Status of BelleII detector and SuperKEKB

Claudia Cecchi University of Perugia and INFN
on behalf of BelleII Collaboration

Outline

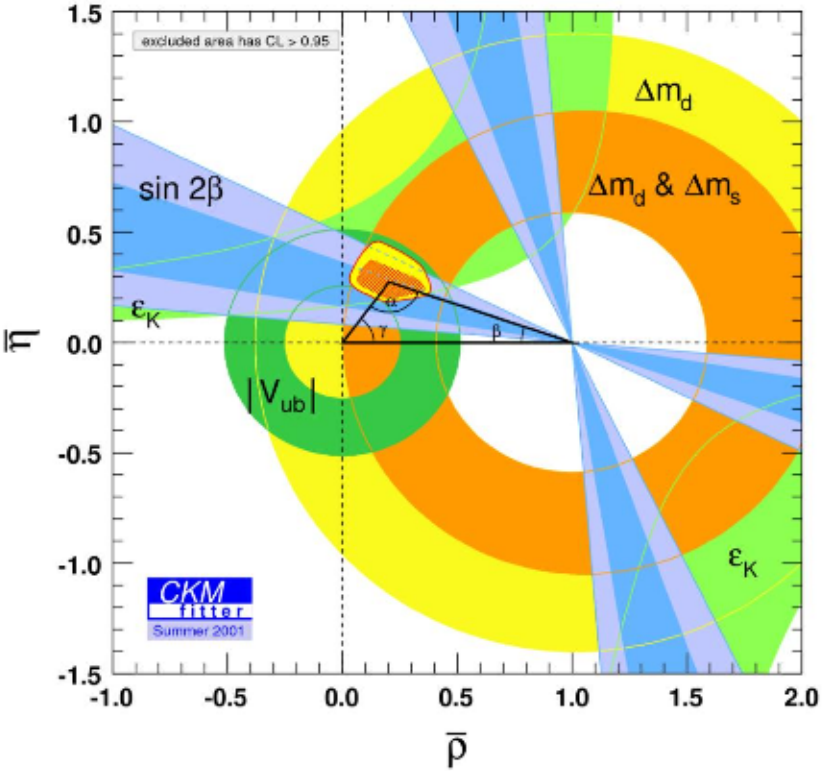
- ✓ **Introduction**
- ✓ **Physics at KEKB and superKEKB**
- ✓ **Machine**
- ✓ **Detector**

Other talks at this conference

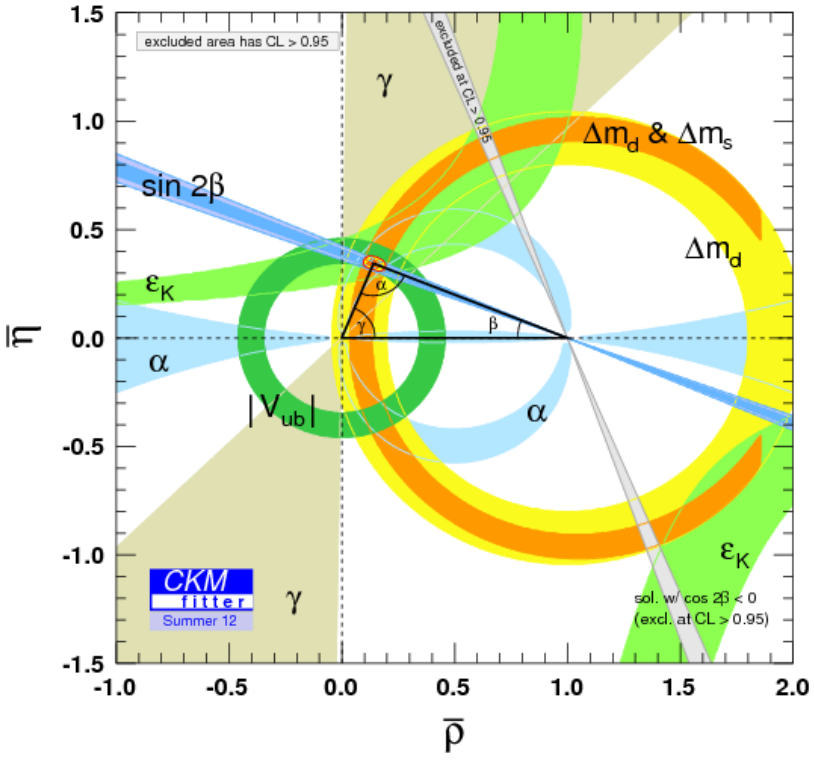
- KL and muon system of BelleII detector by T. UGLOV
- BelleII PID Detectors by M. STARIC
- Status and construction of the BelleII DEPFET Pixel System by F. LUETTICKE
- The Silcion Vertex Tracker of the BelleII experiment by E. PAOLONI

B-factories is a success story

EPS 2001



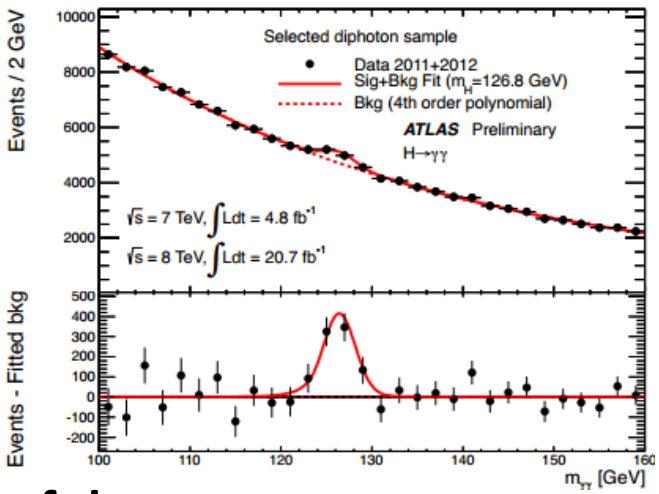
ICHEP 2012

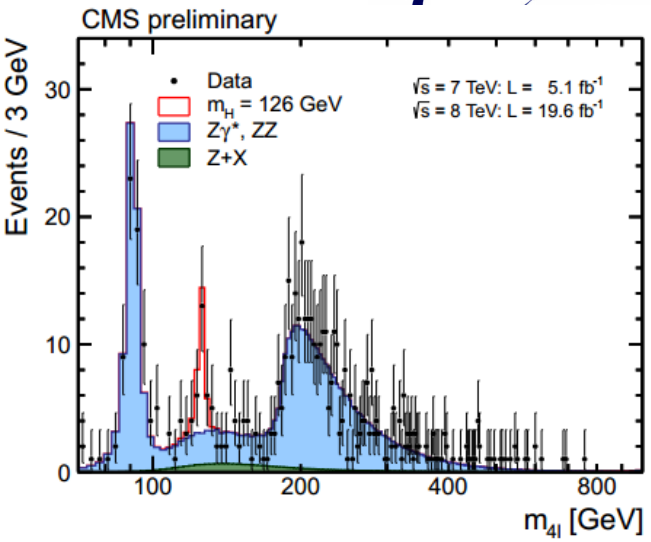


Measurement of CKM matrix elements
Observation of direct CP violation in B decays
Measurement of rare decay modes
Forward Backward asymmetries to search for New Physics
Observation of D mixing
Search for rare τ decays

Introduction: SM end beyond

Higgs boson has been discovered at LHC, another piece of the SM puzzle

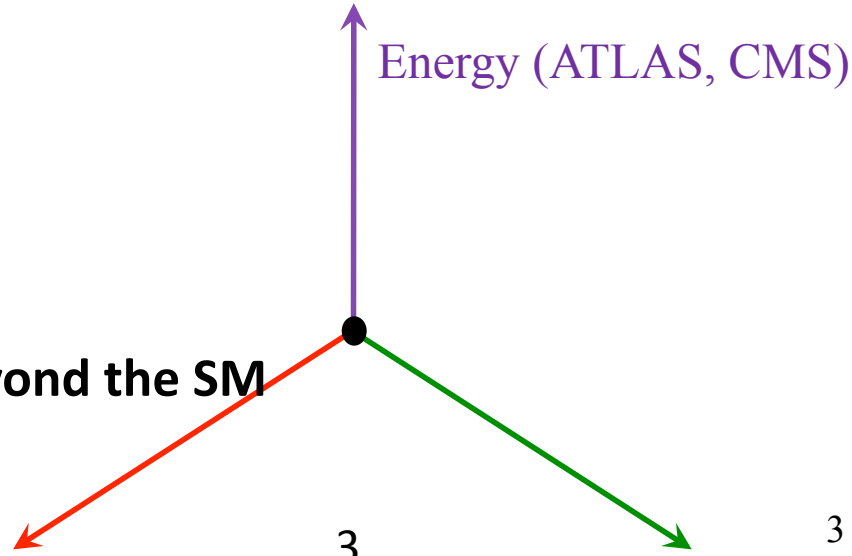




…but the SM is not the end of the story:

1) About ten orders of magnitude difference between the matter-antimatter asymmetry in universe and CP violation content of the SM
1) What is the nature of dark matter?
2) and, the list goes on….

Three different ways of probing New Physics beyond the SM



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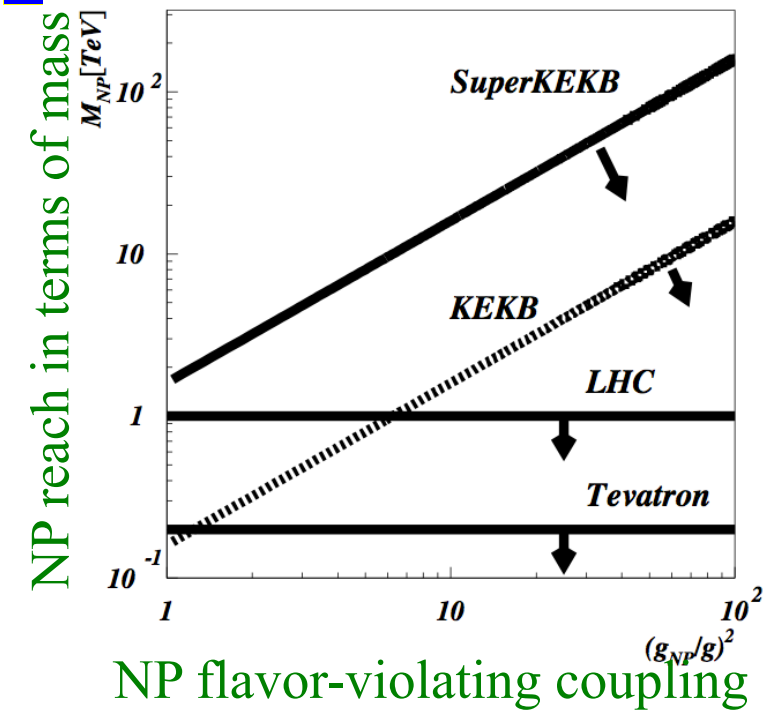
A Flavour Factory in the LHC Era



- A flavor factory (FF) studies processes that occur at one-loop level in the SM but may be of *O*(1) in NP: FCNC, neutral meson mixing, CP violation. These loops probe energy scales that cannot be directly accessed at the LHC.
- If LHC finds NP, precision flavor physics is compulsory to exploit its nature.
- If LHC finds no NP, high statistics B/D/τ decays would be a unique way to search for the O(1 TeV) (MFV) - O(100 TeV) (enhanced flavor violating couplings) scale physics.

A (super) flavor factory searches for NP by phases, CP asymmetries, inclusive decay processes, rare leptonic decays, absolute branching fractions. There is a wide range of observables with which to confront theory.

So wide researches area is possible because of clean event environment and well defined initial state in the e+e− experiments as well as high luminosity and general purpose detector

Belle2: what's special?

