PNNL-SA-81933

Belle II Detector:
status and proposed US contributions

James Fast
Pacific Northwest National Laboratory

International Commitment to Belle-II

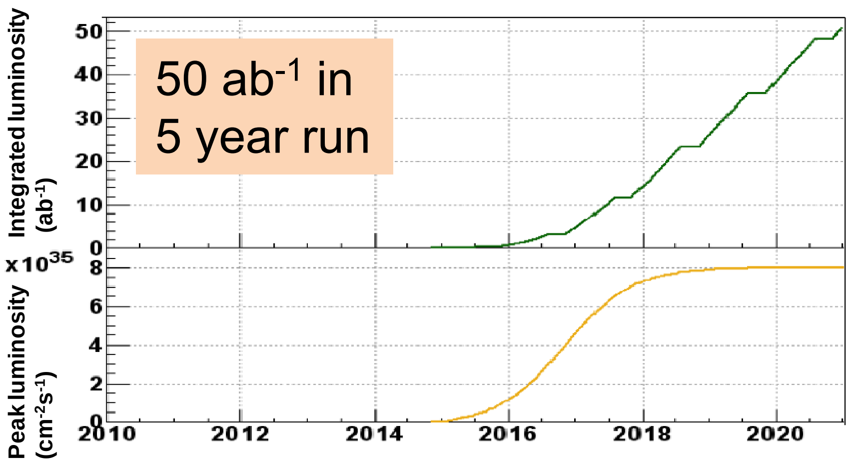
- Belle-II is now a collaboration of ~400 physicists from 57 institutions in 13 countries.

US Groups:
PNNL
Cincinnati
Hawaii
Indiana
Luther College
South Alabama
VPI
Wayne State

Belle II Physics Program
Precision Science complementary to LHC

- B-factories → Is the CKM description in the Standard Model correct?
- Super B-factories → In what way is the Standard Model wrong?
- Belle II at SuperKEKB, with its very high luminosity (40x KEKB), provides opportunities to make unique and important discoveries

- Measurement of CP-violating asymmetries in rare penguin-dominated *B* meson decays
- Precision determination of CKM parameters
- Sensitive searches for lepton flavor violation (LFV) & lepton number violation (LNV) in rare and forbidden *B*, *D* decays
- Searches for CP-violating asymmetries in decays involving mixing

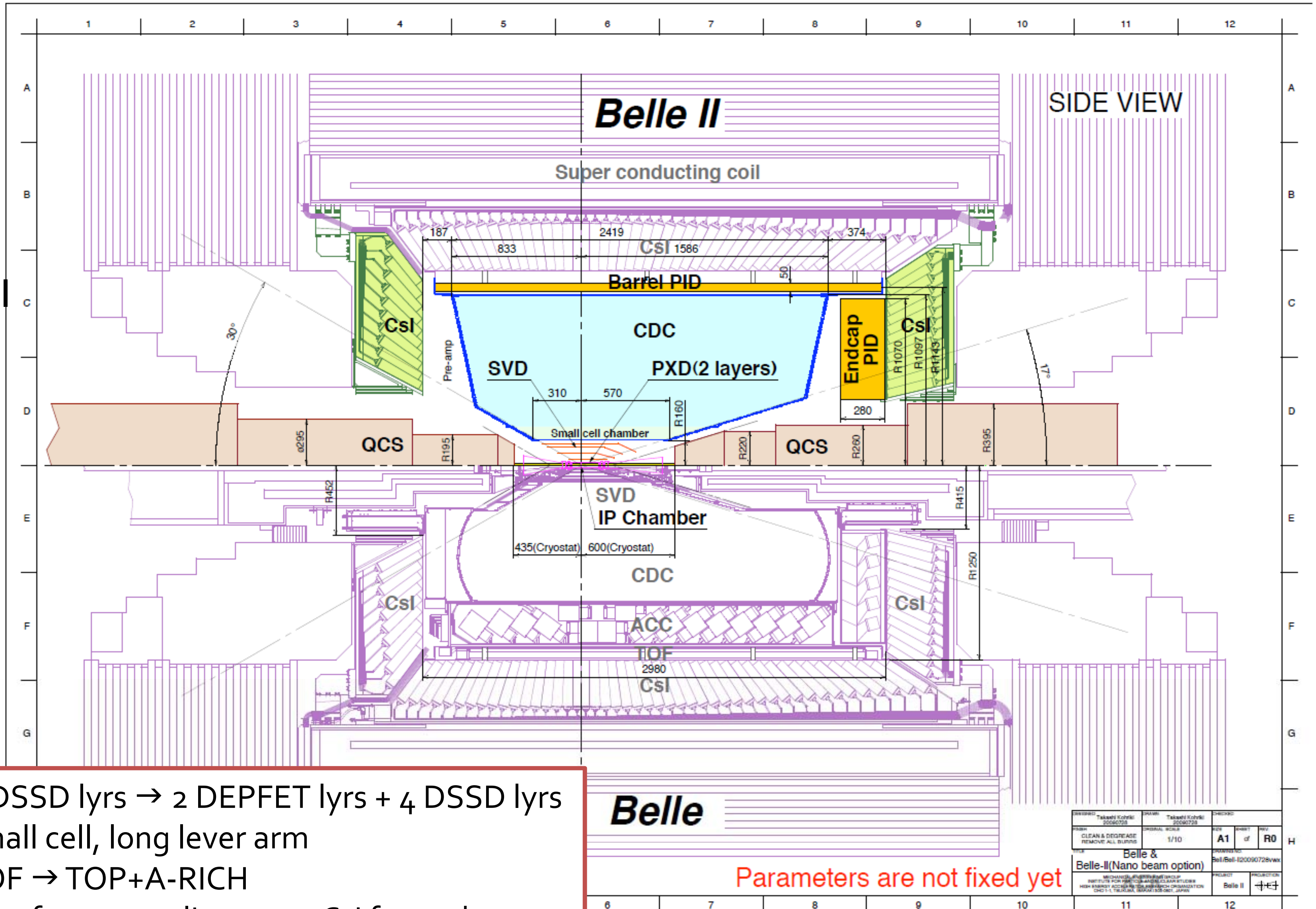


Deviation/consistency with SM expectations across Belle II physics program will elucidate New Physics observed at LHC

Belle-II detector

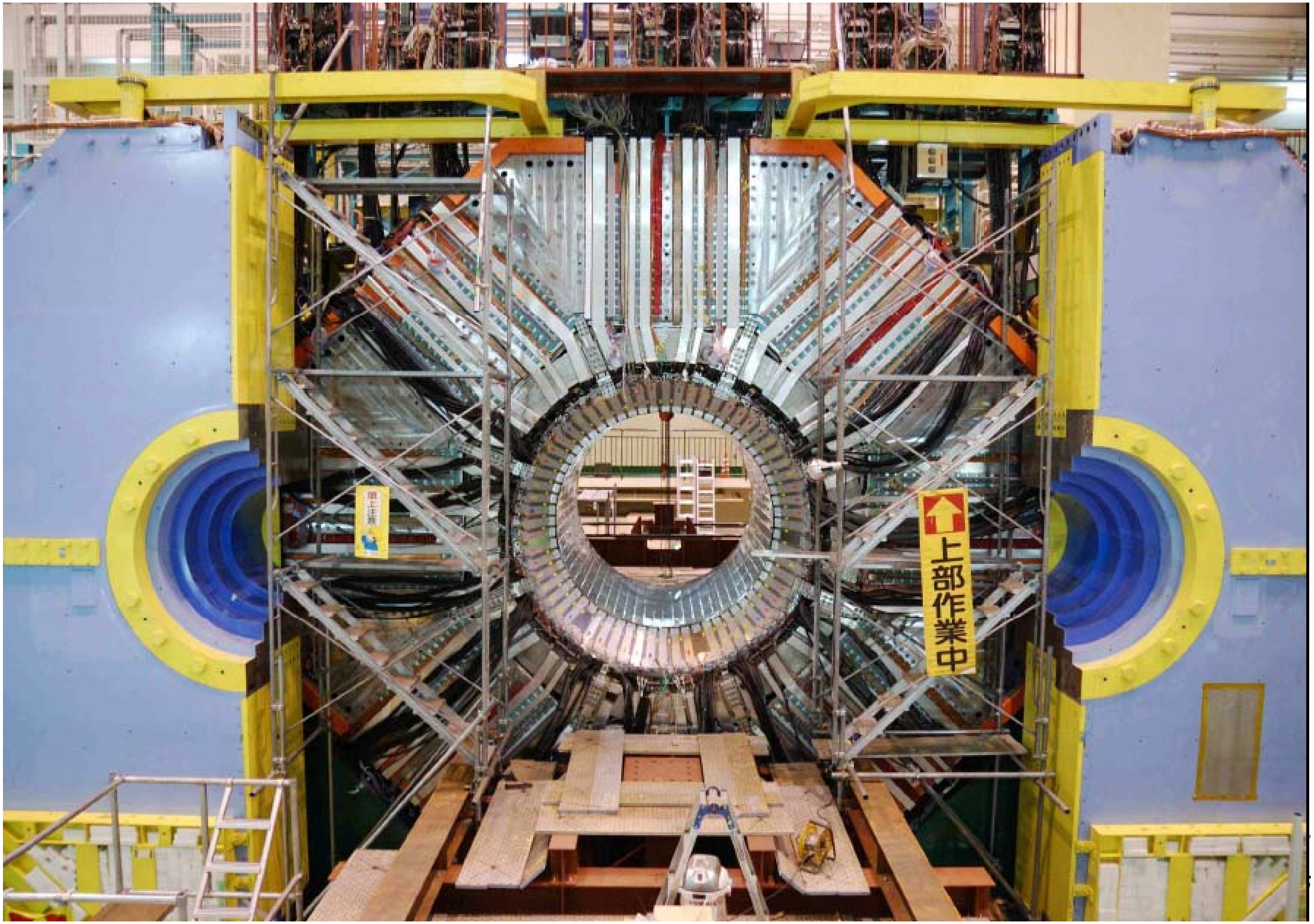
Belle-II

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)

