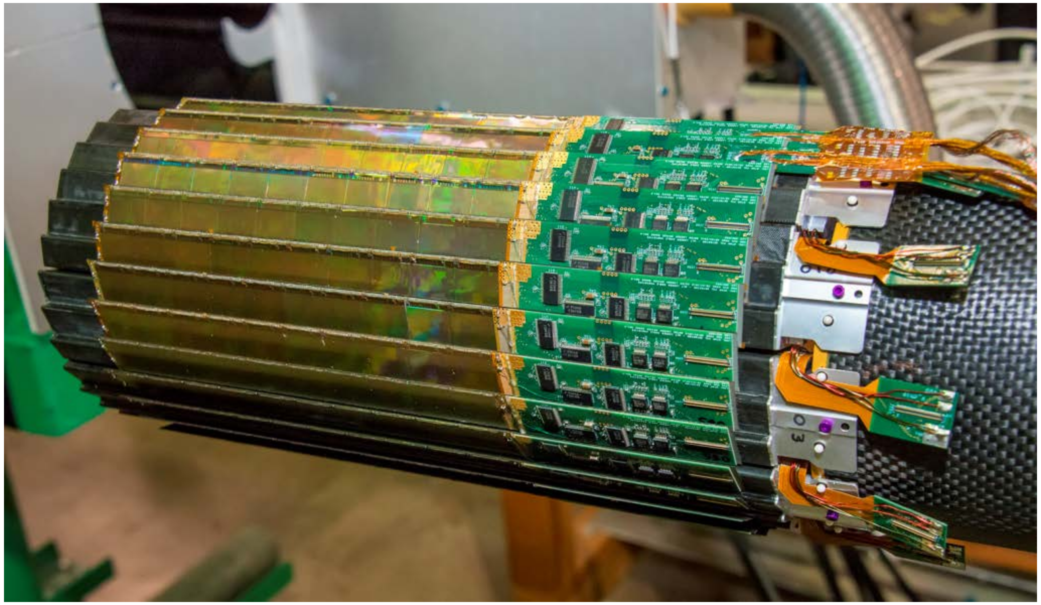
MAPS-based Vertex Detectors at Colliders
From the STAR HFT to the next-generation ALICE ITS and sPHENIX MVTX Upgrades



Giacomo Contin

Lawrence Berkeley National Laboratory

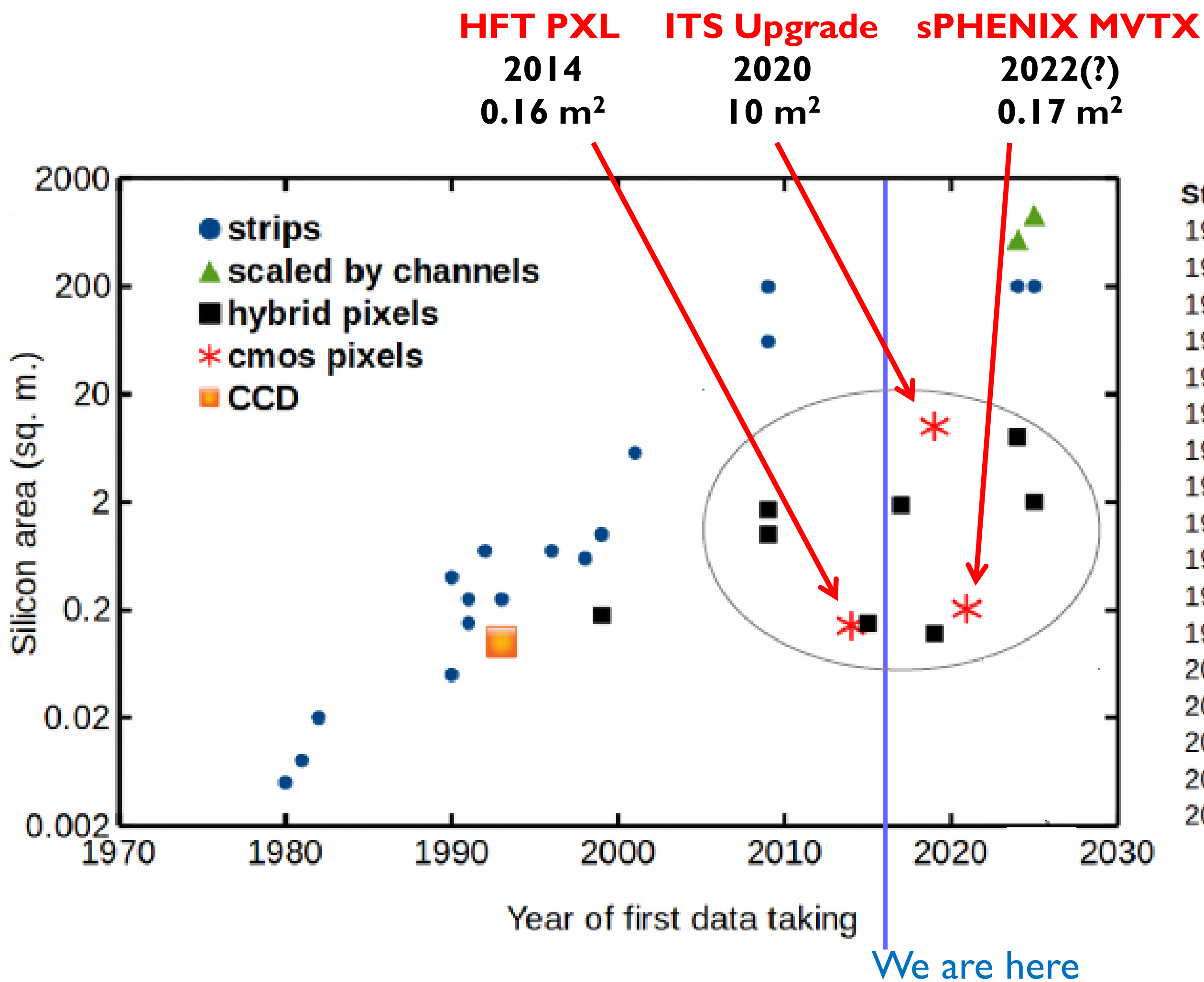
Department of Physics - HEP Seminars

University of Liverpool, October 18th, 2017

Outline

- First MAPS-based Vertex detector:
  - STAR PXL
    - Design
    - Construction
    - Operations experience
- Next generation MAPS:
  - ALICE ITS Upgrade
  - sPHENIX MVTX

