AIDAinnova 3rd Annual Workshop
Catania, 18-21 April 2024
https://indico.cern.ch/event/1307202

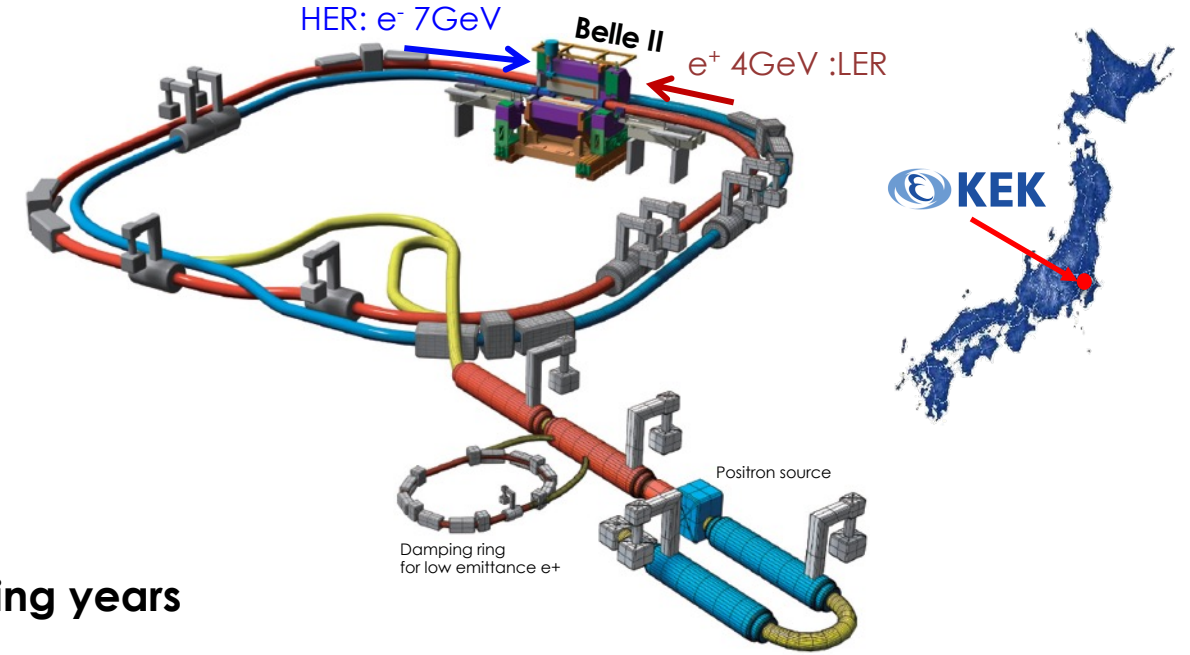
Status of OBELIX for Belle II

Ajit Kumar,
on behalf of the Belle II VTX collaboration

- General concepts for high luminosity super B factory
- On-going activities at SuperKEKB & Belle II (LS1)
- Upgrade plans on the mid-term (LS2)
- Going chiral?

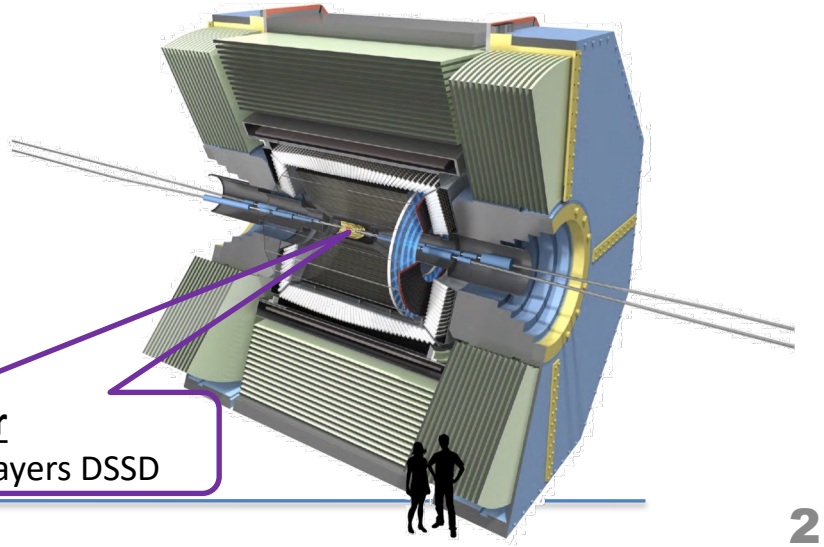
The Belle II experiment

- ## A super B-factory (after Babar and Belle)
  - e+ e- collisions with asymmetric energy $\sqrt{s} = M_{\Upsilon(4S)}$
  - Physics based on integrated luminosity >> ab^{-1}



