ePIC-ZDCの今後の計画

EIC日本グループ会合
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Taskの分担

- 本体の設計見直し
  - コスト見直しも含めた最適化を行う
- Integration & Mechanical design
- 読み出し機器、回路、DAQ
- プロトタイプ製作、テスト、評価
- ソフトウェア開発とシミュレーション計算
- Timelineと目標の設定
  - 分担を決めて検討する

- Timelineと目標の設定
  - Crystal calorimeter
    - 台湾グループ
  - Imaging calorimeter (EM + Hadron)
    - 日本グループ
  - Plastic-scintillator or dual-readout calorimeter
    - 韓国グループ
  - ソフトウェア
    - アメリカグループ（PNNL）

2023年度計画

- Timelineの設定
  - 分担毎に計画を立てる
- ソフトウェア開発
  - アメリカ（PNNL）・アジアグループの協力
- シミュレーション計算
  - 放射線量の確認
- 設計の見直し→ Preliminary design (50% ready)
- プロトタイプ製作
  - Crystal + Imaging calorimeter (W-Si)
- 東北大ELPHでテストビーム
  - 2023年秋のビームタイム
  - アジア（台湾）グループの参加
- 放射線耐性テスト（中性子照射）＠理研RANS
  - ALICE-FoCal-E Padセンサー新旧の比較

放射線量

- “Backgrounds in the Electron Ion Collider Experimental Hall and ZDC Life Time in FLUKA model,” M. Murray, V. Baturin, C. Hyde, et al.
  - ハドロンカロリメータの部分（Table 1のZDC Si 4）でも数年のオペレーションで10^{13} neutron/cm^{2}の中性子Fluenceがあるので、技術的選択において放射線耐性に対する考慮が必要

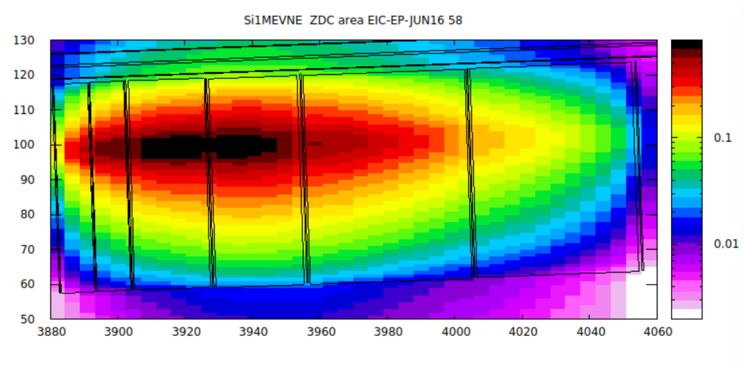


FIG. 5. Neutron MEQ fluence in the area of ZDC from $e(10\ GeV) + p(275\ GeV)$–collisions. Vertical scale: X coordinate perpendicular to the e-beam line (cm); Horizontal scale: coordinate Z along the electron beam line (cm). Electrons travel in $-Z$ direction. Fluence is given in units of neutrons/cm^2 per primary ep–collision. The maximum fluence in the center of ZDC is of 8.E-1 neutrons/cm^2 per primary ep interaction. At maximal luminosity (10^{34}/cm^2/sec the ep interaction rate is $\sim 5 \cdot 10^5$/sec. fff182

One MeV neutron equivalent fluxes F through the silicon material and life time						
Detector.	R_{min}/cm	R_{max}/cm	Z_{mea}/cm	$F_{p+rg}/(cm^2s)$	$F_{e+p}/(cm^2s)$	$F_{tot}/(cm^2OY)$
ZDC Si 1	58	120	3880	1.2E+3	5.5E+4	5.6E+11
ZDC Si 2	59	118	3890	5.4E+3	3.8E+5	3.8E+12
ZDC Si 3	60	119	3910	6.6E+3	7.1E+5	7.1E+12
ZDC Si 4	61	121	3930	4.6E+3	3.6E+5	3.6E+12
ZDC Si 5	62	122	3960	3.6E+3	1.4E+5	1.4E+12
Si in B0	13	22	650	1.2E+3	15.E+4	1.6E+11