MAPS Detectors at Colliders



Strip Detectors

1980 NA1
1981 NA11
1982 NA14
1990 MarkII
1990 DELPHI
1991 ALEPH
1991 OPAL
1992 CDF SVX
1993 L3
1996 CDF SVX'
1998 CLEO III
1999 BaBar
2001 CDF SVXII+ISL
2009 ATLAS SCT
2009 CMS tracker
2025 ATLAS ITK
2025 CMS upgrade

Hybrid Pixels

1999 Delphi
2009 ATLAS
2009 CMS
2015 ATLAS IBL
2017 CMS
2019 velopix
2025 ATLAS
2025 CMS

CMOS Pixels

2014 STAR
2019 ALICE

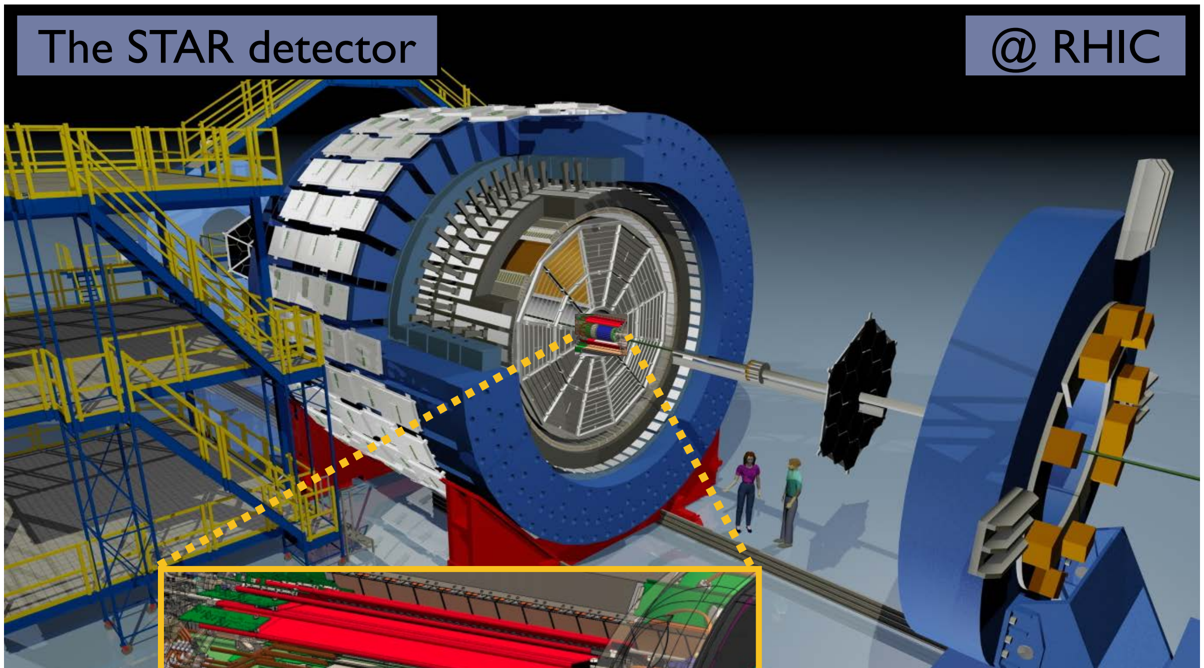
CCDs

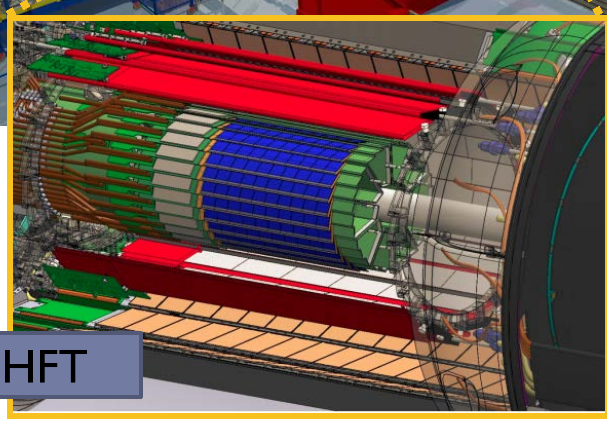
1993 VXD

The STAR Heavy Flavor Tracker

Extend the measurement capabilities in the *heavy flavor* domain, good probe to QGP:

- Direct topological reconstruction of charm hadrons (e.g. $D^0 \rightarrow K\,\pi,\ c\tau \sim 120\ \mu m$)





Need to resolve displaced vertices in high multiplicity environment

TPC – Time Projection Chamber (main tracking detector in STAR)

HFT – Heavy Flavor Tracker

- **SSD – Silicon Strip Detector**
- **IST – Intermediate Silicon Tracker**
- **PXL – Pixel Detector**

Tracking inwards with gradually improved resolution:

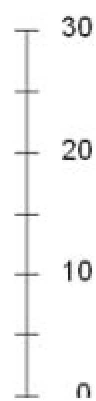
R (cm)

