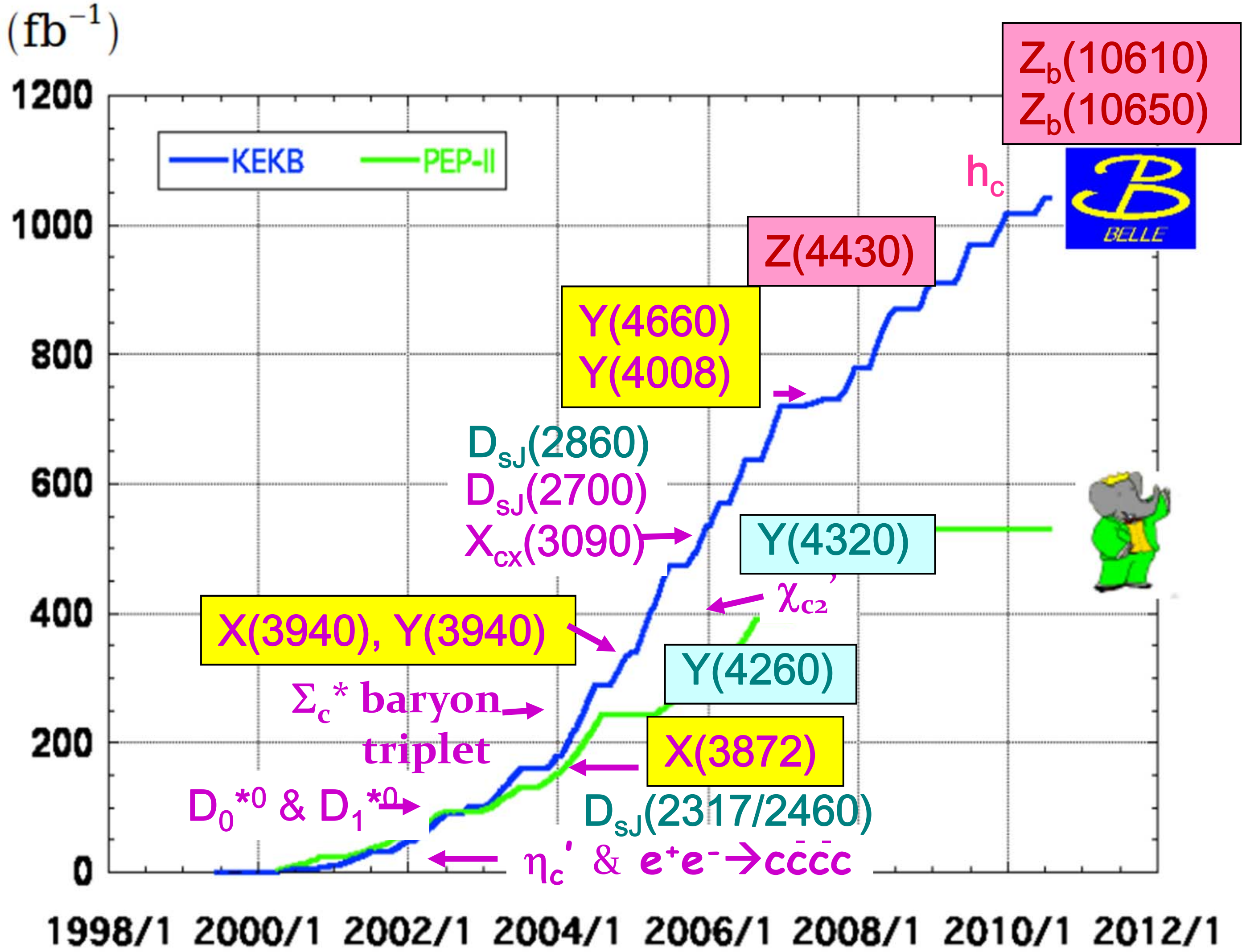
- Forward-backward asymmetry (A_{FB}) in $b \rightarrow sll$ has become a powerfull tool to search for physics beyond SM.

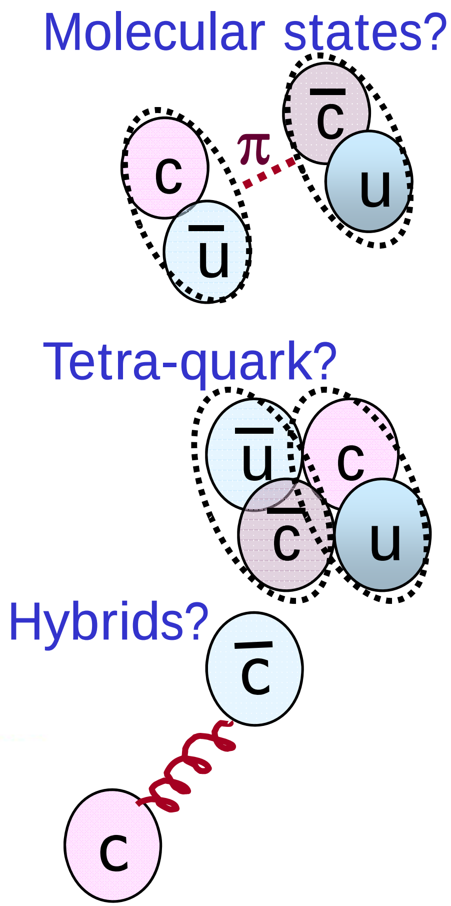


- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons

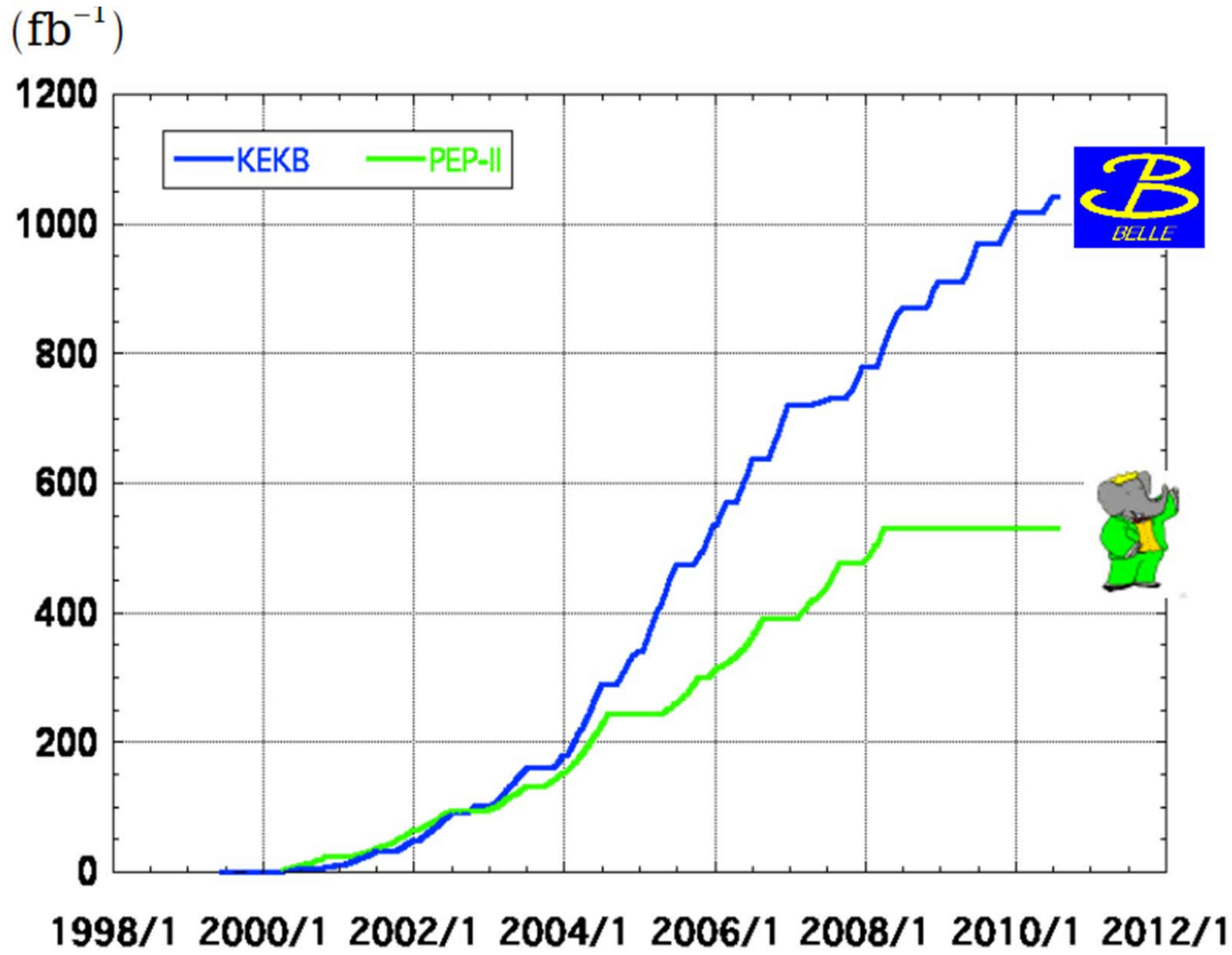
New hadrons at B-factories

Discoveries of many new hadrons at B-factories have shed light on a new class of hadrons beyond the ordinary mesons.





Integrated luminosity at B factories



> 1 ab^{-1}

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 25 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

$\sim$ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

$\sim$ 54 fb^{-1}

Fantastic performance much beyond design values!

What next?

Next generation: Super B factories → search for New Physics

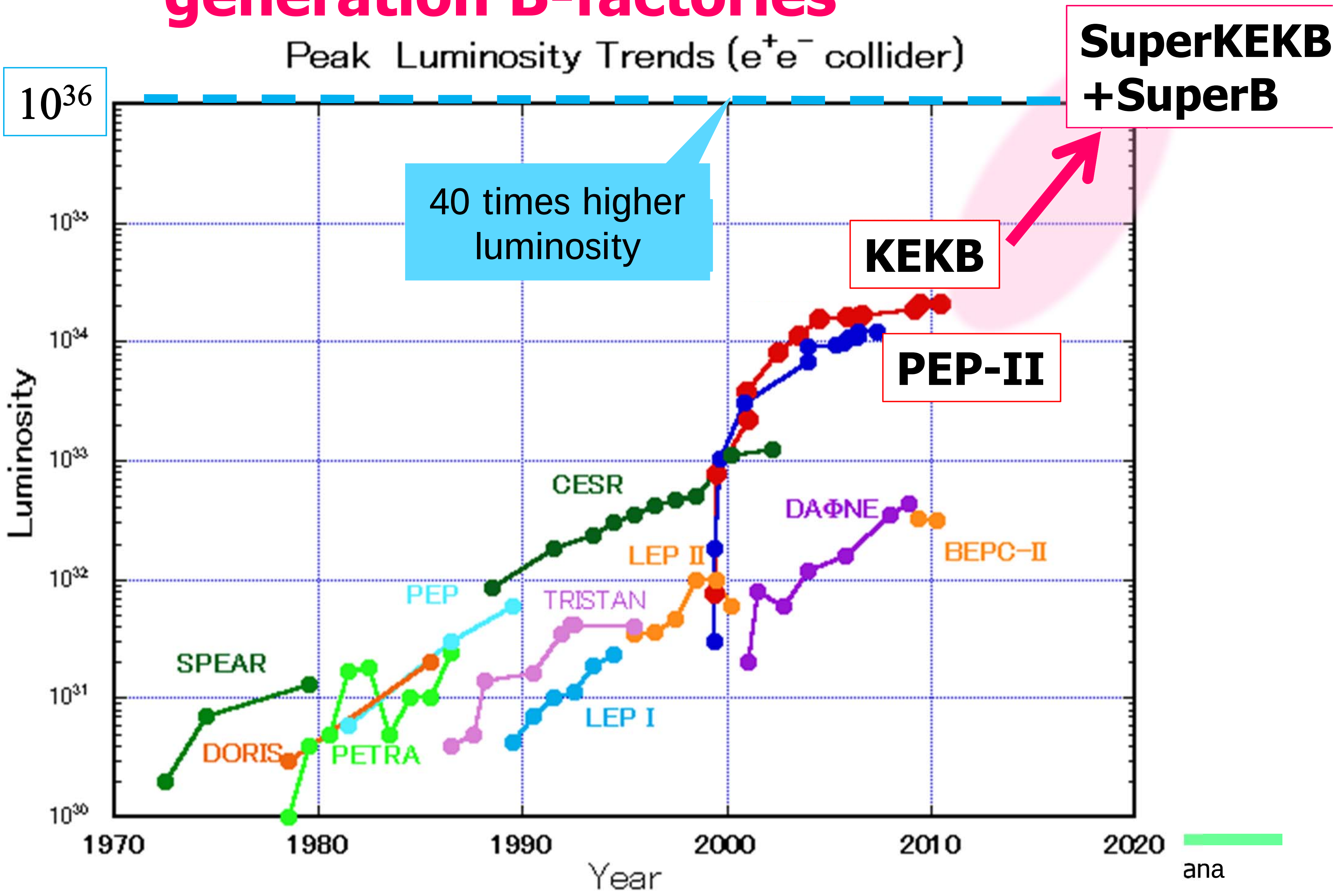
→ Need much more data (two orders!) because the SM worked so well until now

However: it will be a different world in four years, there will be serious competition from LHCb and BESIII

Still, e^+e^- machines running at (or near) Y(4s) will have considerable advantages in several classes of measurements, and will be complementary in many more

→ We will have a 50x larger sample for studies of already found hadrons and searches for new ones

Need O(100x) more data →Next generation B-factories



How to do it?
→ upgrade KEKB and Belle
→ SuperKEKB and Belle II

How to increase the luminosity?

Beam-beam parameter

Lorentz factor

Beam current

$$\boxed{L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)}$$

Lumi. reduction factor (crossing angle)&
Tune shift reduction factor (hour glass effect)
0.8 - 1
(short bunch)

Classical electron radius

Beam size ratio@IP
1 - 2 % (flat beam)

Vertical beta function@IP

(1) Smaller β_y^*

(2) Increase beam currents

(3) Increase ξ_y

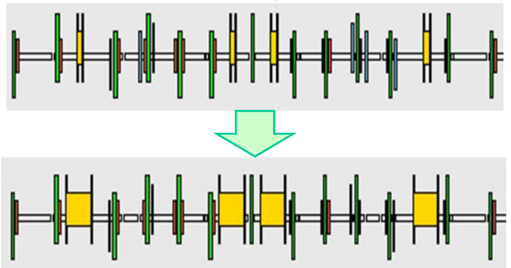
"Nano-Beam" scheme

Collision with very small spot-size beams

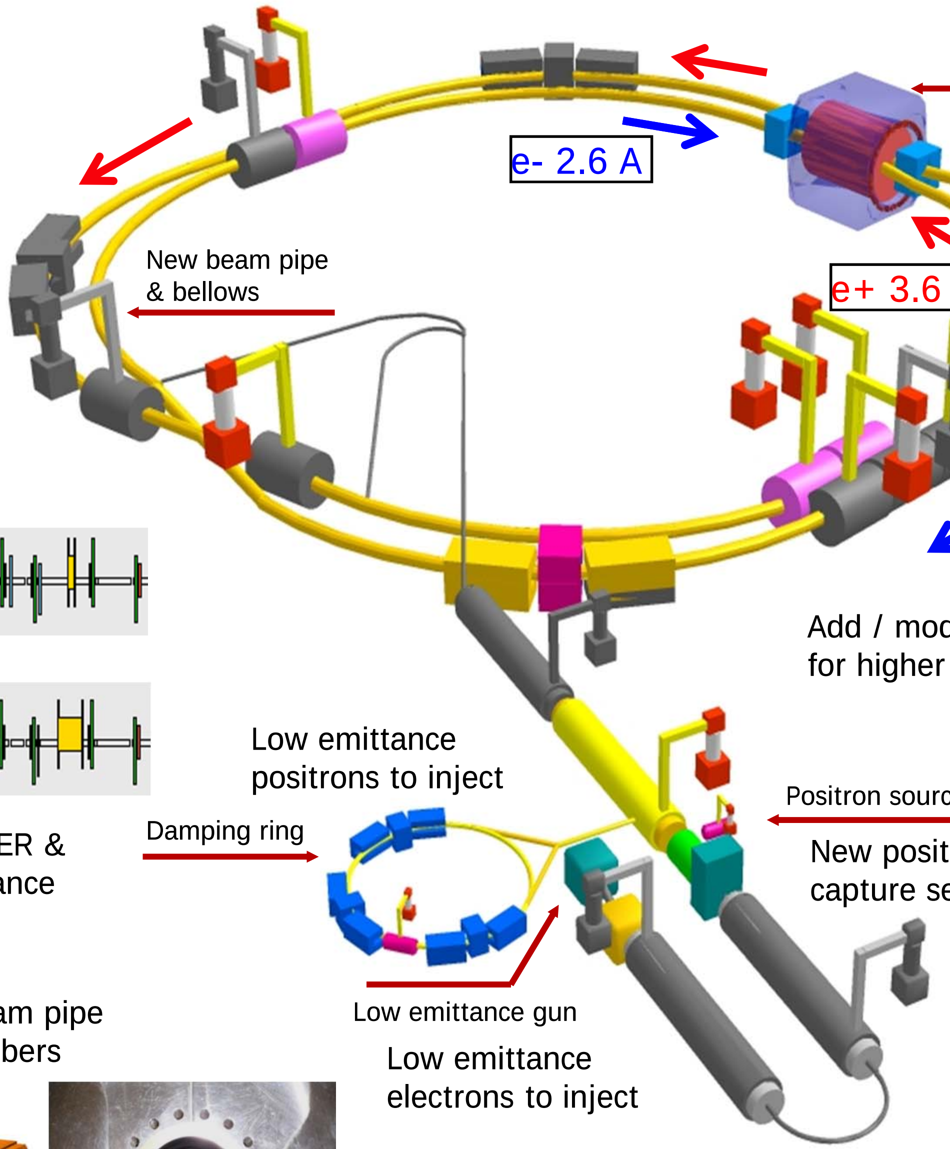
Invented by Pantaleo Raimondi for SuperB