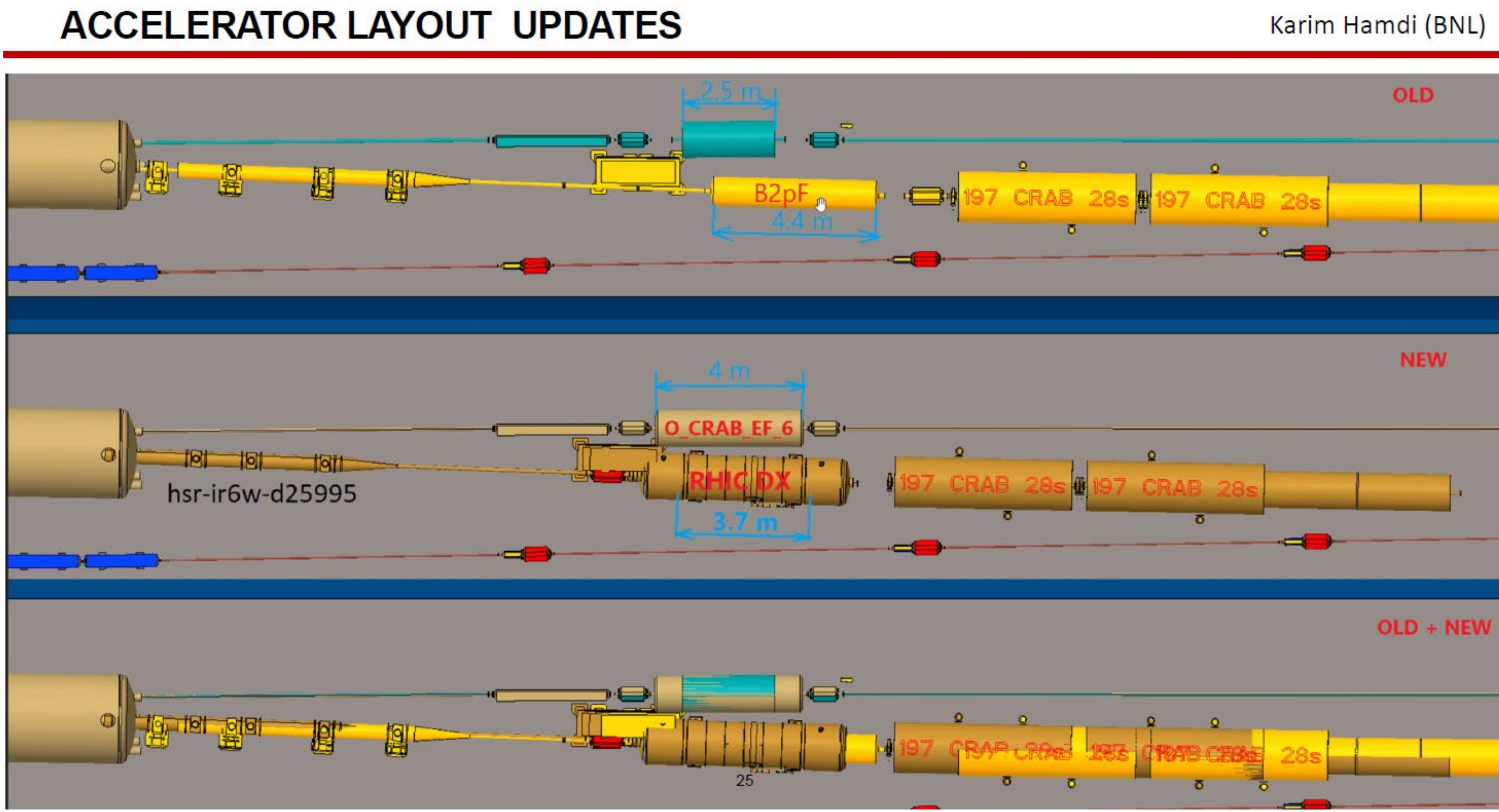
TABLE I. Critical neutron MEQ fluxes in potential locations for readout Si based detectors at the proton beam (275 GeV/c) current 1 A, residual gas pressure 1.E-9 mbar, and $e(10)+p(275)$–interaction rate $0.5\times10^{+6}Hz$ (at the luminosity of 10^{+34}cm^{-2}s^{-1}). Columns: (1) – detector area, (2,3) – radial coordinates in cm, (4)–mean coordinate along the electron beam in cm, (5,6,7)–fluxes from $p+rg$, ep–collisions in units of MEQ neutrons/cm^2/s and from both sources in f MEQ neutrons/cm^2/OY, where OY stands for ”Operational Year” ($10^{+7}s$). The last has to be compared with 10^{+14} for regular silicon readout detectors and 10^{+11} for silicon photo multipliers. ttt1991