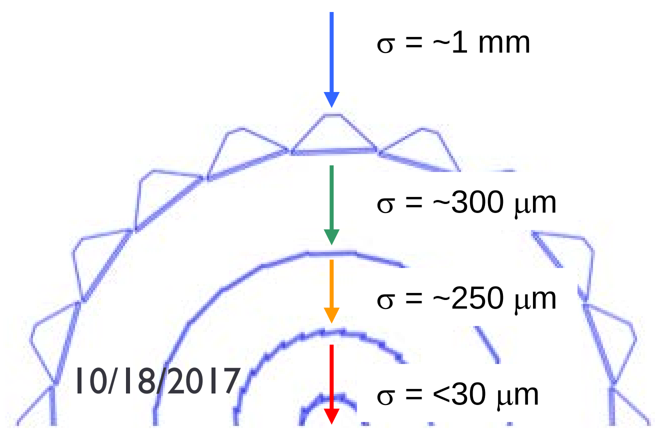
SSD **r = 22**

IST **r = 14**

PXL $\mathbf{r_2 = 8}$

$\mathbf{r_1 = 2.8}$





The PiXeL detector (PXL)

First vertex detector at a collider experiment based on ***Monolithic Active Pixel Sensor*** technology

PXL Design Parameters

DCA Pointing resolution	(10 ⊕ 24 GeV/p·c) μm
Layers	Layer 1 at 2.8 cm radius Layer 2 at 8 cm radius
Pixel size	20.7 μm X 20.7 μm
Hit resolution	3.7 μm (6 μm geometric)
Position stability	5 μm rms (20 μm envelope)
Material budget first layer	X/X_0 = 0.39% (Al conductor cable)
Number of pixels	356 M
Integration time (affects pileup)	185.6 μs
Radiation environment	20 to 90 kRad / year $2*10^{11}$ to 10^{12} 1MeV n eq/cm^2
Rapid detector replacement	< 1 day

356 M pixels on ~0.16 m^2 of Silicon

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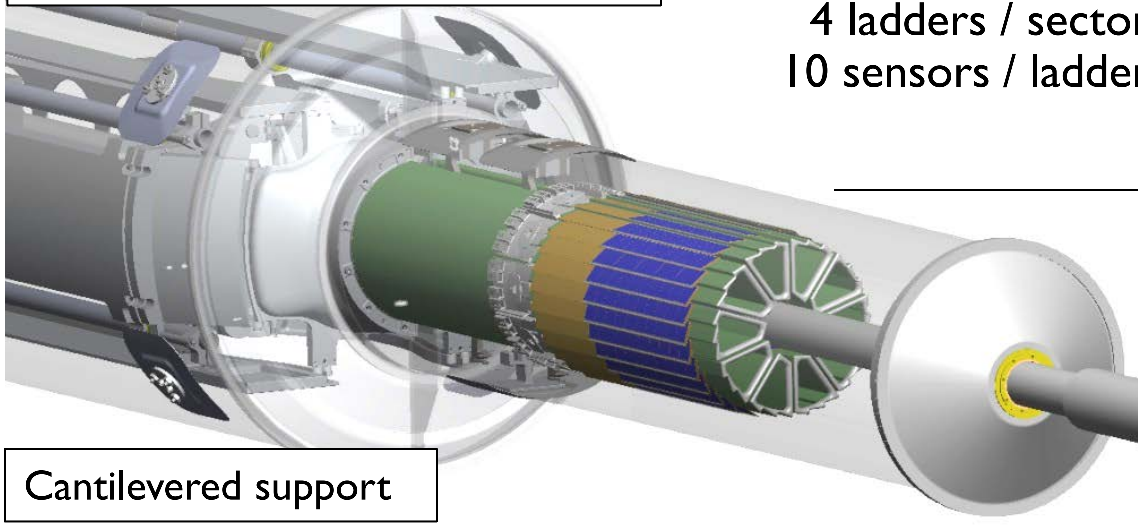
PXL System Overview

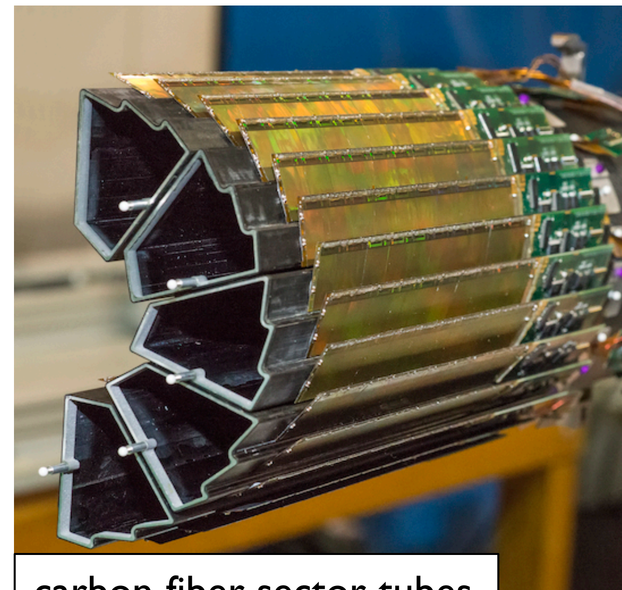
Mechanical support with kinematic mounts (insertion side)



Cantilevered support

10 sectors total
5 sectors / half
4 ladders / sector
10 sensors / ladder

Highly parallel system



carbon fiber sector tubes

Material budget on the inner layer

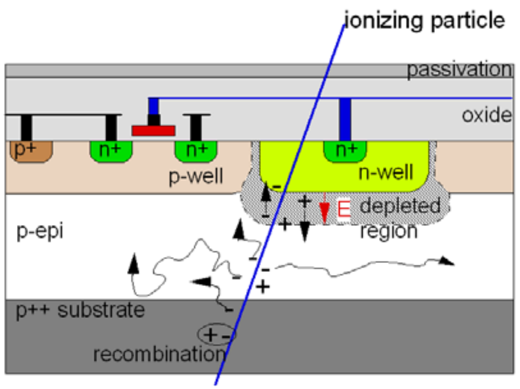
- Thinned sensor: 50 μm - 0.068% X_0
- Aluminum-conductor cable (32 μm-thick traces) - 0.128% X_0
- Carbon fiber stiffener (125 μm) and sector tube (250 μm) - 0.193% X_0
- Air cooled