KEKB → SuperKEKB

Replace short dipoles with longer ones (LER)



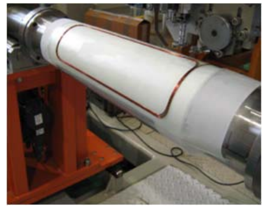
Redesign the lattices of HER & LER to squeeze the emittance



Low emittance positrons to inject

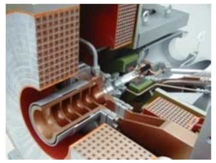
Low emittance electrons to inject

New superconducting /permanent final focusing quads near the IP

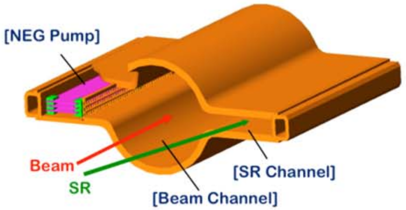


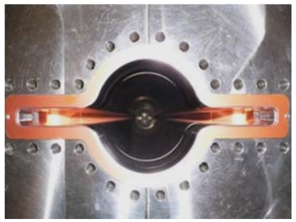
Add / modify RF systems for higher beam current

New positron target / capture section



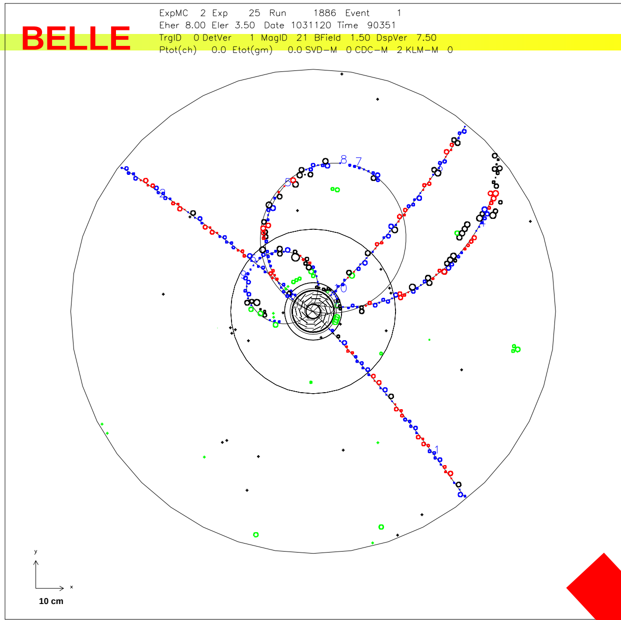
TiN-coated beam pipe with antechambers





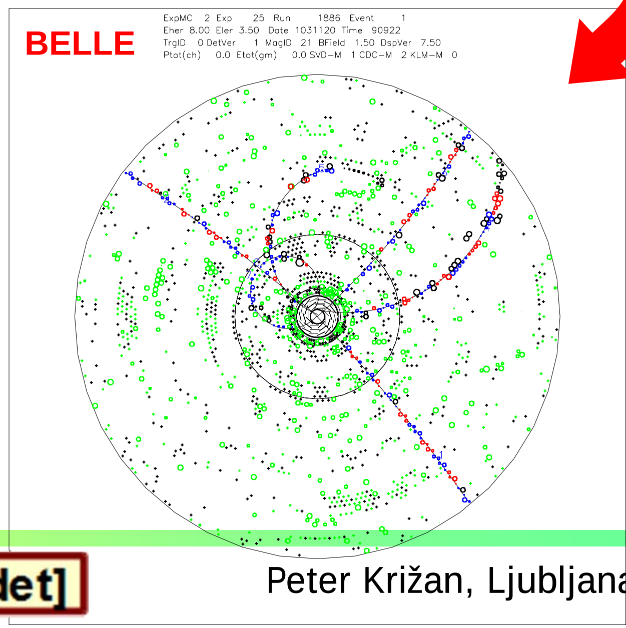
To get x40 higher luminosity

Requirements for the Belle II detector



Critical issues at L= 8 x 10^{35}/cm^2/sec

- **Higher background (×10-20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low p μ identification ← $s\mu\mu$ recon. eff.
  - hermeticity ← ν "reconstruction"

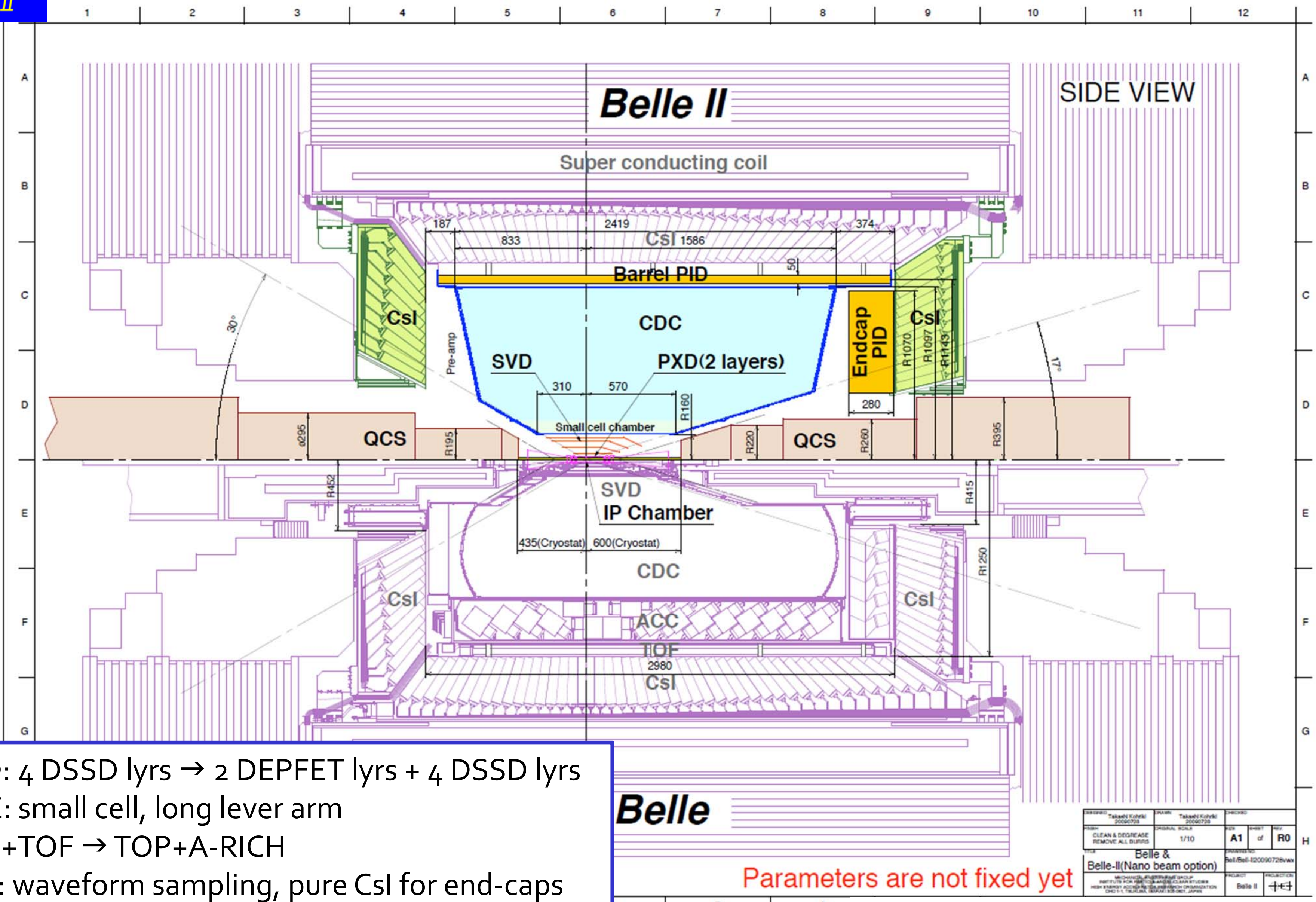


Solutions:

- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

TDR published arXiv:1011.0352v1 [physics.ins-det]

Belle II in comparison with Belle

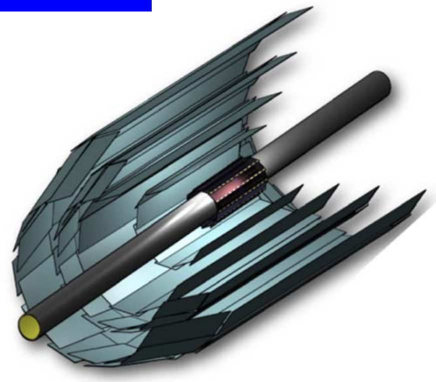


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

Y. Ushiroda, ICHEP2010

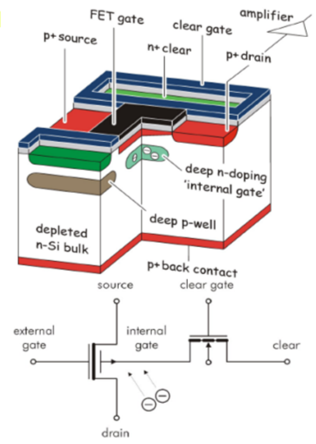
Vertex Detector

DEPFET:
http://aldebaran.hll.mpg.de/twiki/bin/view/DEPFET/WebHome

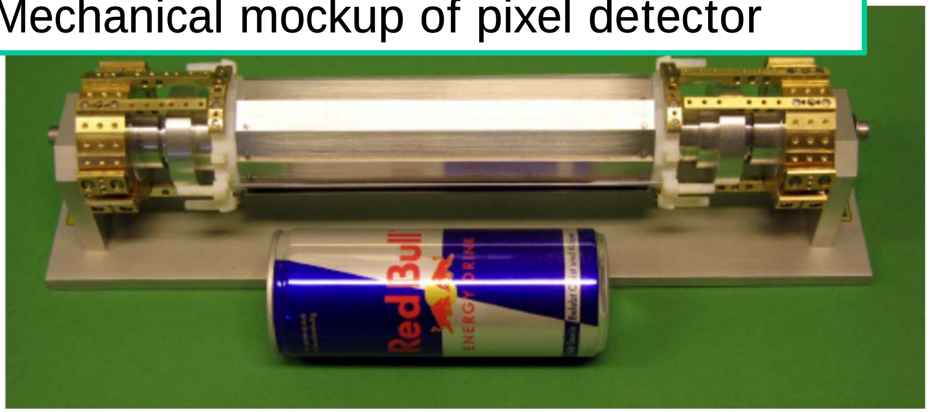


Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

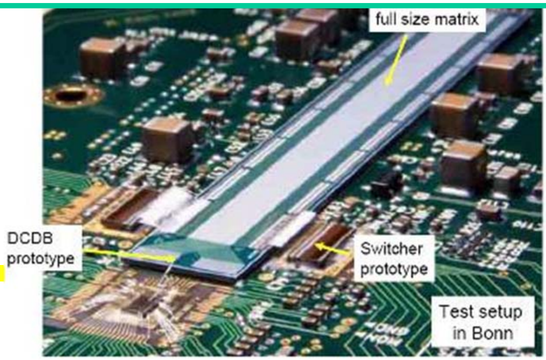
DEpleted P-channel FET

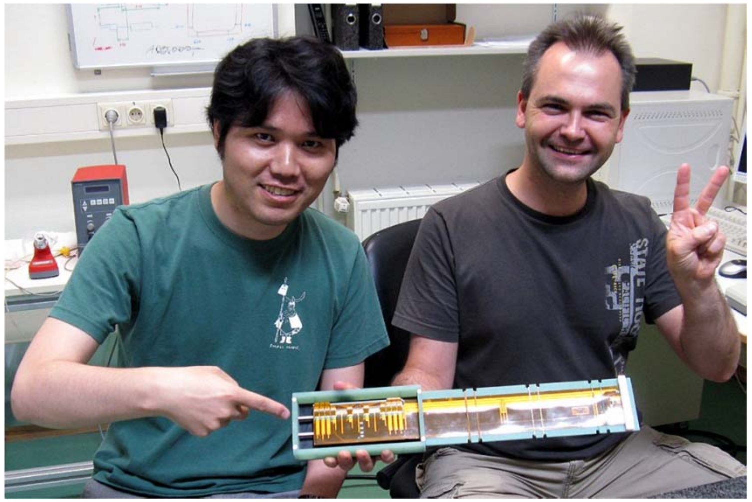


Mechanical mockup of pixel detector



Prototype DEPFET pixel sensor and readout

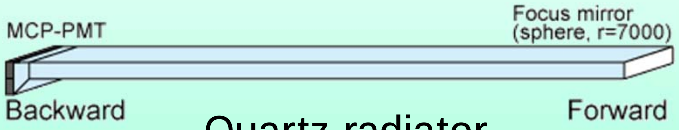




A prototype ladder using the first 6 inch DSSD from Hamamatsu has been assembled and tested.

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



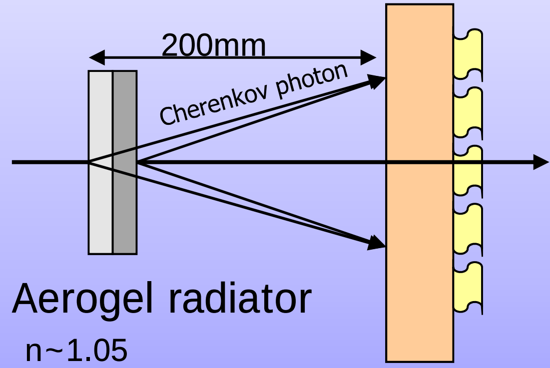
Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

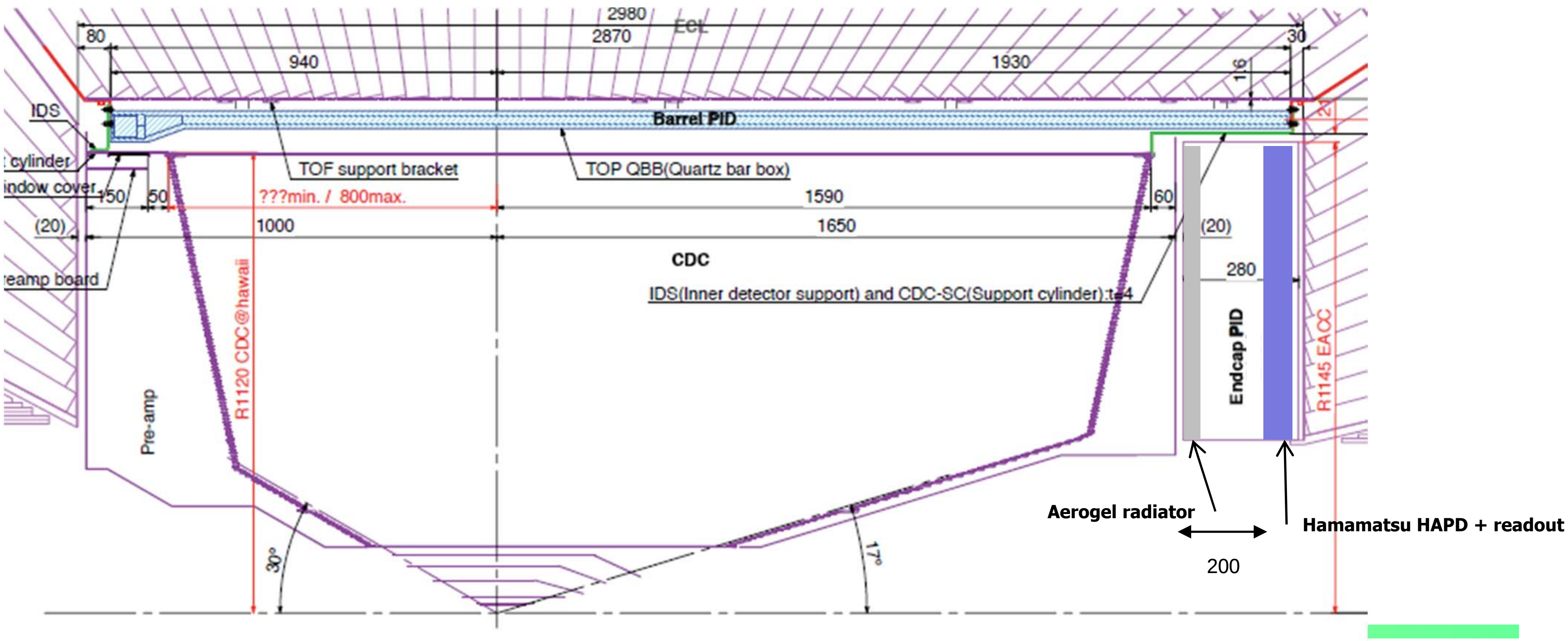
Endcap PID: Aerogel RICH (ARICH)