Belle detector today – ready for upgrade



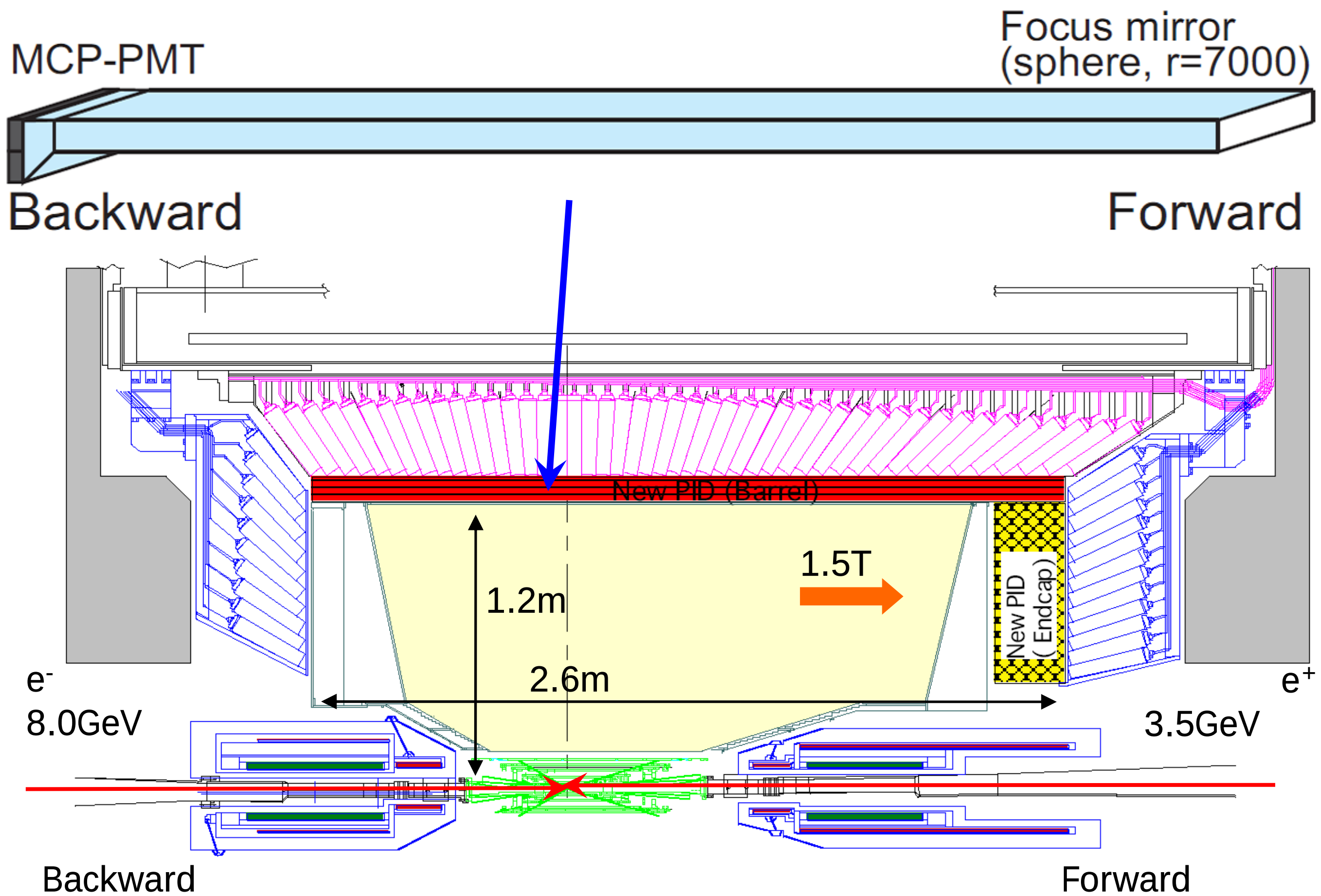
US Contributions to Belle II

- US contributions to critical particle identification systems
  - iTOP system (barrel PID)
    - Providing quartz optical elements
  - KLM (muon system upgrade, endcap and barrel)
    - Providing replacement of inner layers of BKLM
  - ASICs and front end electronics
    - Hawaii-designed “oscilloscope on a chip” ASIC
    - Front end electronics for iTOP, KLM, beamstrrahlung monitor
- US to provide beamstrrahlung monitors for accelerator
  - Primary feedback mechanism for understanding beam spot at IP
- US proposing to lead commissioning detector effort
  - Critical to avoid damage to new inner detector elements at start-up
- US (PNNL) hosting “tier 1” computing facility for Belle II
  - 10% demonstration system being brought on line for Belle
    - Part of US response to Fukushima disaster
    - PNNL is lead lab coordinating DOE response efforts

iTOP: an imaging time-of-propagation detector

Space constrained by existing calorimeters

Quartz radiator + mirror + expansion block + MCP-PMT

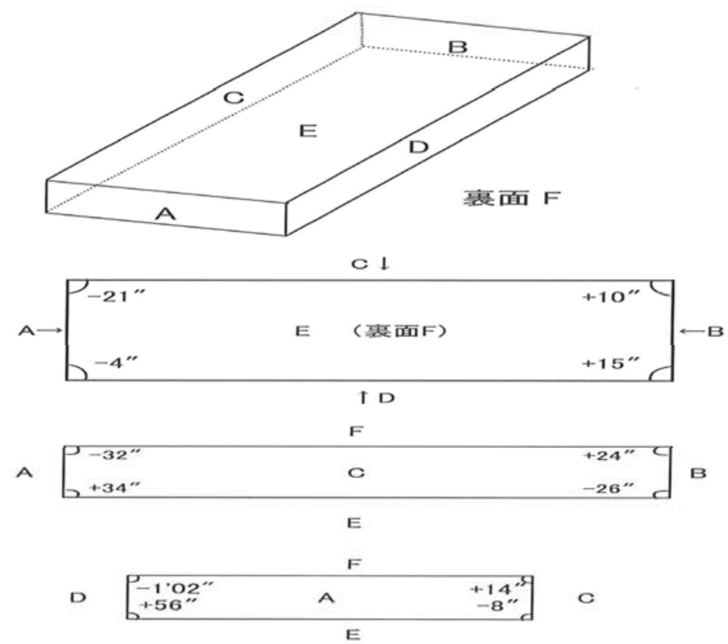


Metrology report from Okamoto prototype

検 査 成 績 表

会 社 名	名古屋大学　理学研究科（N研）様	注 文 数	1枚
品　　名	クオーツバー　OK−07−SQB−915	納 入 数	1枚
材　　質	合成石英 SUPRASIL−P20	総合判定	良

検査項目	仕様書規格	検査データ 1	判定
外　　径	915mm±0.5	915.18mm	良
外　　径	400mm±0.2	400.07mm	良
厚　　さ	20mm±0.1	19.998mm	良
角　　度	A⊥C	−21″	良
	A⊥D	−4″	良
	A⊥E	+34″	良
	A⊥F	−32″	良
	B⊥C	+10″	良
	B⊥D	+15″	良
	B⊥E	−26″	良
	B⊥F	+24″	良
	C⊥E	−8″	良
	C⊥F	+14″	良
	D⊥E	+56″	良
	D⊥F	−1′02″	良
平行度	A//B	15″	良
平行度	C//D	1′10″	良
平行度	E//F	5″	良
面精度	2λ	良	良
表面粗さ	5Å	良	良
角　度	5分	良	良