0.388% X_0

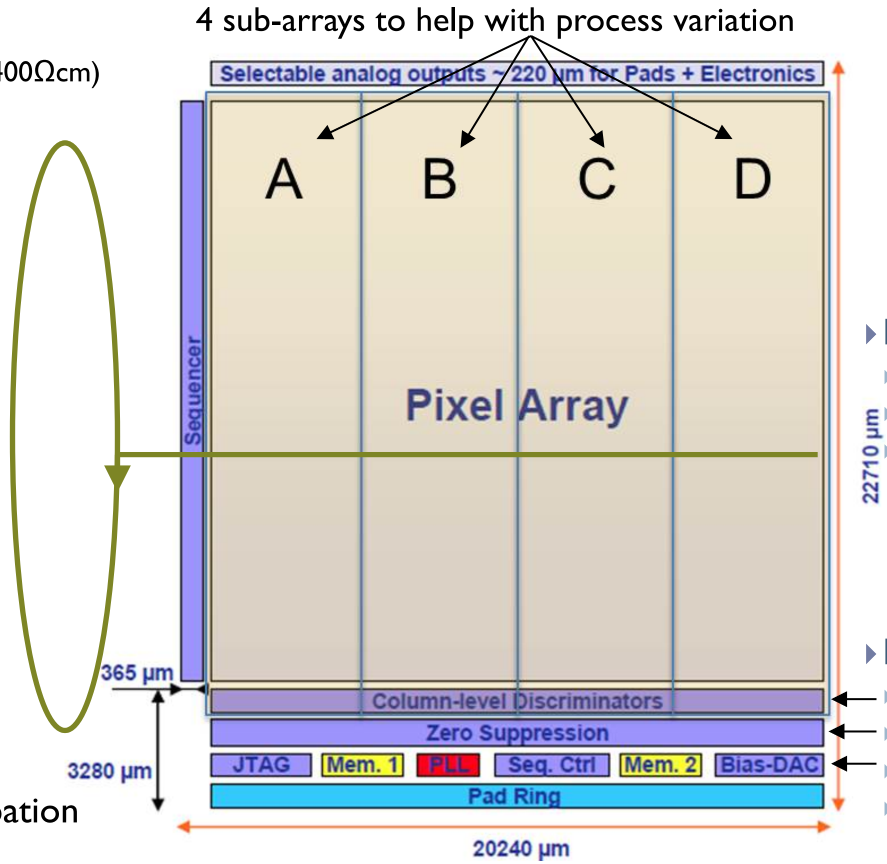
Ladder with 10 MAPS sensors (~ 2×2 cm each)

PXL MAPS sensor

- *Ultimate-2:* third MIMOSA-family sensor revision developed for PXL at IPHC, Strasbourg
- ***Monolithic Active Pixel Sensor*** technology



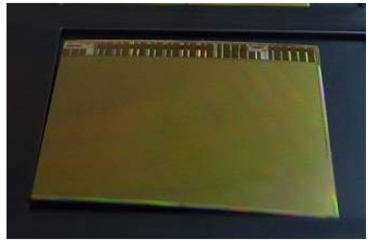
- High resistivity p-epi layer (400Ωcm)
  - Reduced charge collection time
  - Improved radiation hardness
- S/N ~ 30
- MIP Signal ~ 1000 e-
- **Rolling-shutter readout**
  - A row is selected
  - For each column, a pixel is connected to discriminator
  - Discriminator detects possible hit
  - Move to next row
- 185.6 µs integration time
- ~170 mW/cm² power dissipation



- **Pixel matrix**
  - 928 rows * 960 columns = ~1M pixel
  - In-pixel amplifier
  - In- pixel Correlated Double Sampling (CDS)
- **Digital section**
  - End-of-column discriminators
  - Integrated zero suppression (up to 9 hits/row)
  - Ping-pong memory for frame readout (~1500 w)
  - 2 LVDS data outputs @ 160 MHz

PXL Material Budget

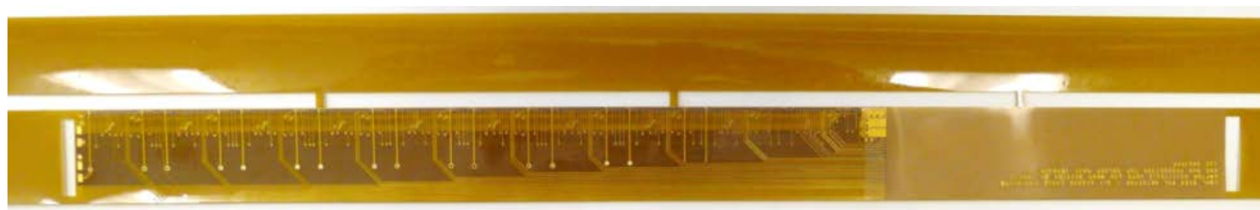
- Thinned Sensor
  - 50 µm
  - 0.068% X_0



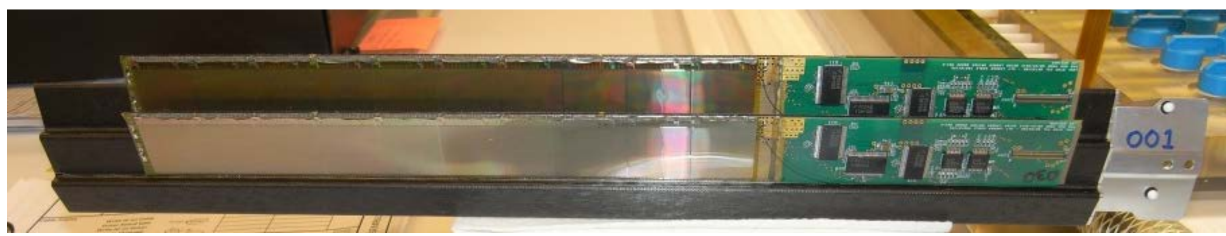
- Curved sensor
- 40-60% yield after thinning, dicing and probe testing
- Fully characterized before installation

- Flex Cable
  - Aluminum-Kapton
  - two 32 µm-thick Al layers
  - 0.128% X_0
    - *Copper* version → 0.232% X_0