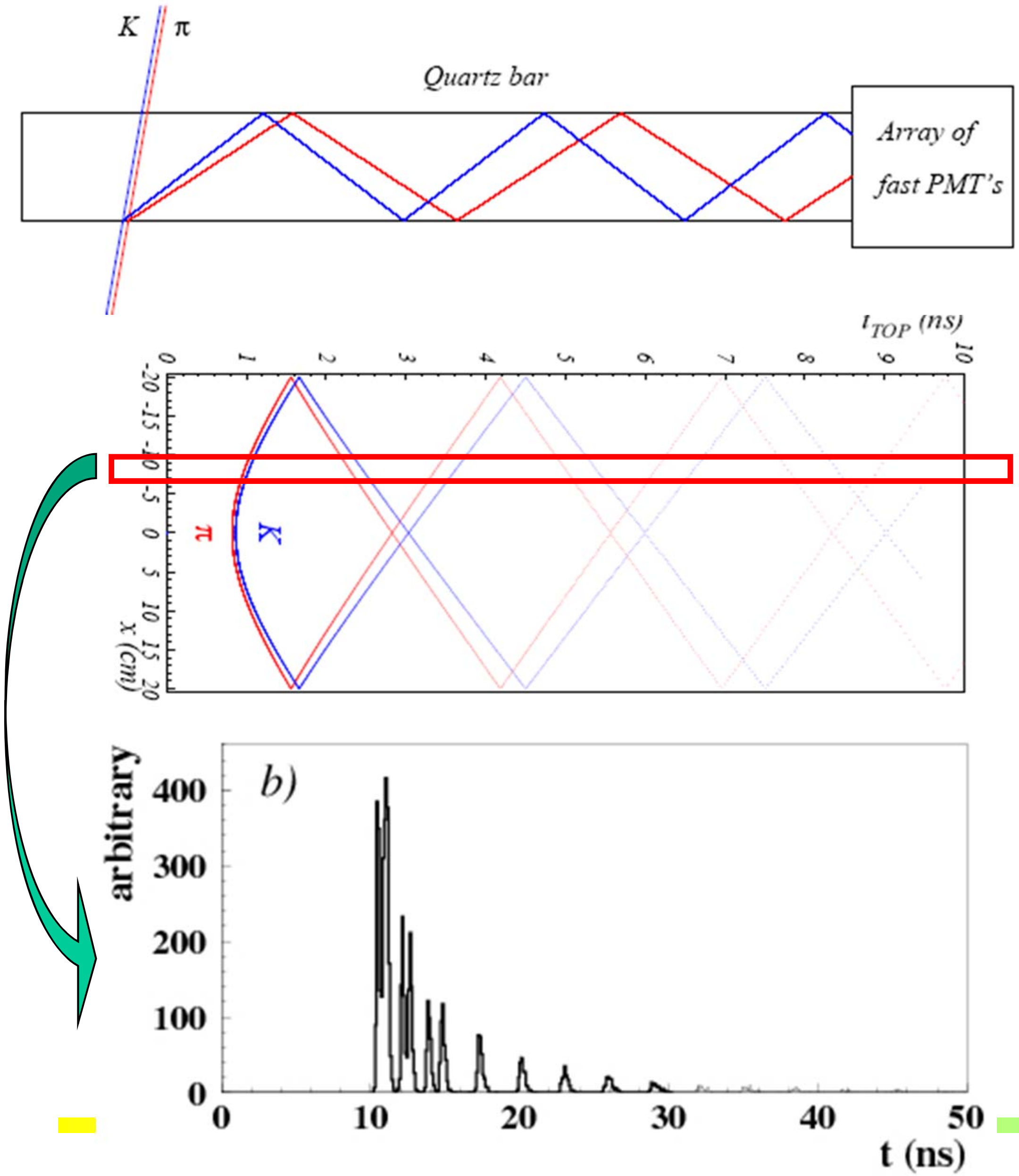
Aerogel radiator

n~1.05

Hamamatsu HAPD
+ new ASIC



Barrel PID: Time of propagation (TOP) counter



DIRC-like device without a large expansion volume:

Pattern in the **coordinate-time** space ('ring') of a pion and kaon hitting a quartz bar with ~300 MCP PMT channels

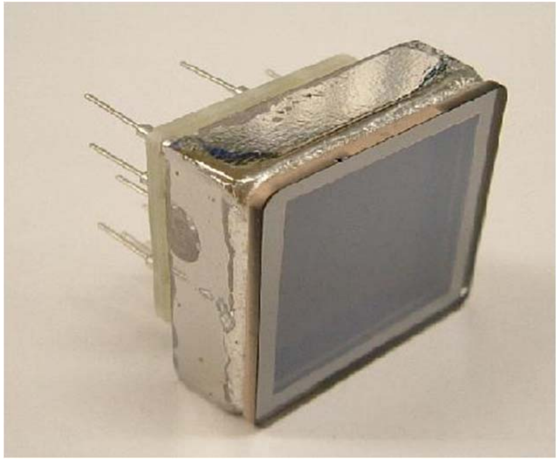
Time distribution of signals recorded by one of the PMT channels:

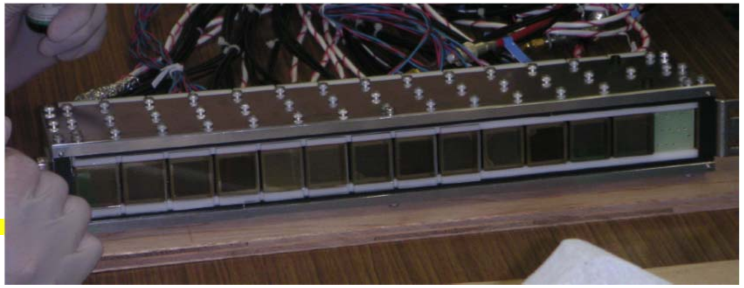
→ different for π and K

Barrel PID: Time of propagation (TOP) counter

- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from two coordinates and the time of propagation of the photon
  - Quartz radiator (~2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5 T

SL10 MCP-PMT



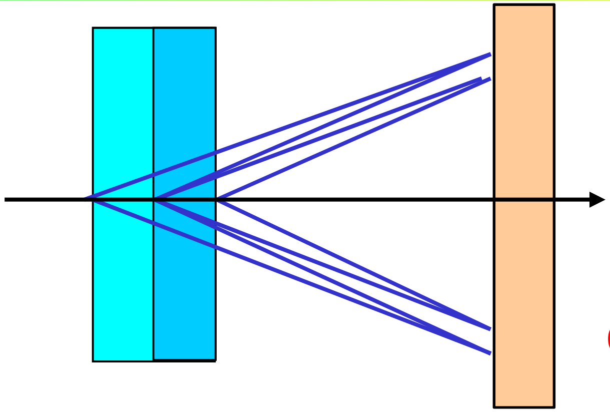


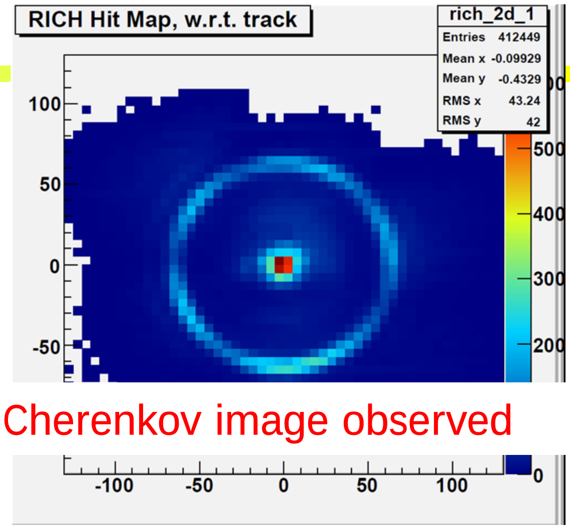
Photon detector array

Aerogel RICH (endcap PID)

RICH with a novel "focusing" radiator – a two layer radiator

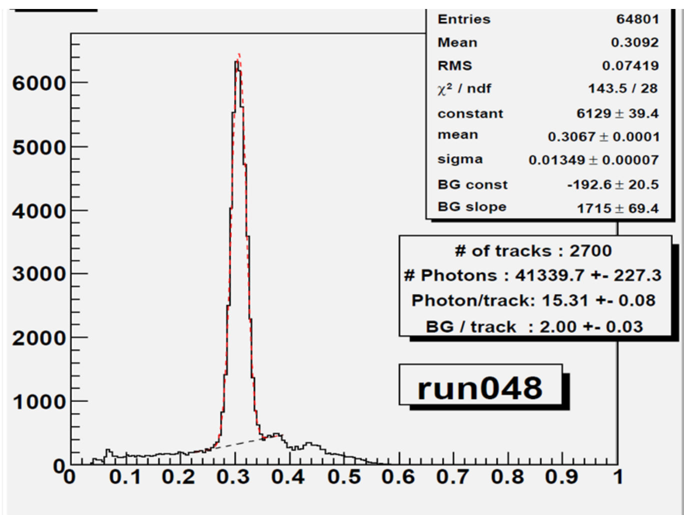
Employ multiple layers with different refractive indices → Cherenkov images from individual layers overlap on the photon detector.

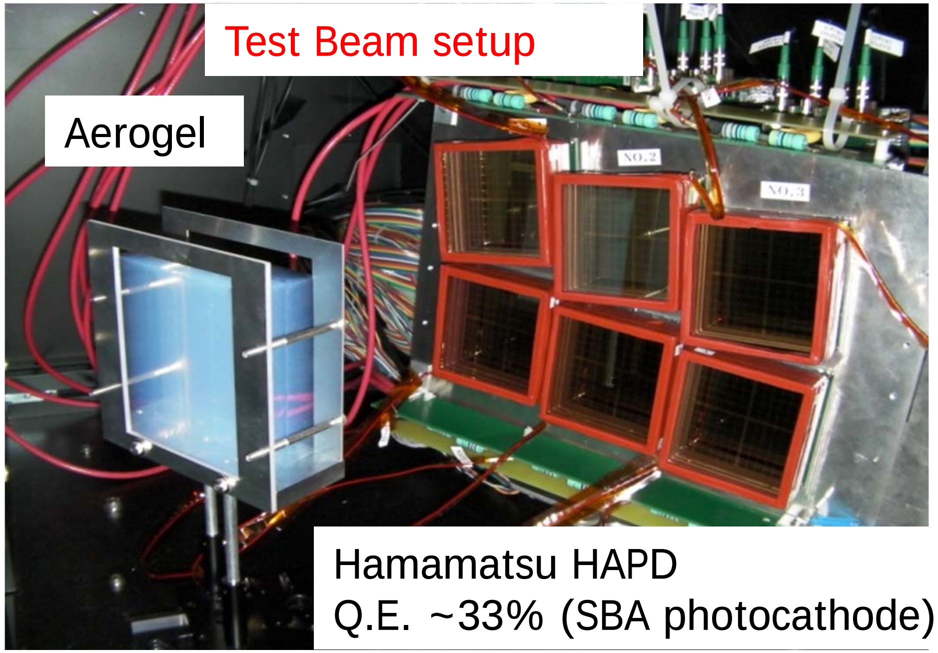




Clear Cherenkov image observed

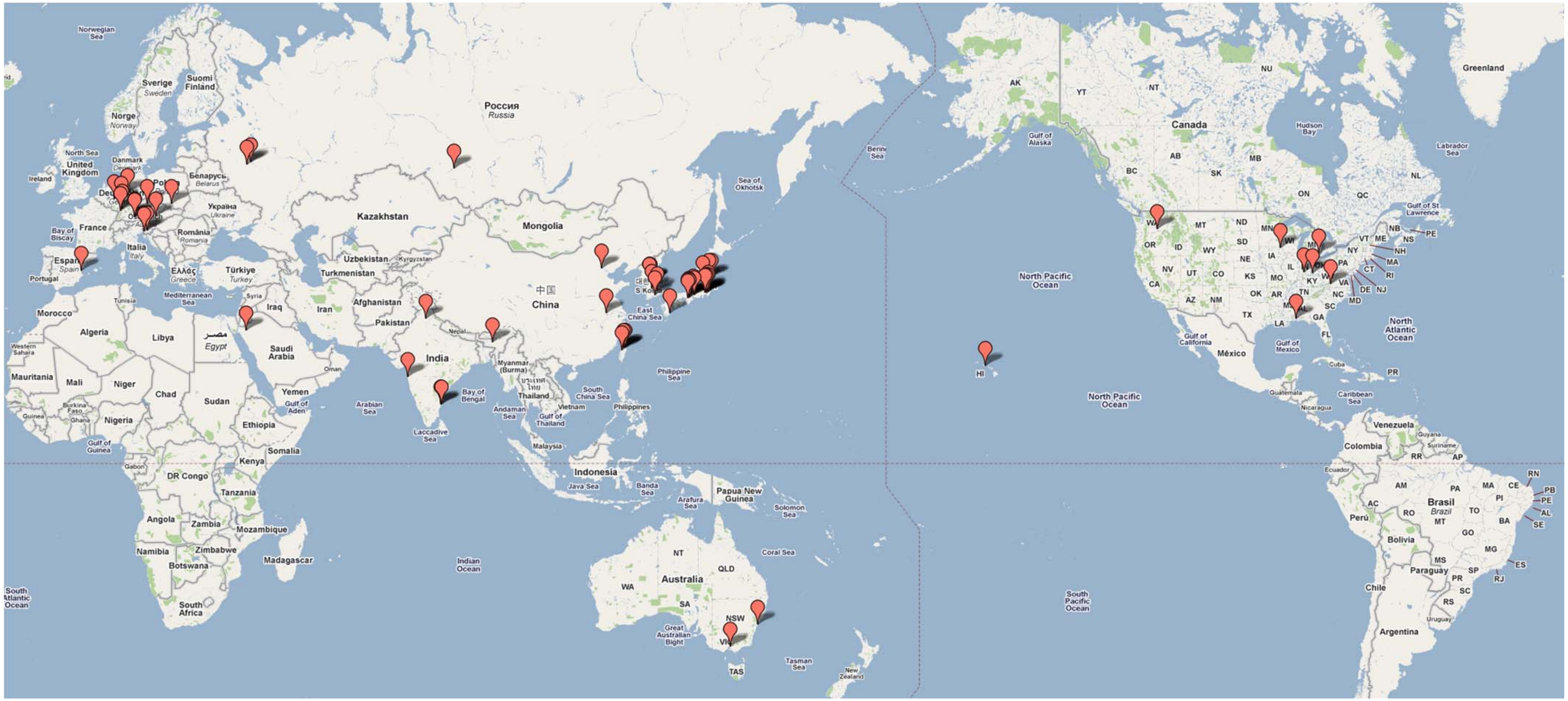
Cherenkov angle distribution





6.6 σ π/K at 4GeV/c !

Belle II Collaboration



15 countries, ~60 institutions

~400 collaborators

European groups of Belle-II

- Austria: HEPHY (Vienna)
- Czech republic: Charles University in Prague
- Germany: U. Bonn, U. Giessen, U. Goettingen, U. Heidelberg, KIT Karlsruhe, LMU Munich, MPI Munich, TU Munich
- Poland: INP Krakow
- Russia: ITEP (Moscow), BINP (Novosibirsk), IHEP (Protvino)
- Slovenia: J. Stefan Institute (Ljubljana), U. Ljubljana, U. Maribor and U. Nova Gorica

A sizeable fraction of the collaboration: in total ~150 collaborators out of ~400!

SuperKEKB/Belle II funding Status

Belle II

KEKB upgrade has been approved

- 5.8 oku yen (~MUSD) for Damping Ring (FY2010)
- 100 oku yen for machine -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government by December 2010; the project is in the JFY2011 budget as approved by the Japanese Diet end of March 2011

Several non-Japanese funding agencies have also already allocated sizable funds for the upgrade.

→construction started!

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Press Release

大学共同利用機関法人 KEK 高エネルギー加速器研究機構

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last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

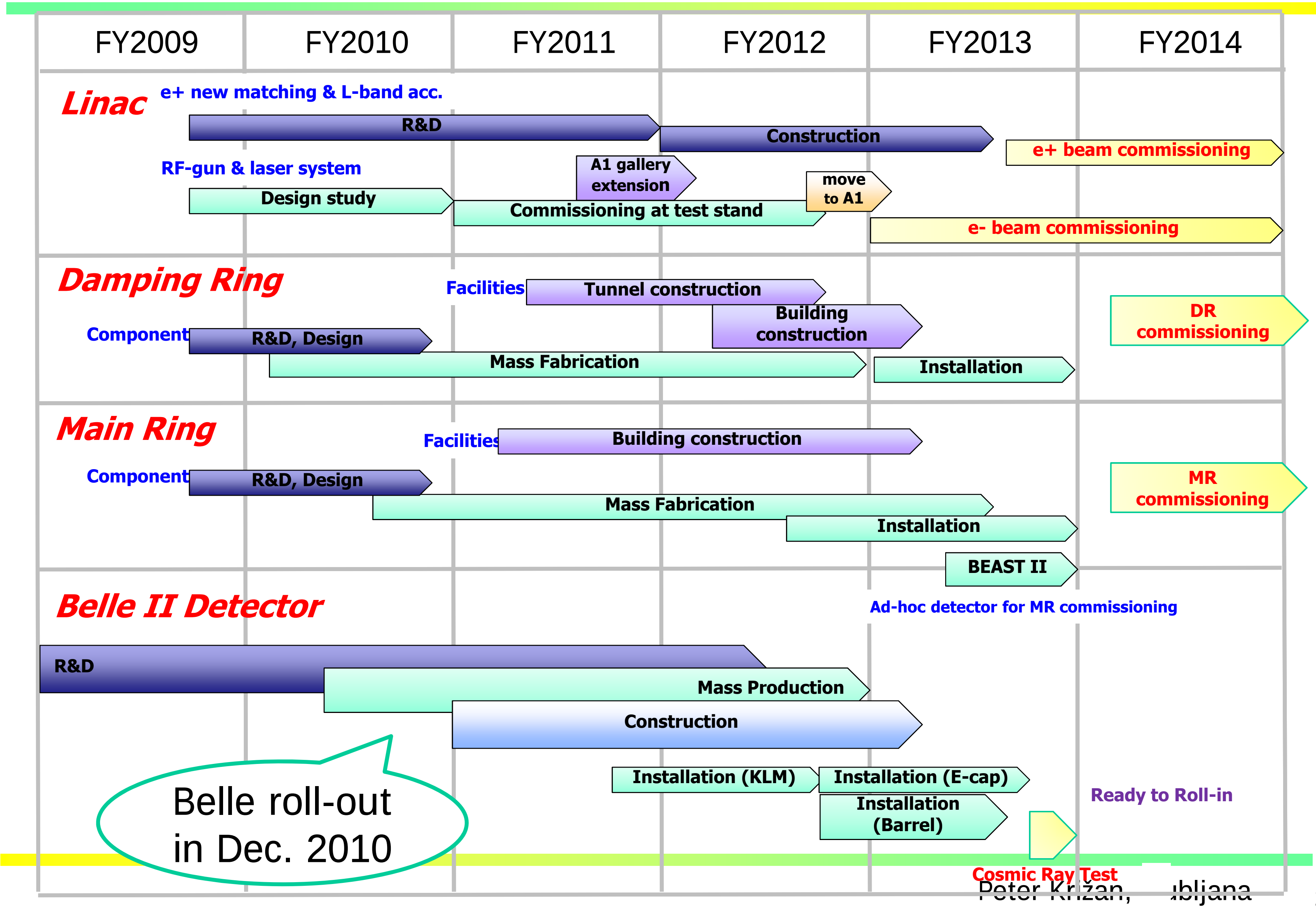
The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

[Media Contact] Youhei Morita,
Head of Public Relations Office, KEK
tel. +81-29-879-6047

| proffice@kek.jp | Copyright | Send Question

Construction Schedule of SuperKEKB/Belle II



KEKB/Belle status: official statement

„As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for.