Thanks to its clean e^+e^- environment:

- **Low background, high trigger efficiency, excellent photon & π^0 reconstruction capability, high flavor-tagging efficiency with low dilution factor**
- **Good kinematic resolution → Dalitz-plot analyses are straightforward.**
  Absolute branching fraction can be measured
- **Ideal for measuring decay channels with large missing energy**

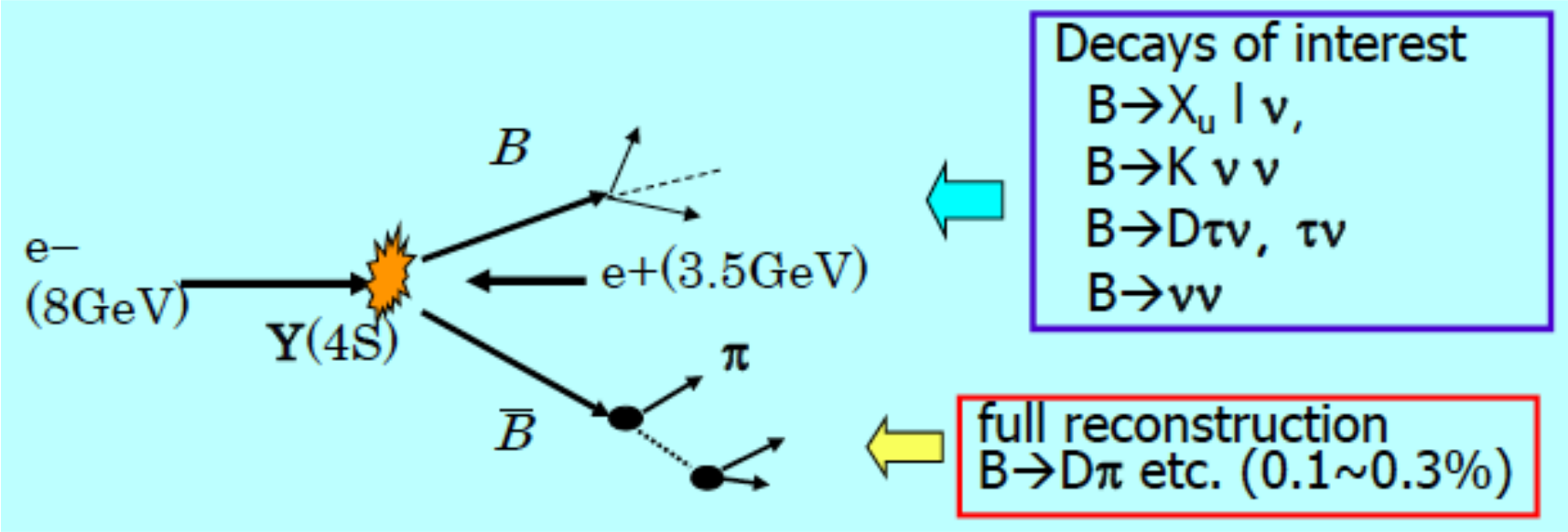
Observable	Belle 2006 ($\sim$0.5 ab^{-1})	Belle II/SuperKEKB (5 ab^{-1})	(50 ab^{-1})
Hadronic $b \to s$ transitions			
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020
$\Delta\mathcal{S}_{K^0_S K^0_S K^0_S}$	0.33	0.105	0.037
$\Delta\mathcal{A}_{\pi^0 K^0_S}$	0.15	0.072	0.042
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°
Radiative/electroweak $b \to s$ transitions			
$\mathcal{S}_{K^0_S\pi^0\gamma}$	0.32	0.10	0.03
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%
$A_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005
C_9 from $A_{FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%
C_{10} from $A_{FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%
C_7/C_9 from $A_{FB}(B \to K^*\ell^+\ell^-)$	-		5%
R_K		0.07	0.02
$\mathcal{B}(B^+ \to K^+\nu\nu)$	†† $< 3\ \mathcal{B}_{SM}$		30%
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	†† $< 40\ \mathcal{B}_{SM}$		35%
Radiative/electroweak $b \to d$ transitions			
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15
$\mathcal{B}(B \to X_d\gamma)$	-	24% (syst.)	
Leptonic/semileptonic B decays			
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{SM}$	4.3 ab^{-1} for 5σ discovery	
$\mathcal{B}(B^+ \to \ell\nu\nu)$	-	6%	3%
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%

Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\lvert V_{us}\rvert$ $[K \to \pi\ell\nu]$	**	0.1%	K-factory
$\lvert V_{cb}\rvert$ $[B \to X_c\ell\nu]$	**	1%	Belle II
$\lvert V_{ub}\rvert$ $[B_d \to \pi\ell\nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K^0_S$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5°	Belle II
ϕ_3	***	3°	LHCb
CPV			
$S(B_s \to \psi\phi)$	**	0.01	LHCb
$S(B_s \to \phi\phi)$	**	0.05	LHCb
$S(B_d \to \phi K)$	***	0.05	Belle II/LHCb
$S(B_d \to \eta' K)$	***	0.02	Belle II
$S(B_d \to K^*(\to K^0_S\pi^0)\gamma))$	***	0.03	Belle II
$S(B_s \to \phi\gamma))$	***	0.05	LHCb
$S(B_d \to \rho\gamma))$		0.15	Belle II
A^d_{SL}	***	0.001	LHCb
A^s_{SL}	***	0.001	LHCb
$A_{CP}(B_d \to s\gamma)$	*	0.005	Belle II
rare decays			
$\mathcal{B}(B \to \tau\nu)$	**	3%	Belle II
$\mathcal{B}(B \to D\tau\nu)$		3%	Belle II
$\mathcal{B}(B_d \to \mu\nu)$	**	6%	Belle II
$\mathcal{B}(B_s \to \mu\mu)$	***	10%	LHCb
zero of $A_{FB}(B \to K^*\mu\mu)$	**	0.05	LHCb
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	***	30%	Belle II
$\mathcal{B}(B \to s\gamma)$		4%	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab^{-1})
$\mathcal{B}(K \to \pi\nu\nu)$	**	10%	K-factory
$\mathcal{B}(K \to e\pi\nu)/\mathcal{B}(K \to \mu\pi\nu)$	***	0.1%	K-factory
charm and τ			
$\mathcal{B}(\tau \to \mu\gamma)$	***	$3 \cdot 10^{-9}$	Belle II
$\lvert q/p\rvert_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5°	Belle II

Power of e^+e^-: full reconstruction method

Fully reconstruct one of the B meson to

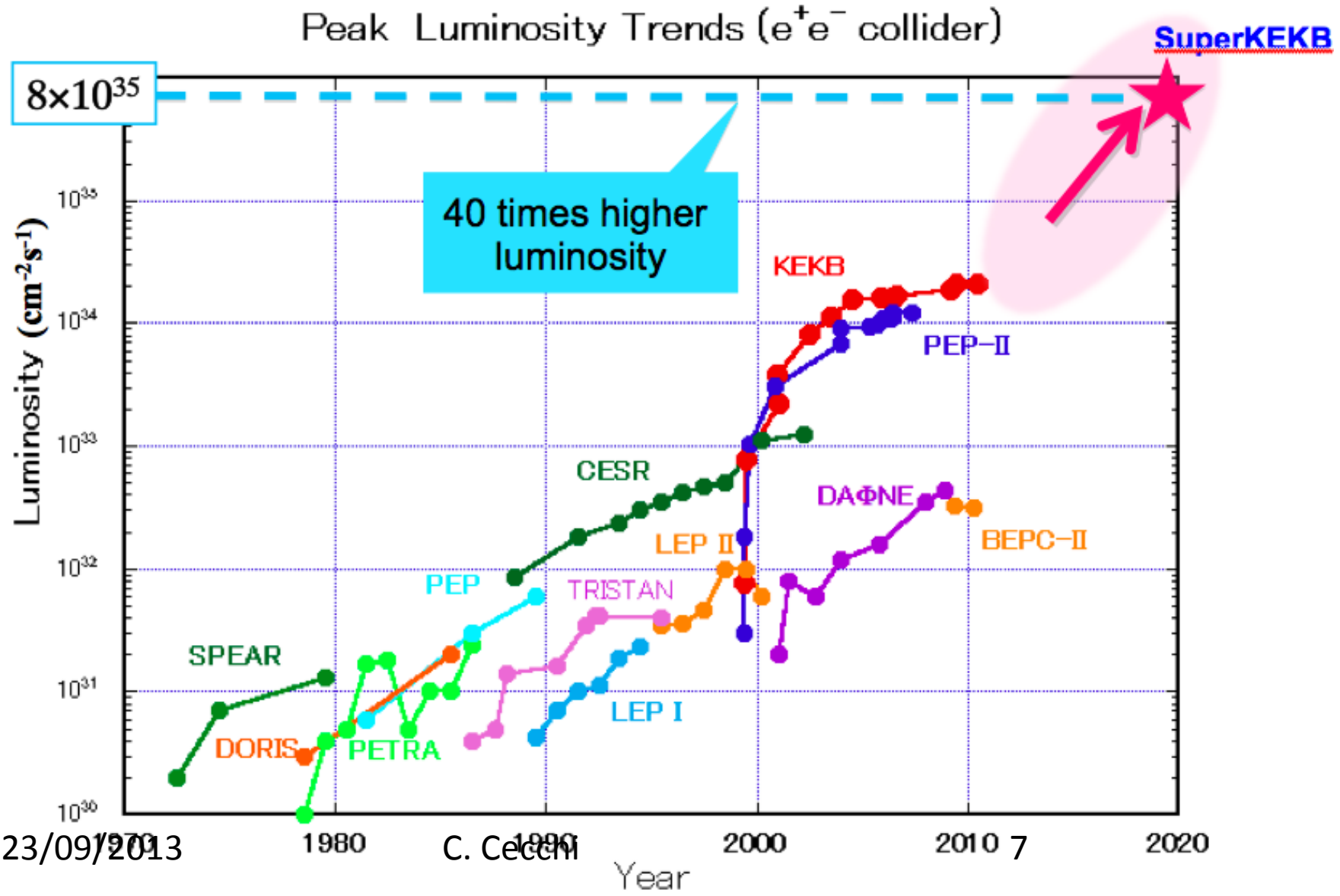
- Tag B flavour/charge
- Determine B momentum
- Exclude decay products of one B from further analysis



Powerful tool for channels with neutrinos in the final state

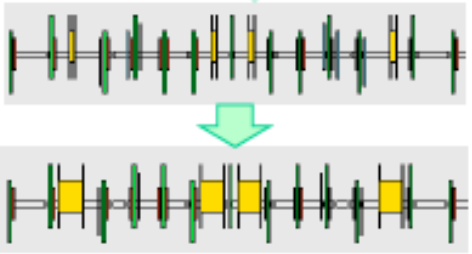
What is needed to achieve those results?