検査年月日	平成 20 年 10月 16日	検査責任者	岡本
社　　名	有 限 会 社 岡 本 光 学 加 工 所		

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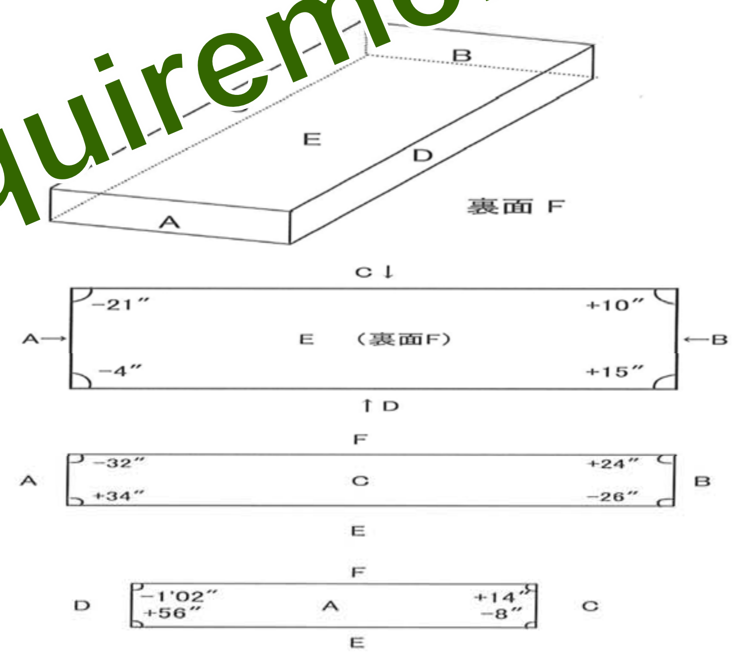
	A⊥D	−4″	良
	A⊥E	+34″	良
	A⊥F	−32″	良
	B⊥C	+1[illegible]	[illegible]
	B⊥D	+15[illegible]	[illegible]
	B⊥E	−26″	良
	B⊥[illegible]	[illegible]24″	良
	[illegible]	−8″	良
	[illegible]	+14″	良
	[illegible]⊥E	+56″	良
	D⊥F	−1′02″	良
平行度	A//B	15″	良
平行度	C//D	1′10″	良
平行度	E//F	5″	良
面精度	2λ	良	良
表面粗さ	5Å	良	良
角　度	5分	良	良

Meets Requirements



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TDR reviewer's comment

Follow-up Review Report for Belle II TDR

http://b2comp.kek.jp/~twiki/bin/view/Public/WebHome

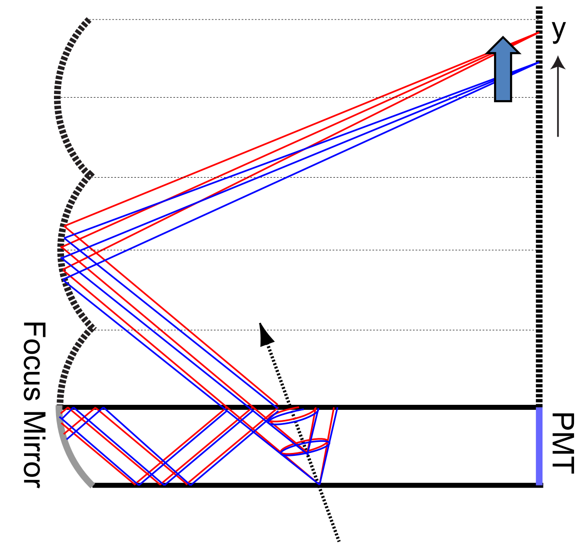
5.2.2 Comments and Recommendations

At present, production of quartz bars is likely to be a bottleneck in the TOP construction schedule. Therefore, it should be the highest priority item. New suppliers from the US have been identified which could accelerate the radiator production schedule. We are looking forward to more detailed report on the status of the quartz bar R&D for the next BPAC meeting.

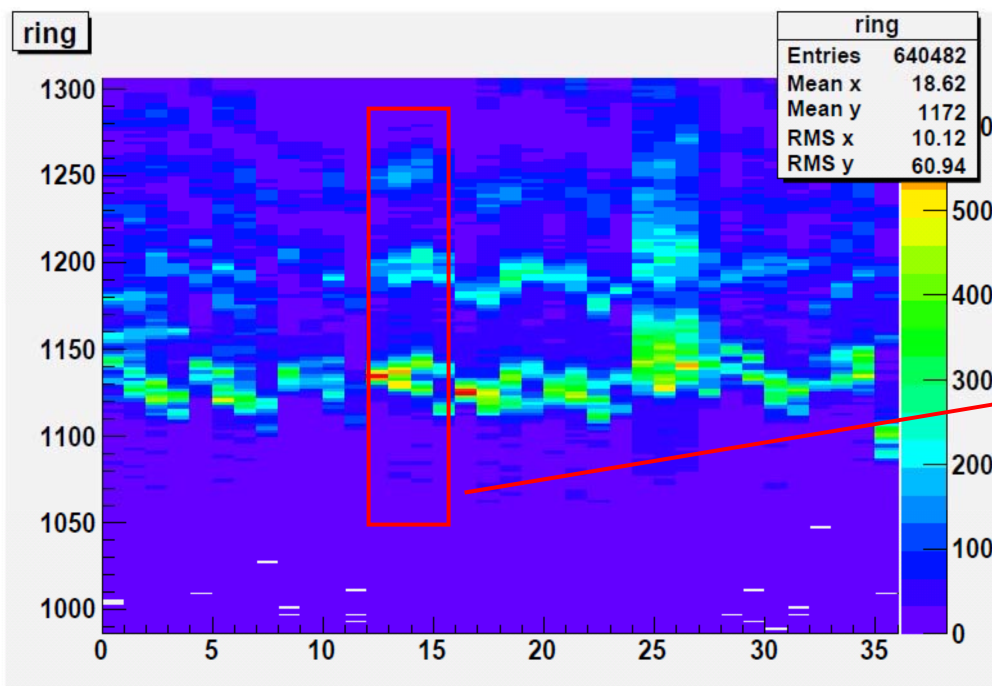
Choice of 1-bar configuration for TOP radiators mitigates, to some extent, dependence of the detector performance on the event start-time jitter. However, even 50 ps RMS spread, twice as large as assumed in the simulation for the performance studies, may not be trivial to achieve. Studies of TOP performance for a wider range of the time jitter and an articulated plan how to keep the jitter under control would be needed.

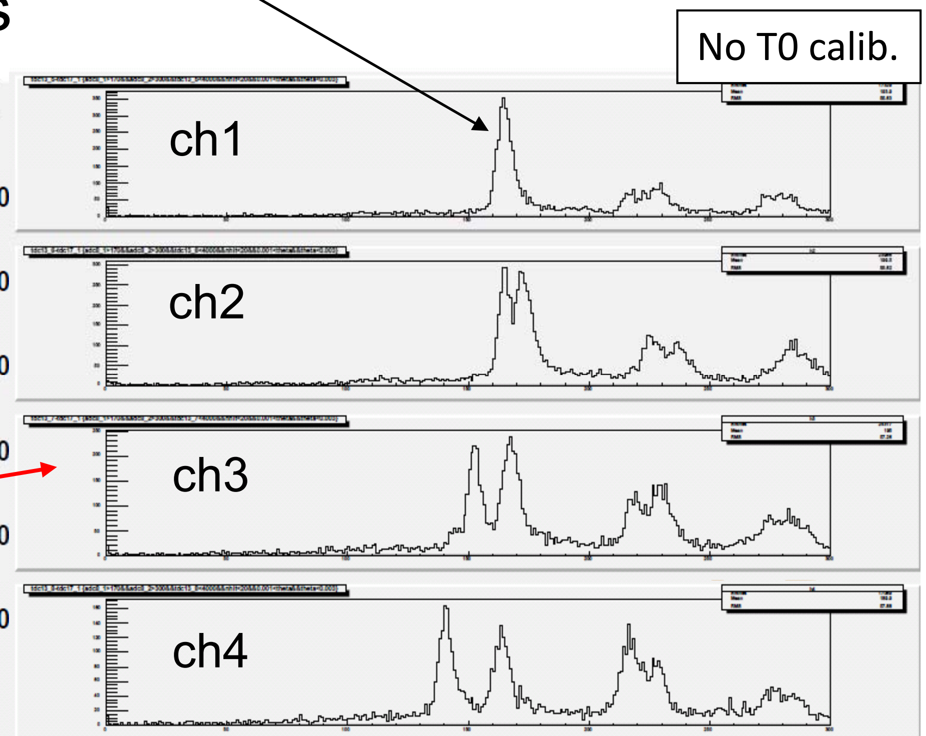
- **Prototype quartz bar from US vendor delivered to Nagoya recently**
  - **Main concern is meeting chip specification**
- **RFI process for quartz production completed in July**
  - **Three vendors have responded; two others have are interested in RFP**
- **RFP is in preparation**
  - **Will include full production of all optics**
  - **Single vendor and multi-vendor awards are under consideration**

Test Beam Data (cosθ=0.3)



- Tilted incidence
- Complicated ring image
- Expected time distribution along y-channel
- Good time resolution : ~95ps