The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary.

We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.“

KEKB/Belle status

Fortunately enough:

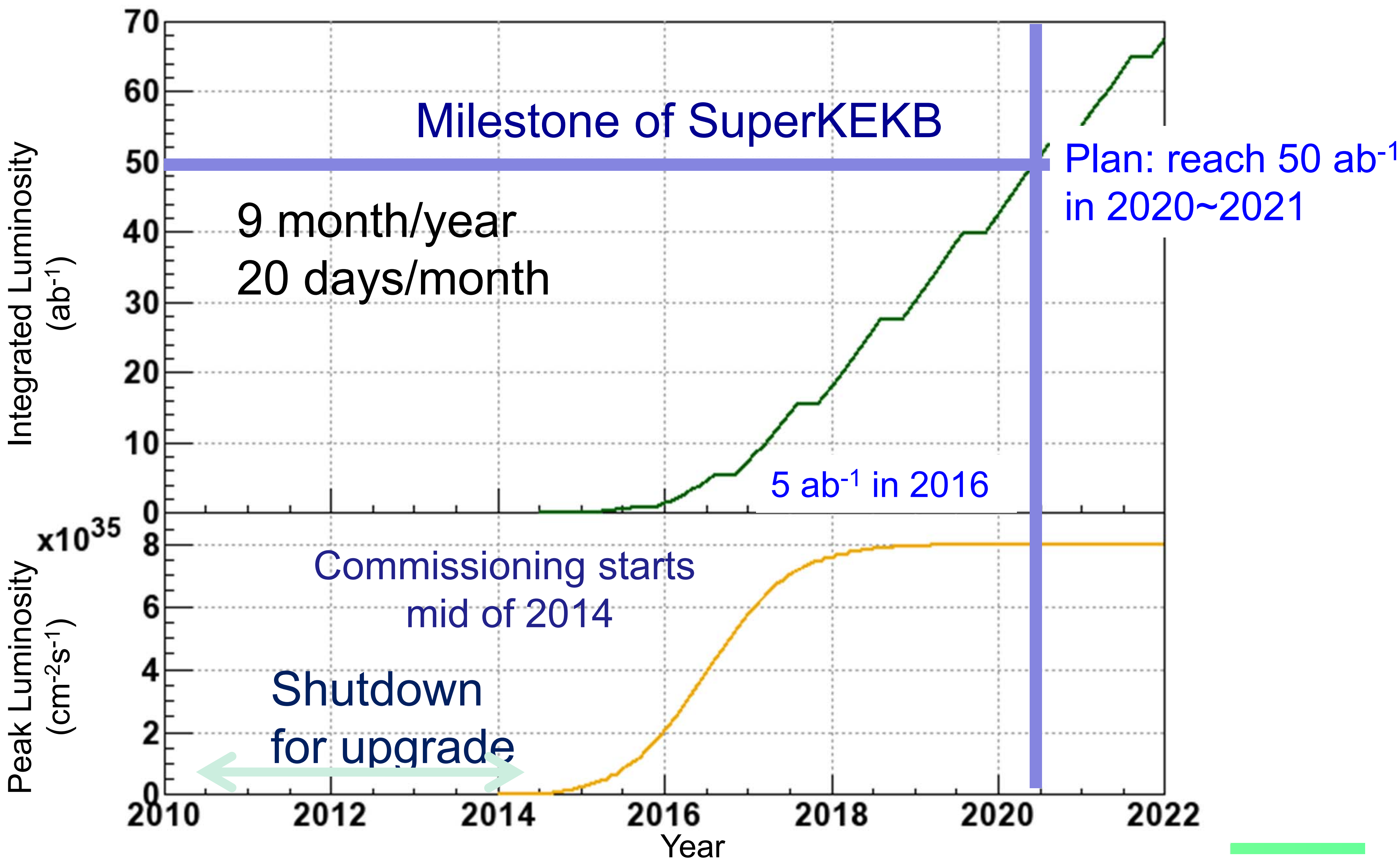
- KEKB stopped operation in July 2010, and the low energy ring was to a large extent disassembled
- Belle was rolled out to the parking position in December.

The 1400 tons of Belle moved by ~6cm (most probably by 20cm in one direction, and 14cm back)…

We are checking the functionality of the Belle spectrometer (in particular the CsI calorimeter), so far all OK in LED and cosmic ray tests!

The lab (Tsukuba campus) has to a large extent recovered from the earthquake, back to normal operation – including the power supply for the computing center for Belle data analysis for summer conferences…

Luminosity upgrade projection



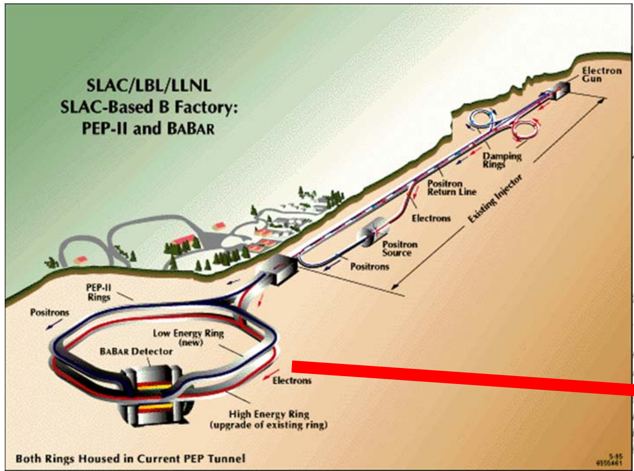
→ Talk by Boris Shwartz, Friday

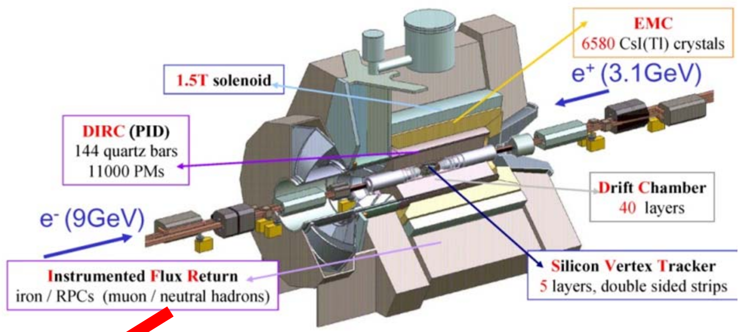
Super B factory in Italy: SuperB

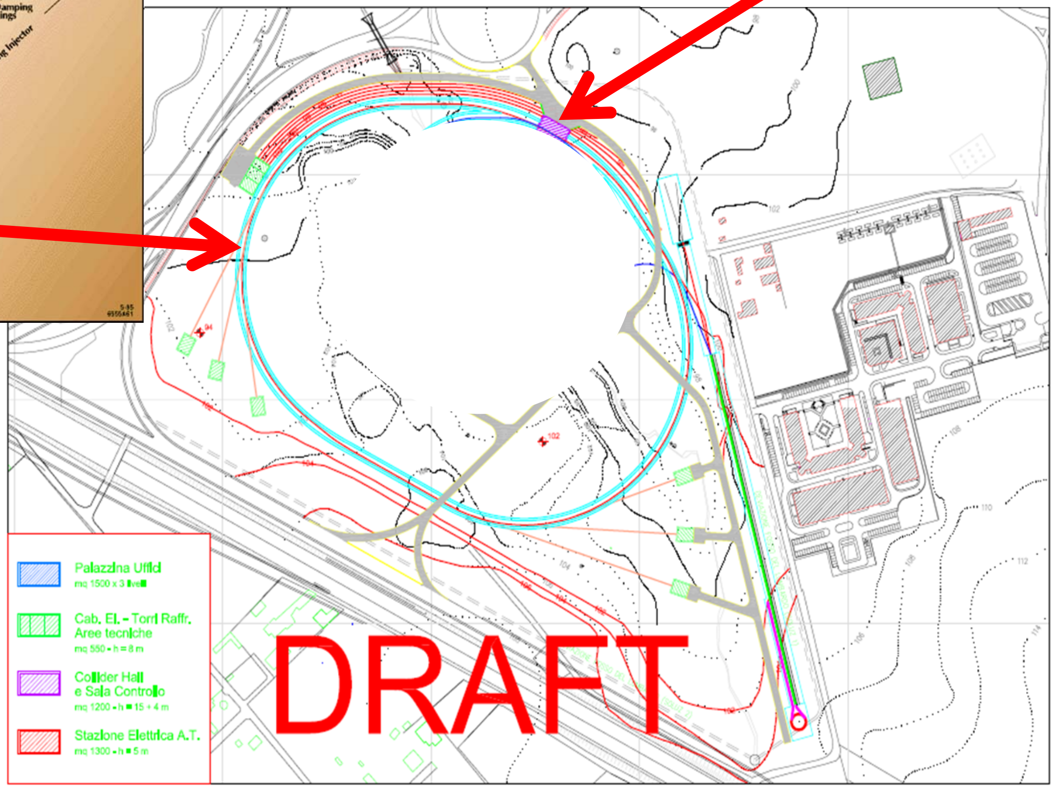
Construct a new tunnel near Frascati

→ Move magnets from PEP-II

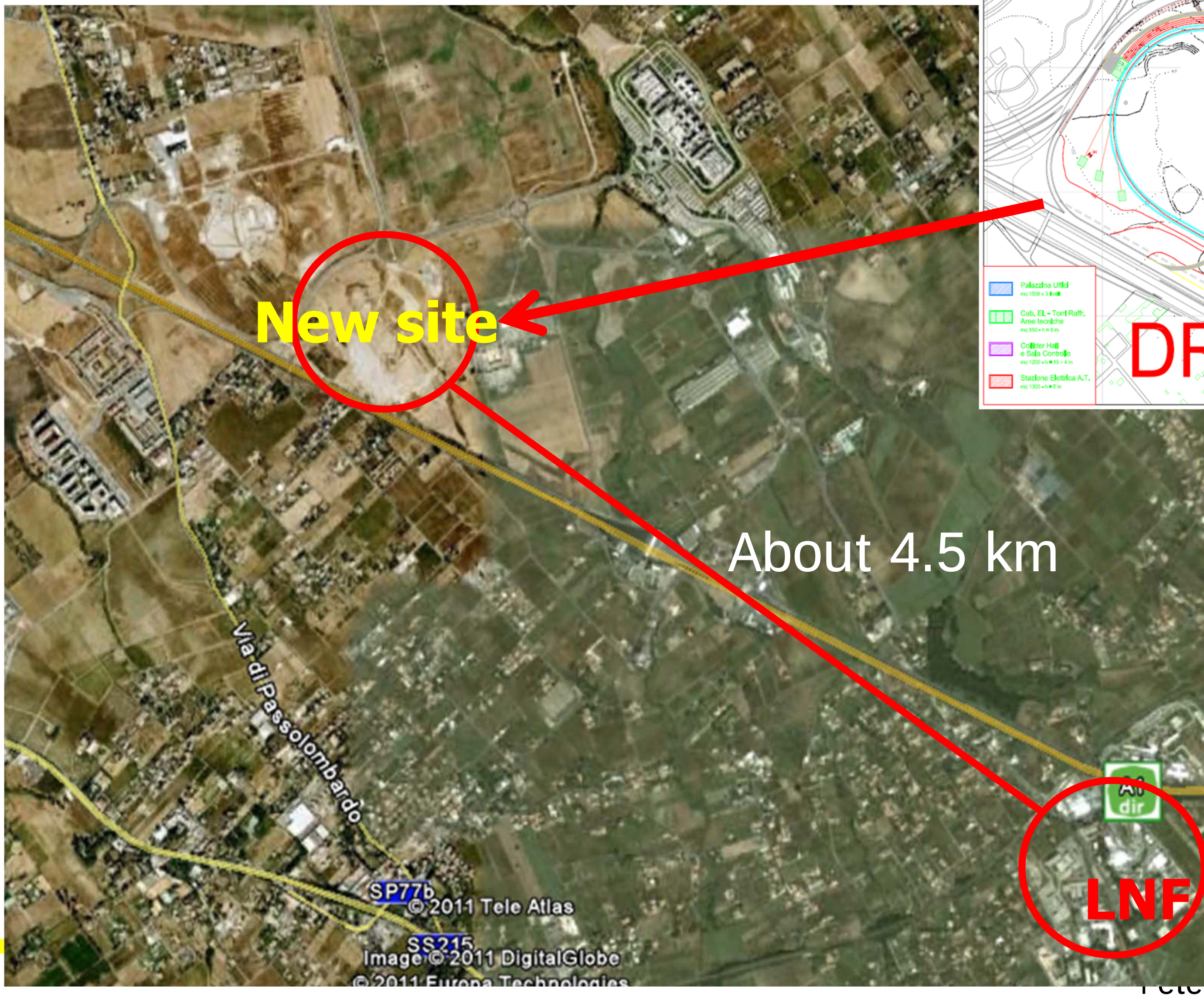
→ Move BaBar, upgrade with new detectors

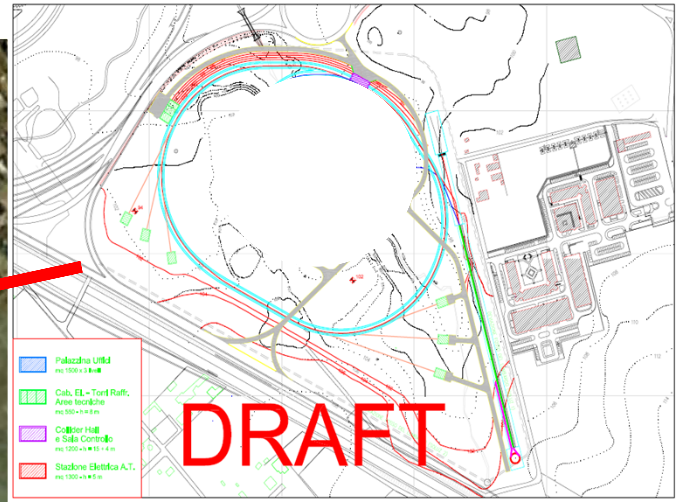






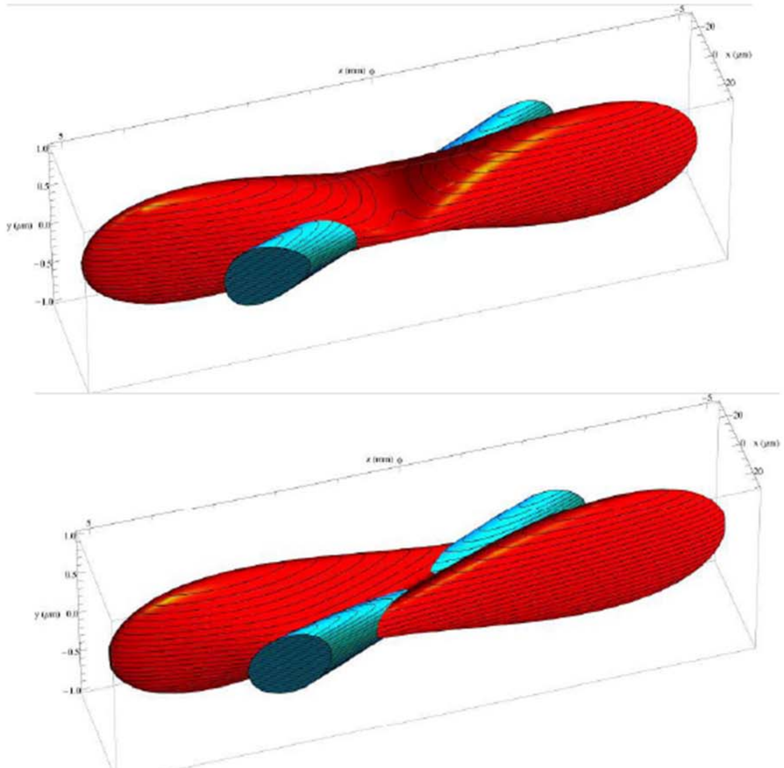
SuperB site: Tor Vergata University campus