50x more data → superKEKB

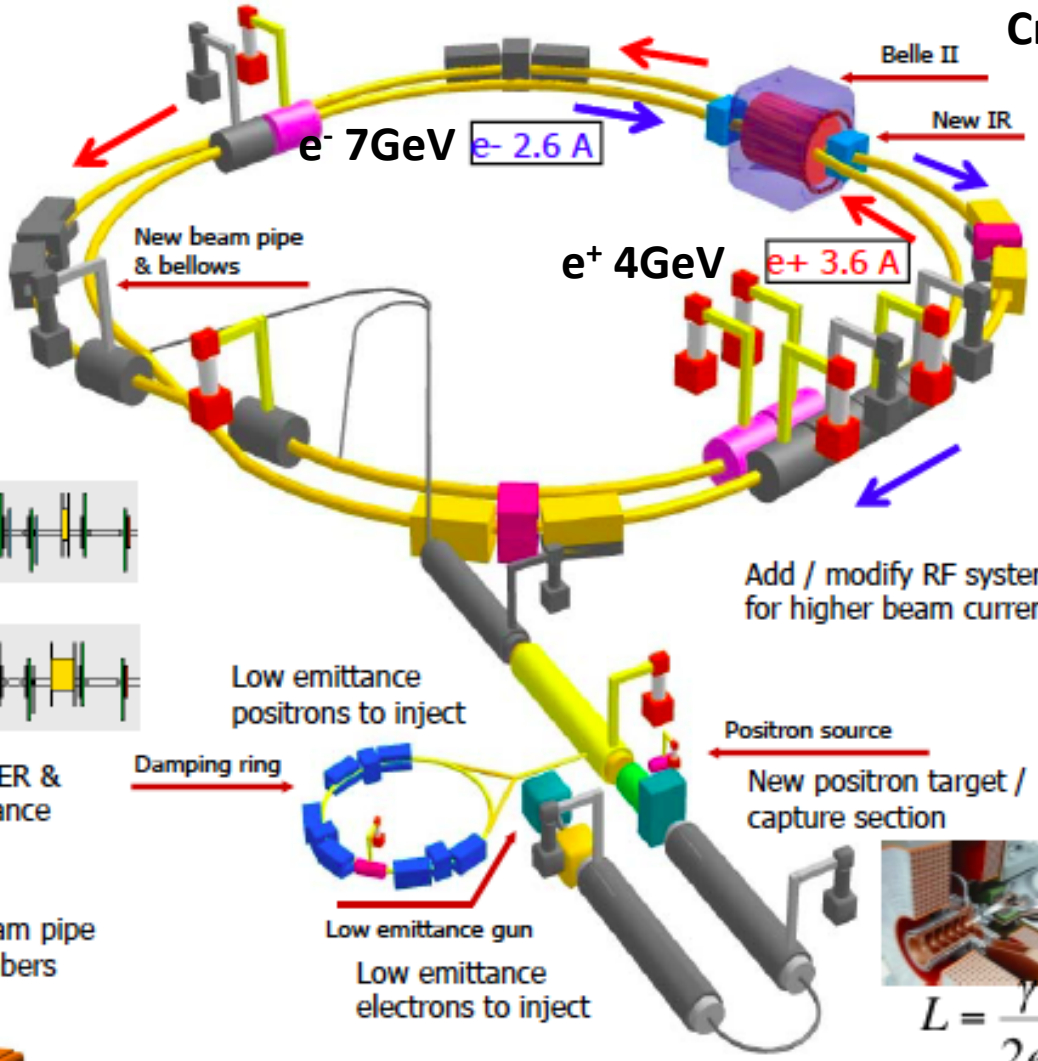


KEKB to SuperKEKB

Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

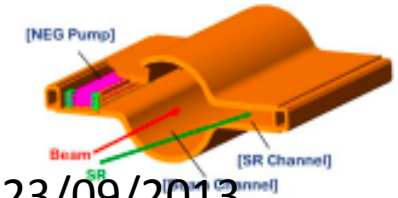


Crossing angle 83 mrad

New superconducting /permanent final focusing quads near the IP

Add / modify RF systems for higher beam current

TiN-coated beam pipe with antechambers

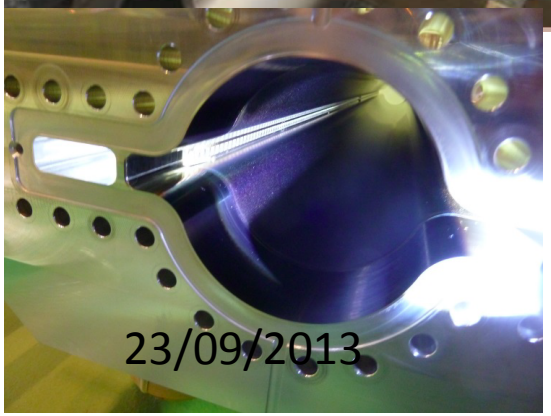


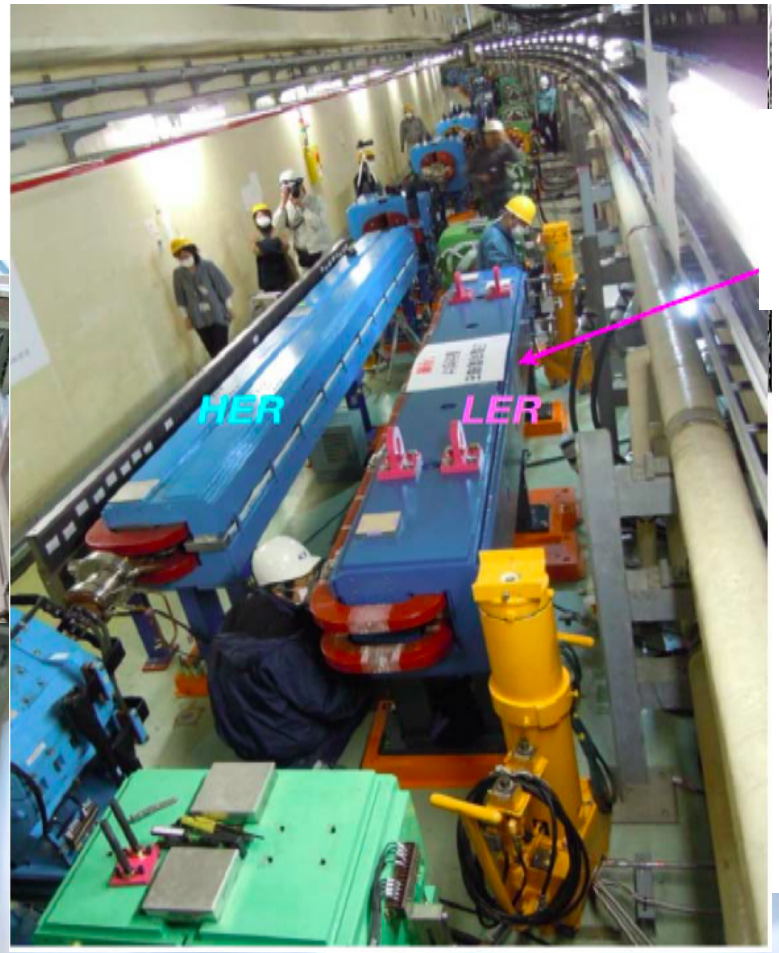
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

To obtain x40 higher luminosity

TARGET L = 8×10^{35} cm^{-2} s^{-1}

New Al LER beam pipe with TiN coating
Arc beam pipe section completed





All 100, 4m dipole magnets installed in the LER

Damping ring: tunnel construction finished spring 2013.

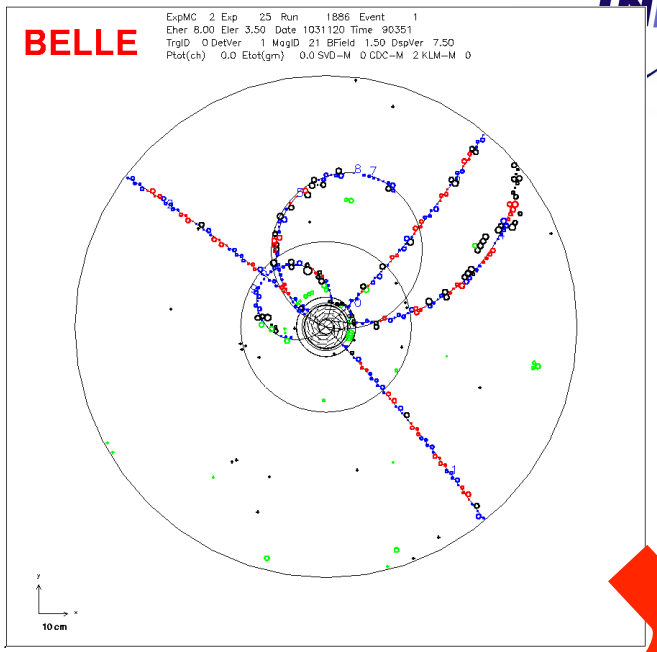
Fabrication of accelerator components ongoing. Installation starts 2014.
DR commissioning starts 2015

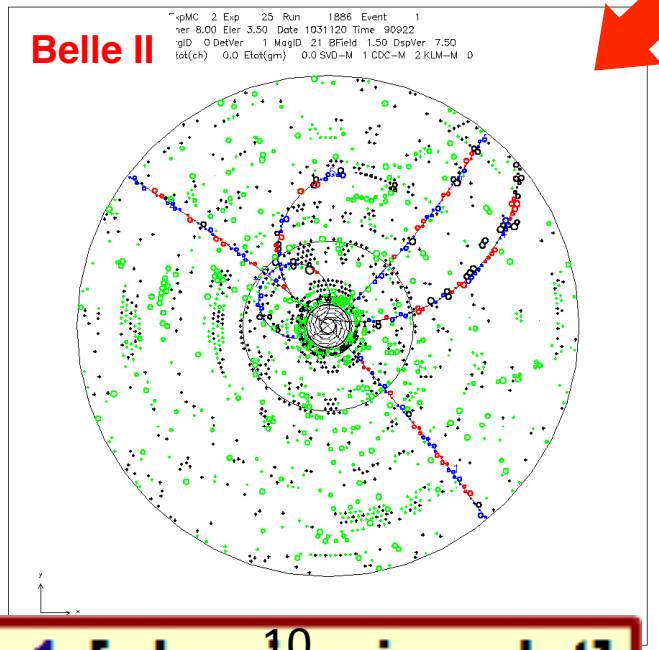
Need new detector: background!

Perugia INFN Istituto Nazionale di Fisica Nucleare

Critical issues at L= 8×10^{35} $cm^{-2}s^{-1}$

- **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 ← sμμ efficiency
  - hermeticity ← ν "reconstruction"





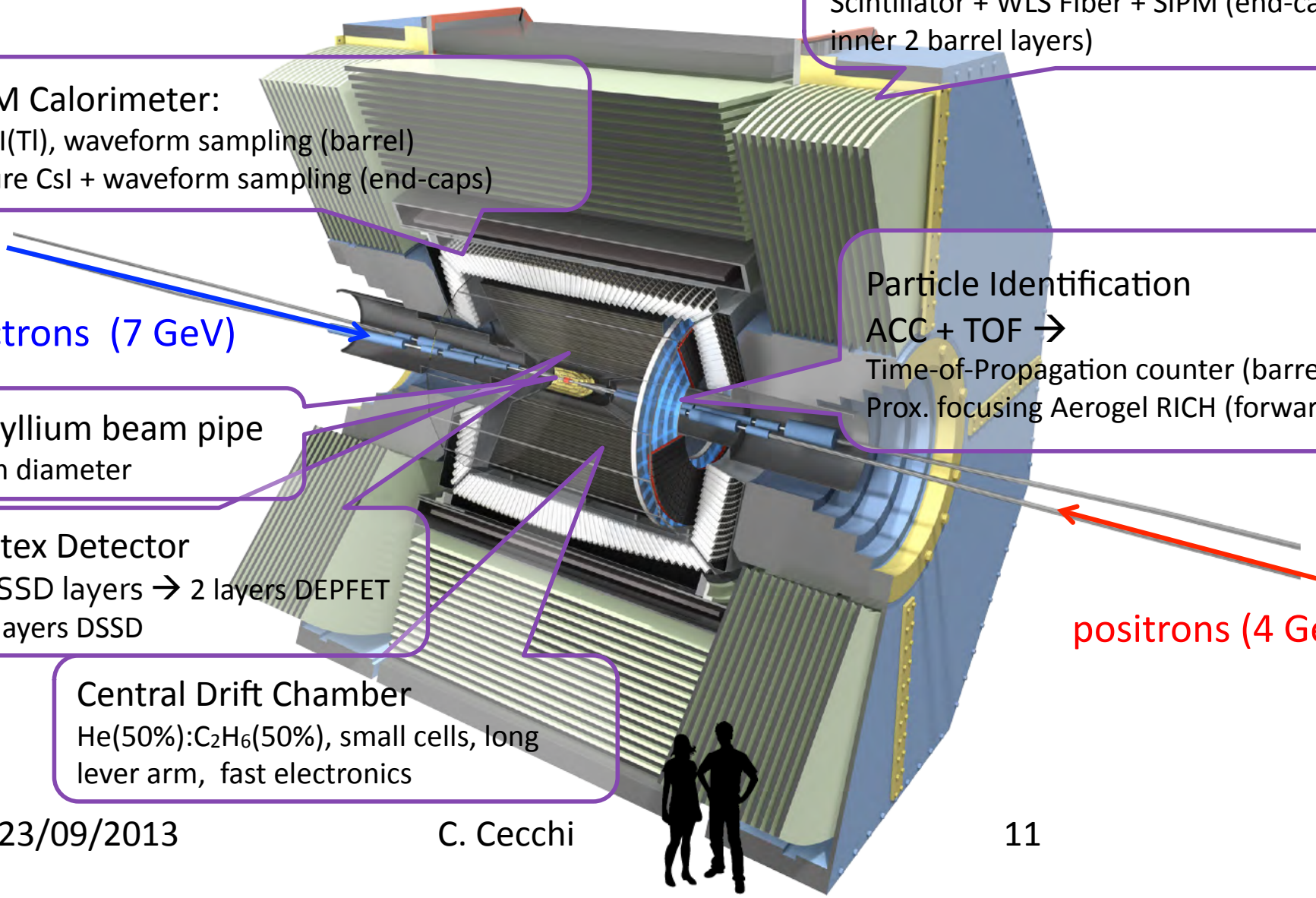
Have to employ and develop new technologies to make such an apparatus work!