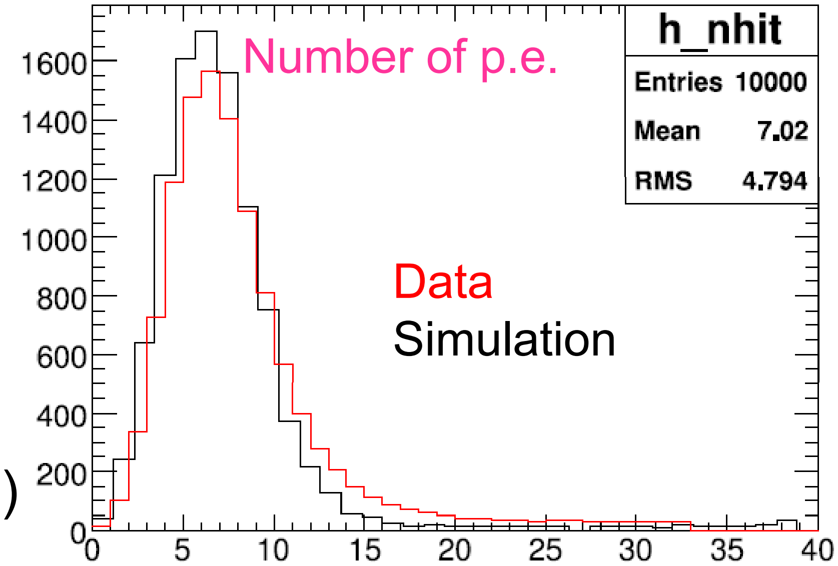
Performance for different T0 jitter

GEANT-based MC, cross-checked using analytical simulation

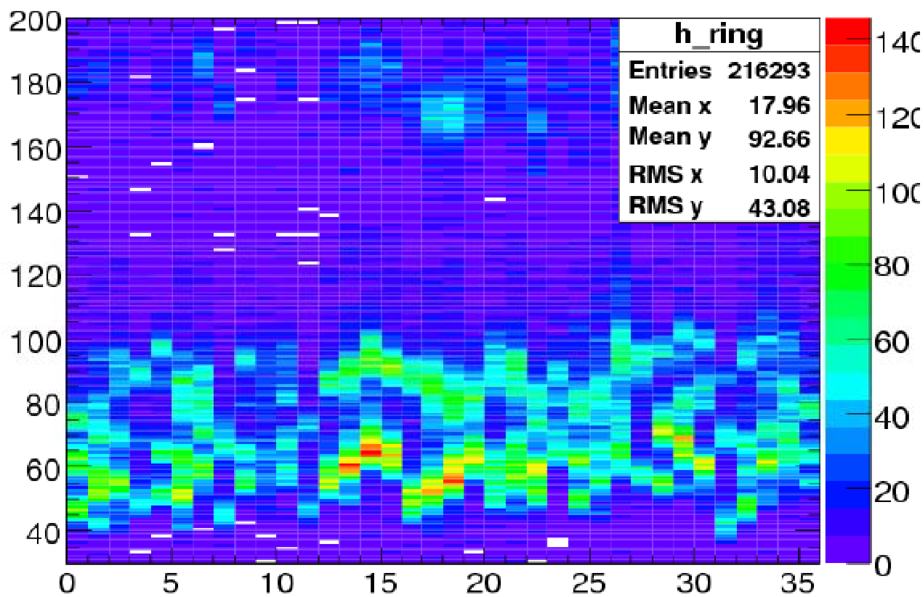
T0 jitter	B→ππ Efficiency(%)	Fake rate(%)	B→ργ Efficiency(%)	Fake rate(%)
25ps	94.5	5.9	98.4	2.3
50ps	93.1	7.3	98.1	2.8
75ps	91.2	9.0	97.4	3.5
100ps	89.4	10.7	96.7	4.3
200ps	84.0	15.9	93.7	7.6

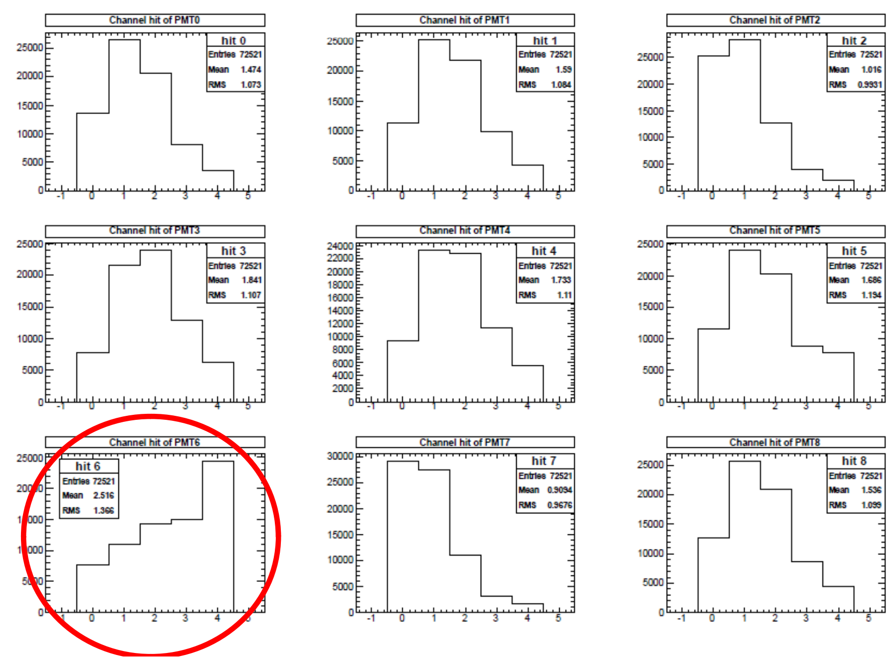
- Results of cross-check show consistent trend
- 2x worse fake rate for 100ps T0 jitter compared to 25ps
- For reference <= 40ps in Belle TOF
- Add dedicated (independent) Beam Position Monitor timing

Test Beam (cosθ=0.5)



- Tilted incidence
- N_{hit} for each MCP-PMT
  - Distributions normal (QE variations)
  - PMT6 shows large N_{hit}.
    → Large cross talk due to high gain and low discriminator thresholds
- Basic agreement in (scaled) # of detected photo-electrons