Nano-beam collisions with crab waist

Pantaleo Raimondi



Without
Crab-sextupoles

With
Crab-sextupoles

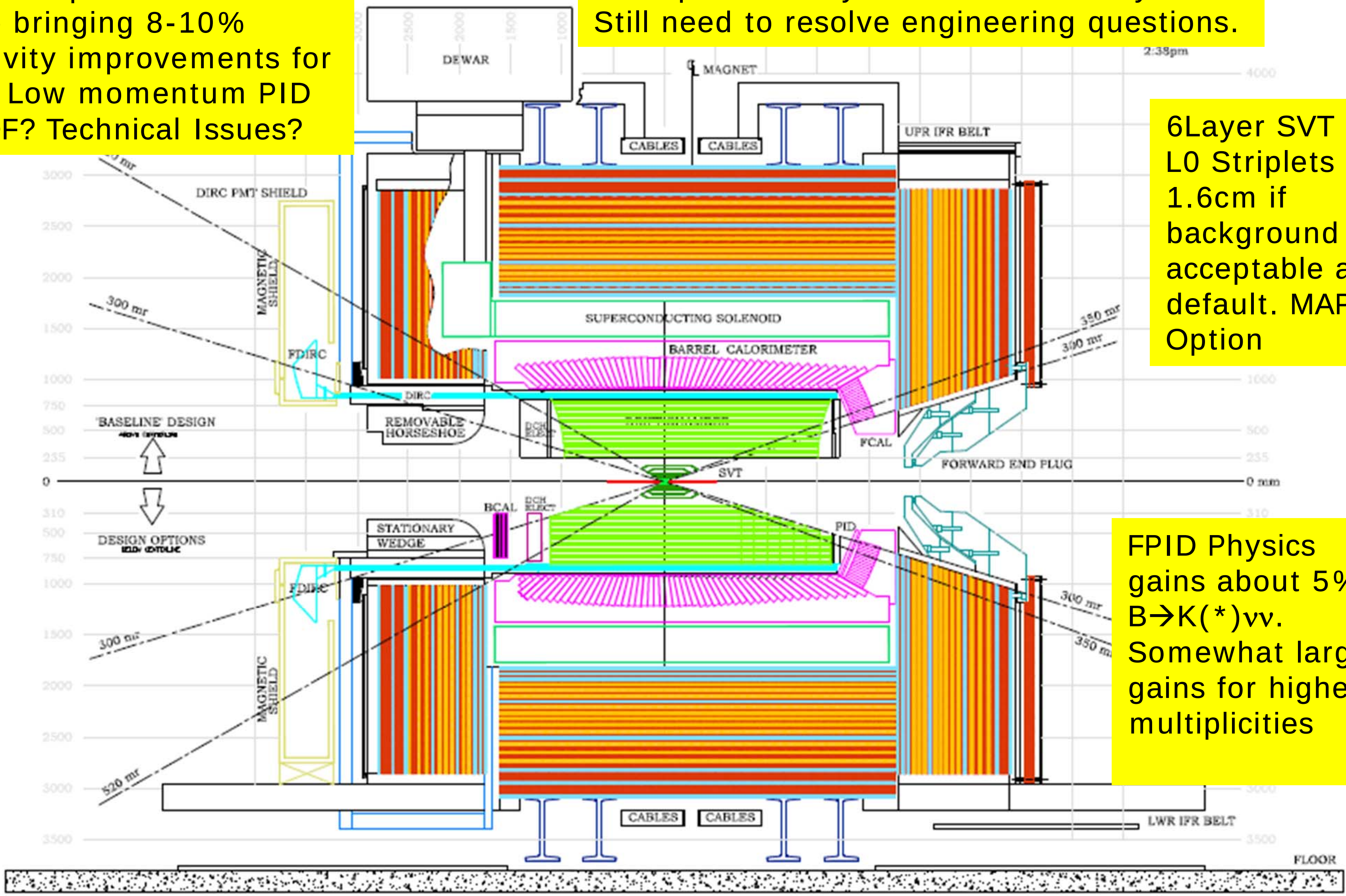
Crab waist scheme: successfully tested in the DAΦNE ring

Other features: run at charm threshold, polarized e beam

SuperB Detector (with options)

BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for $B \rightarrow \tau \nu$. Low momentum PID via TOF? Technical Issues?

IFR Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.



6Layer SVT L0 Striplets @ 1.6cm if background is acceptable as default. MAPS Option

FPID Physics gains about 5% in $B \rightarrow K(^*)\nu\nu$. Somewhat larger gains for higher multiplicities

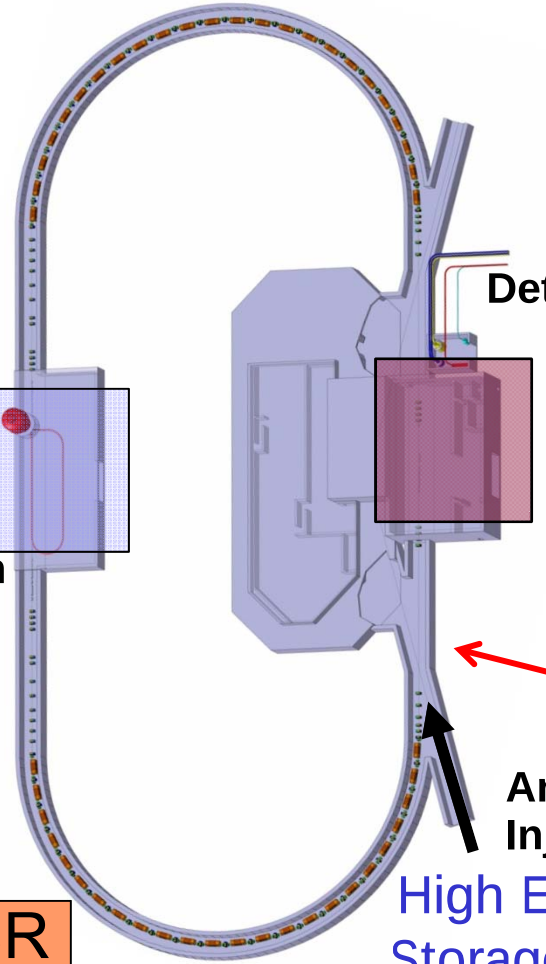
M. Giorgi, ICHEP2010

SuperB Status

- SuperB has been approved as the first in a list of 14 Italian “flagship” projects within the new 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”
- At the end of 2010 an initial sum of 19 MEuros has been allocated
- A sum of the order of 50 MEUR is expected for 2011 budget

From a talk by Roberto Petronzio at the XVII SuperB Workshop and Kick Off Meeting - La Biodola (Isola d'Elba) Italy, May 30, 2011

PANDA at FAIR: $\bar{p}p$



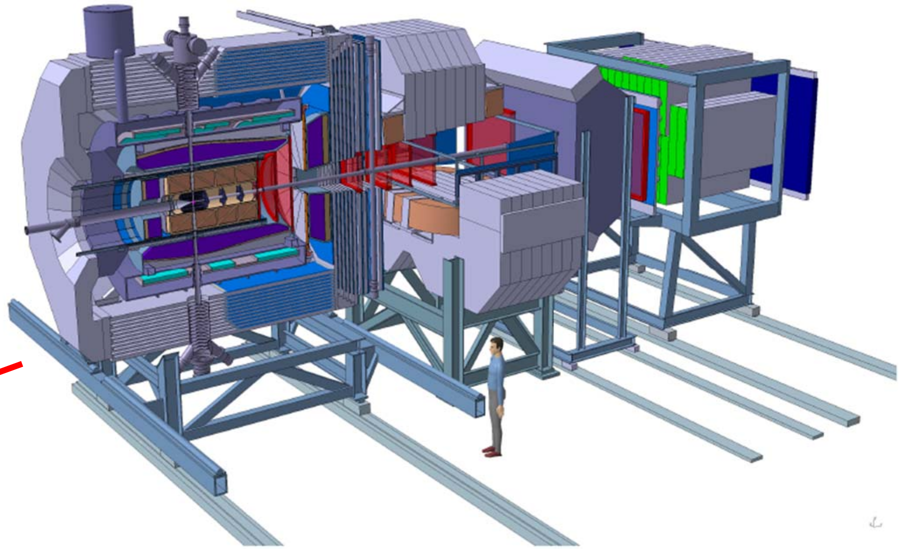
Detector

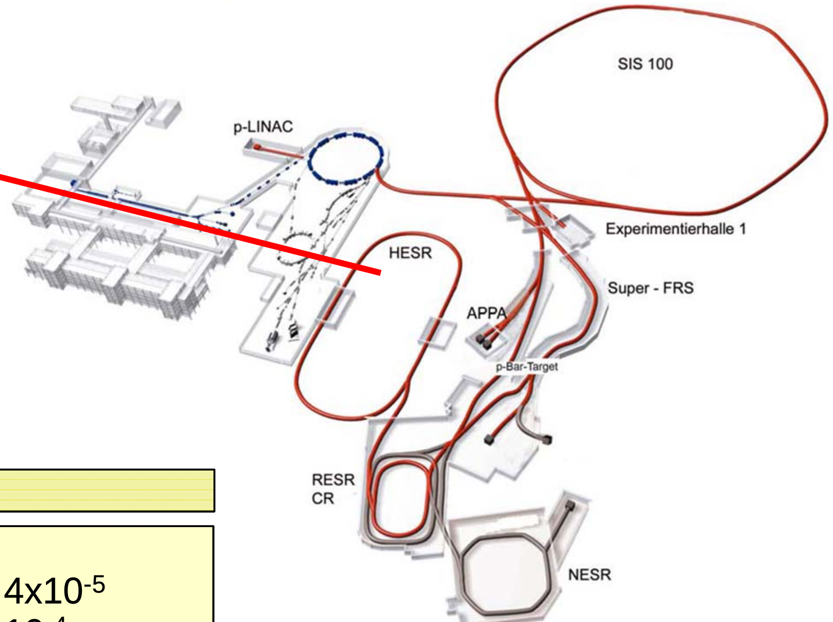
Electron cooler

Antiproton Injection

HESR

High Energy Storage Ring





Cooling: electron/stochastic

P_{max} = 15 GeV/c

High resolution: L = 10^{31} cm^{-2} s^{-1} $\delta p/p < 4\times10^{-5}$

High luminosity: L = $2\cdot10^{32}$ cm^{-2} s^{-1} $\delta p/p < 10^{-4}$

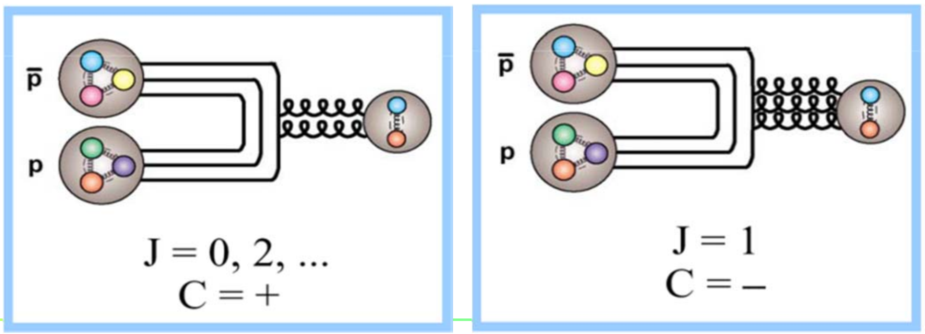
PANDA Physics Program

- Meson spectroscopy:
  - D mesons
  - charmonium
  - glueballs, hybrids, tetraquarks, molecules
- Charmed and multi-strange baryon spectroscopy
- Electromagnetic processes (pp→e^+e^-, pp→$\gamma\gamma$, Drell-Yan)
- Properties of single and double hypernuclei
- Properties of hadrons in nuclear matter

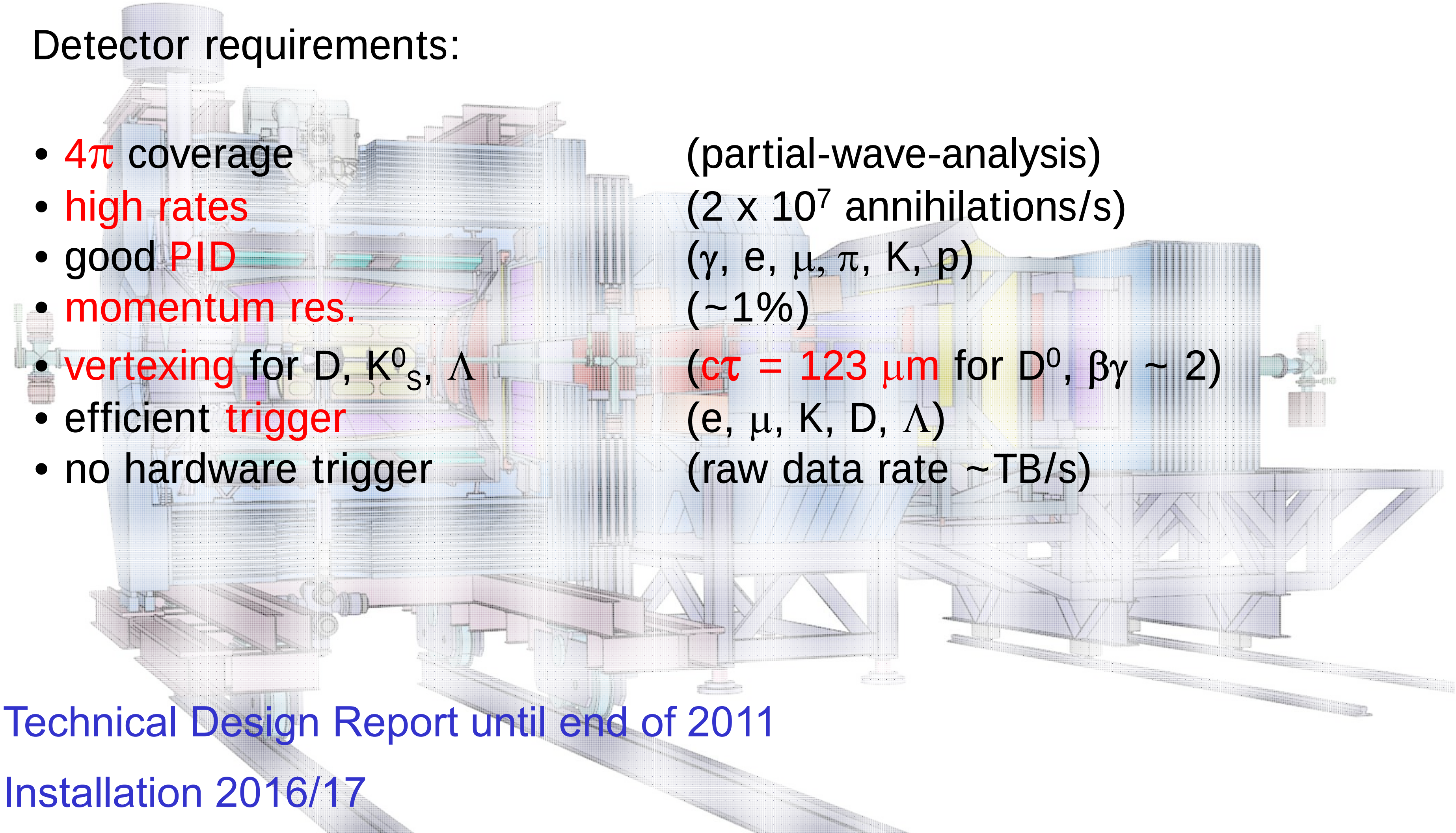
Why anti-protons?

- Gluon rich process
- Gain ~ 2GeV in annihilation
- B = 0 system
- All fermion-antifermion quantum numbers accessible
- Very high mass resolution in formation reactions
- High L states angular momentum accessible

Formation:



PANDA Spectrometer



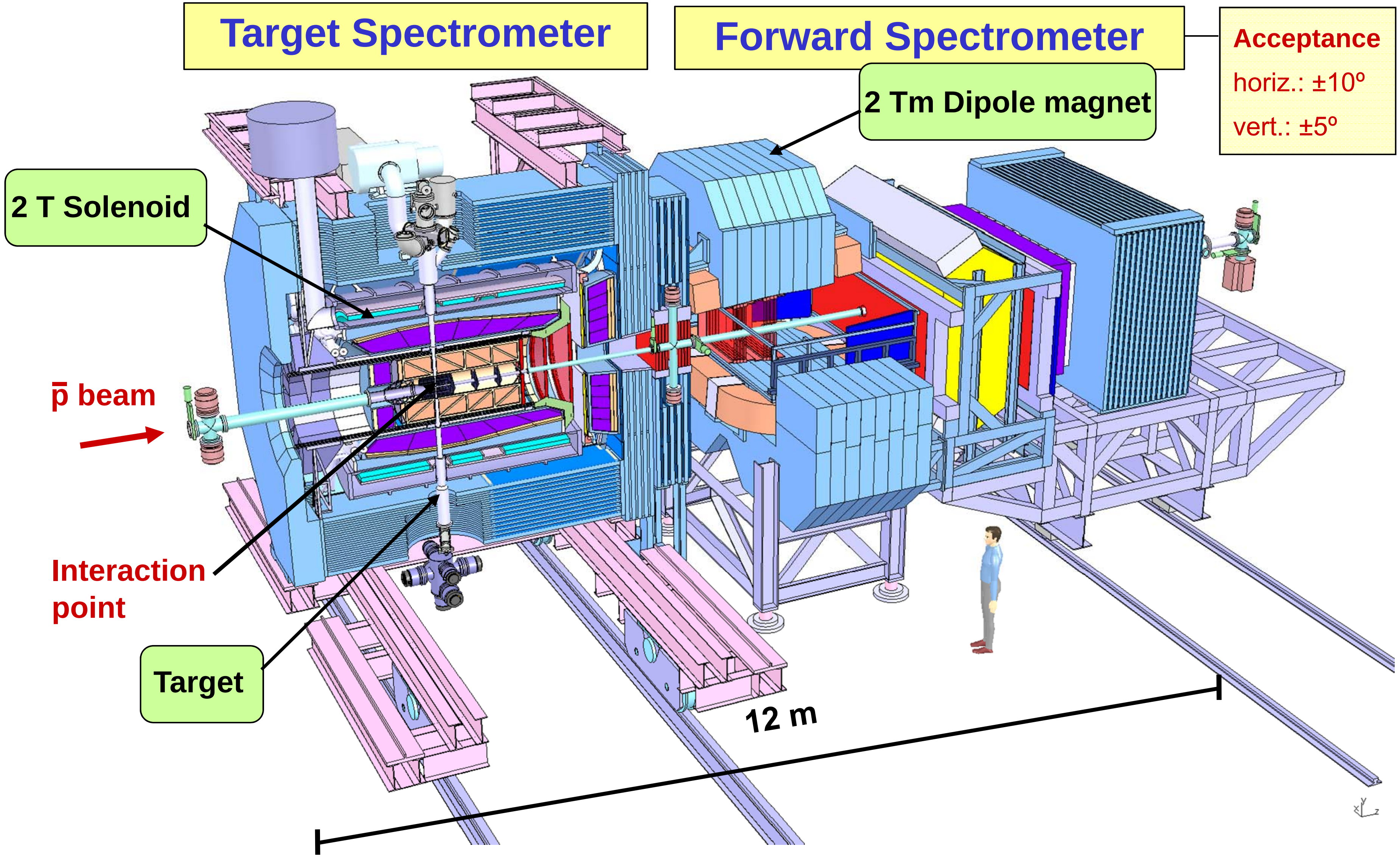
Detector requirements:

- 4π coverage (partial-wave-analysis)
- high rates (2×10^7 annihilations/s)
- good PID (γ, e, μ, π, K, p)
- momentum res. (~1%)
- vertexing for D, K^0_S, Λ ($c\tau$ = 123 μm for D^0, $\beta\gamma$ ~ 2)
- efficient trigger (e, μ, K, D, Λ)
- no hardware trigger (raw data rate ~TB/s)

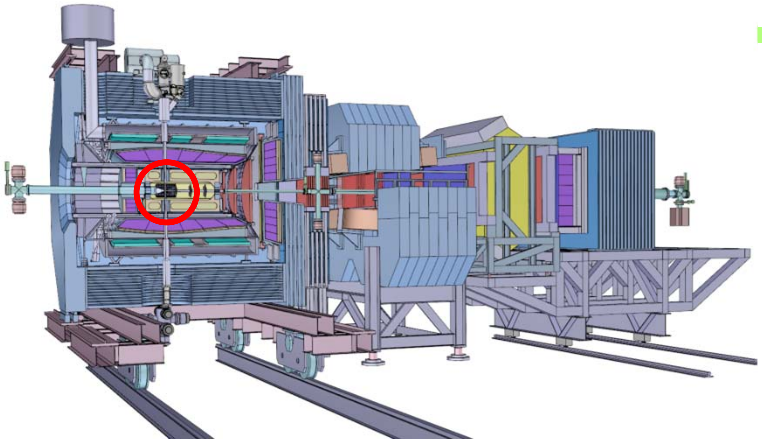
Technical Design Report until end of 2011

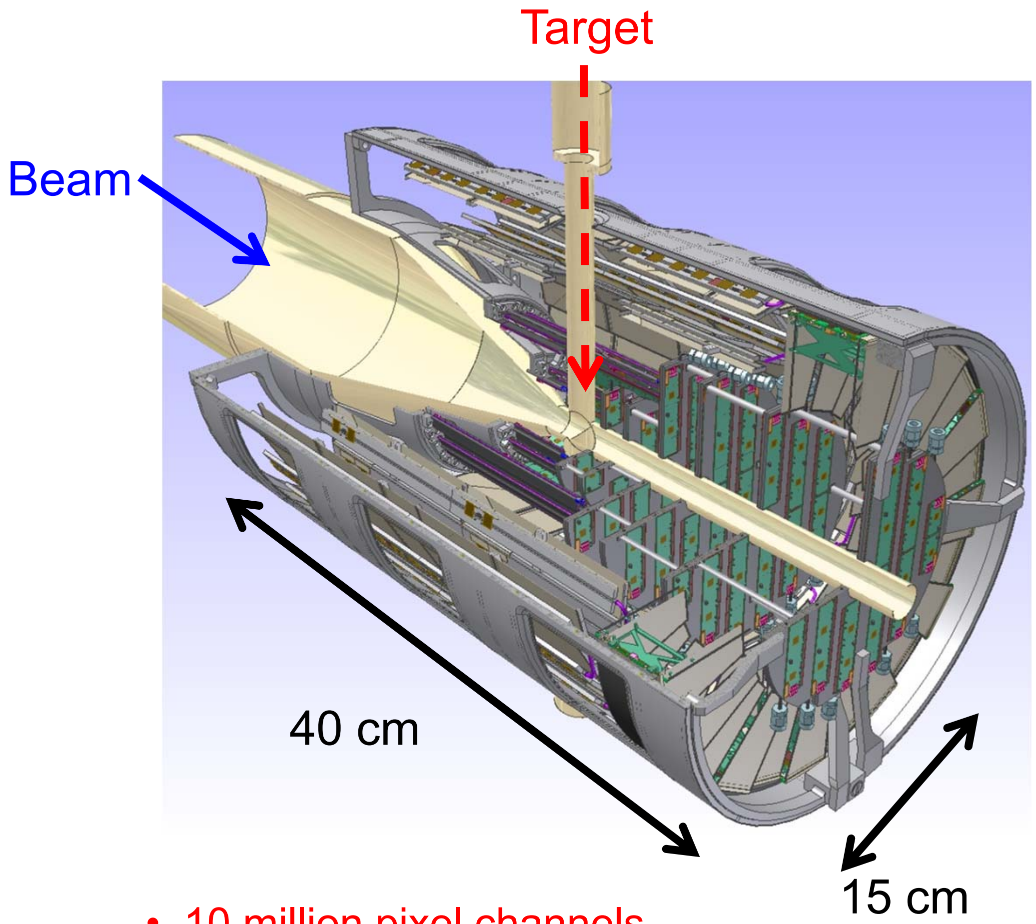
Installation 2016/17

PANDA Spectrometers



Micro-Vertex-Detector

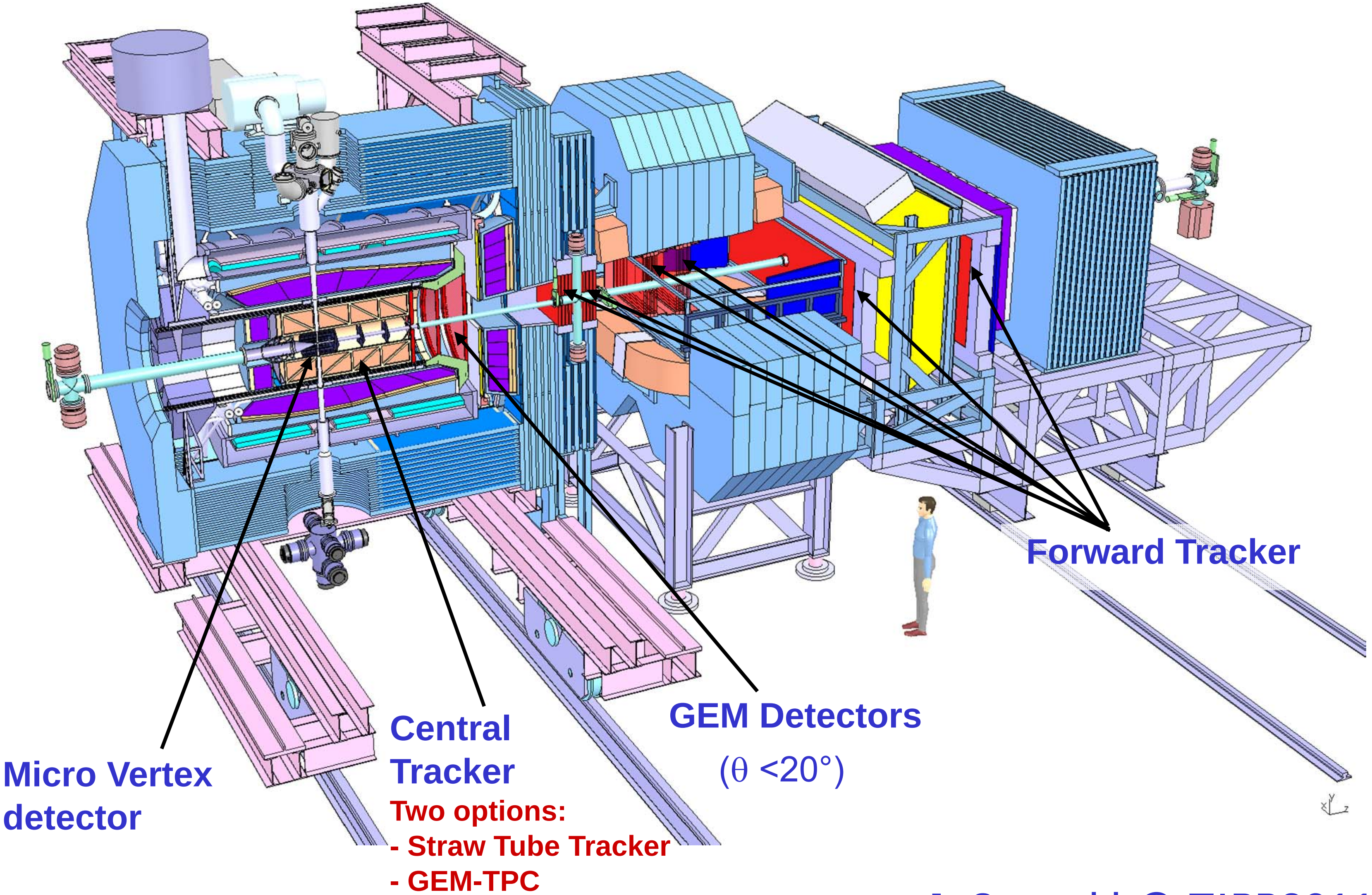




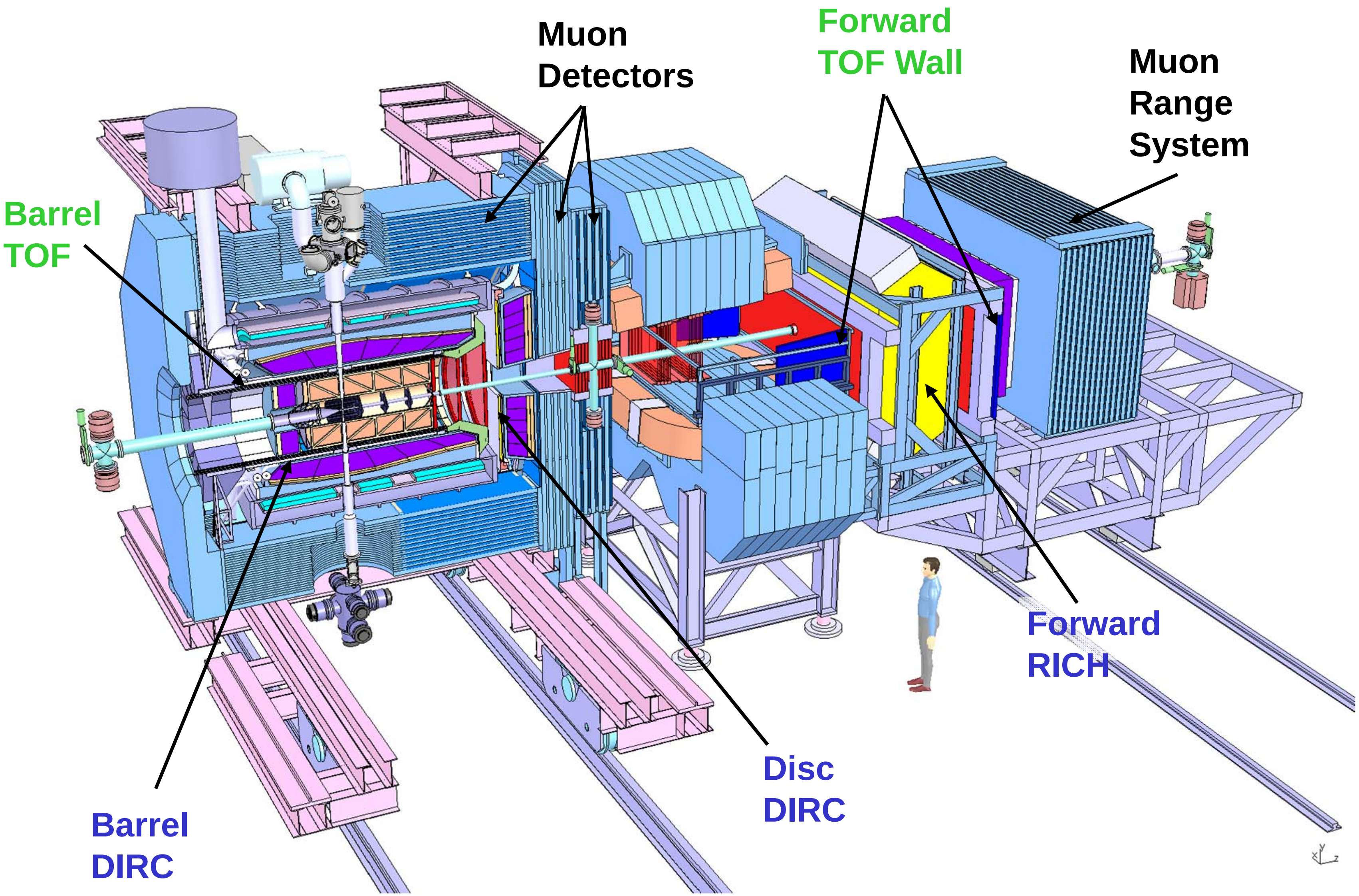
Target:
pellets (frozen droplets)
or cluster jet (nanoparticles)

- 10 million pixel channels on 176 modules
- 200,000 strip channels on 254 modules

Tracking Detectors



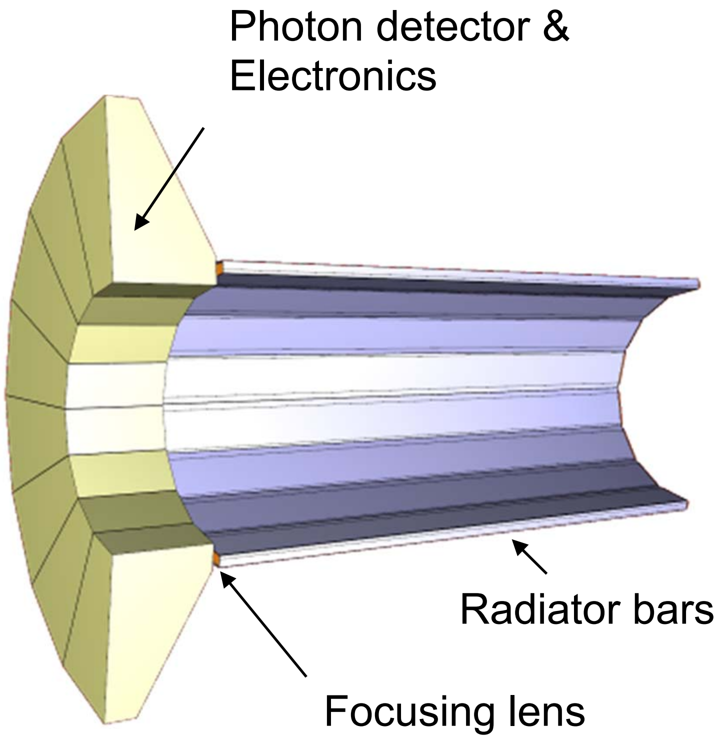
PID


Muon
Detectors
Forward
TOF Wall
Muon
Range
System
Barrel
TOF
Forward
RICH
Disc
DIRC
Barrel
DIRC

Barrel DIRC

- Similar to BaBar DIRC
- π/K separation 0.5 < p < 4 GeV/c
- Inner radius: 48 cm
- Radiator: 96 bars, fused silica (n=1.47), size: 17mm (T) x 33mm(W) x 2500mm (L)
- Compact photon detector: array of MCP-PMT (Burle Planacon) in magnetic field 0.5 -1 T

  total 7000-10000 channels
- Time of propagation → dispersion corrections (3D-DIRC concept – *x,y,t*)
- Focusing optics



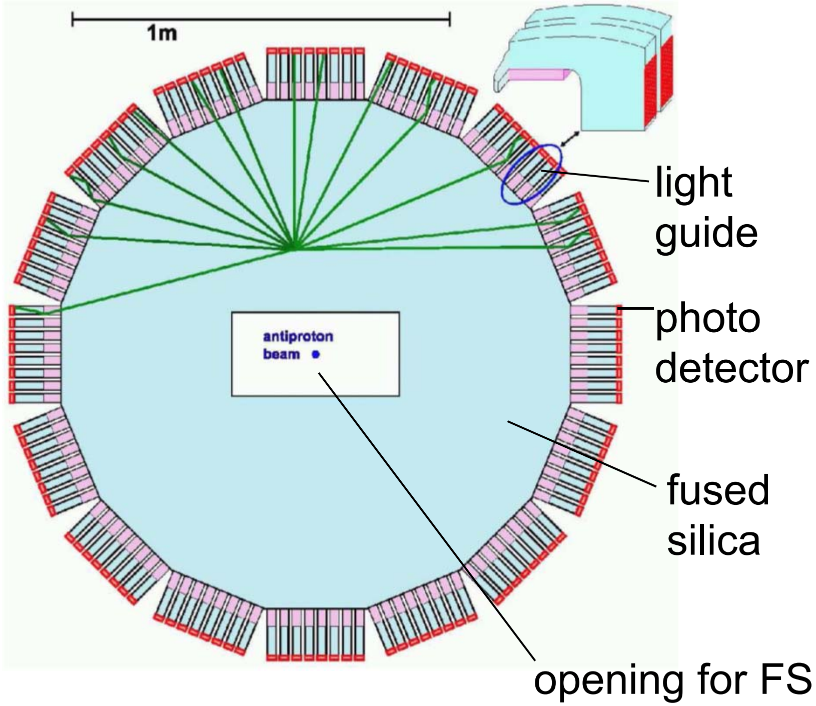
Disc DIRC

Radiator: fused silica 20 mm thick, R =1m

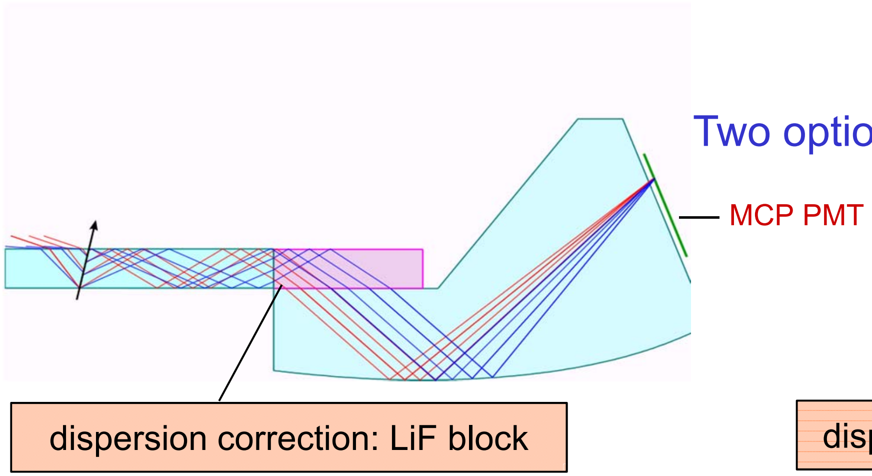
π/K separation up to 4 GeV/c

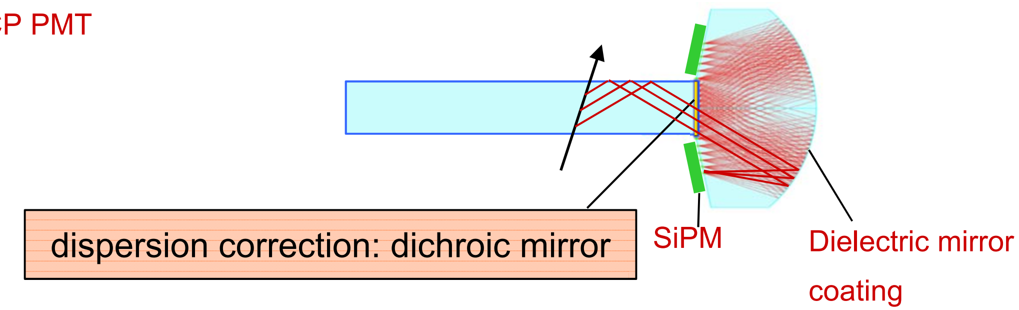
Focusing light guide

Photon detector in ~1T field
capable of rates 0.75 MHz/cm^2
(MCP-PMTs or dSiPMs)