- Power and signal lines
- Wire bond encapsulant largest contribution
- Acrylic adhesive to deal with different CTE



- Carbon fiber supports
  - 125 µm stiffener
  - 250 µm sector tube
  - 0.193% X_0



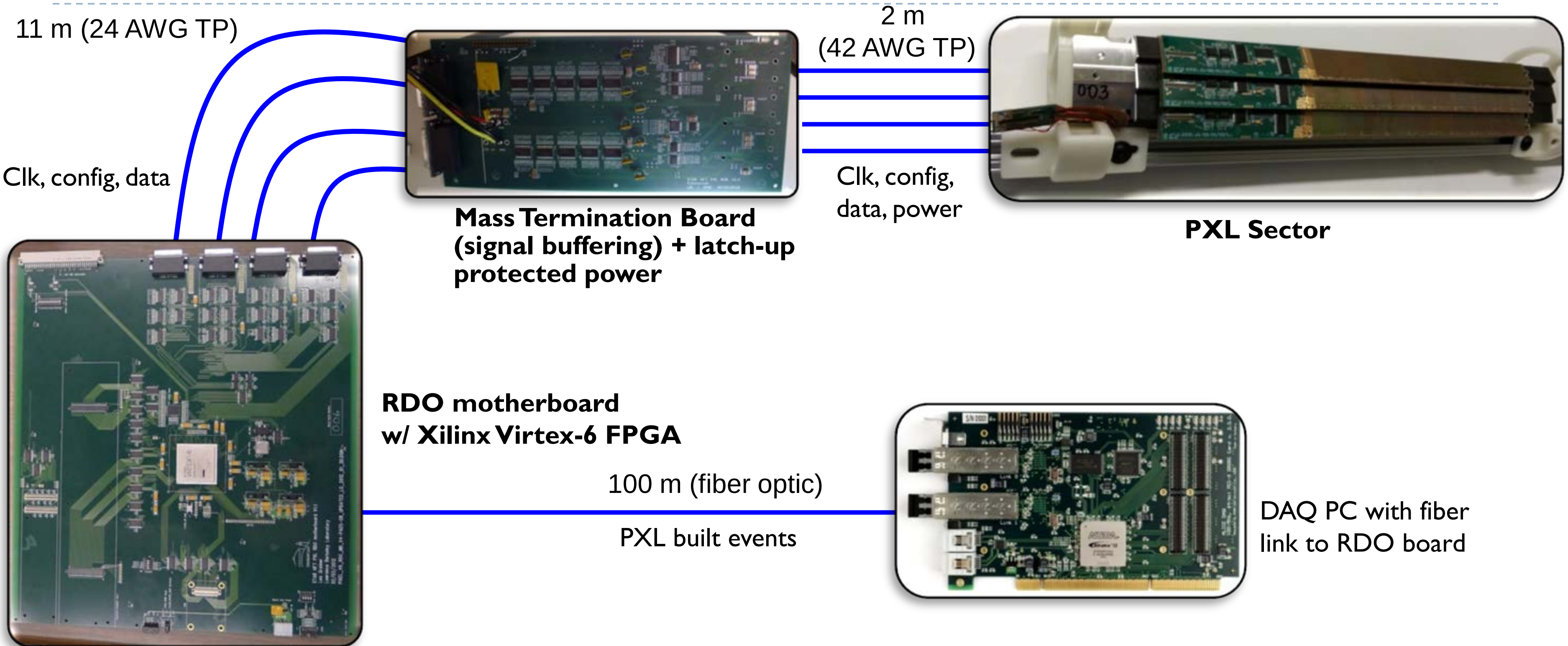
- Cooling
  - Air cooling: negligible contribution

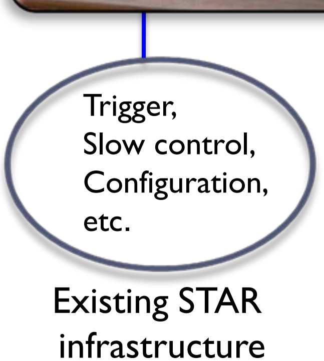
- **Total material budget on inner layer: 0.388% X_0**

(0.492% X_0 for the Cu conductor version)