議論

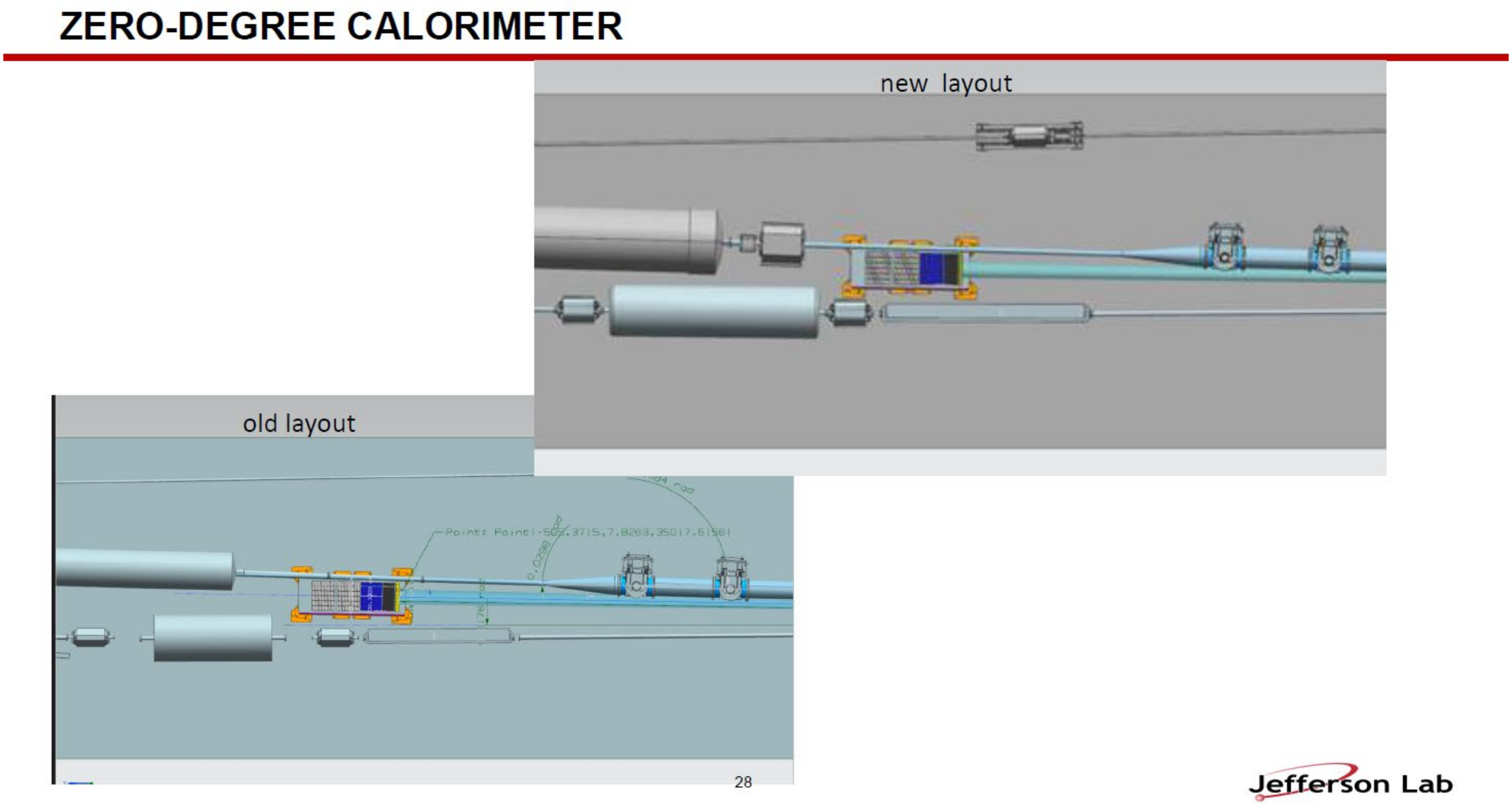
- 設計の見直し→ Preliminary design (50% ready)
  - ハドロンカロリメータはImagingカロリメータ（Pb-Si）ではなくクォーツ＋プラスチックシンチレータのdual-readoutカロリメータ?
    - ビーム軸付近以外と後段はプラスチックシンチレータのみ？
    - 設計の単純化
  - EM imagingカロリメータのlayer数を減らす？