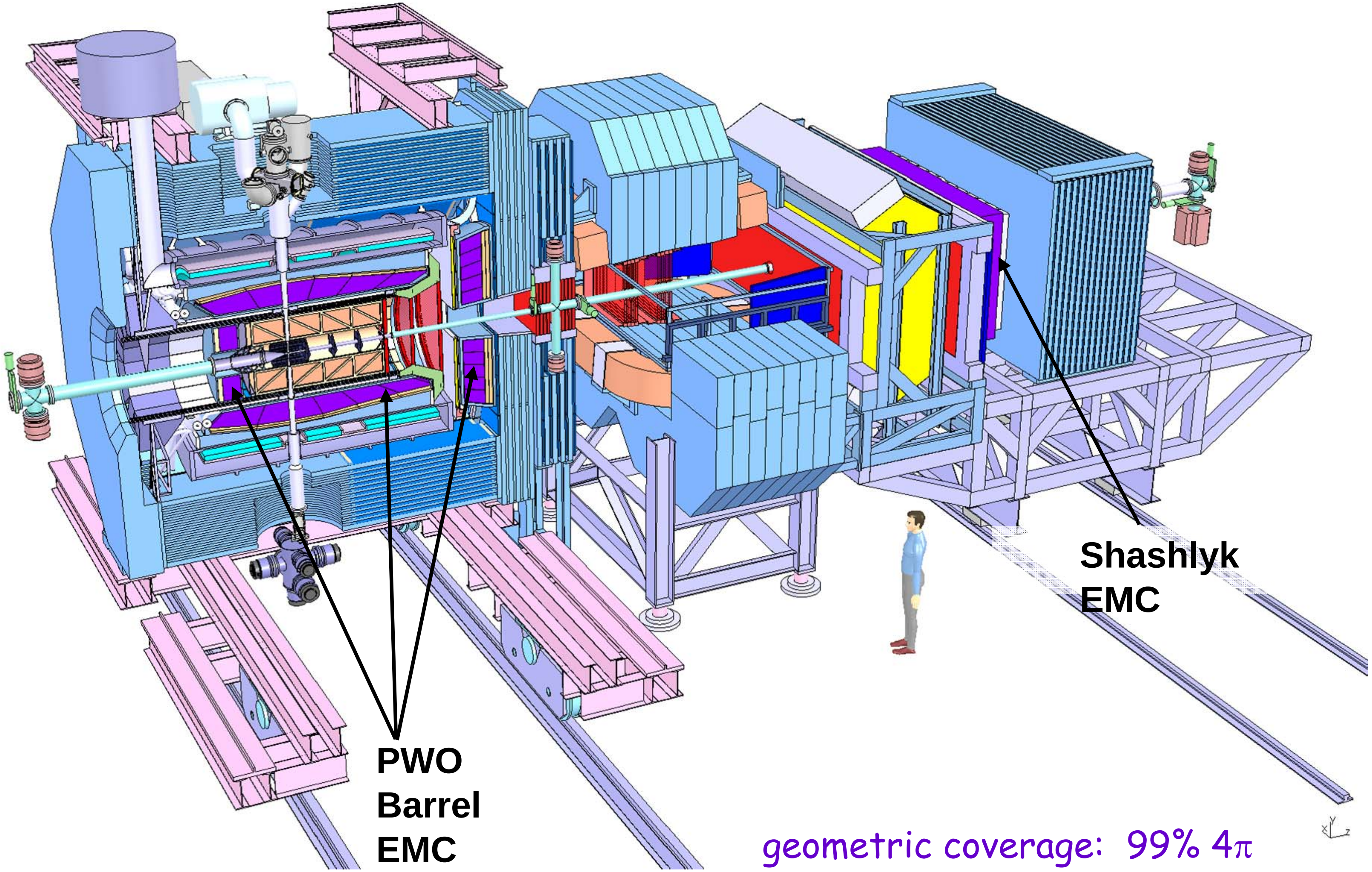


Two options for light guides





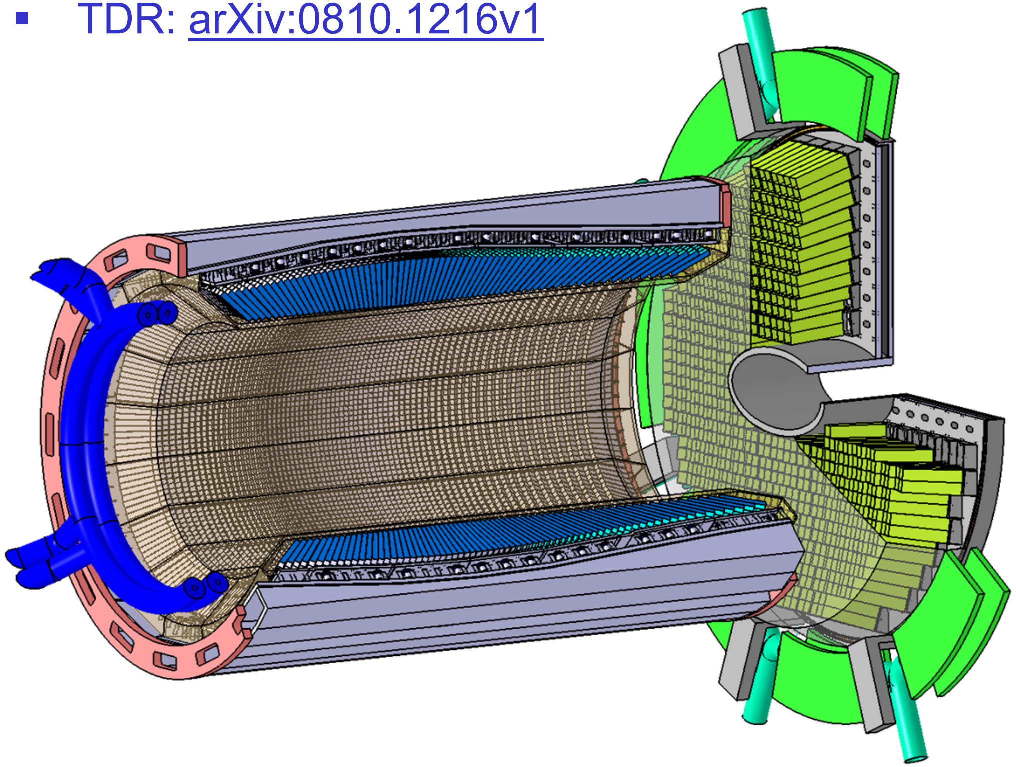
Electromagnetic Calorimeters

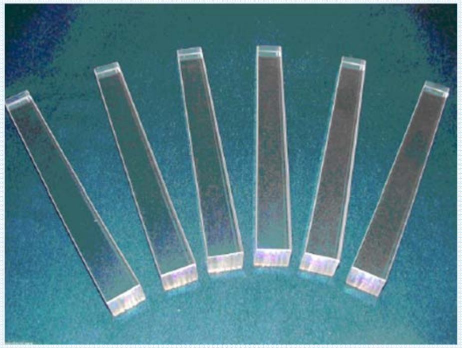


geometric coverage: 99% 4π

PWO calorimeter

- 15552 PWO-II crystals
  (barrel – 11360, forward end-cup – 3600, backward – 592)
- Inner radius of barrel 57 cm
- Thickness 22 X_0
- cooled down to -25ºC (±0.1ºC)
- Energy resolution 1.54% / √E[GeV] + 0.3%
- TDR: arXiv:0810.1216v1





PWO II crystals
- dense and fast
- increased light yield:
  - **improved PWO II** (**2x** CMS)
  - **T= -25ºC** (**x4** T=+ 25ºC)
- Dimensions 2 cm x 2 cm x 20 cm

Photosensors

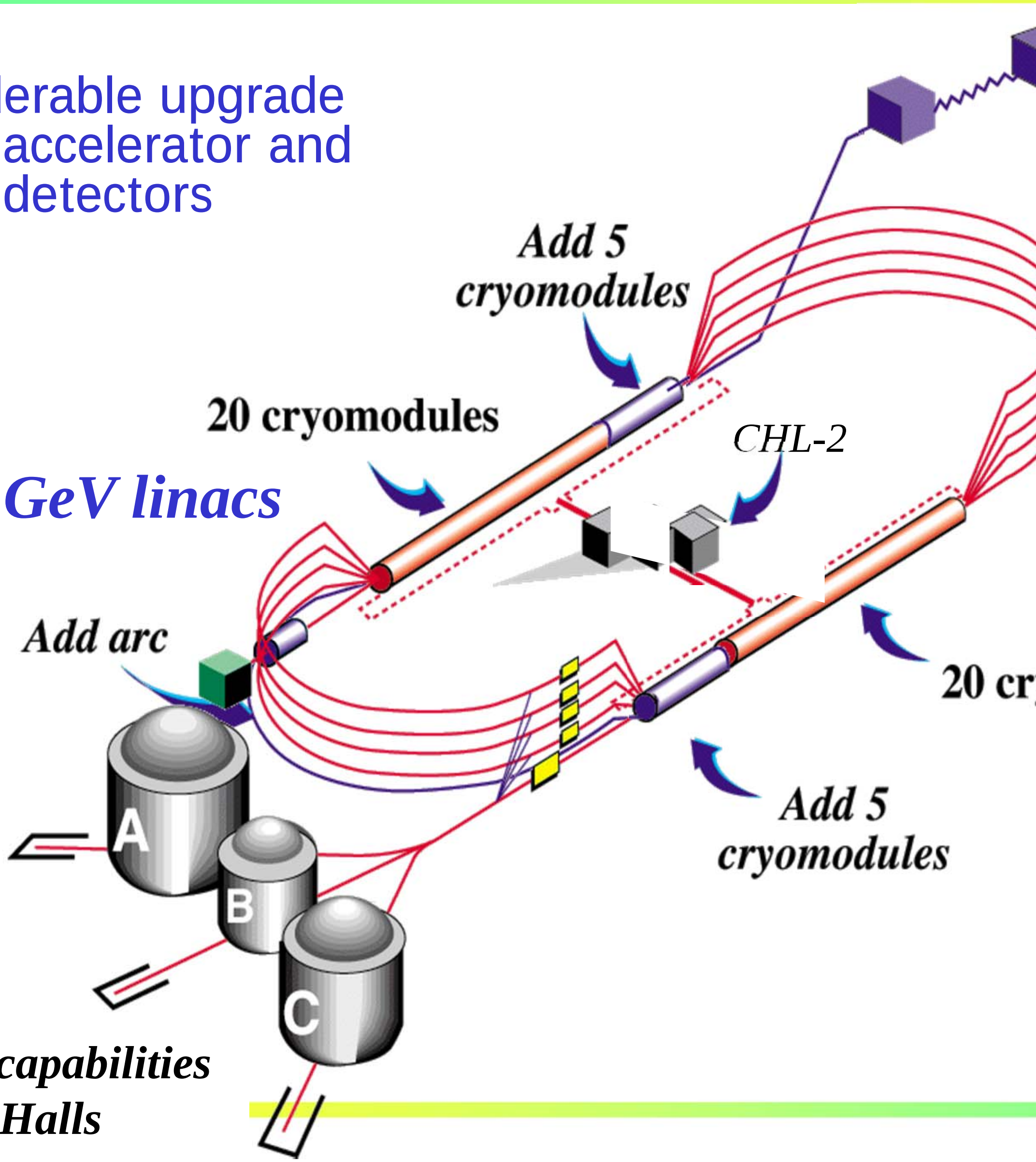
LAAPDs (barrel)
Active area 14 x 7 mm^2
- 2 LAAPDs glued to one crystal
- preamplifier-shaper: APFEL-ASIC, 350 nm CMOS

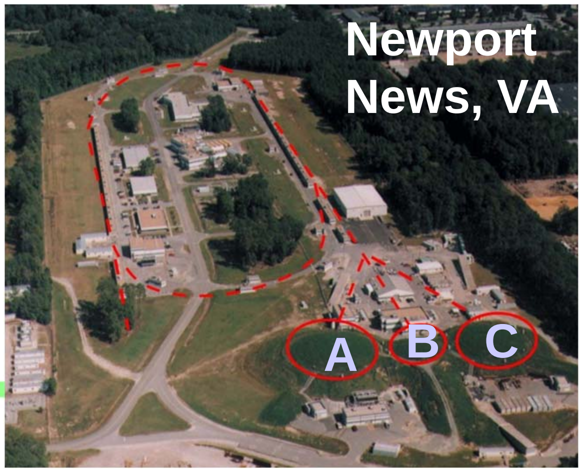
VPTs (forward end-cup)
- preamplifie-shaper: LNP-P

Experiments at the 12 GeV CEBAF

Considerable upgrade of the accelerator and of the detectors

Two* 1.1 *GeV linacs

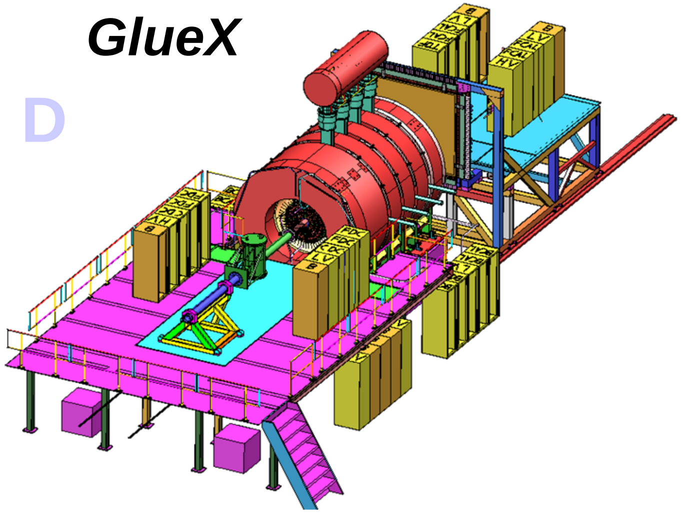




Enhanced capabilities in existing Halls

New capabilities in Halls B and D

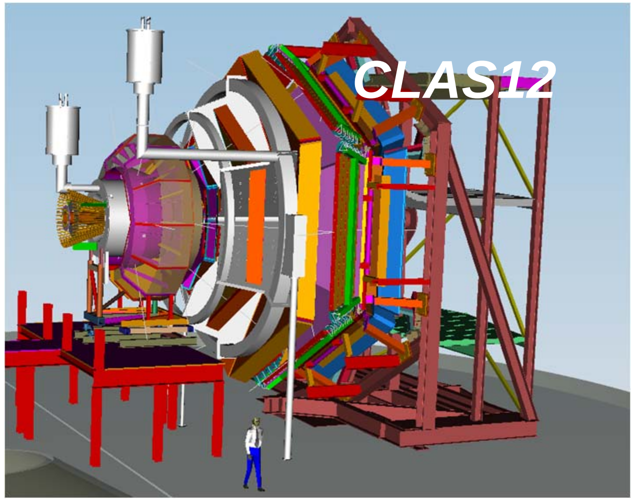
D



9 GeV tagged polarized photons
and a 4π hermetic detector

Exploring origin of confinement by studying exotic mesons.