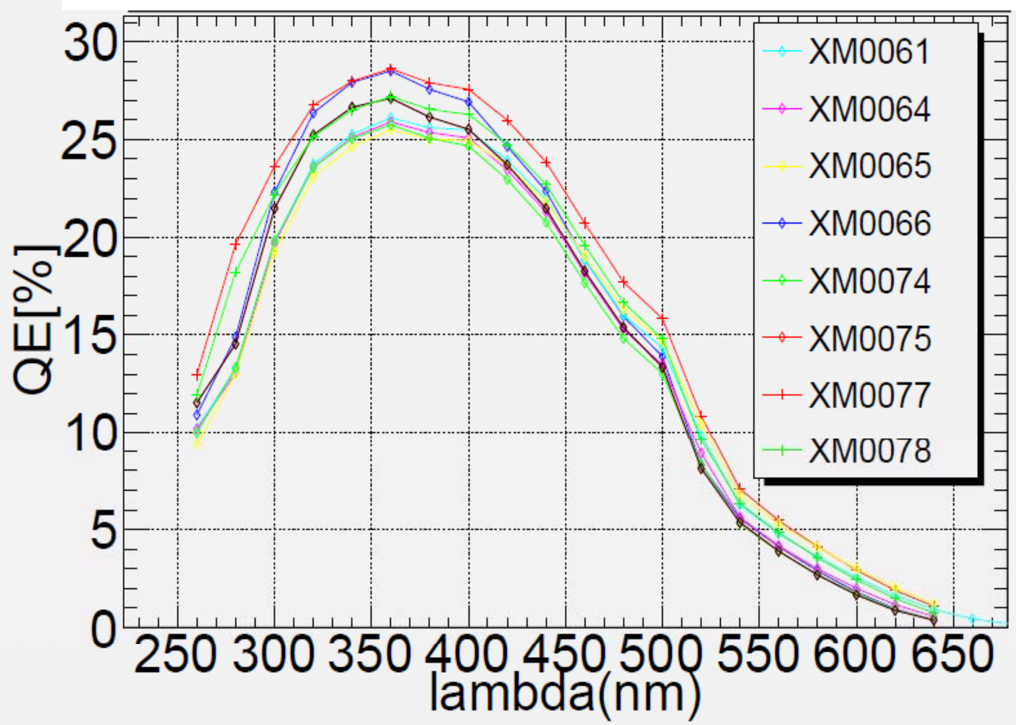


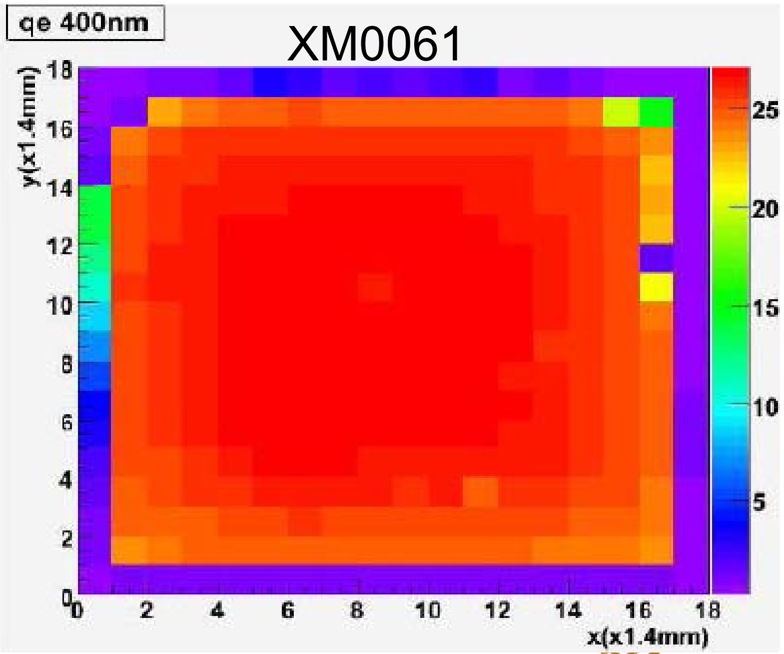


Production photo-cathode (Super Bi-Alkali)

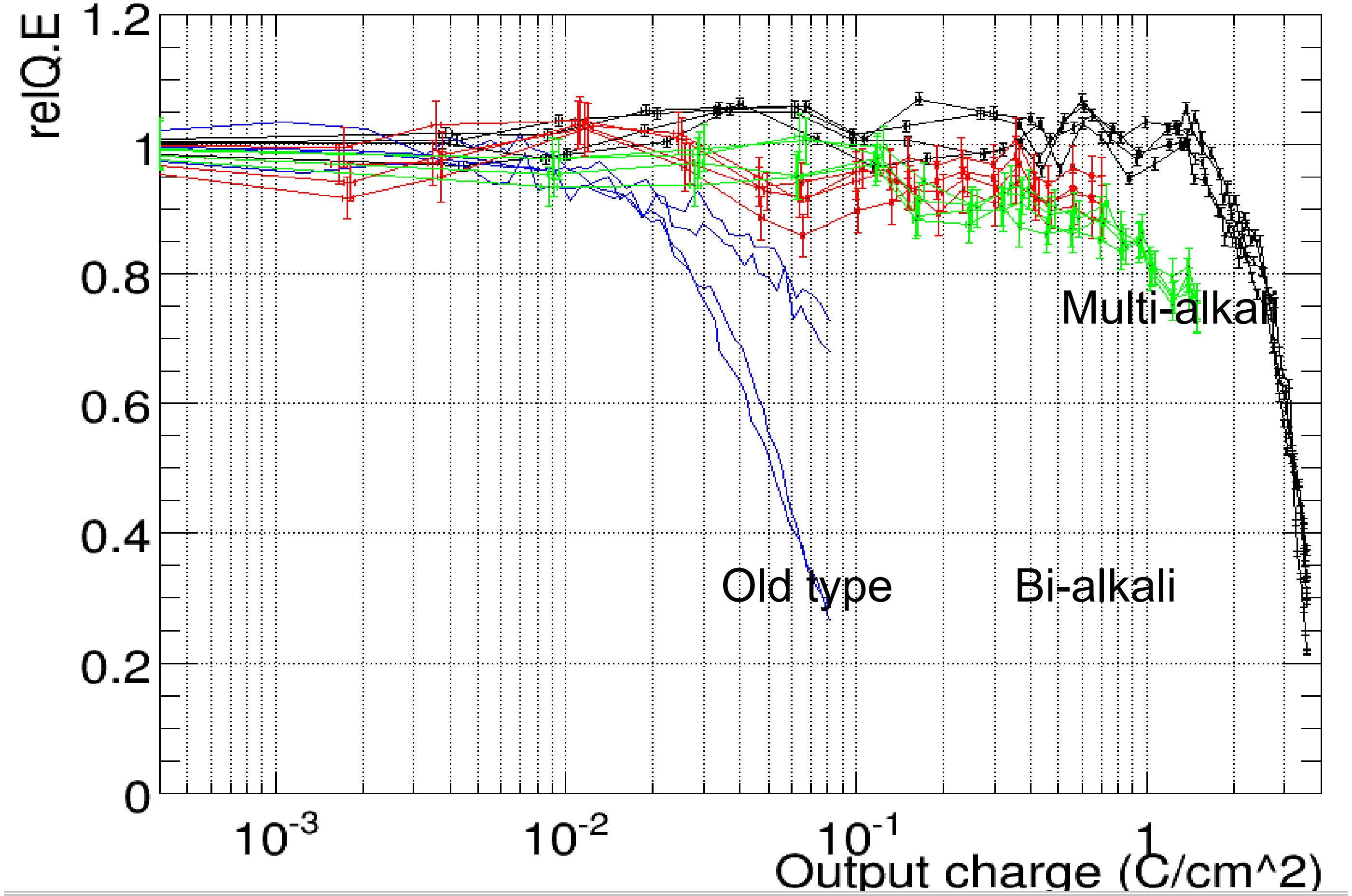
- MCP-PMT with super bi-alkali photo-cathode technique
  - Provided by HPK (28% for Bi-alkali and 24% for Multi-alkali)
  - Specification is 28-32% nominal, 24% minimum for production

QE distributions for recent samples



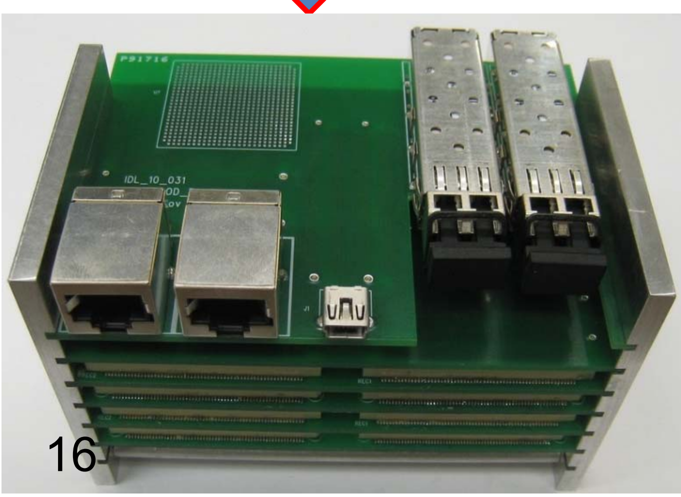


MCP-PMT (SL-10) Lifetime

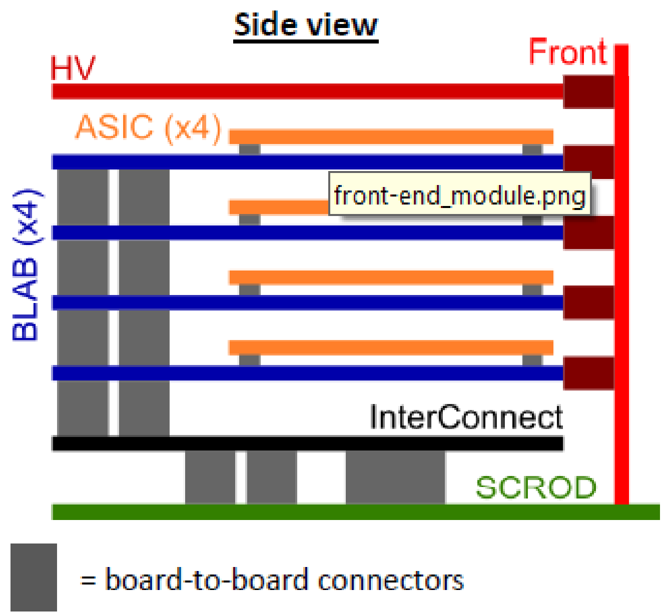


- Recent status
  - 1~2 C/cm² for 80% QE drop

iTOP electronics package – highly integrated



New Front-end Board Stack



Front
- Connects HV board to PMTs
- Connects PMT output to ASIC input

HV
- High voltage components for PMTs
- Cooling for high voltage components

Standard Control, Read-Out, Data (SCROD)
- FPGA (ASIC control)
  - Virtex4, Spartan6
- 2 Fiber transceivers
- 2 RJ45
  - Clock Distribution
  - LVDS (JTAG)
- Mini USB – for easy bench testing

Digitizer Boards (BLAB)
- Carrier card for ASICs
  - 4 ASIC daughter cards per carrier
- ASIC in-situ testing components
  - e.g., pulser for channel checks

ASIC
- 1 BLAB3 per card
- DACs

Interconnect Board
- Connects SCROD & BLAB
  -Layout of connectors are forced to be unique because of size constraints
- Power regulation/distribution