- ## The SuperKEKB collider @ KEK, Tsukuba, Japan
  - Currently world highest luminosity 4.7 10^{34} $cm^{-2}.s^{-1}$
  - Restarting after long shutdown 1 (2022-23)
  - **Instantaneous luminosity ramping up > 10^{35} $cm^{-2}.s^{-1}$ in coming years**

- ## Belle II upgrade program
  - Increased robustness against beam-induced background rate
  - More physics per integrated luminosity
  - *Framework* CDR validated, to be public soon

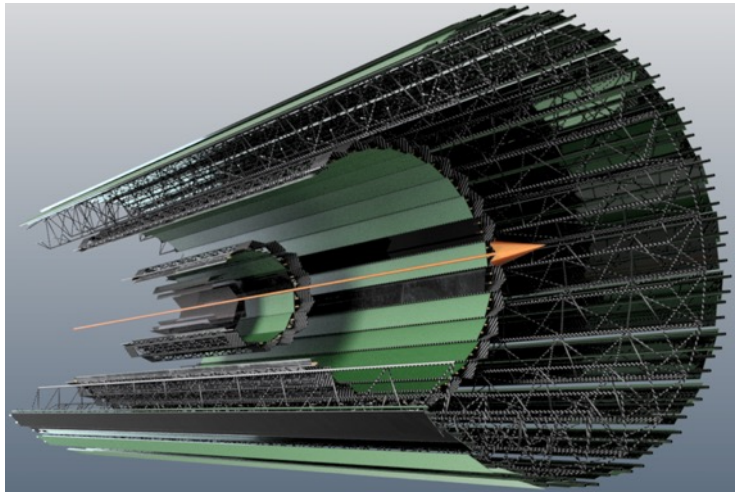


Current vertex Detector
2 layers DEPFET pixels + 4 layers DSSD

Vertex detector upgrade: the VTX project

Concept = 5 layers with pixel sensors

- high space-time granularity & low material budget
  - very low occupancy <$\mathcal{O}(10^{-4})$ => tracking efficiency
  - Better tracking efficiency at low momentum
  - Higher vertexing precision / current VXD
- Lighter services & "easy" geometry
  - adaptable to potential change of interaction region



Max radius 18 cm & length 70 cm => 1 m^2

Technical choices

- **Same pixel sensor** for all layers **= OBELIX MAPS** (main option)
  - SOI (alternative)
  - 30-40 µm pitch with 100 ns integration time
- All-silicon ladders (PXD-inspired) for 2 inner layers (0.1% X_0) = **iVTX**
  - See M.Vos' talk during WP10
- "Standard" supported ladders (ALICE-ITS2 inspired) for 3 outer layers (0.5-0.8 % X_0) = **oVTX**
  - See F.Pallas' talk during WP10

University of Bergamo
University of Bonn
University of Dortmund
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Queen Mary University London
CPPM Marseille
IJClab Orsay
INFN Pavia
INFN & University of Pisa
IPHC Strasbourg
KEK Tsukuba
IFIC Valencia
HEPHY Vienna