B



CLAS upgraded to higher (10^{35}) luminosity and coverage

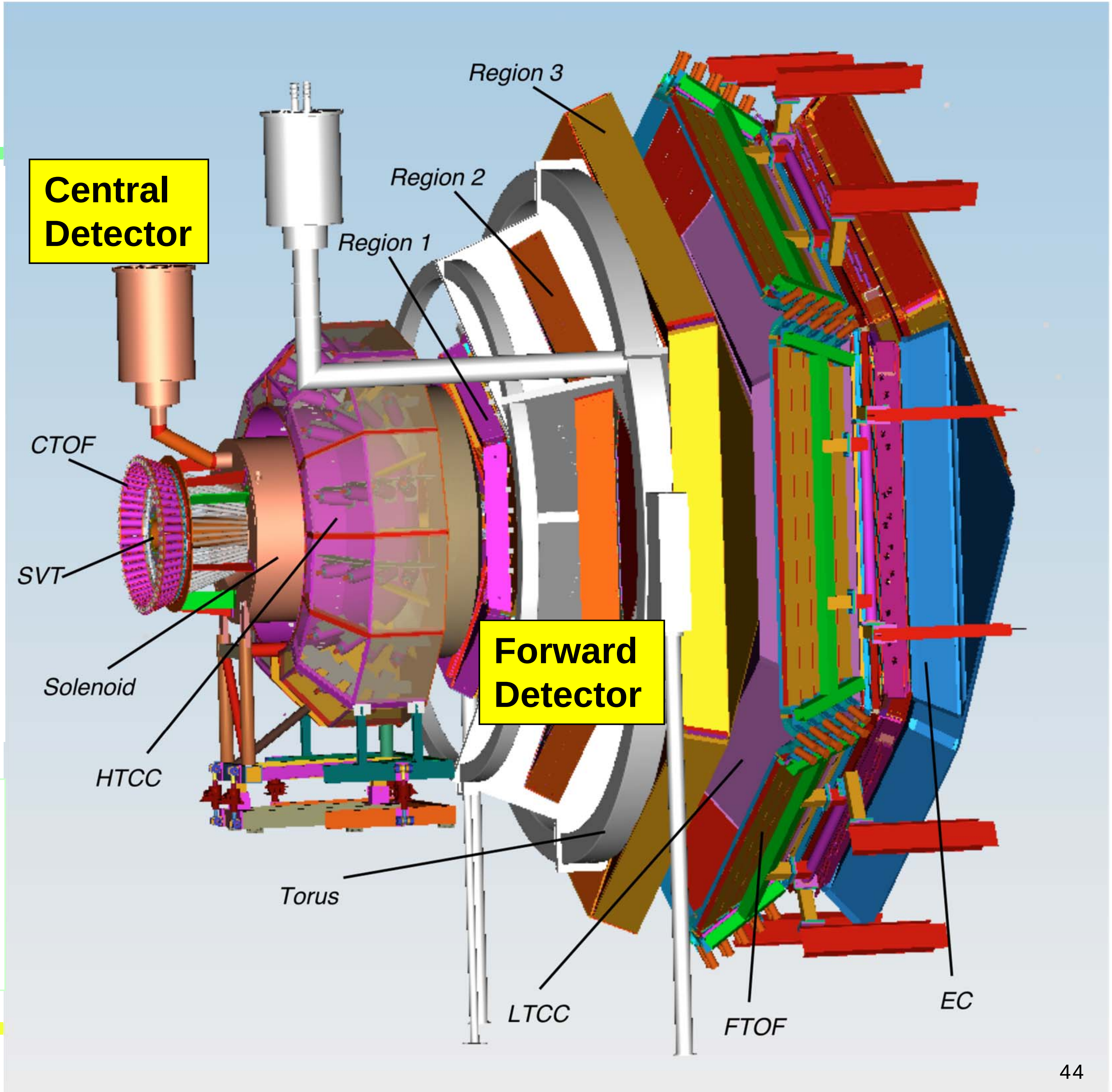
Nucleon structure via generalized parton distributions.

CLAS12

Forward spectrometer
- *TORUS magnet*
- *Forward vertex tracker*
- *HT Cherenkov Counter*
- *Drift chamber system*
- *LT Cherenkov Counter*
- *Forward ToF System*
- *Preshower calorimeter*
- *E.M. calorimeter*

Central Detector
- *SOLENOID magnet*
- *Barrel Silicon Tracker*
- *Central Time-of-Flight*

Proposed equipment
- *Small angle tagger*
- *RICH to replace LTCC*
- *Micromegas in CD*
- *Neutron detector in CD*



CLAS12 - Capabilities

Capabilities to measure exclusive processes at 12 GeV

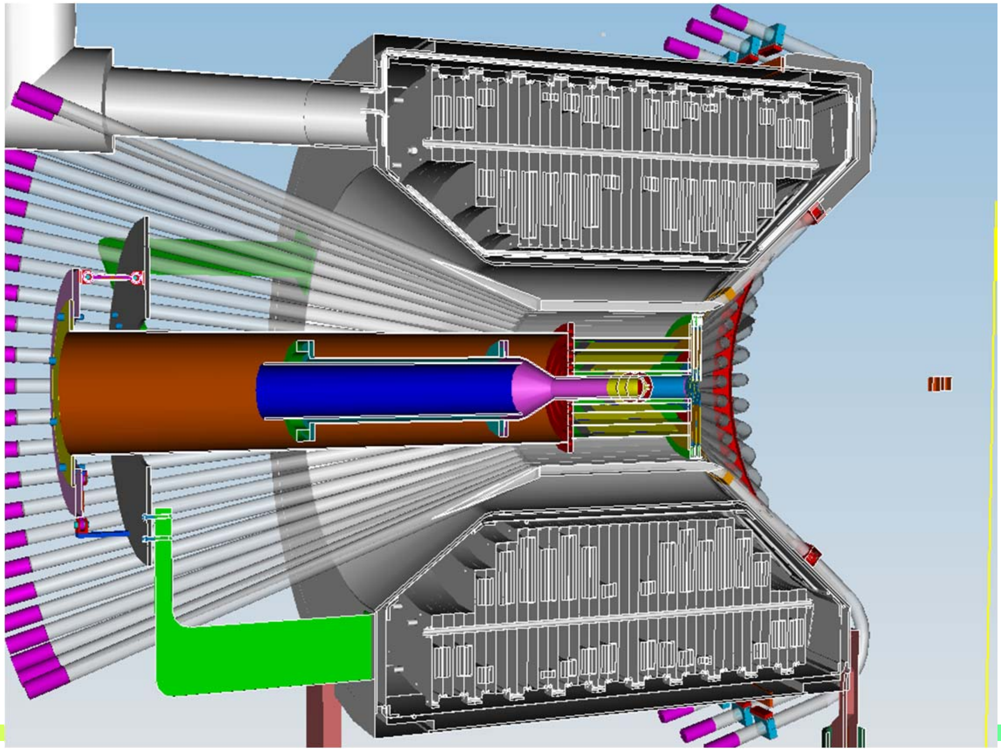
- Operating luminosity up to 10^{35} $cm^{-2}sec^{-1}$ - small cross sections
- High momentum and small polar angles
- Particle ID to high momentum for e^-/π^-, $\pi/K/p$, γ/π^o separation
- Momentum & angle resolution for use of missing mass techniques
- Coverage of large ranges in polar and azimuth angles
- Identify detached vertices for weakly decaying strange baryons

Solution:

- Reduce DC occupancies to reach higher luminosities
  - Reduced solid angle seen by each cell, reduce time window
  - Improved magnetic shielding for Møller background
- Upgrade the forward PID system
  - Additional high-threshold Cherenkov detector for π, K, p rejection
  - Improve timing resolution of the Time-of-Flight detectors
  - Improve calorimeter granularity for π^o/γ separation
  - Add tracking capabilities for improved vertex resolution
- Complement the forward detection system with central detector
  - Tracking and magnetic analysis at large angles with solenoid magnet
  - Particle identification capabilities with central Time-of-Flight system

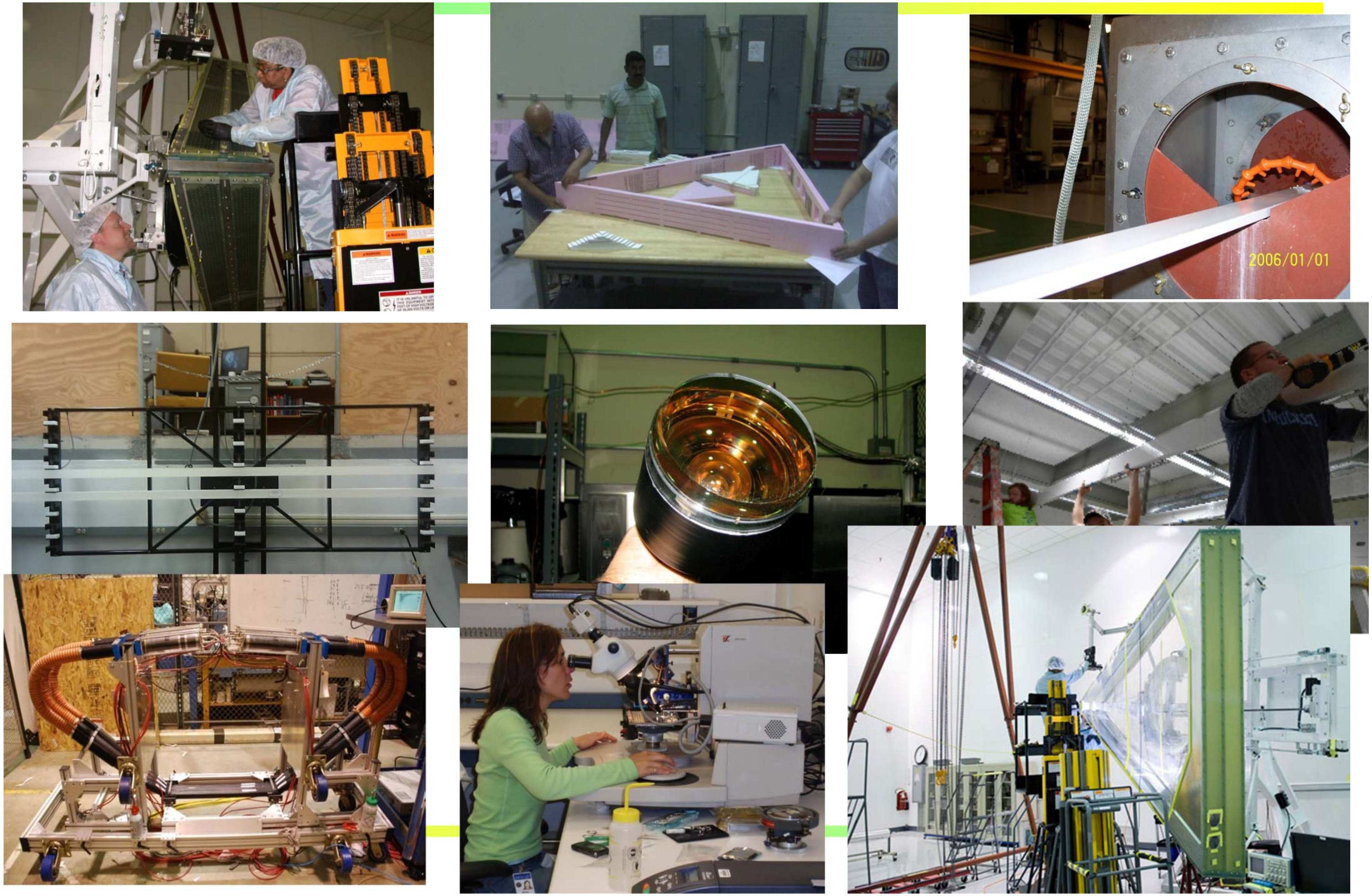
CLAS12 – Central Detector

- SVT - Charged particle tracking in 5T field
- Vertex reconstruction
- $\Delta T < 60$psec in CTOF for particle id
- Moller electron shield
- Polarized target operation $\Delta B/B < 10^{-4}$ in 2.5x4 cm cylinder around center



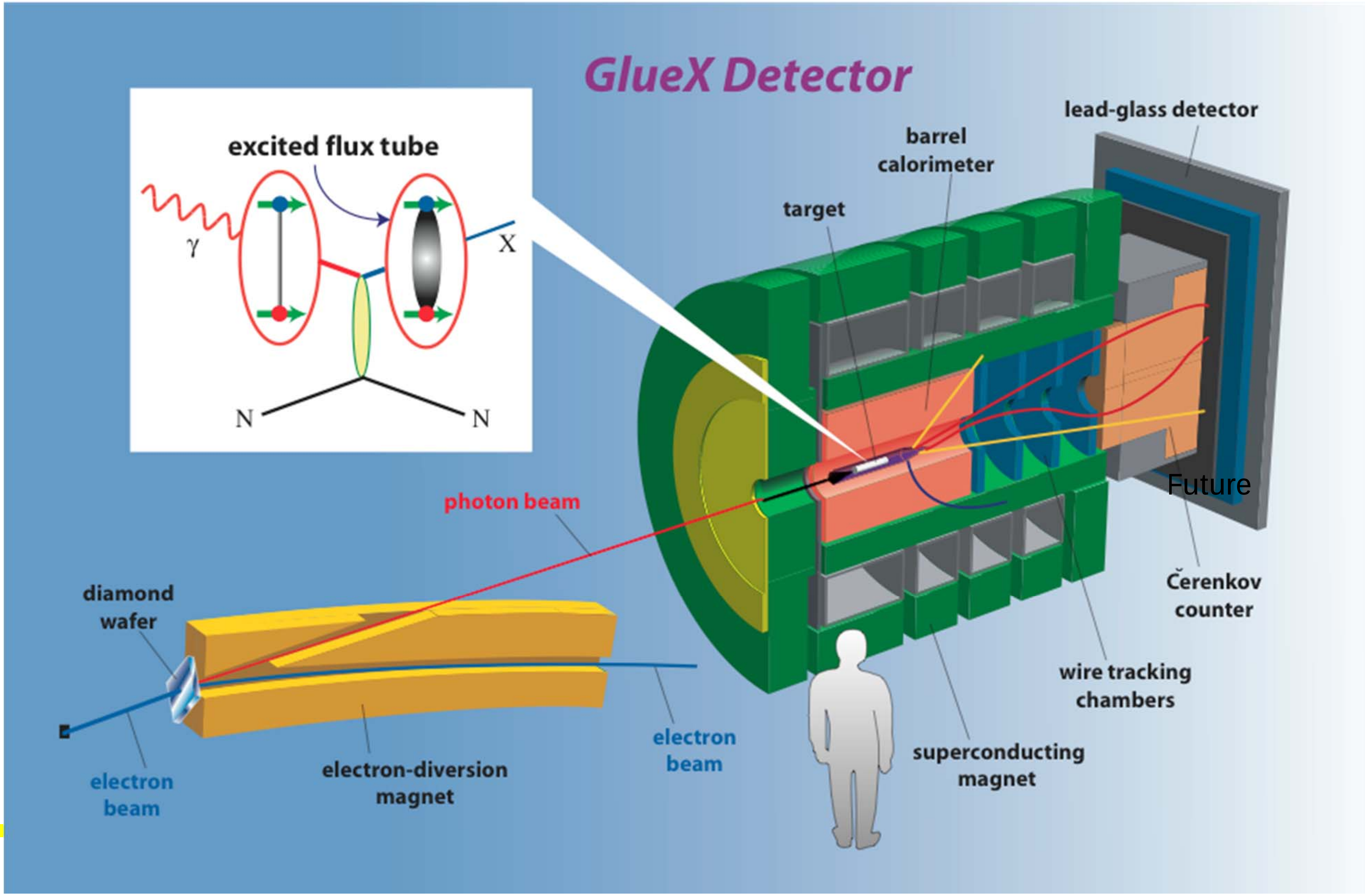
CLAS12 status:

Construction on schedule for installation start in 10/2012



The GlueX Detector in Hall D

Goal: search for exotic hybrids

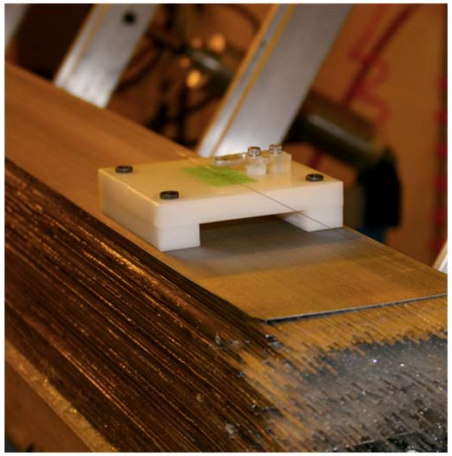


GlueX status

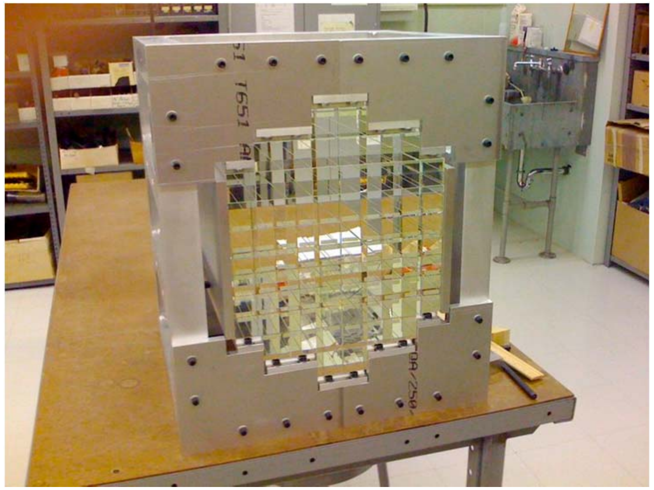
Detector construction: well underway

CDC

BCAL



FCAL



→ Status: on-track for first beam in 2014.

→ Talk by Igor Senderovich, this session

Summary

B factories have proven to be an excellent tool also for hadron physics, with reliable long term operation, constant improvement of the performance, achieving and surpasing design perfomance

Major upgrade at KEK in 2010-14 → SuperKEKB+Belle II, L x40, construction started

SuperB in Frascati: build a new tunnel, reuse (+ugrade) PEP-II and BaBar

PANDA at FAIR: TDR end of 2011, installation 2016/17

JLAB: CLAS12 on schedule for installation start in 10/2012

JLAB: GlueX on-track for first beam in 2014

Expect a new, exciting era of discoveries in hadron physics