- Timelineと目標の設定
  - Pre-TDR → CD3a (2024.1)
    - Preliminary design (50% ready): 2023.8?
  - TDR → CD2/3 (2025.4)
    - Final design (85% ready): 2024.4?
    - Specs/docs/first article, etc.
  - Construction: 2025-2030?
    - Start: 2025.5?
  - Integration: 2030-2031?

ePIC-ZDC geometry update



ePIC-ZDC geometry update

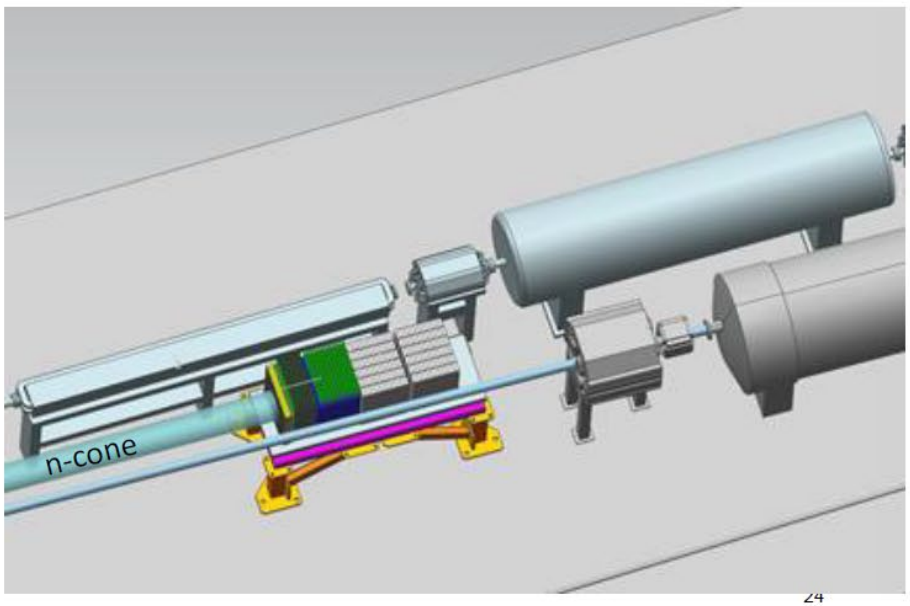


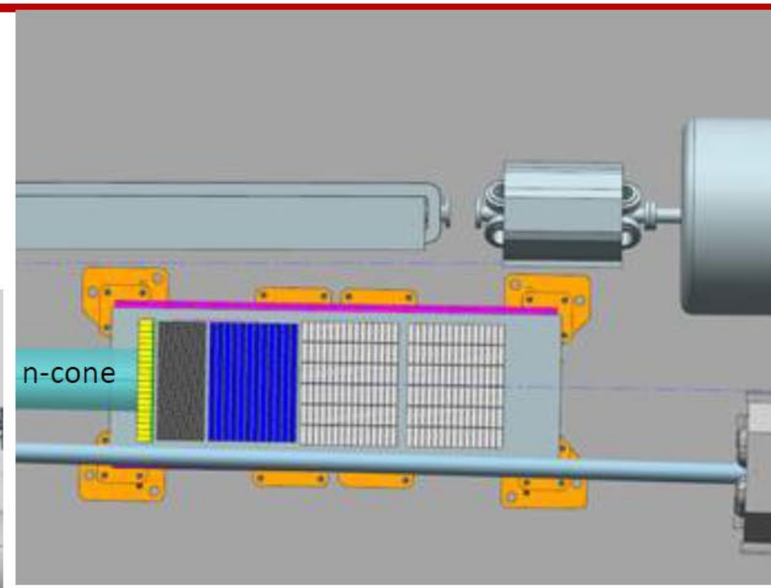
ePIC-ZDC geometry update

ZDC

“Stay-clear” zone around the beam-pipe
Placement of readout boards

Z-placement , transverse size





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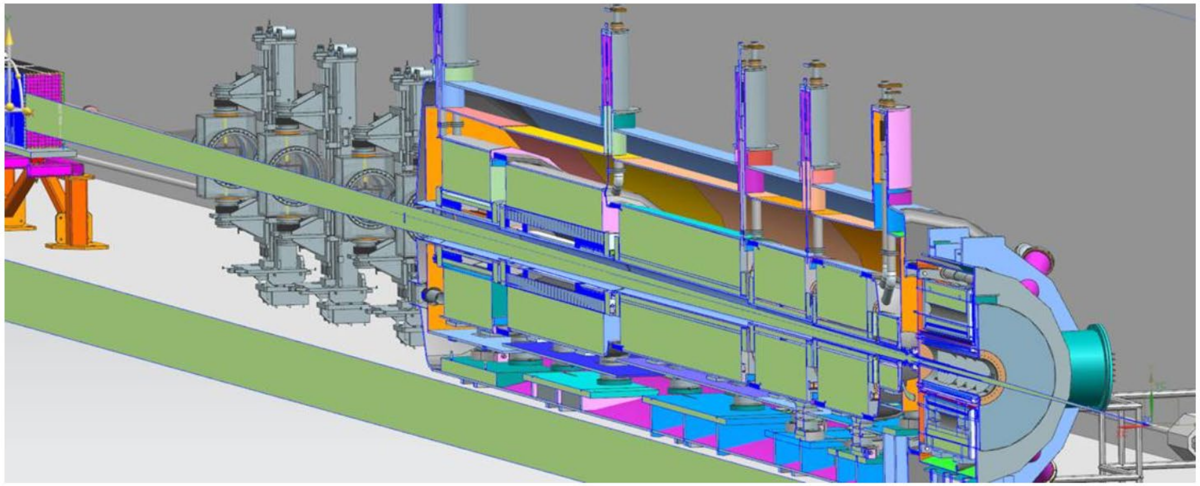
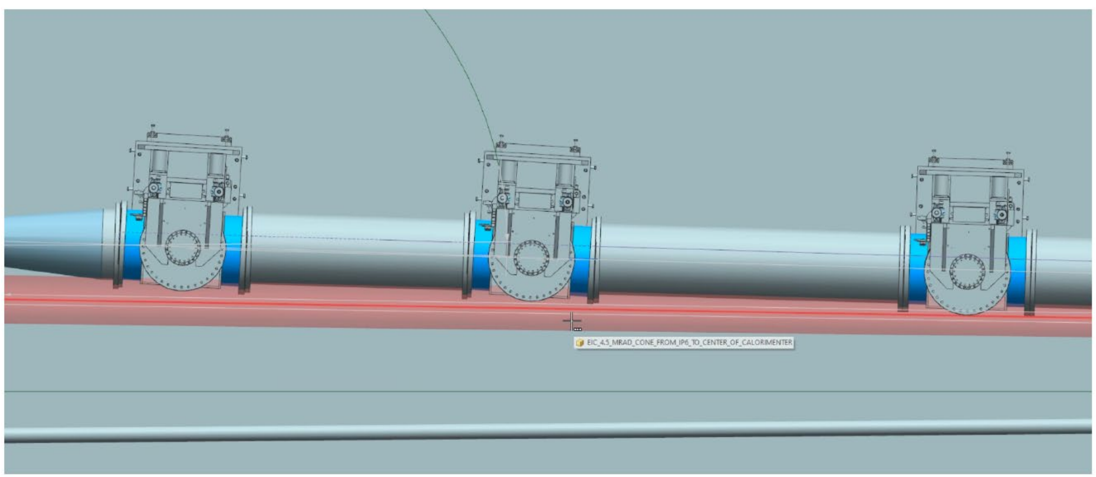
Neutron cone