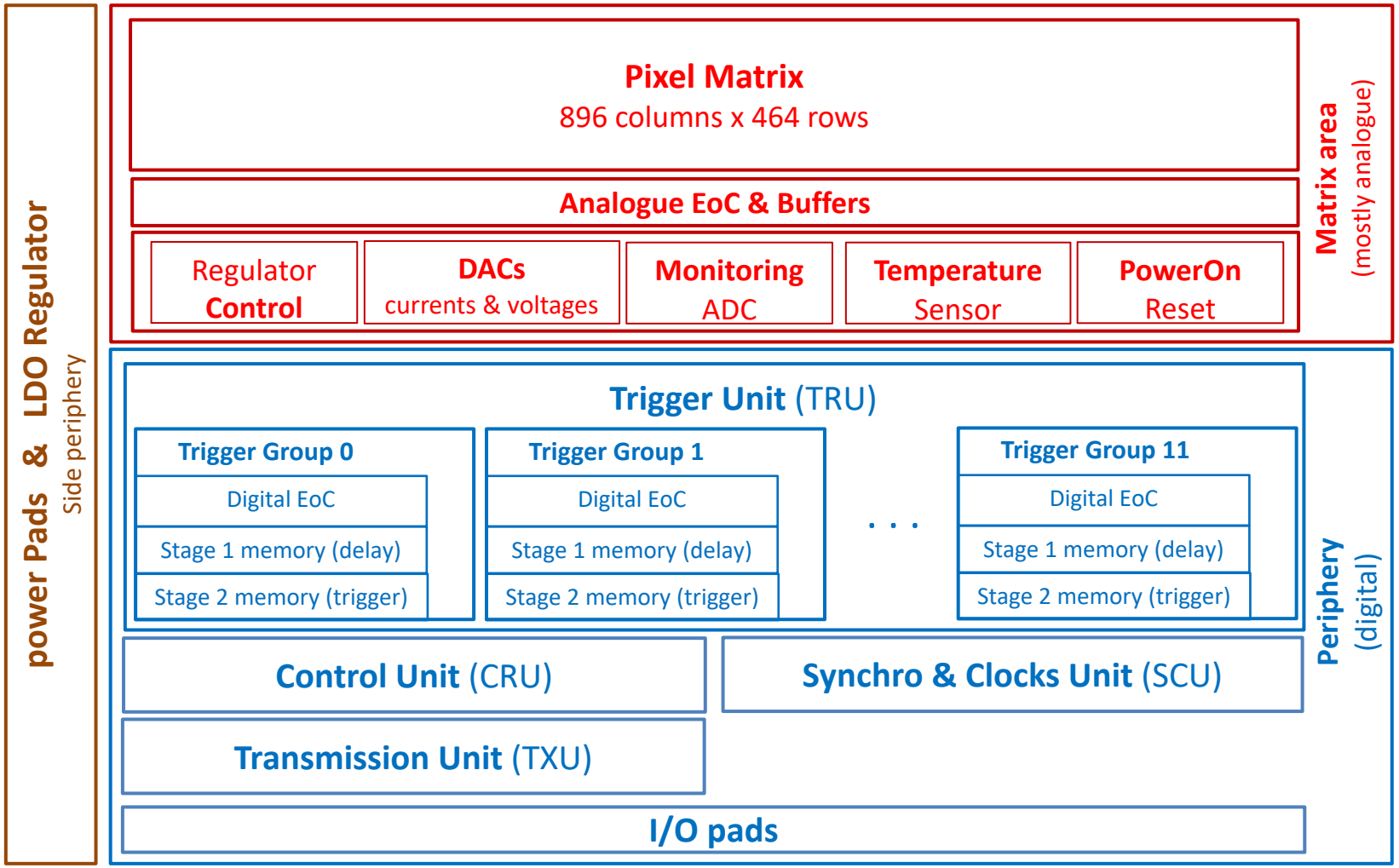
OBELIX key features

- Pixel matrix with **detection efficiency** proven at radiation levels ($5x10^{14}$ n_{eq}/cm^2) and time-stamping at 50 ns
  - Matrix extended from **TJ-Monopix2** (F. Hügging's talk)
  - BCID clock slowed to 20 MHz
  - Radiation-tolerance tested during July 2023 beam
- Handling of Belle II **trigger rate** (30 kHz) **& delay** (10 µs) at hit rates (120 MHz)
  - Implementation of trigger logic (TRU) in digital design
  - Verification with simulation
- Power dissipation adapted (<200 mW/cm^2) to **air cooling** (inner layer) and **water cooling** (outer layer)
  - Optimised digital logic
  - Reduced analogue biasing under test
- **Simplified** system integration
  - LDO power regulator on chip
  - 1 LVDS (320 MHz) output per chip