HFT DCA pointing resolution:
$(10 \oplus 24/p)$ µm

PXL Detector Powering and Readout Chain



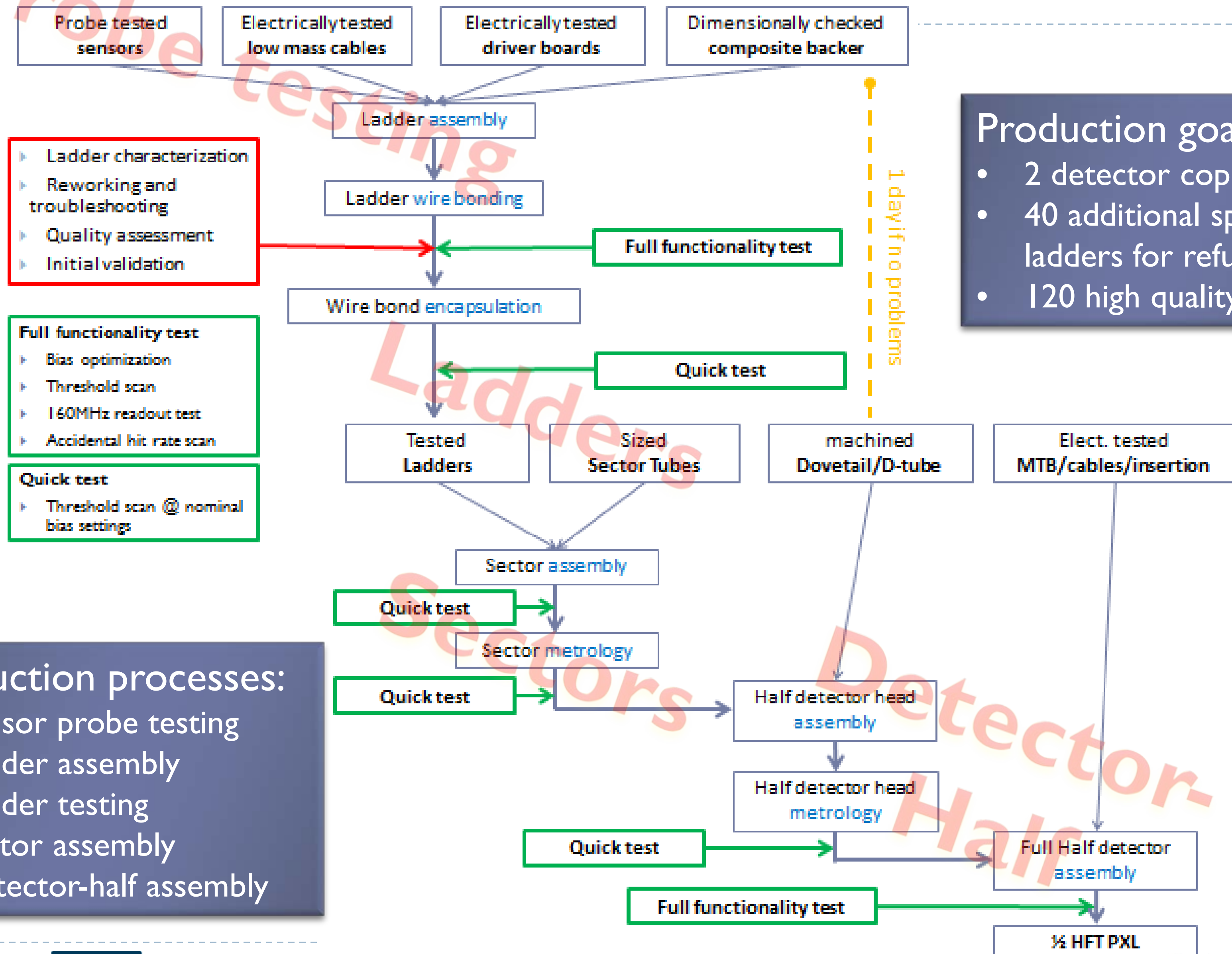


<u>Highly parallel system</u>

- 4 ladders per sector
- 1 Mass Termination Board (MTB) per sector
- 1 sector per RDO board
- 10 RDO boards in the PXL system

- Construction

PXL Production, Assembly and QA



Production goals:

- 2 detector copies
- 40 additional spare ladders for refurbishment
- 120 high quality ladders

Production processes:

- Sensor probe testing
- Ladder assembly
- Ladder testing
- Sector assembly
- Detector-half assembly

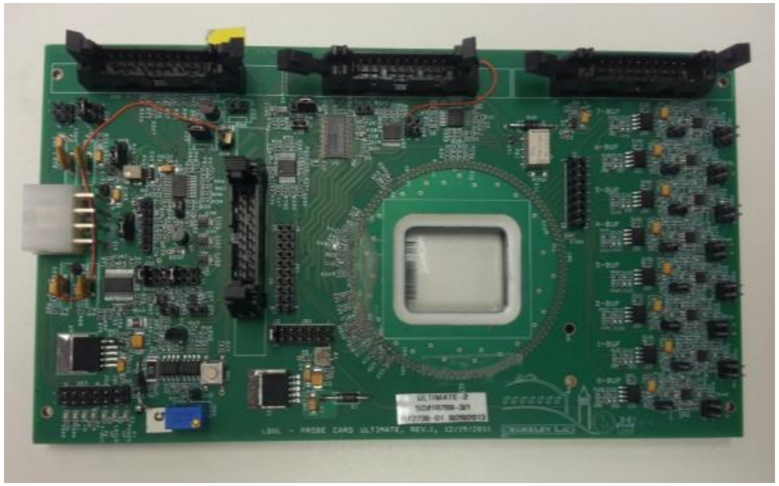
PXL Probe Testing

- **Thinned and diced 50 μm-thick sensors**
- **Full sensor characterization**
- **Full speed readout (160 MHz)**

- **Custom made vacuum chuck**
- Testing up to 18 sensors per batch (optimized for sensor handling in 9-sensor carrier boxes)
- Manual alignment (~1 hr)
- LabWindows GUI for system control
- Automated interface to a database

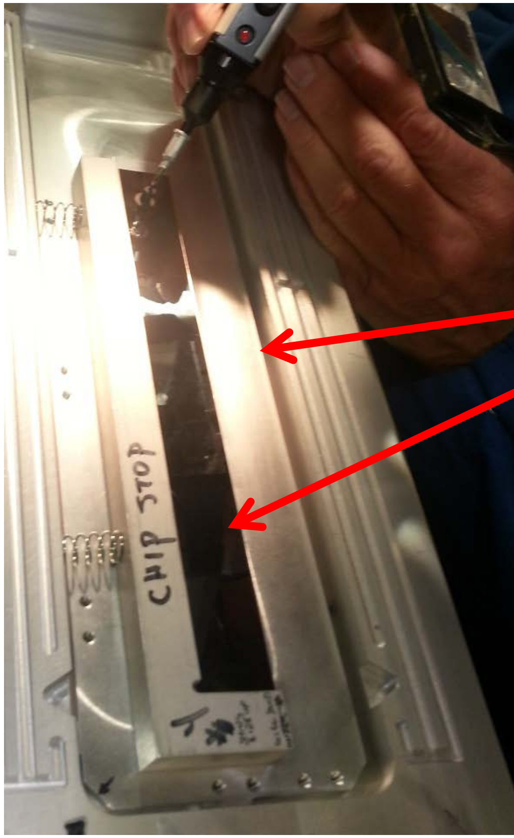
curved thinned sensors

- Sensors built-in testing functionality
- **Proper probe pin design for curved thinned sensors**
- Yield 46% - 60% (spare probe cards)
- Administrative control of sensor ID