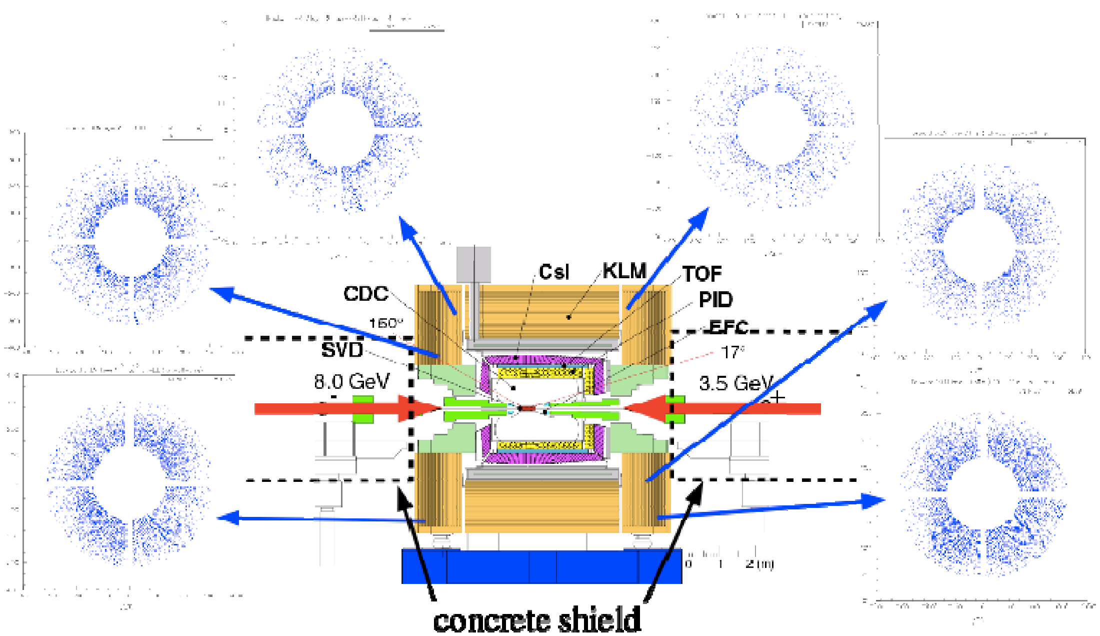
After a number of design iterations:
Incompressible @ 68.5mm height

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

K_L and muon (KLM) System Upgrades

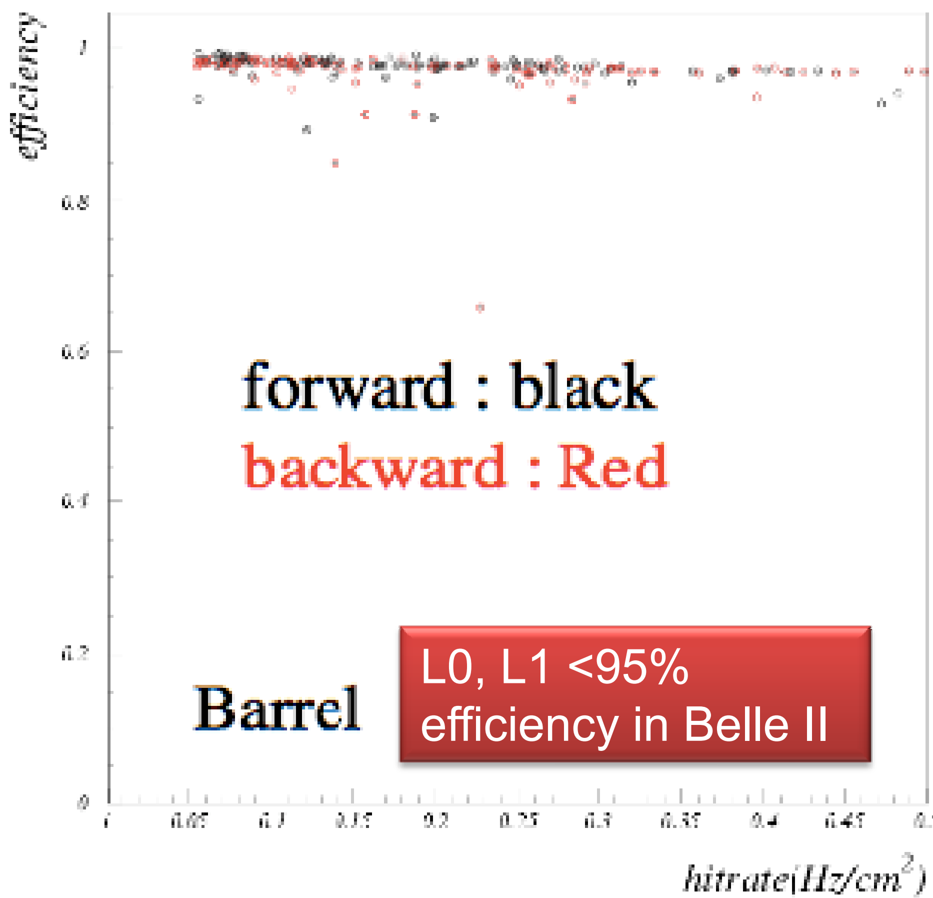
- Virginia Tech was responsible for RPC system in Belle
  - Natural to take leadership role on upgrade to KLM
- Belle II background rates are too high for some elements
- Solution: Replace RPCs with plastic scintillators
  - Also update electronics throughout system

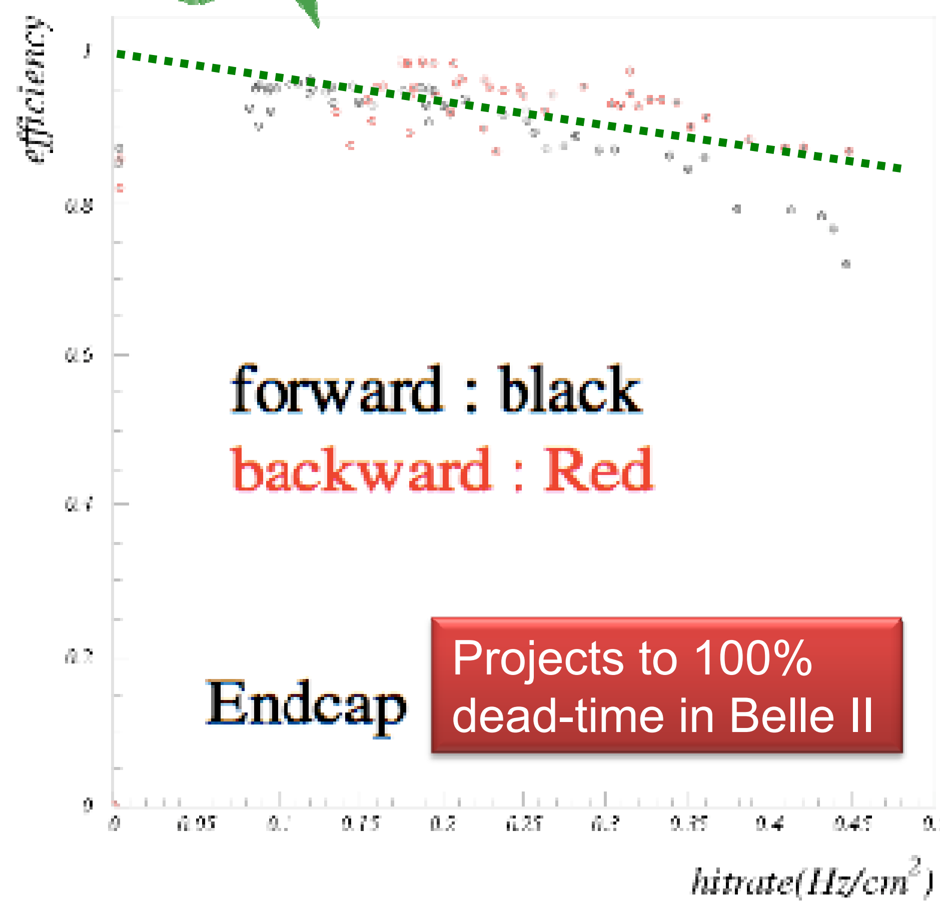


Belle's endcap KLM is bombarded by beam-induced soft neutrons ... *not enough exterior shielding*

Endcap needs complete replacement

High-resistivity glass electrodes in existing RPCs cause efficiency to drop with increasing ambient neutron rate





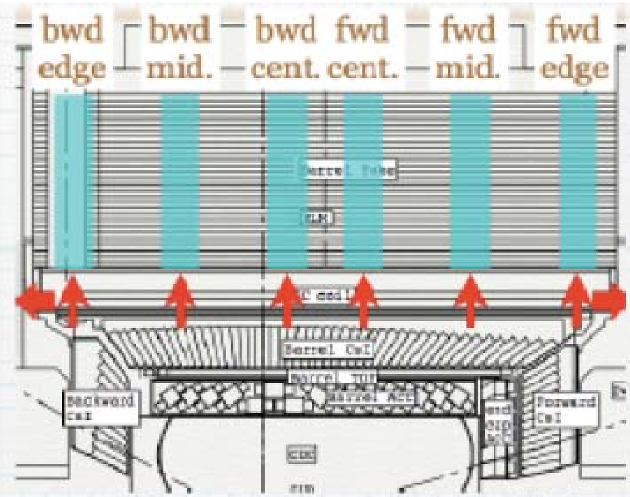
Barrel L0 and L1 Replacement

Latest background projections say parts of inner layers of Barrel RPCs will be subjected to high rates (mainly Touschek-related background).