=> See M. Babeluk's talk at last AIDAinnova workshop: https://indi.to/6nzms

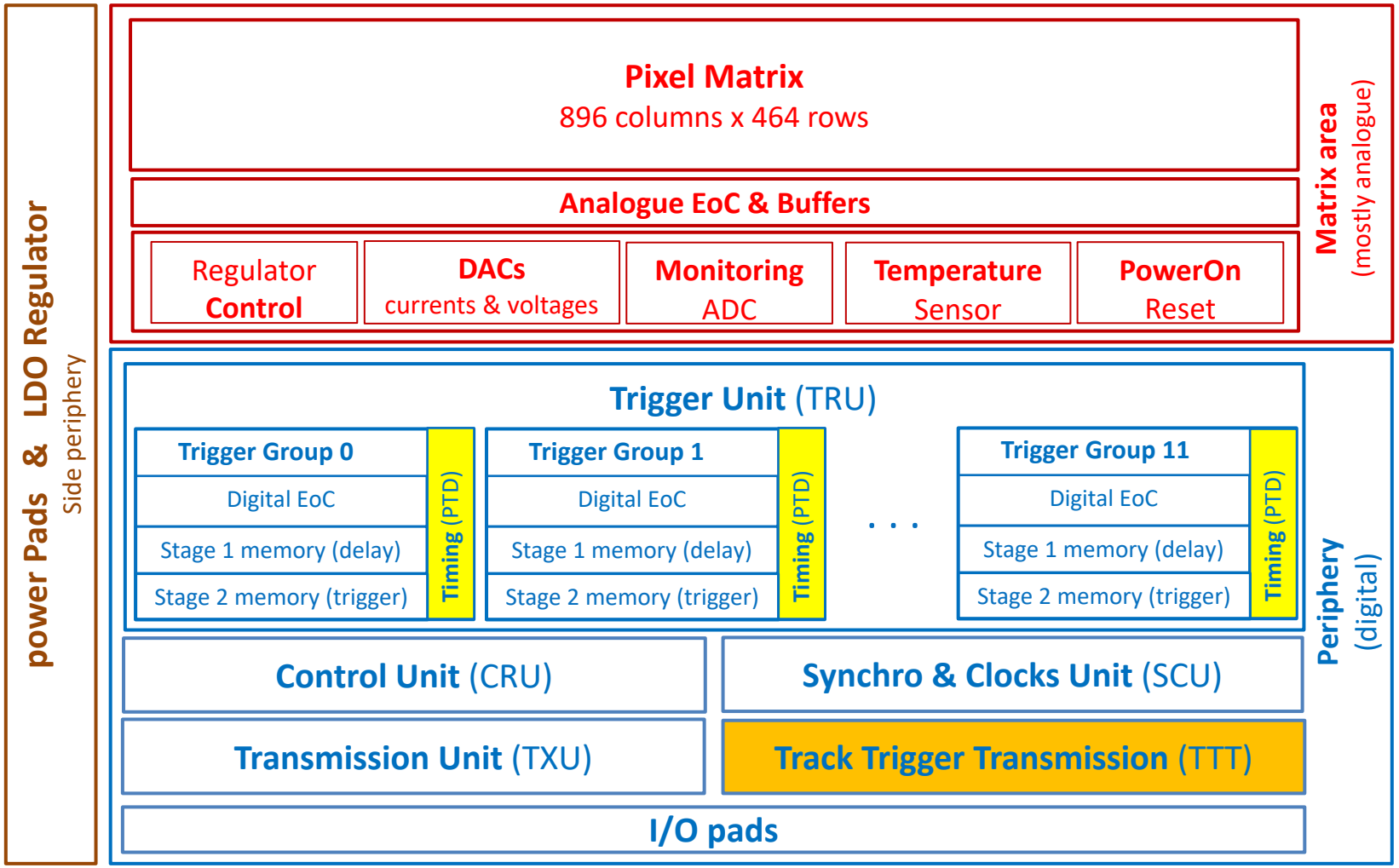
OBELIX-1 main functional blocs

Pitch	33 µm
Signal ToT	7 bits
Integration time	50 To 100 ns
Hit rate max for 100% eff.	120 MHz/cm^2
Trigger handling	30 KHz with 10 µs delay
Power (with hit rate)	120 to 200 mW/cm^2 (1 to 120 MHz/cm2)
Bandwidth	1 output 320 MHz