Probe card with readout electronics

Ladder Assembly



Sensor positioning

Precision vacuum chuck fixtures to **position sensors by hand**

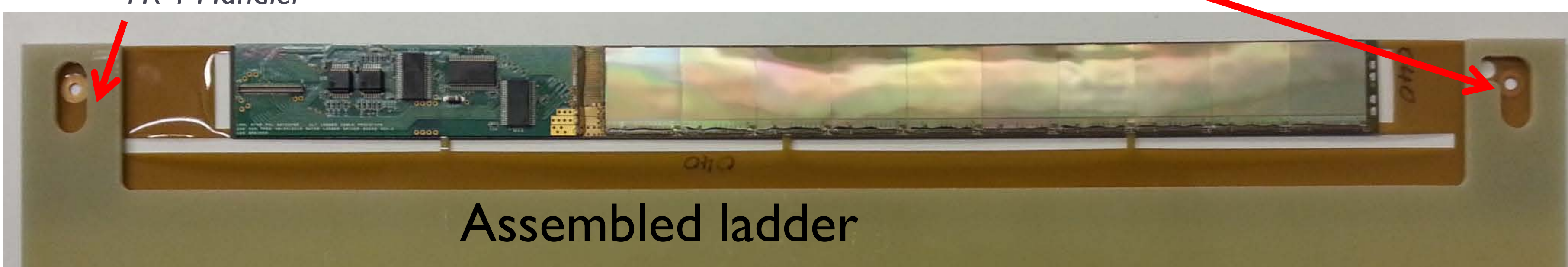
Sensors are positioned **with butted edges.** Acrylic adhesive prevents CTE difference based damage.

Weights taken at all assembly steps to track material and as QA.

Hybrid cable with carbon fiber stiffener plate on back in position to glue on sensors.

Cable reference holes for assembly

FR-4 Handler



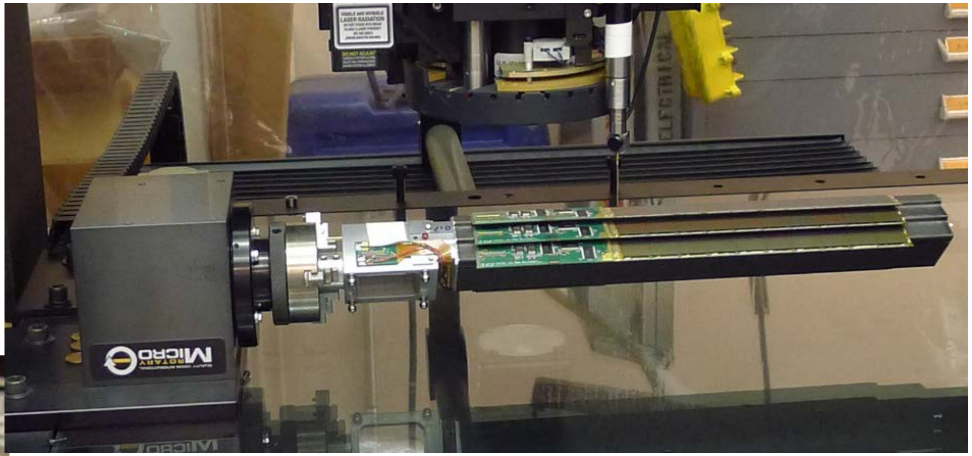
Assembled ladder

From ladders to sectors… to detector halves

Sector assembly fixture

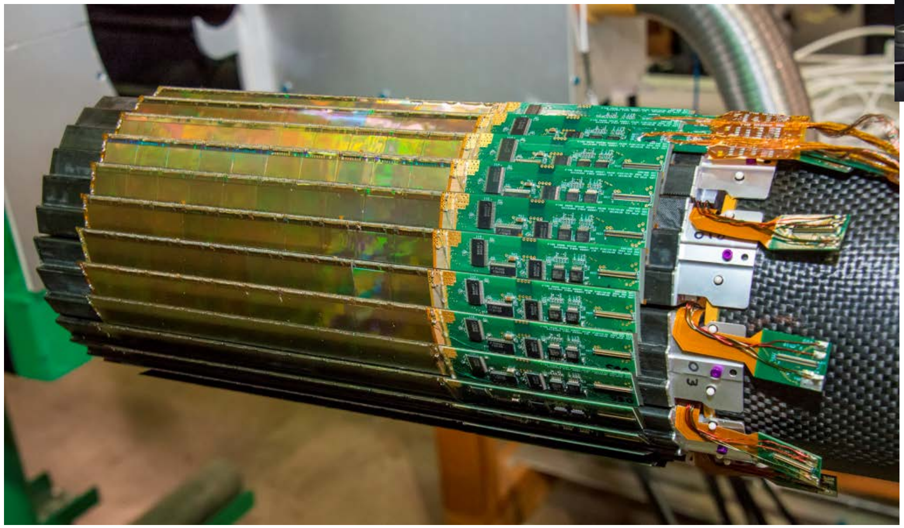
Sectors

- Ladders are glued on carbon fiber sector tubes in 4 steps
- Pixel positions are measured and related to tooling balls
- After touch probe measurements, sectors are tested electrically for damage from metrology



Sector in the metrology setup

A detector half

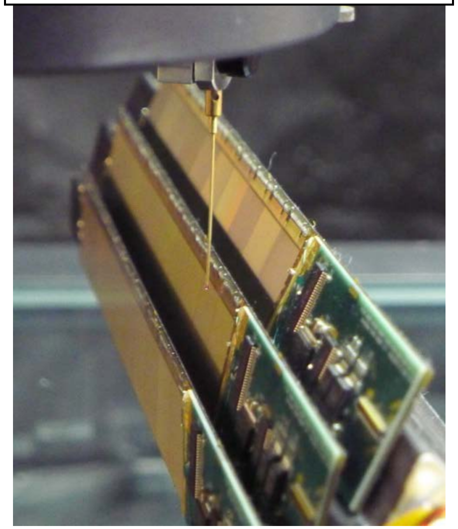


Detector half

- Sectors are mounted in dovetail slots on detector half
- Metrology is done to relate sector tooling balls to each other and to kinematic mounts