4.5 mrad cone towards ZDC (in green)



NEUTRON-CONE (NEED TO CHECK!)



W-Si module design

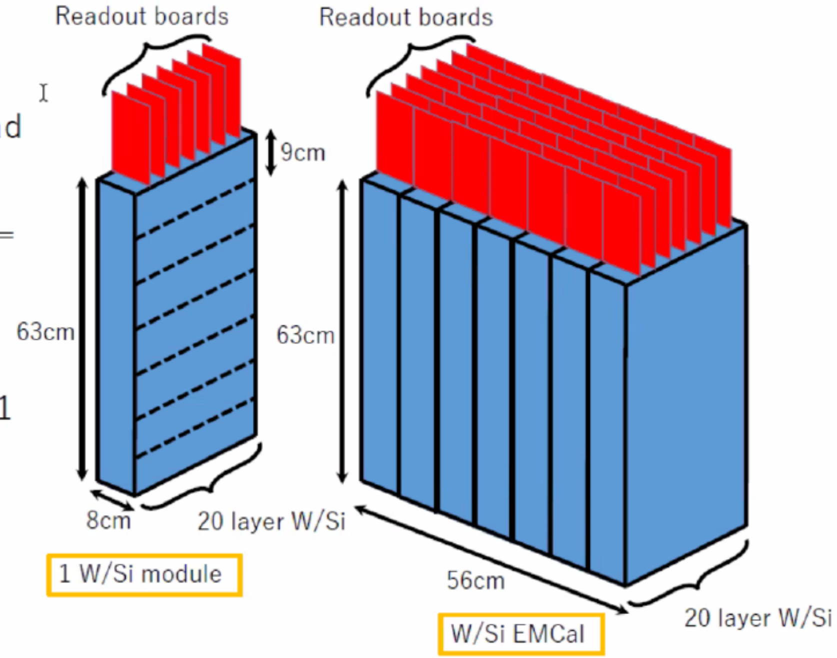
FAR-FORWARD - ZDC

Overleaf document
(internal notes, preTDR)
- requirements
- current design and motivations

Meetings with Yuji & Yuji

W/Si EMCal

- This is an design example using 8cm x 9cm ALICE-FoCal-E Pad Sensor
  - 1 pad = 1cm x 1cm
  - 1 sensor = 9 cm x 8cm = 72 pads
  - 1 tower = 20 layers
  - 1 module = 7 towers
  - ZDC W/Si = 7 modules
- 1 sensor is readout by 1 HGCROC (72 ch)
- 3 layers readout by 1 readout board in this design
- Similar design possible for the Pb/Si HCal