OBELIX-1 optional features

Pitch	33 µm
Signal ToT	7 bits
Integration time	50 To 100 ns
Time stamping	<5 ns for hit rate < 10 MHz/cm^2
Hit rate max for 100% eff.	120 MHz/cm^2
Trigger handling	30 KHz with 10 µs delay
Input to trigger	~10 ns resolution with low granularity
Power (with hit rate)	120 to 200 mW/cm^2 (1 to 120 MHz/cm2)
Bandwidth	1 output 320 MHz



OBELIX-1 specifications & layout

Pitch	33 µm
Signal ToT	7 bits
Integration time	50 To 100 ns
Time stamping	~5 ns for hit rate < 10 MHz/cm^2
Hit rate max for 100% eff.	120 MHz/cm^2
Trigger handling	30 KHz with 10 µs delay
Trigger output	~10 ns resolution with low granularity
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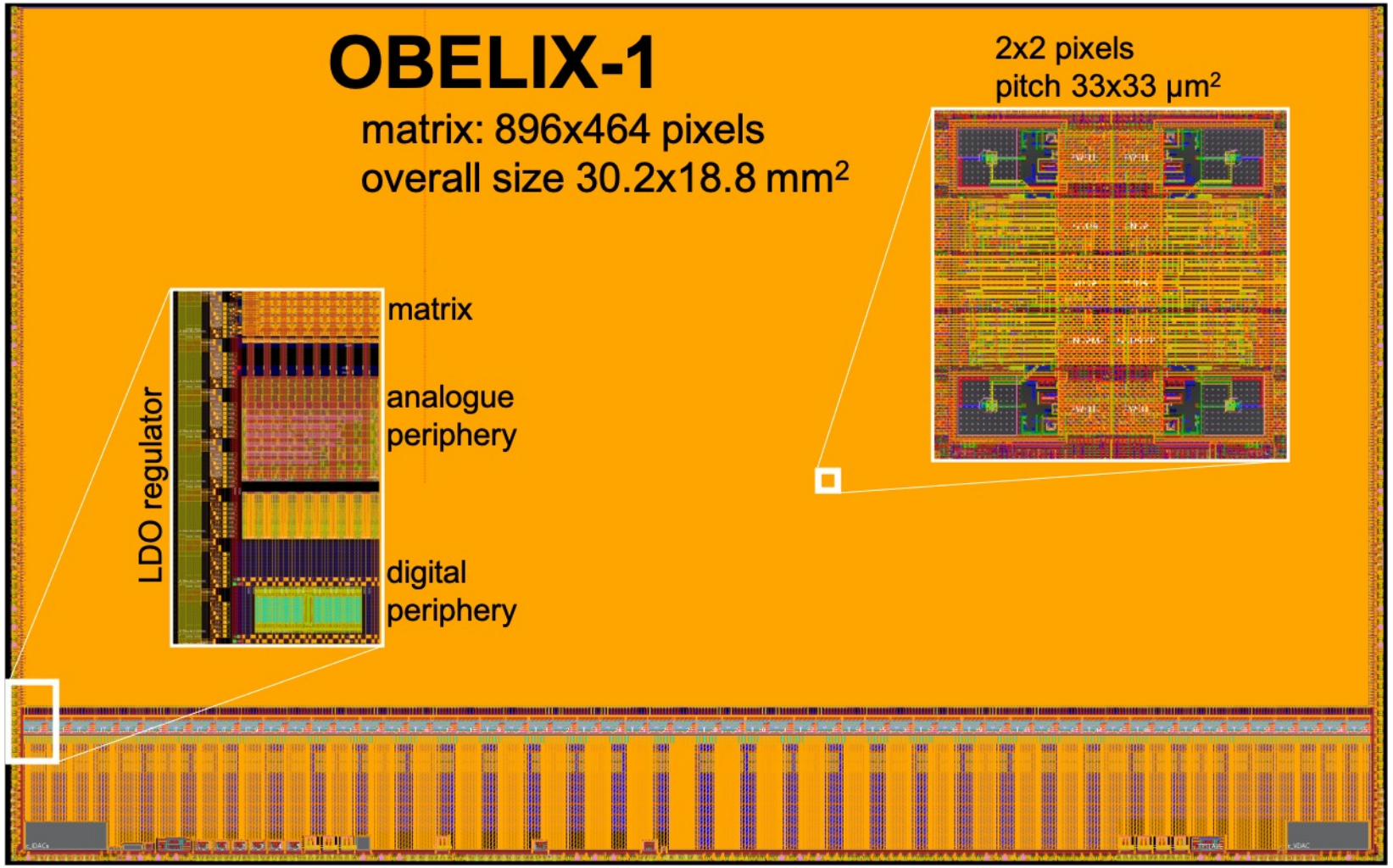