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

Detector: from Belle to Belle2

KL and muon detector:
RPC →Resistive Plate Counter (barrel outer layers)
Scintillator + WLS Fiber + SiPM (end-caps, inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling (barrel)
Pure CsI + waveform sampling (end-caps)



electrons (7 GeV)

Particle Identification
ACC + TOF →
Time-of-Propagation counter (barrel)
Prox. focusing Aerogel RICH (forward)

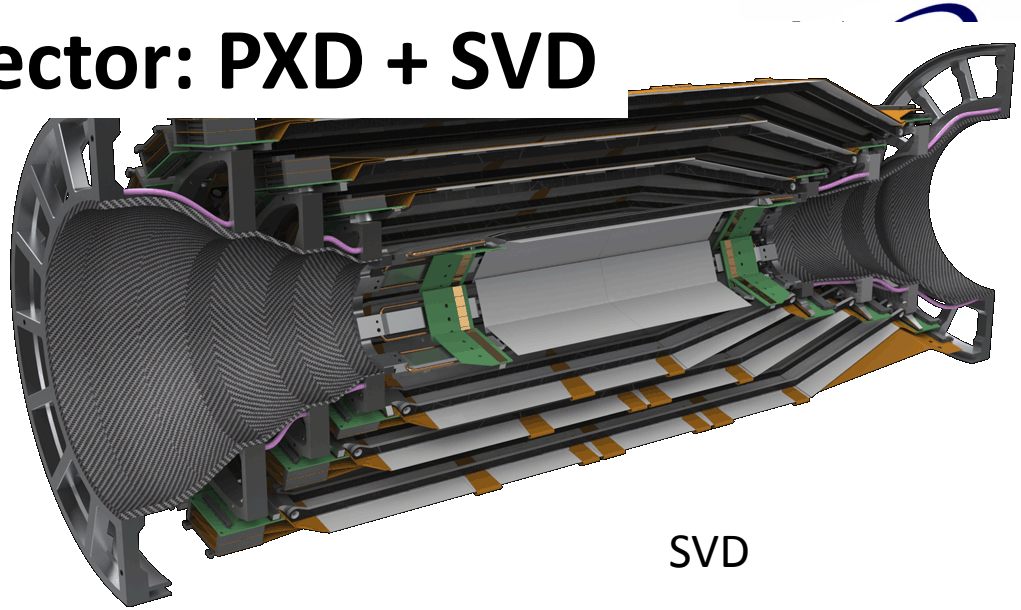
Beryllium beam pipe
2 cm diameter

Vertex Detector
4 DSSD layers → 2 layers DEPFET
+ 4 layers DSSD

positrons (4 GeV)

Central Drift Chamber
He(50%):C_2H_6(50%), small cells, long lever arm, fast electronics

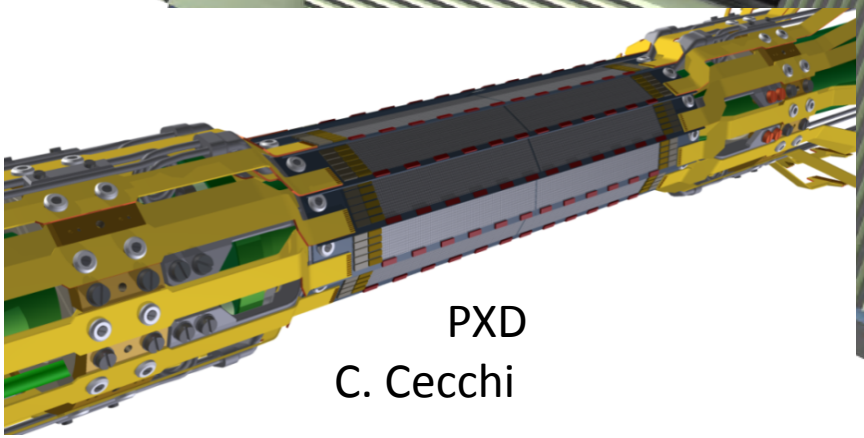
Vertex Detector: PXD + SVD



SVD

Beryllium beam pipe
2cm diameter

Vertex Detector (PXD+SVD)
2 layers DEPFET + 4 layers DSSD



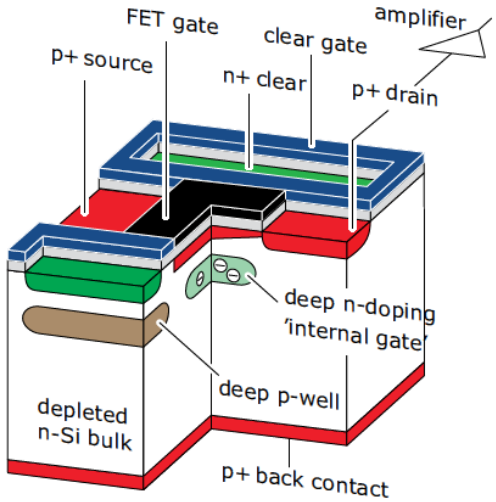
PXD

Beam Pipe	**r = 10mm**
PXD (2 layers DEPFET)	
Layer 1	**r = 14mm**
Layer 2	**r = 22mm**
SVD (4 layers DSSD)	
Layer 3	**r = 38mm**
Layer 4	**r = 80mm**
Layer 5	**r = 104mm**
Layer 6	**r = 135mm**

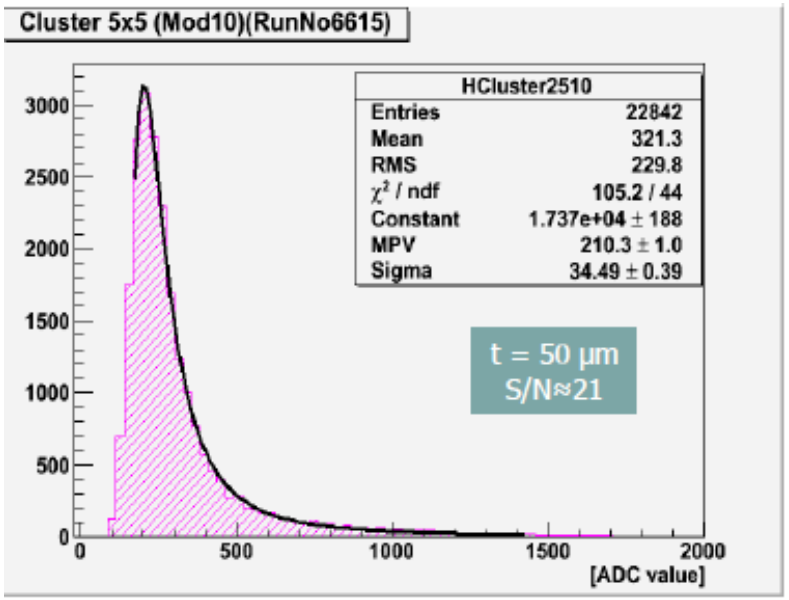
PXD: Pixel Detector

Mechanical mockup of the pixel detector

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



DEPFET pixel sensor



DEPFET sensor: very good S/N

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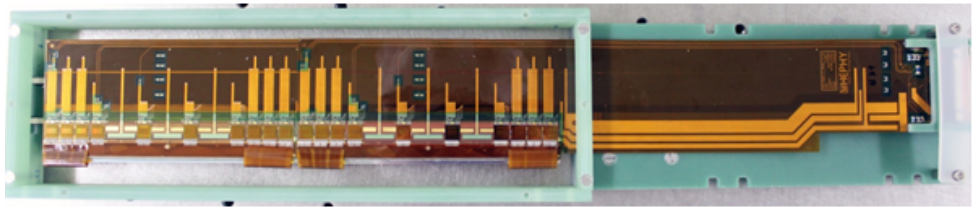
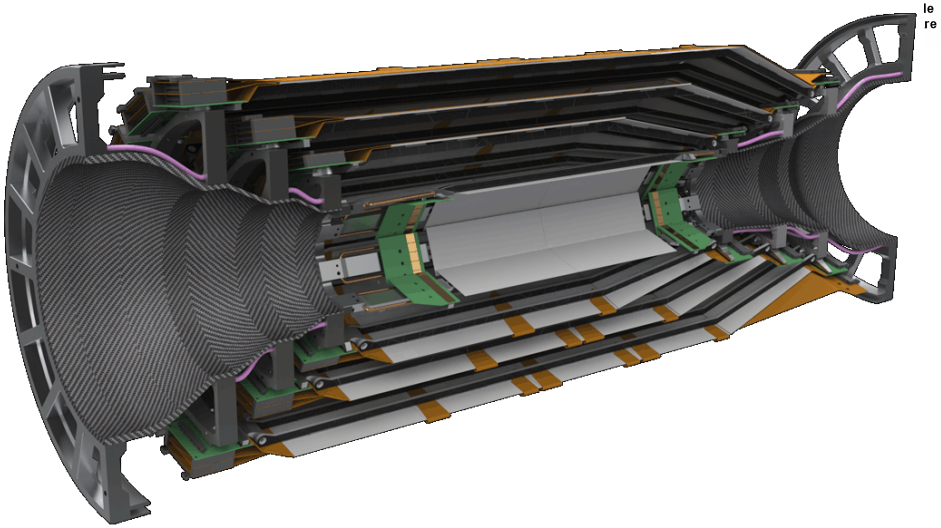
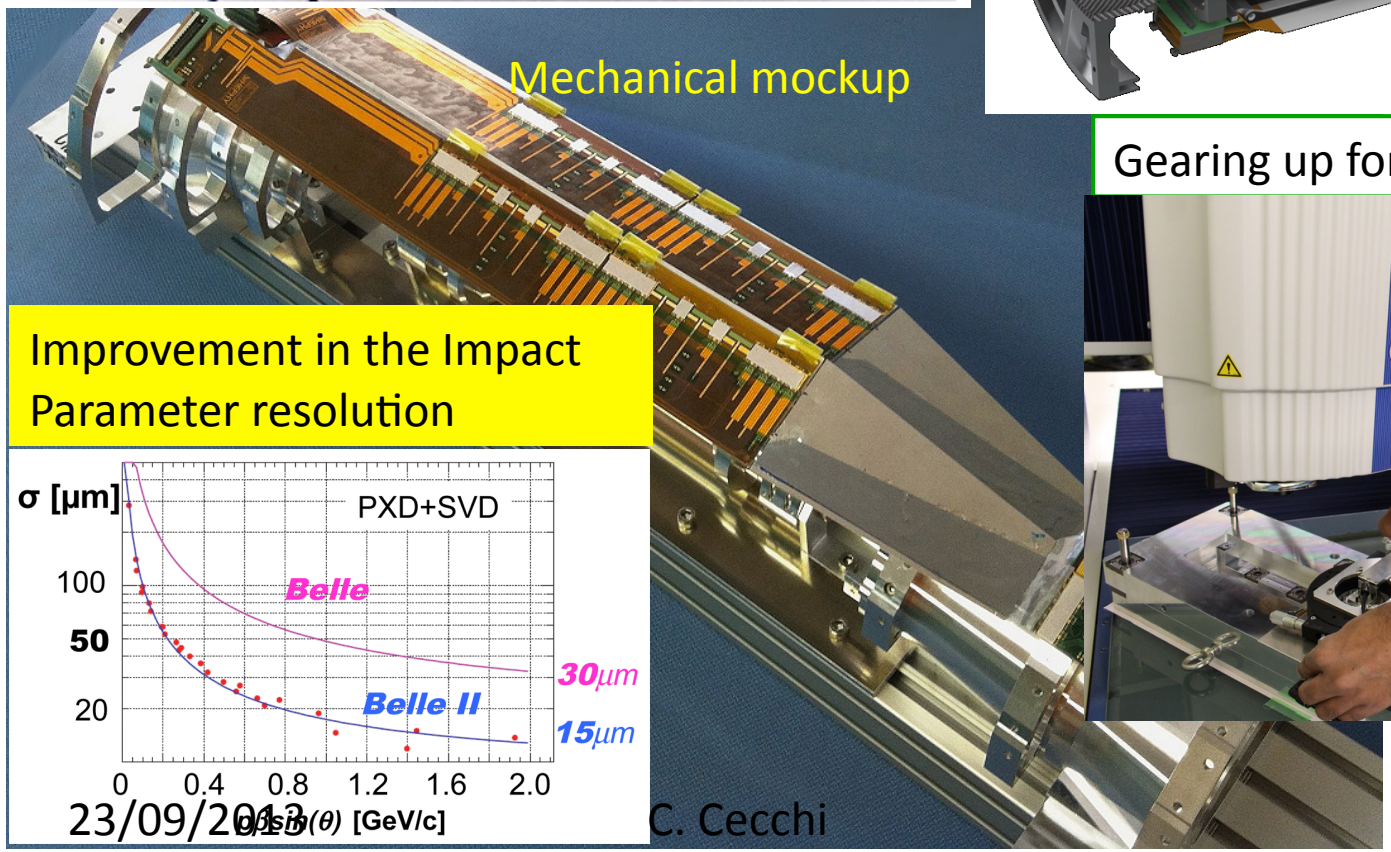
SVD: Silicon Vertex Detector