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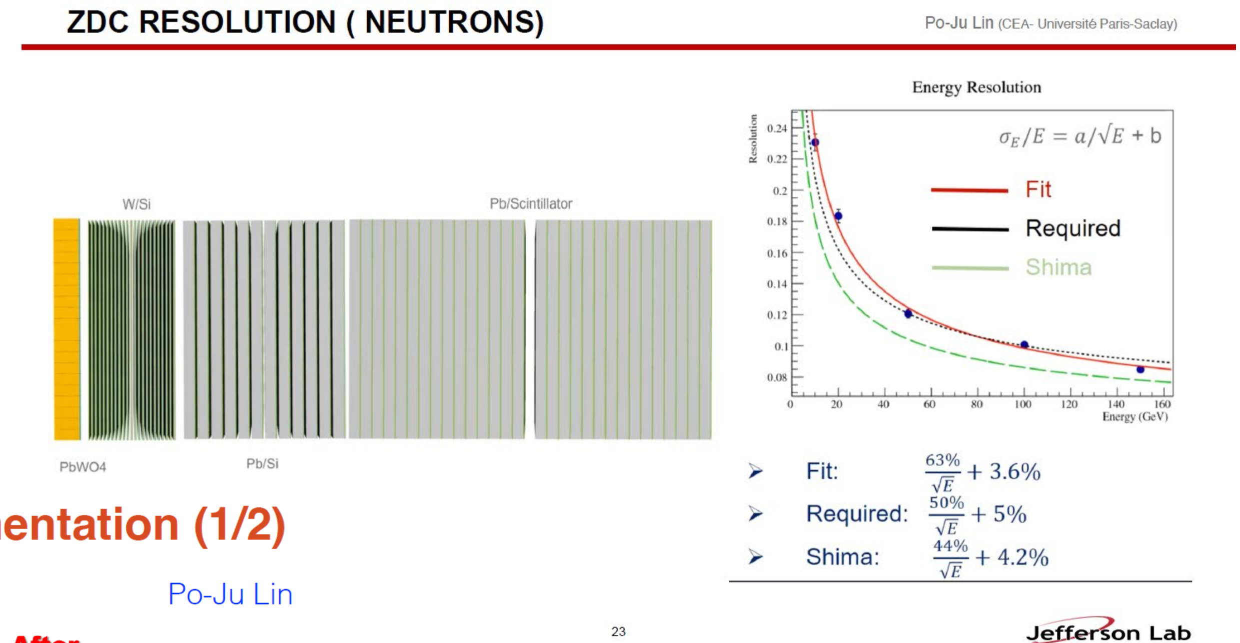
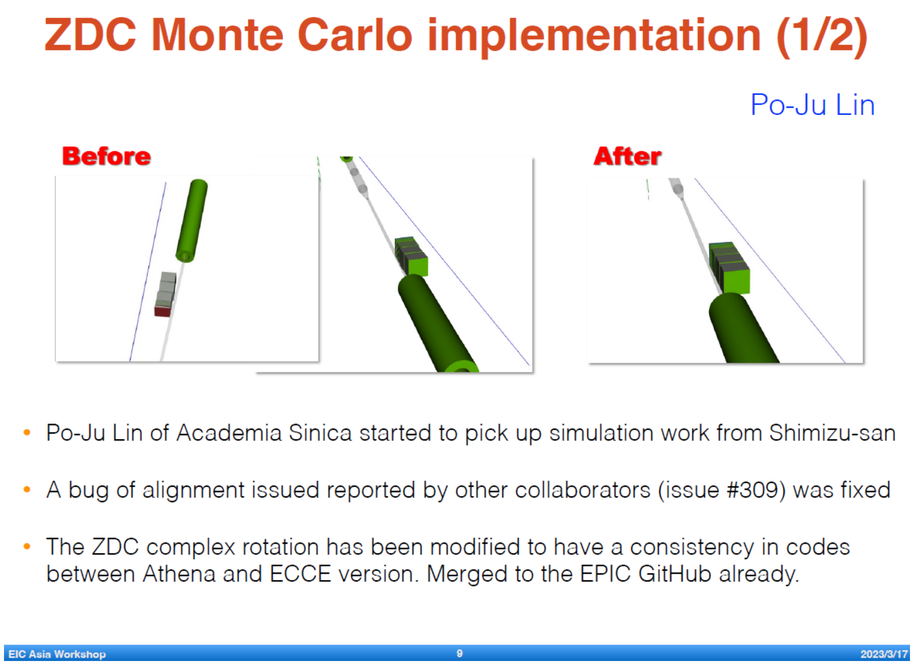
Simulation study