TJ-Monoipix2 test at DESY beam – July 2023

Conditions

- Electron beam at 5 GeV
- ADENIUM (ALPIDE) telescope

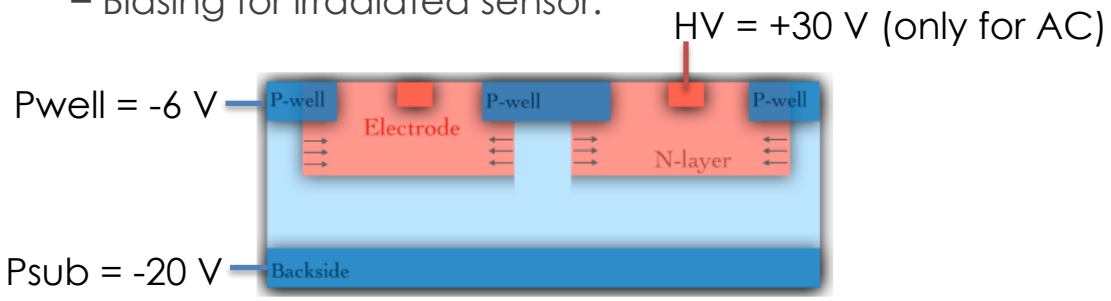
Irradiated sensor

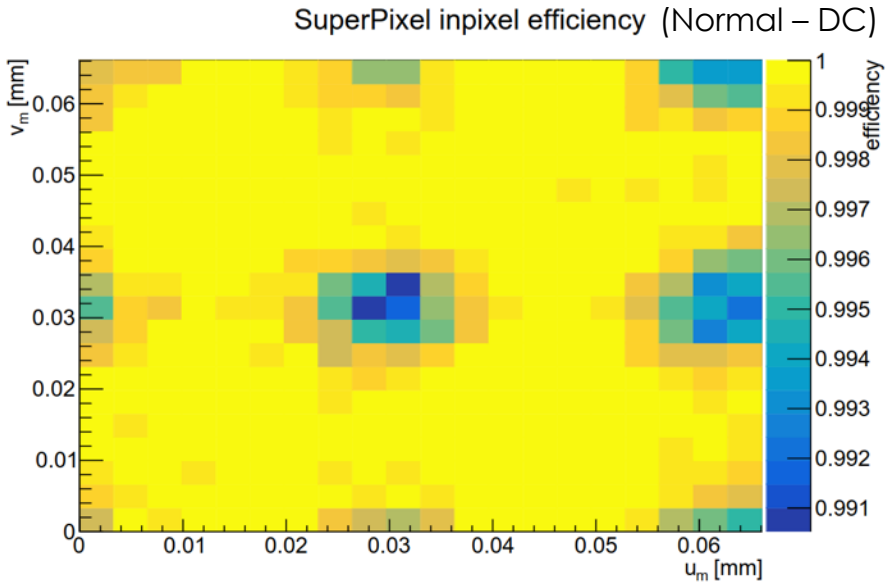
- 5 x 10^{14} n_{eq}/cm^2 (with 24 MeV protons)

ampli	coupling	Efficiency (%)
Normal	DC	99.99
Cascode	DC	99.79
Normal	AC (HV)	99.13
Cascode	AC (HV)	98.11