Origami chip-on sensor

- A low-mass solution for double-sided readout
- Flex fan-out pieces wrapped to the opposite side





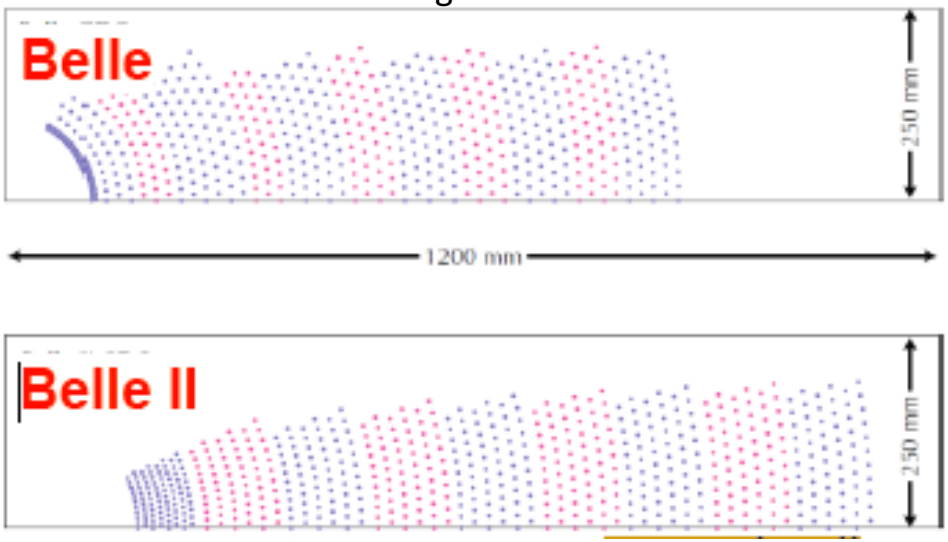


Improvement in the Impact Parameter resolution

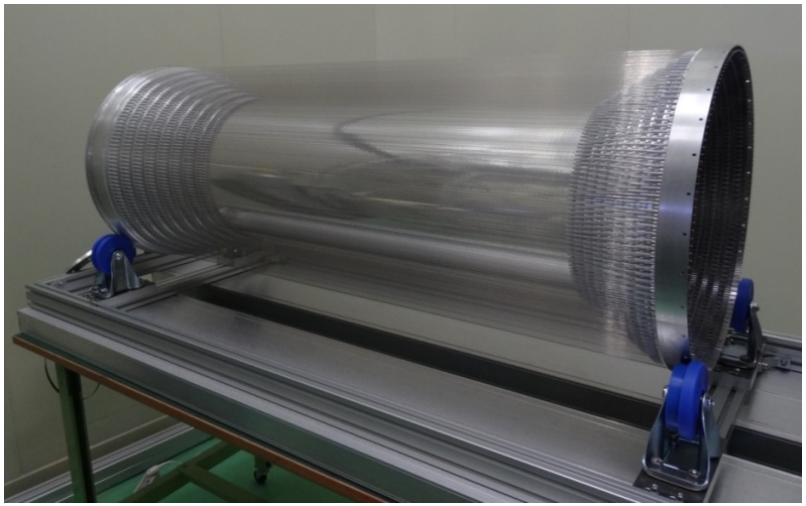
Gearing up for ladder production!

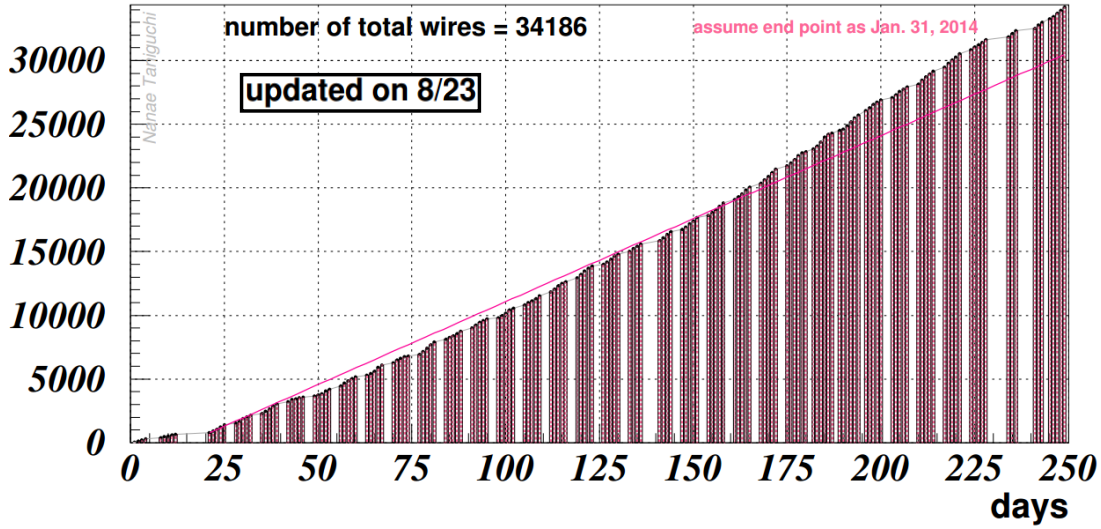
CDC: Central Drift Chamber

Wires configuration



Much bigger than in Belle!





Wire stringing of small cell part has been completed.
Gas leak check and HV test were done and were OK.
Cosmic ray test is going on.

Exceeding the expectation

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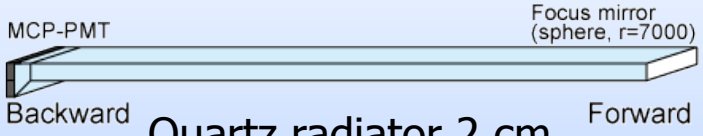
PID: Particle Identification Devices

Perugia

Barrel PID: Time of Propagation Counter (TOP)



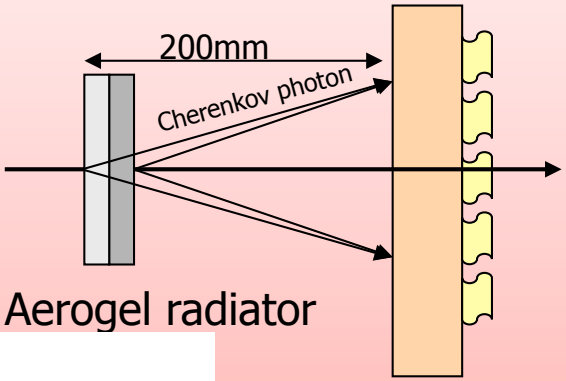
Quartz radiator 2 cm

Focusing mirror

Small expansion block

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

Endcap PID: Aerogel RICH (ARICH)



Hamamatsu HAPD
+ new ASIC

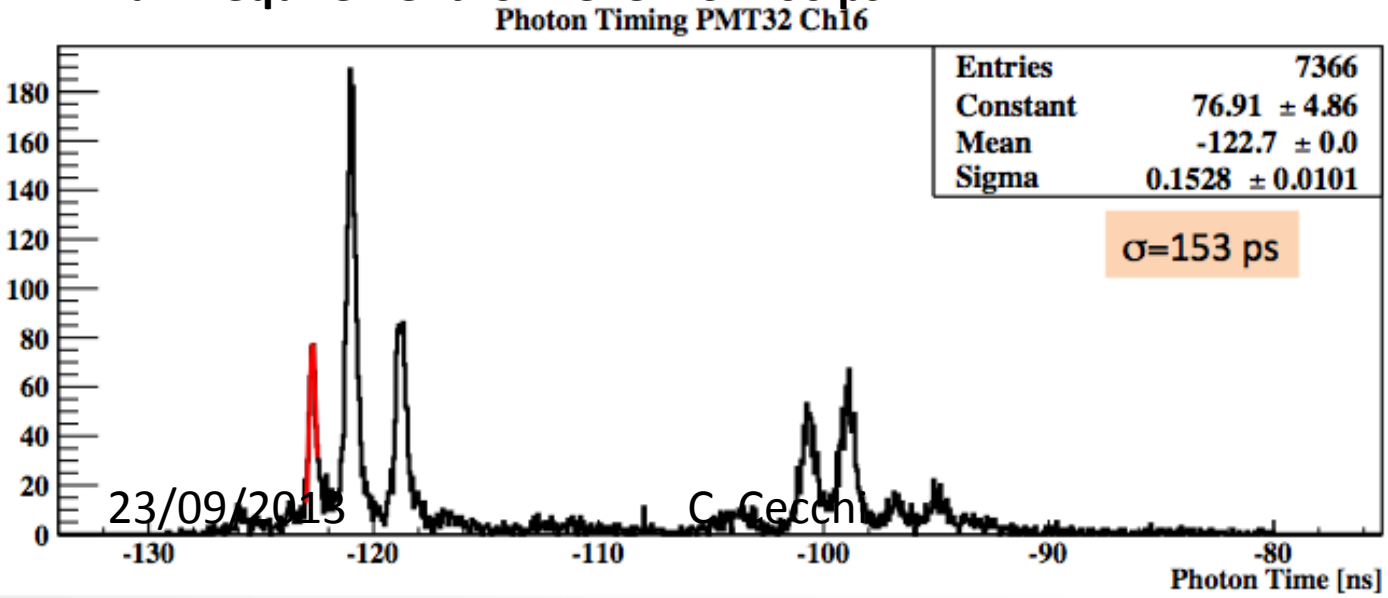
Cherenkov ring imaging with precise time measurement

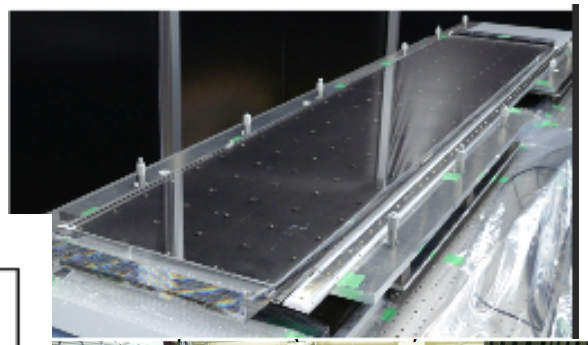
Device uses the internal reflection of Cerenkov ring images