	Bwd Edge	Bwd Mid.	Bwd Cent.	Fwd Cent.	Fwd Mid.	Fwd Edge
L00	14.6	4.3	1.8	1.9	2.7	6.5
L01	8.9	2.5	1.1	1.2	1.6	3.9
L02	3.3	1.0	0.4	0.4	0.6	1.5

(Hz/cm²)

L01& L02 are calculated by assuming rate∝exp(-0.5xlayer)



Nakano-san's slide in September IDM

- Loss of barrel hits at forward end for hard muons is recovered in endcap
- Loss of barrel hits at backward end for soft muons: low μ ID efficiency
- Would be prudent to use scintillators/WLS fiber/SiPM in barrel layers 0, 1

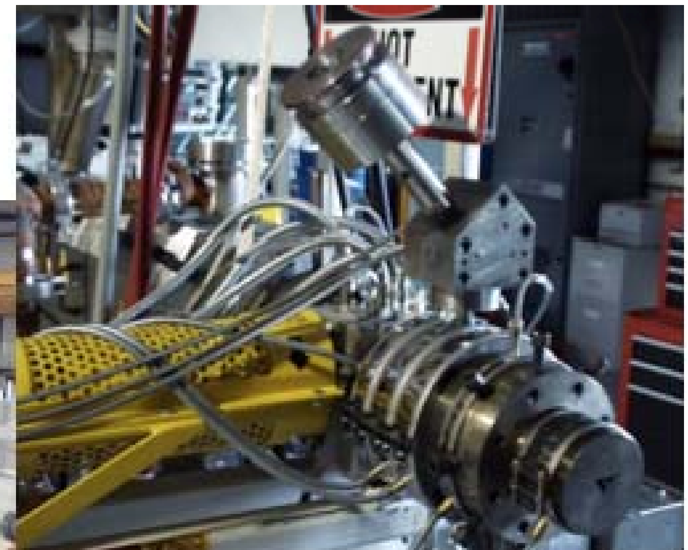
✓ *relatively easy to extract/insert these without dismantling iron supports*

✓ *plastic in layer 0,1 will better shield outer barrel layers from neutrons*

Utilize Fermilab Scintillator Extrusion Facility

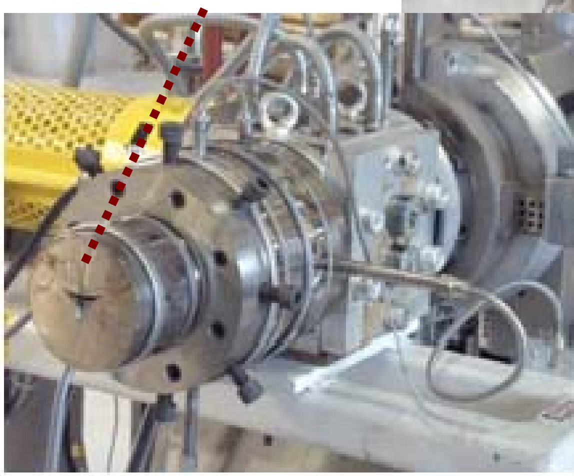
Scintillator-strip extrusion with exterior TiO_2 coating and a channel for wavelength-shifting fiber

Scint & TiO_2 co-extruder



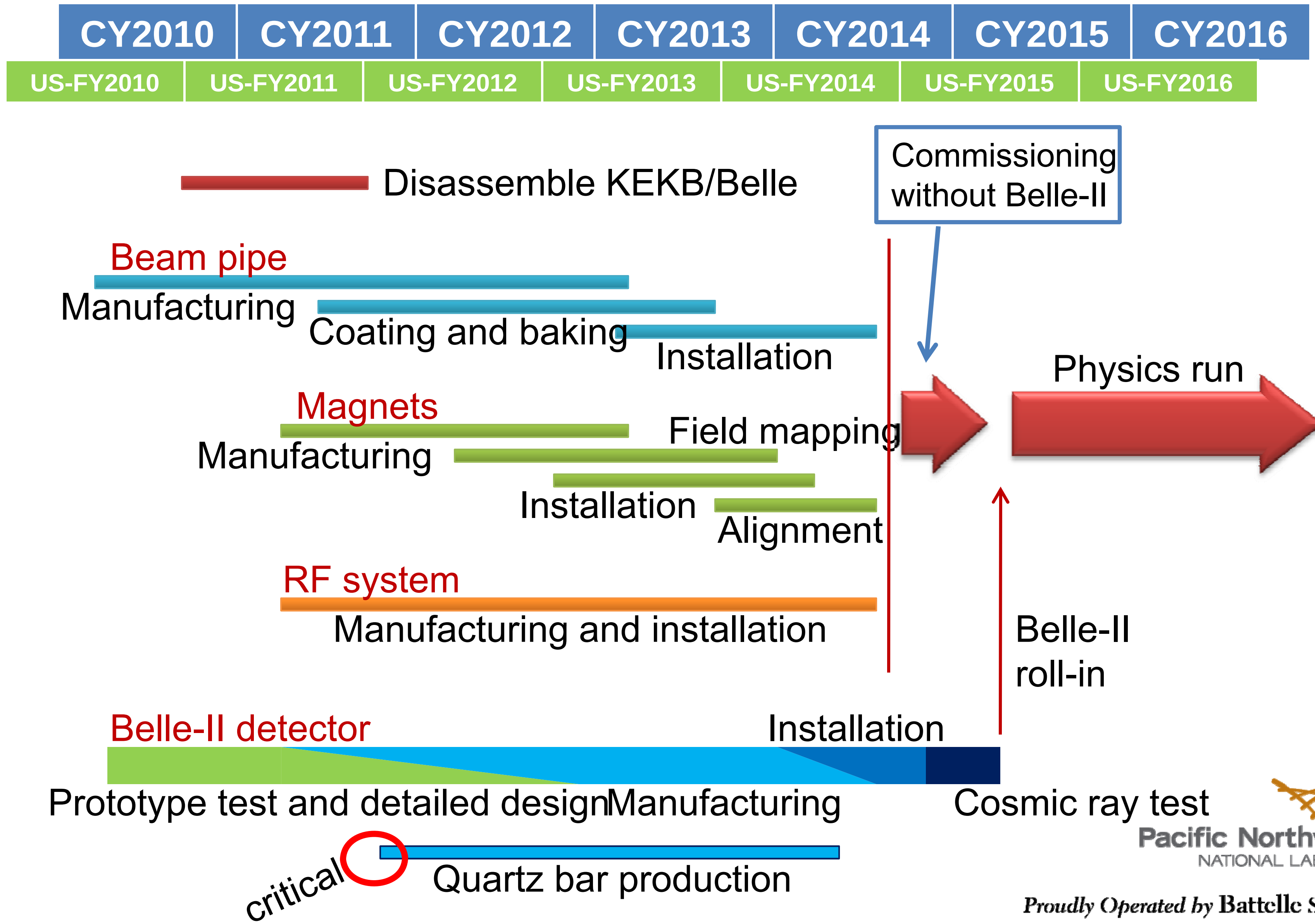
Production line

Custom die



Used for
- ★MINERνA
- ★T2K near detector
- ★ILC R&D

SuperKEKB Schedule



Summary

- Belle-II Detector upgrade is underway to provide improved performance at x50 luminosity
- US contributions to critical particle identification systems
  - iTOP system (barrel PID)
  - KLM (muon system upgrade, endcap and barrel)
  - ASICs for front ends of these systems and beam monitors
- US (PNNL) hosting “tier 1” computing facility for Belle II
  - 10% demonstration system being brought on line for Belle
- US Belle II at CD-0 (imminent)
  - CD1 planned for early 2012
  - CD2/3 timely for construction funding in FY13-14
- SuperKEKB scheduled for 2015 startup

Belle II Technical Design Report


KEK Report 2010-1
October 2010
H

Belle II Technical Design Report

Belle II

Edited by: Z. Doležal and S. Uno

High Energy Accelerator Research Organization

- 480 pages
- ~400 authors
- Numerous revisions
- Almost all technology decisions finalized
- In Belle, published a Progress Report 2 years into construction

Follow-up Review Report for the Belle II TDR

Review Panel Members:
M. Demarteau (ANL), T. Nakada† (EPFL), T. Skwarnicki (Syracuse),
M. Sullivan (SLAC), and W. Trischuk (Toronto)
†Chair

3 December 2010

1 Introduction

A review of the Belle II Technical Design Report (TDR) took place on 21st, 23rd and 24th of May, 2010 at KEK, where the all detector subsystems, including the interface to the collider, were discussed. One of the recommendations of that review was a more detailed study of the machine induced backgrounds, in particular the synchrotron radiation from the tail of the beam distribution beyond what had been investigated by the time of the TDR.