TJ-Monopix-2 under test

- Room temperature
- threshold 250-300 e-
- 4 front-ends
  - 2 amplifers : normal (NF) and cascode (CASC)
  - 2 diode couplings: DC and AC (or HV)
- Sensitive layer
  - epitaxy 30 µm
  - Biasing for irradiated sensor:



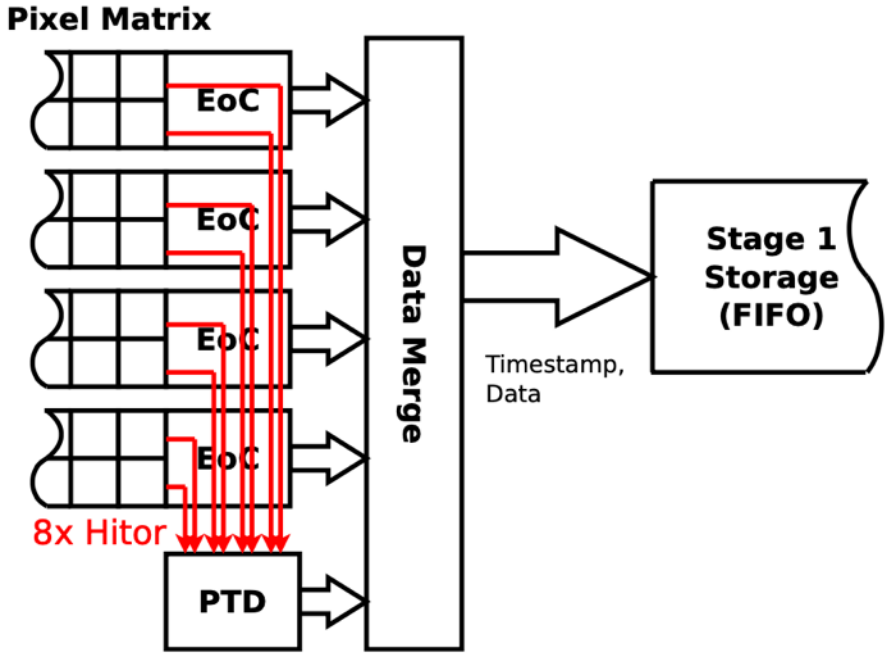


> Only 1 sensor tested
> No study yet with temperature

Finer time resolution

Concept of PTD module

- Exploit hit-OR = asynchronous OR of all pixel outputs in one column
- Time sampling at max chip clock (169.7 MHz) = **2.95 ns**
  - PTD does not know fired pixel position
  - Time-position correlation possible if only 1 pixel in column
    => **max hit-rate allowed ~10 MHz/cm²**
- Output status of 8 macropixels each ~100 ns



Cost

- Power hungry feature => disabled for inner layers (iVTX)
- Absolute resolution limited by time-walk
  and process-voltage-temperature variations
- Calibration compulsory

- Time resolution measured in test beam
  - After calibration (time-walk…)
  - 3 ns for irradiation sensor (5×10^{14} n_{eq}/cm^2)

Input to trigger

- ## Concept of TTT module
  - Exploit hit-OR = asynchronous OR of all pixel outputs in one column
  - Group N=112 columns on 1 macropixel = 1 striplet of 14 x 3 mm^2
    - 8 macropixels per sensor
  - Build 8 bits (status of each macropixels) within **30 ns**
  - Output 8 bits status of each ~100 ns