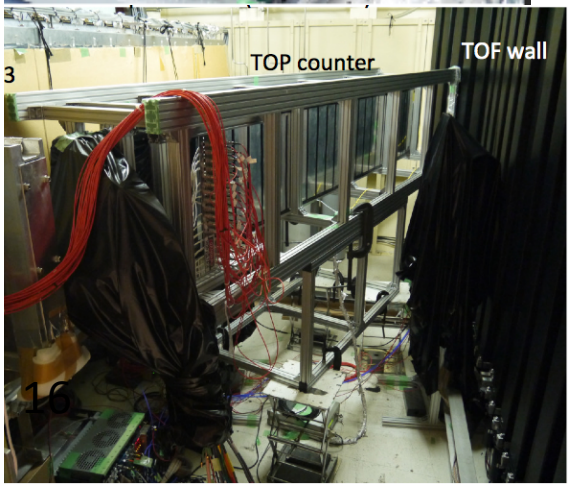
Excellent time resolution ~40 ps

Single photon sensitivity in 1.5 T

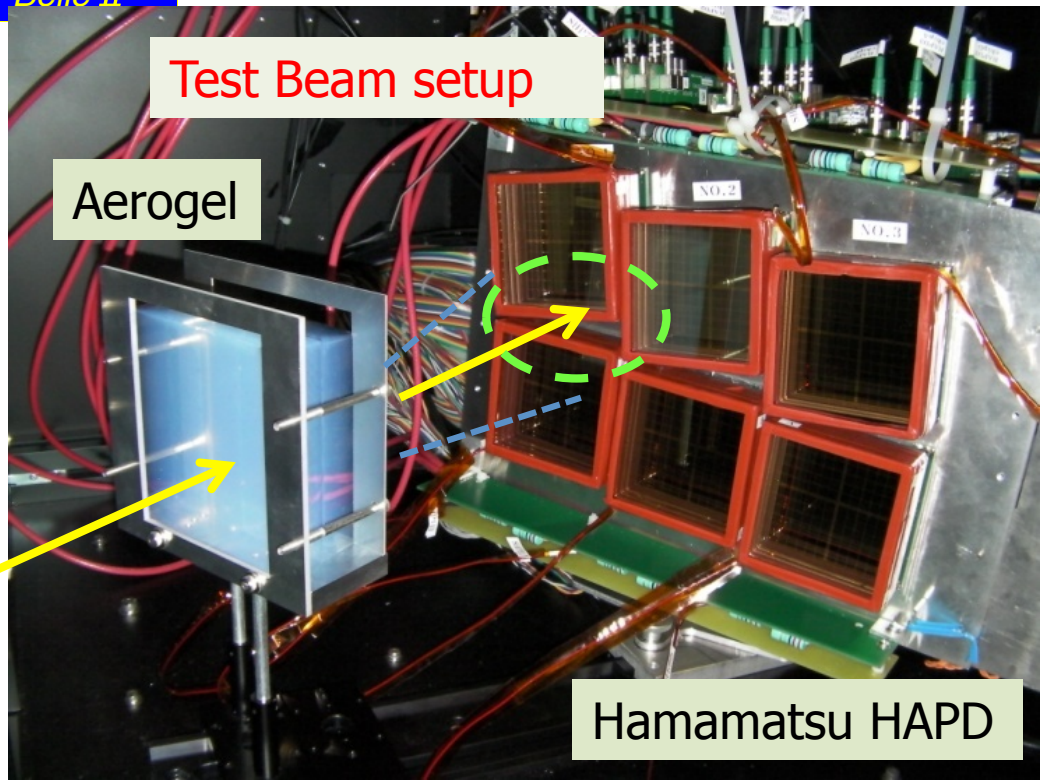
NEW TEST BEAM result on TOP: IRS3B Timing resolution meets minimum requirement for Belle II of 100 ps

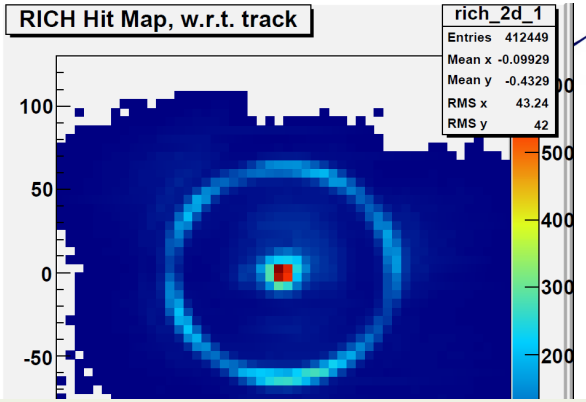






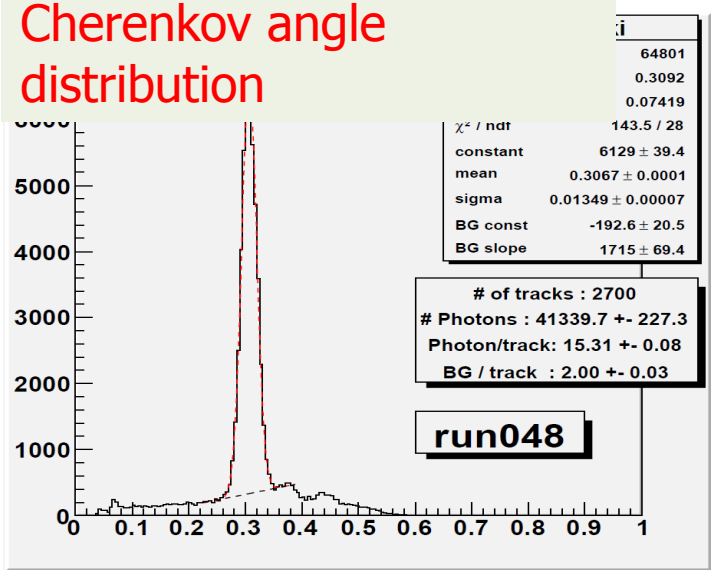
Endcap PID: Aerogel RICH





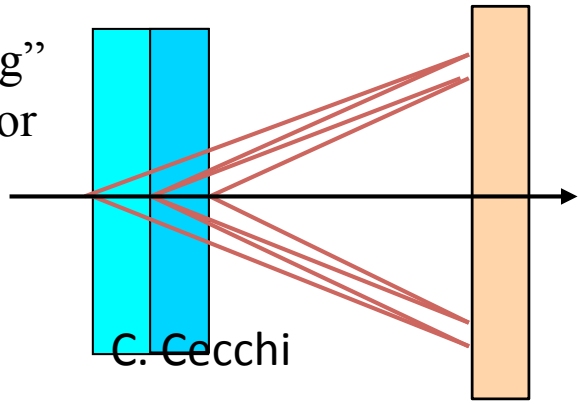
Clear Cherenkov image observed

Cherenkov angle distribution



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

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



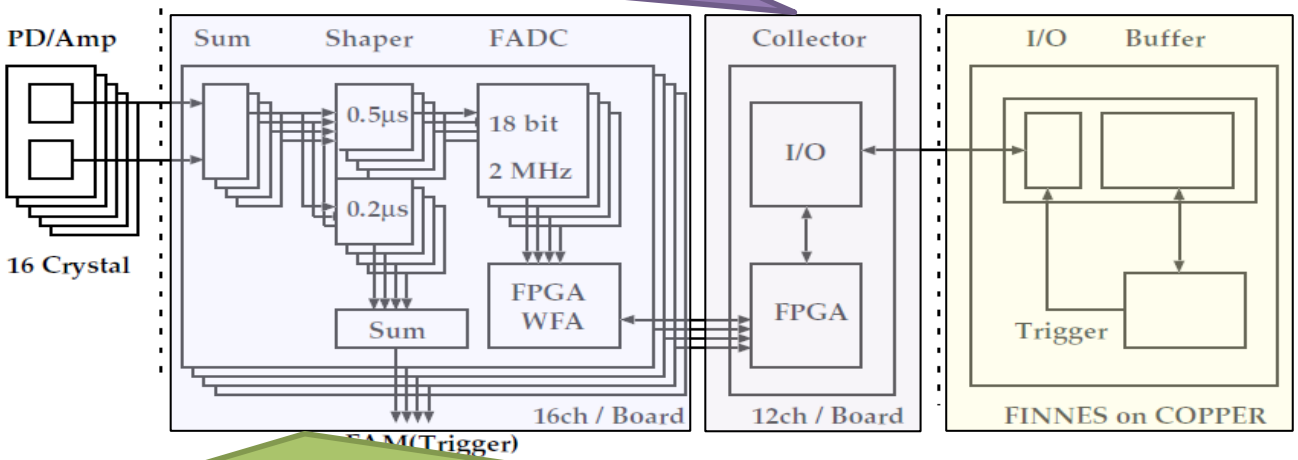
6.6 σ π/K at 4GeV/c !

ECL: Barrel

Upgrade needed because oh higher rates

Barrel → electronics to waveform sampling and fitting

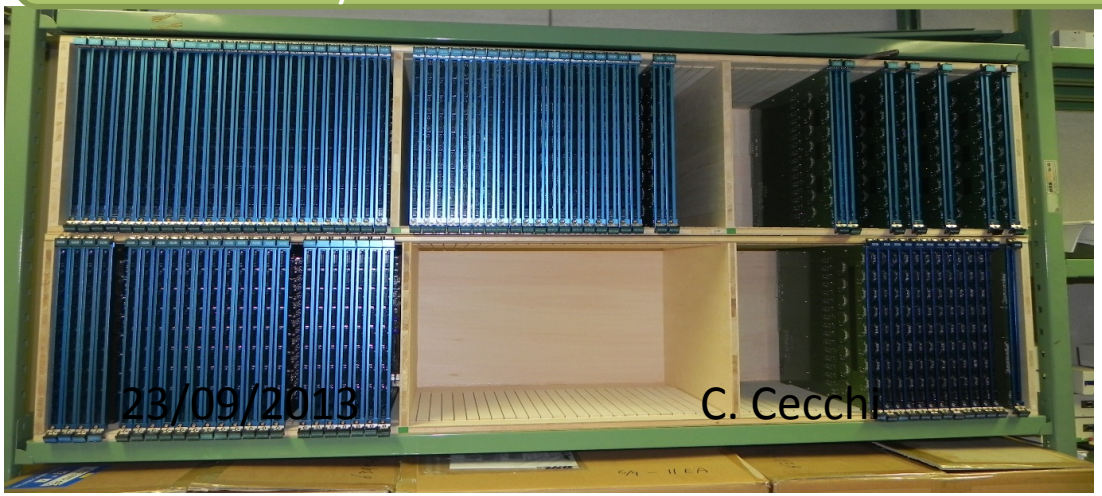
Firmware for Belle2Link readout was developed and is being tested.
Firmware to upload ShaperDSP firmware and coefficients under development



16 sample points within the signal window are fitted to calculate A and t_0

$F(t) = A\, f(t-t_0)$

112 ShaperDSP modules has been produced and tested
Another 280 by end of this FY



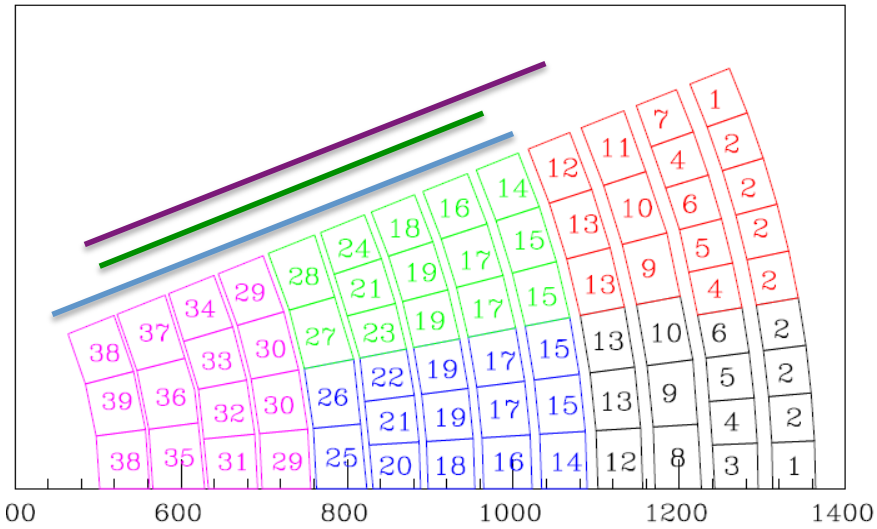
- **Bias voltage filters has been modified for BWD endcap**
- **FWD to be done in Feb.-Mar.**