- Energy resolution by Po-Ju





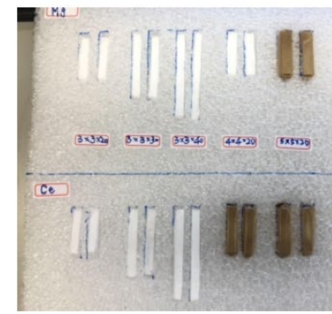
LYSO Crystal by Taiwan group

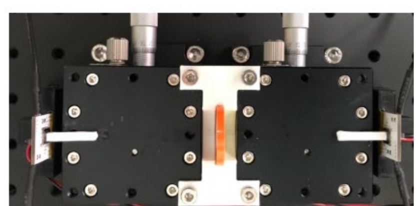
$PbWO_4$ vs LYSO vs SciGlass

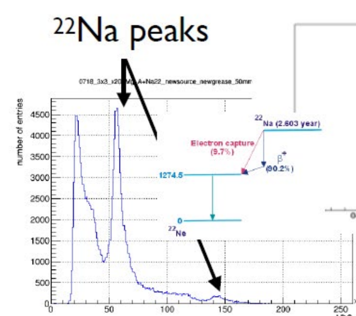
	X_0	LY (ph/MeV)	T dep. of LY (%/K)	Decay time (ns)	λ_{em} nm
$PbWO_4$ (CMS)	0.89 cm	200	-1.98	5 (73%) 14 (23%) 110 (4%)	420
LYSO	1.14 cm	30,000 (market standard)	-0.28	36	420
SciGlass	2.4-2.8 cm	>100		22-400	440-460

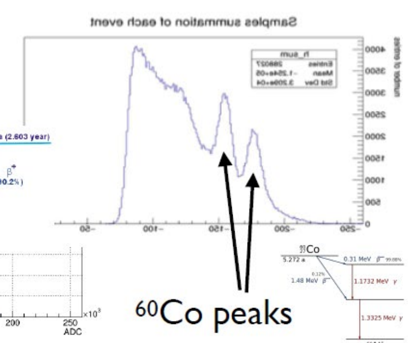
LYSO crystal characterization

- NTU is setting up measurements for
  - absolute light yield of LYSO crystal using PMTs
  - time resolution of LYSO using SiPM
  - reach coincident time resolution of ~130ps





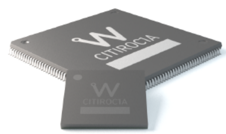




Crystal readout by Taiwan group

Readout (1/2)

- available readout board with Citiroc1A from wee roc for multichannel SiPM (Chih-Hsun Li, Academia Sinica) → can be used for first prototype study
- need a suitable readout for critical fluence value ($10^{14}/cm^2$)
  - CMS ECAL
    - barrel: APD, up to $4 \times 10^{13}/cm^2$
    - endcap: VPT (vacuum phototriodes), up to $7 \times 10^{15}/cm^2$
  - CMS MTD BTL (LYSO tiles with SiPM readout)
    - radiation (4/ab): $2 \times 10^{14}/cm^2$



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Readout (2/2)

- extensive studies of radiation damage, including temperature effects and annealing on SiPM were performed by CMS MTD
- HPK MPPC-HDR2-3015 used by CMS in R&D in 2019
- However, there are challenges
  - need to operate at -45°C to suppress the noise from increased dark count rate and avoid SiPM SPAD saturation
  - still high power consumption → specific packaging and mechanical support for heat extraction for stable operation

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