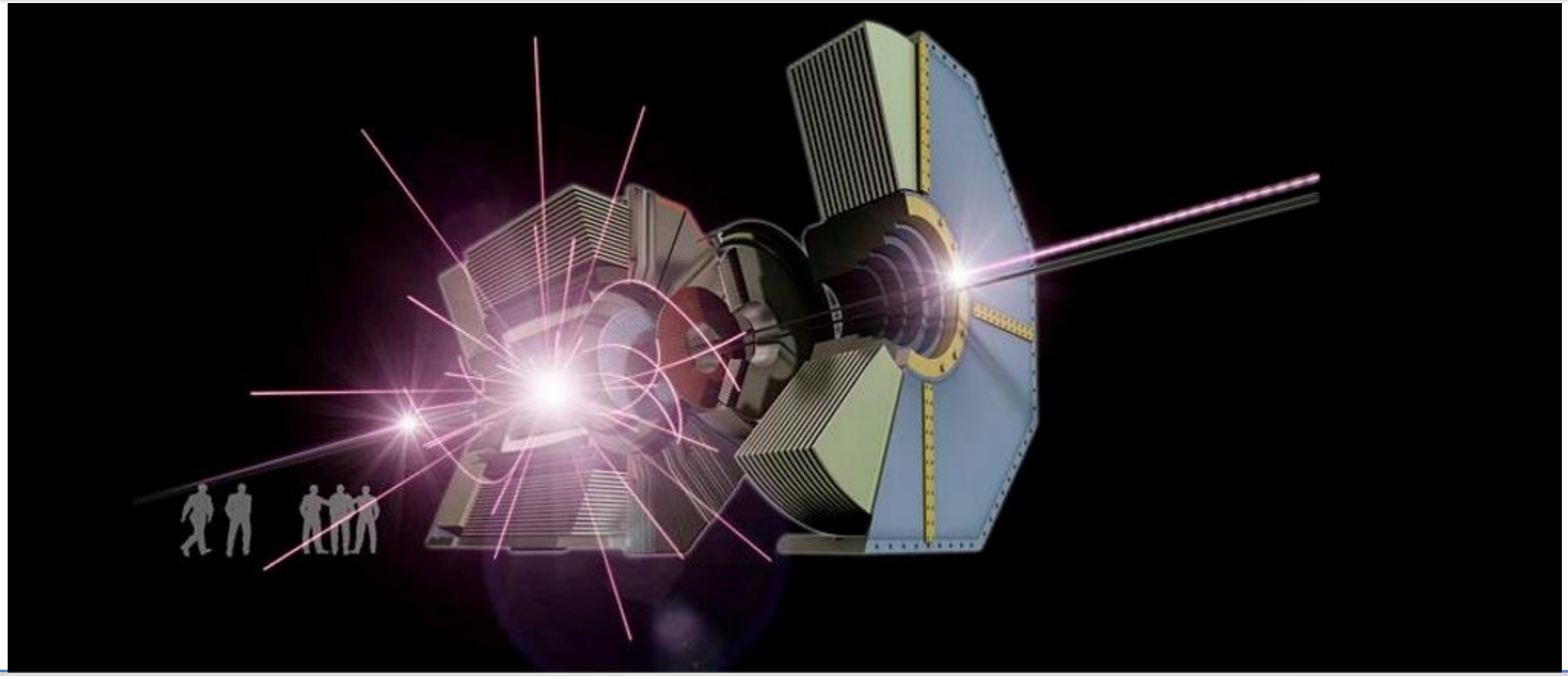
- ## On-going activities on this exploratory feature:
  - Simulation on-going, taking into account time-walk, hitOR delay along column and time binning
  - Additional power under evaluation
  - Low granularity not useful at 120 MHz/cm2 of inner layer => **only for 3 outer layer**
    - Tracking strategy under construction for evaluation

Summary and outlook

- TJ-Monopix2 matrix for Belle II upgrade
  - Validation with first beam test with irradiated sensor at Belle II expected fluence
  - Additional beam test in 2024 for systematic studies

- OBELIX design
  - All features designed for April but power regulator
  - Simulation and verification on-going
  - Next internal review mid-April 204
    - submission expected few months after

SUPPLEMENTARY SLIDES



Belle II detector

Upgraded or new / Belle

KLong and muon detector (KLM) upgraded
Resistive Plate Chambers (barrel outer layers)
Scintillator + WLSF + SiPM's (end-caps , inner 2 barrel layers)

EM Calorimeter (ECL) upgraded
CsI(Tl), waveform sampling (barrel+ endcap)

Particle Identification new
TOP detector system (barrel)
Prox. focusing Aerogel RICH (fwd)

electrons (7 GeV)

Final focusing magnets new

Beryllium beam pipe
2cm diameter new

positrons (4 GeV)

SuperCond. Solenoid
1.5 T magnetic field

Vertex Detector (VXD = PXD+SVD) new
2 layers DEPFET pixels + 4 layers DSSD

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

Belle II, another view