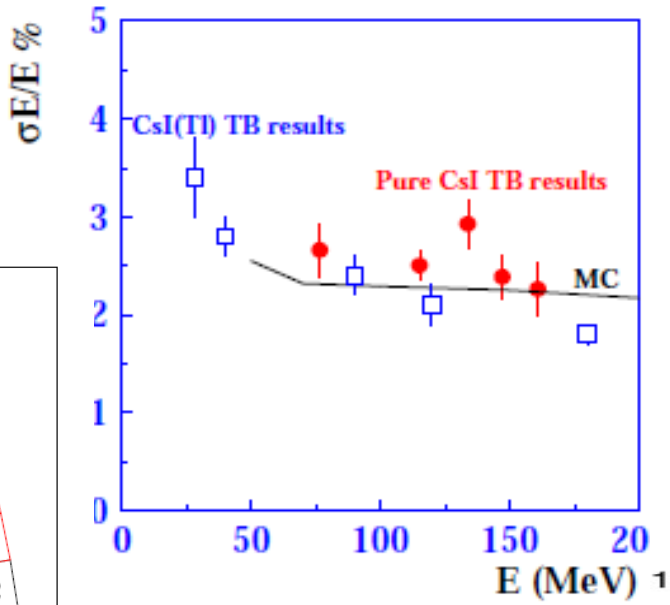
ECL: Endcap

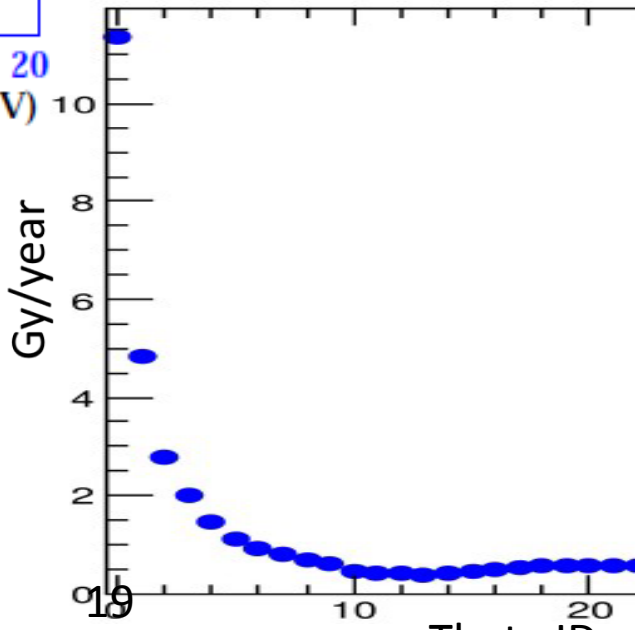
Perugia

Endcap upgrade : CsI(Tl) → pure CsI +
Photopentode (baseline)
APD-UV (R&D ongoing)

a) From 0 to 8
b) From 1 to 8
c) From 1 to 9





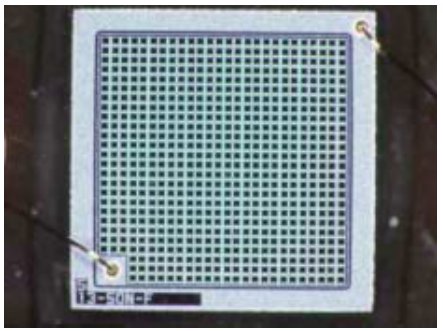


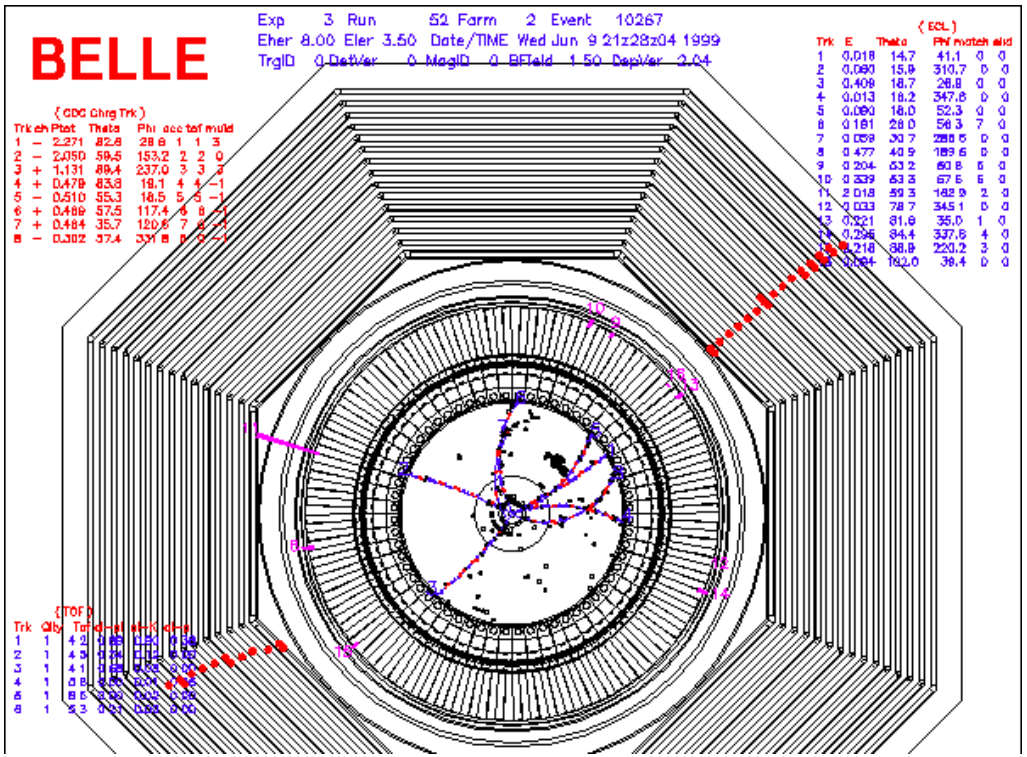
a) 672 pure CsI + 480 CsI(Tl)
b) 48 CsI(Tl) + 624 pure CsI + 480 CsI(Tl)
c) 48(?) + 720 pure CsI + 384 CsI(Tl) (exclude 1st layer from trigger and maintain same number of trigger cells)

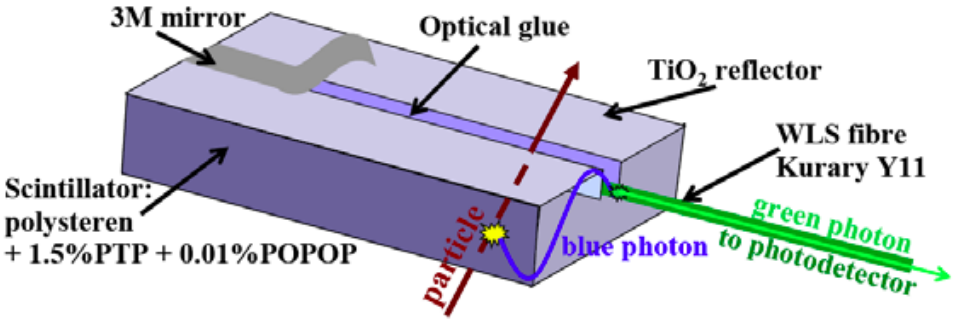
KLM: K_L and muon detector

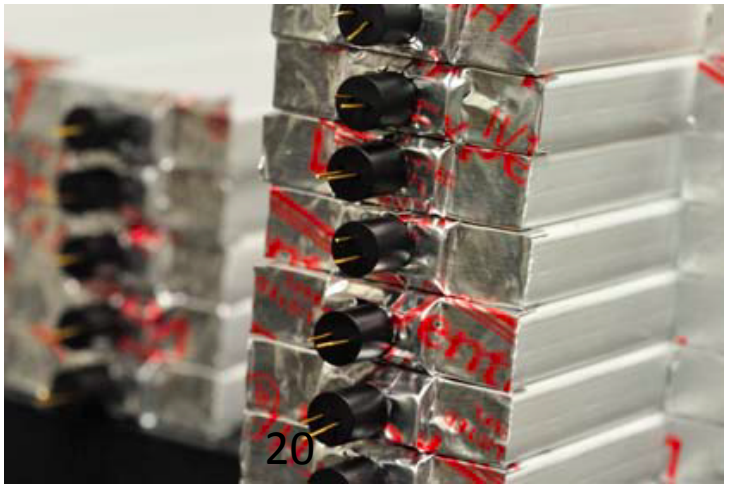
RPC → scintillator * WLSF + MPPC (Endcap)
2 layers of Barrel (TBD)

Limited by higher background rate, mainly neutrons.





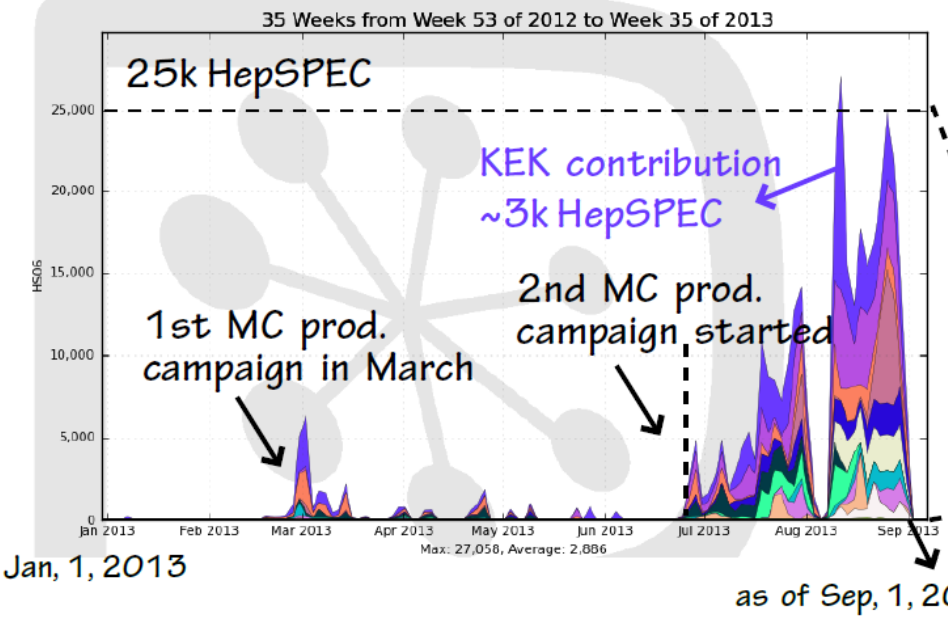




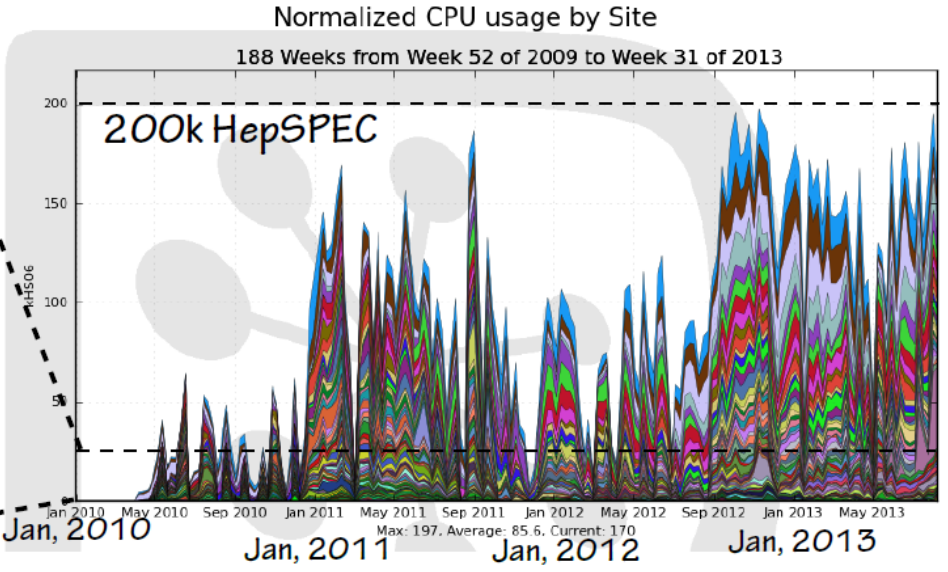
Computing resource status

We are now under the 2nd Belle II MC production campaign (July 22,2013 - Sep. 8, 2013)