Since then, more studies on the machine induced background were done resulting in modifications to the layout of the interaction region. A follow-up meeting for the TDR review took place on the 7th of November. It focused on the interaction region and the two sub-systems closest to the beam, i.e. the Pixel Detector and Silicon Vertex Detector. An overview on the progress of the other sub-systems and a presentation of collaboration matters were shown as well.

The committee heard of impressive progress being made by the machine team. The current KEKB machine was turned off on the 30th of June after just over eleven years of operation. The SuperKEKB machine parameters have been modified so that the High Energy Ring magnets in the arc sections and most of the beam pipe parts will be reused. This leads to a significant reduction in the construction cost, while maintaining the design peak luminosity of 8×10^{35} cm^{-2}s^{-1}.

2 Interaction Region and Related Issues

2.1 Interaction Region Layout

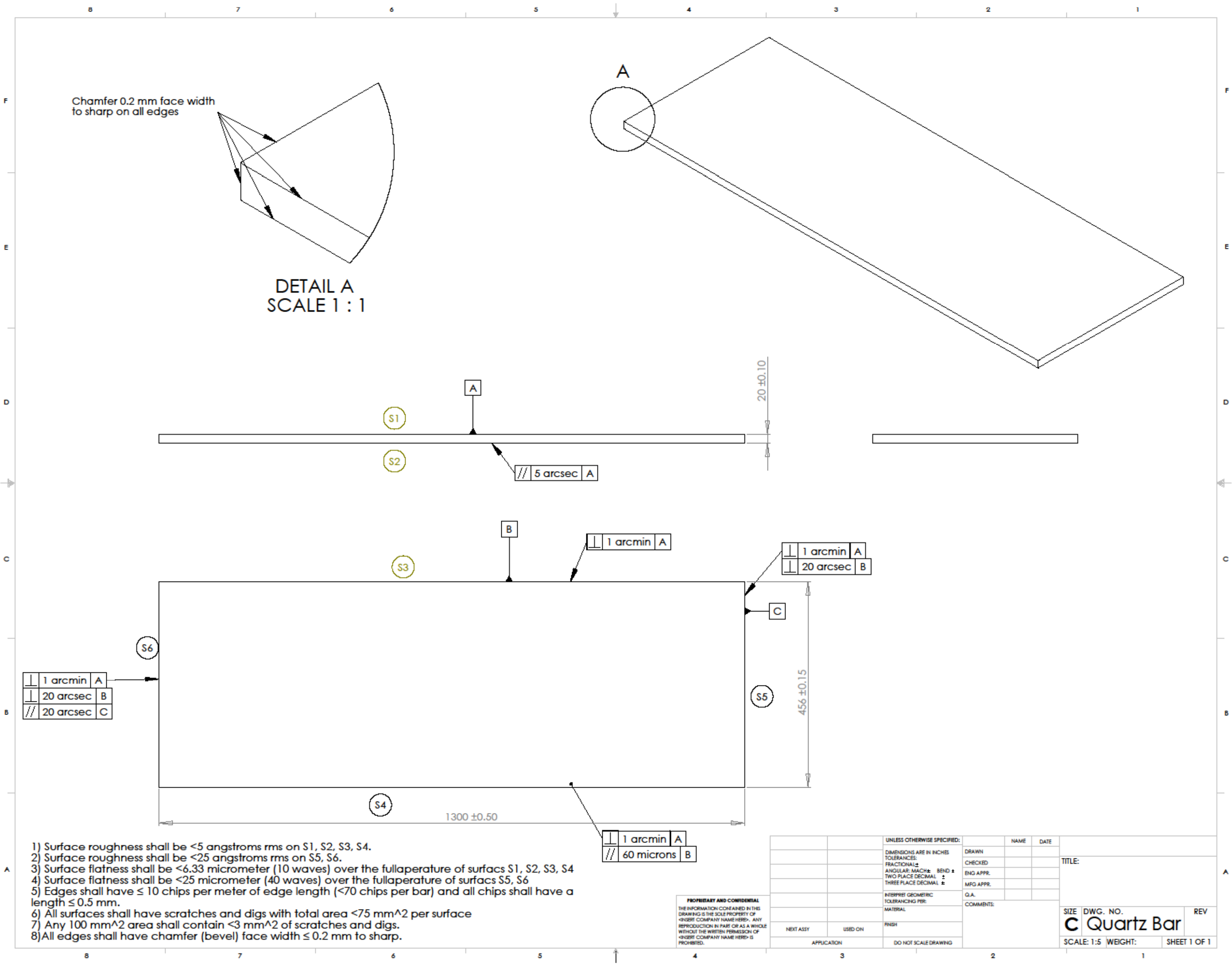
2.1.1 Progress Since Last TDR Review

The Belle II team has made significant progress in developing a sound Interaction Region (IR) layout and design. During the last review, it was discovered that Synchrotron Radiation (SR) was able to strike the detector "physics" beam pipe which is defined as

1

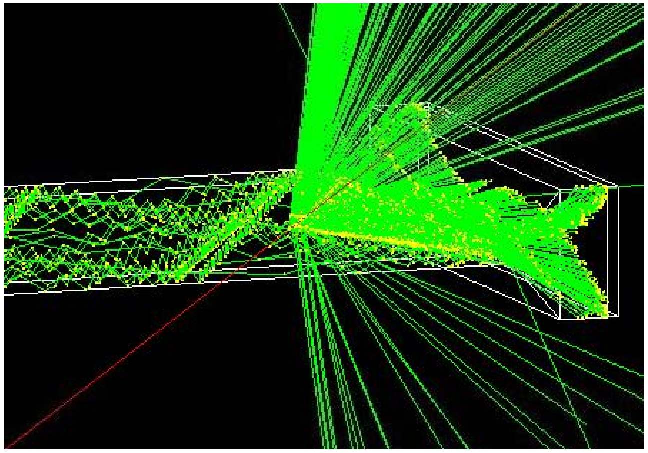
TDR submitted to external reviewers April 13, 2010
Initial review held May 21 – 24, 2010
Revised, published Oct 28, 2010 [KEK "green book" and arXiv:1011.0352]
Follow-up Nov. 7, 2010
Further questions addressed in February, 2011 Belle PAC meeting

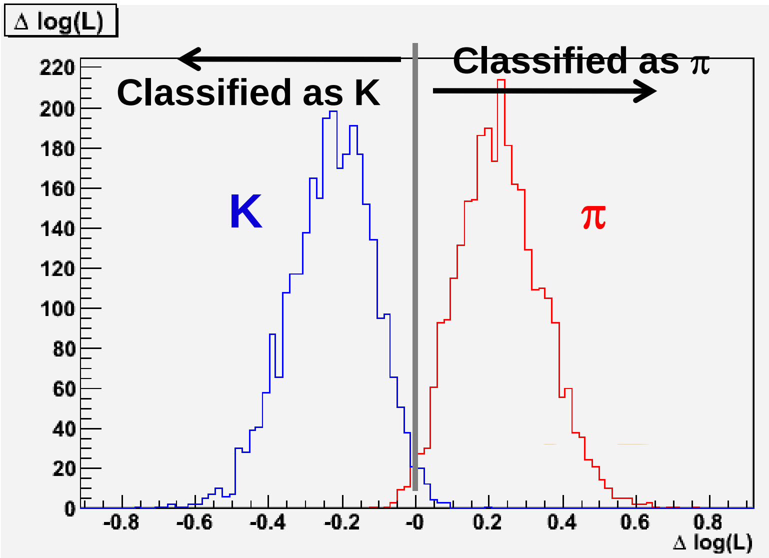
Quartz Optics Specifications Developed



iTOP Simulation Studies

- Independent simulations:
  - Geant4 (Hawaii)
  - Standalone code (Ljubljana)
  - Belle Geant3 + standalone code (Nagoya)
- All utilize a log(likelihood) approach to determine particle classification.
  - PDFs are defined in x,y, and t
  - Geant-based versions take probability distribution functions (PDFs) from simulated events.
    - ➔Extremely time consuming to generate the PDFs, but can include all the effects (scattering, ionization, delta-rays, etc.) that Geant provides.
  - Ljubljana code utilizes analytical expressions for the likelihood functions.
    - ➔ Much faster!
    - ➔ Used for evaluating performance of different optics geometries etc.





NIM A623 (2010) 297-299.

Belle II Integrated Luminosity Projection