- CPU Belle II normalized CPU



LHCb normalized CPU (Jan. 2010-)



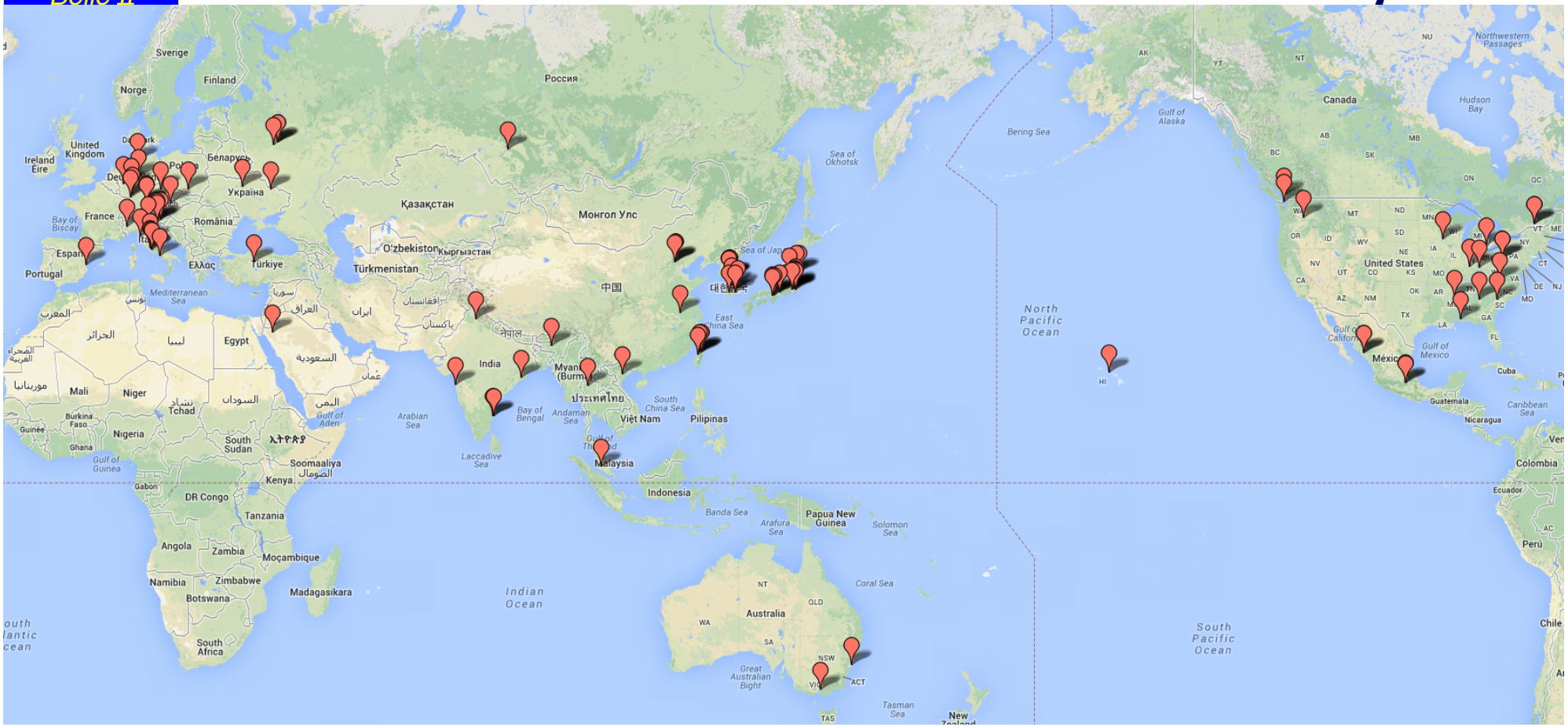
Thanks to the detailed tuning of DIRAC, many MC production's shift workers, and the new sites joining the Belle II computing

- Storage (Disk, Tape) : ~0.3 PB
  Only for MC data

Storage (Disk, Tape) : ~26 PB
including Data, MC, User data

To increase the computing resources is another key towards the success of Belle II

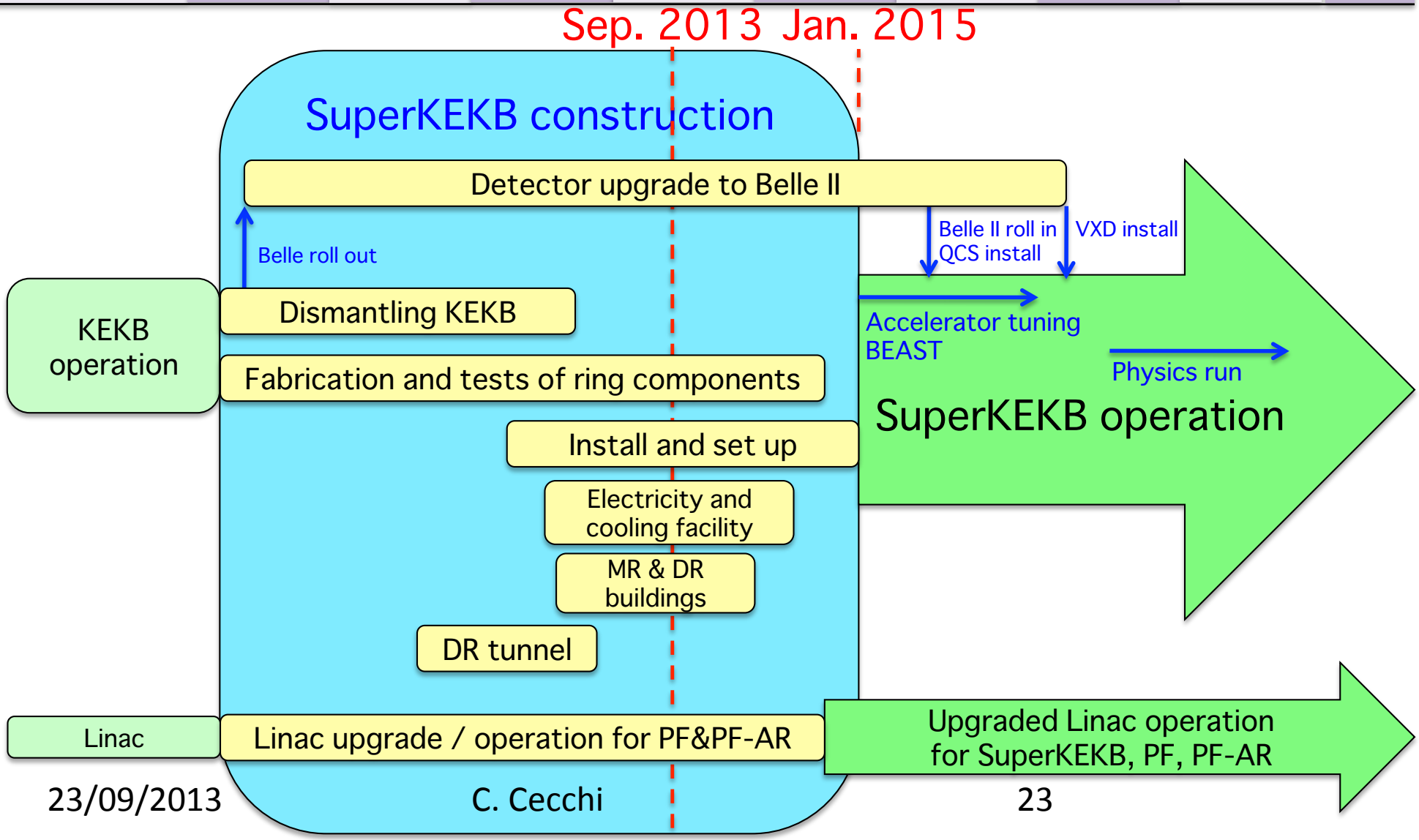
BelleII Collaboration



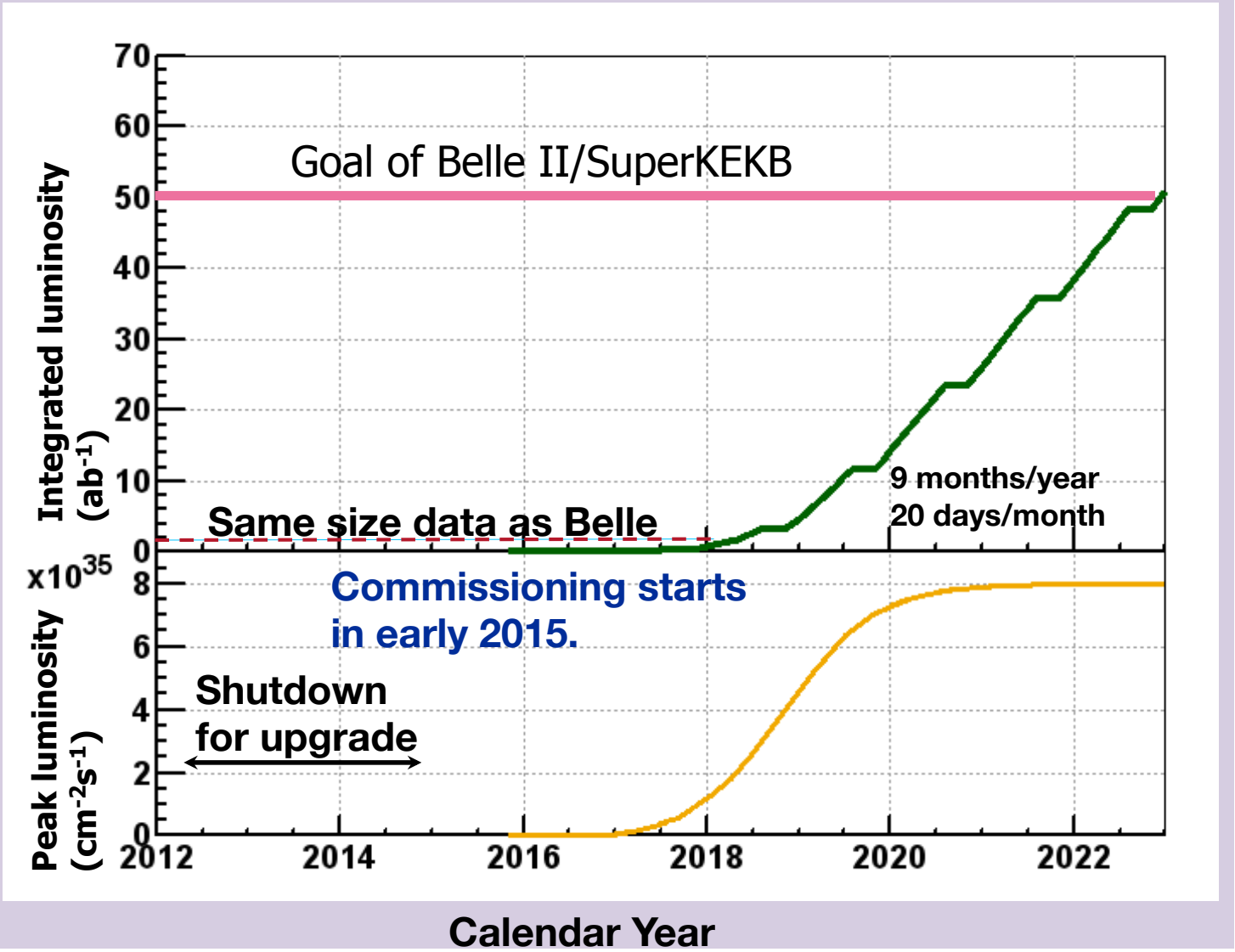
23 countries, 94 institutions, 518 collaborators

SuperKEKB/Belle II schedule

Calendar	2010	2011	2012	2013	2014	2015	2016	2017	···
Japan FY	2010	2011	2012	2013	2014	2015	2016	2017	··



SuperKEKB luminosity projection



→ Aim to reach 50 ab^{-1} by the end of 2022

Summary

- e^+e^- B factories have proven to be an excellent tool for flavor physics.
  Reliable and long term operation → important of physics results

- Major upgrade of KEKB factory to SuperKEKB (×50 data)
  will provide suitable probe for NP complementary to LHC

- Construction is proceeding at full speed (2010-2015)

Thanks for your kind attention