PXL Position Control

Sector in the metrology setup



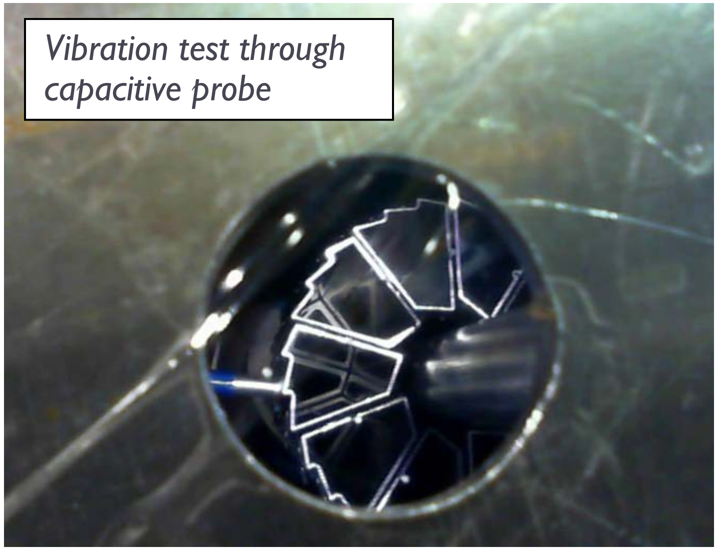
- Metrology survey
  - 3D pixel positions on sector (within ~10 μm) are measured with touch probe and related to tooling balls
  - Sector tooling ball positions related to kinematic mounts to relate pixel positions to final PXL location

  → Detector-half is fully mapped

- Position stability
  - Vibration at air cooling full flow: ~5 μm RMS
  - Stable displacement at full air flow: ~30 μm
  - Stable displacement at power on: ~5 μm

  → Global hit position resolution: ~ 6.2 μm

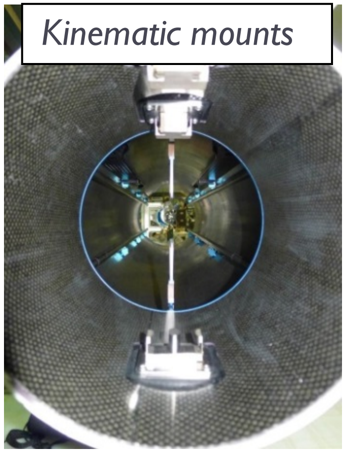
HFT DCA pointing resolution: $(10 \oplus 24/p)$ μm



Vibration test through capacitive probe

G. Contin | gcontin@lbl.gov
HEP Liverpool 10/18/2017

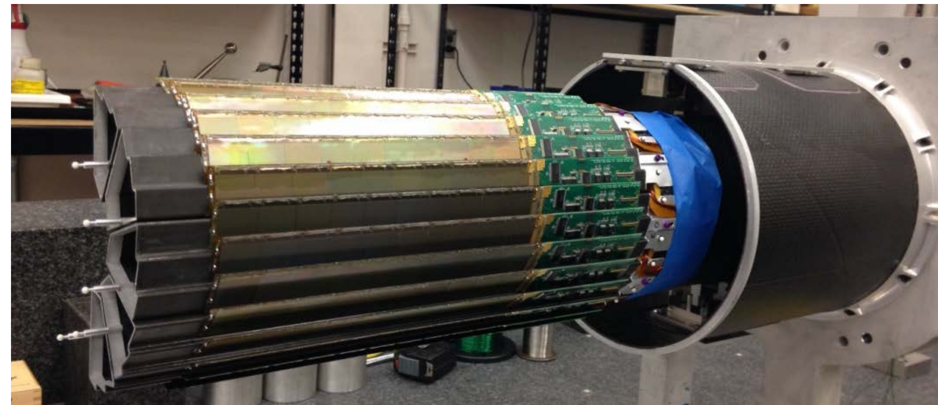
PXL Installation in STAR



Kinematic mounts

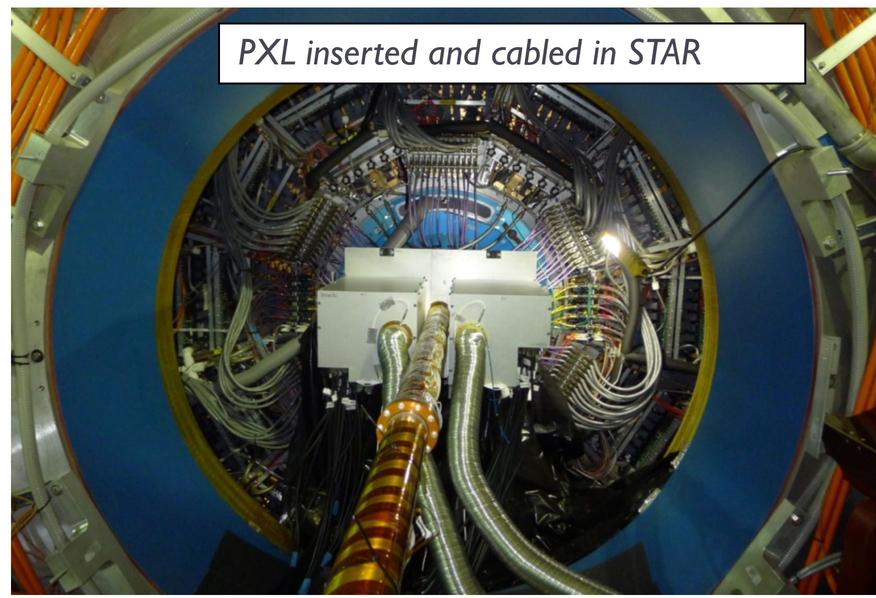
Novel insertion approach

- Inserted along rails and locked into a kinematic mount inside the support structure
- It can be replaced in < 1 day with a spare copy



duplicate, truncated PXL support tube with kinematic mounts

Insertion in STAR

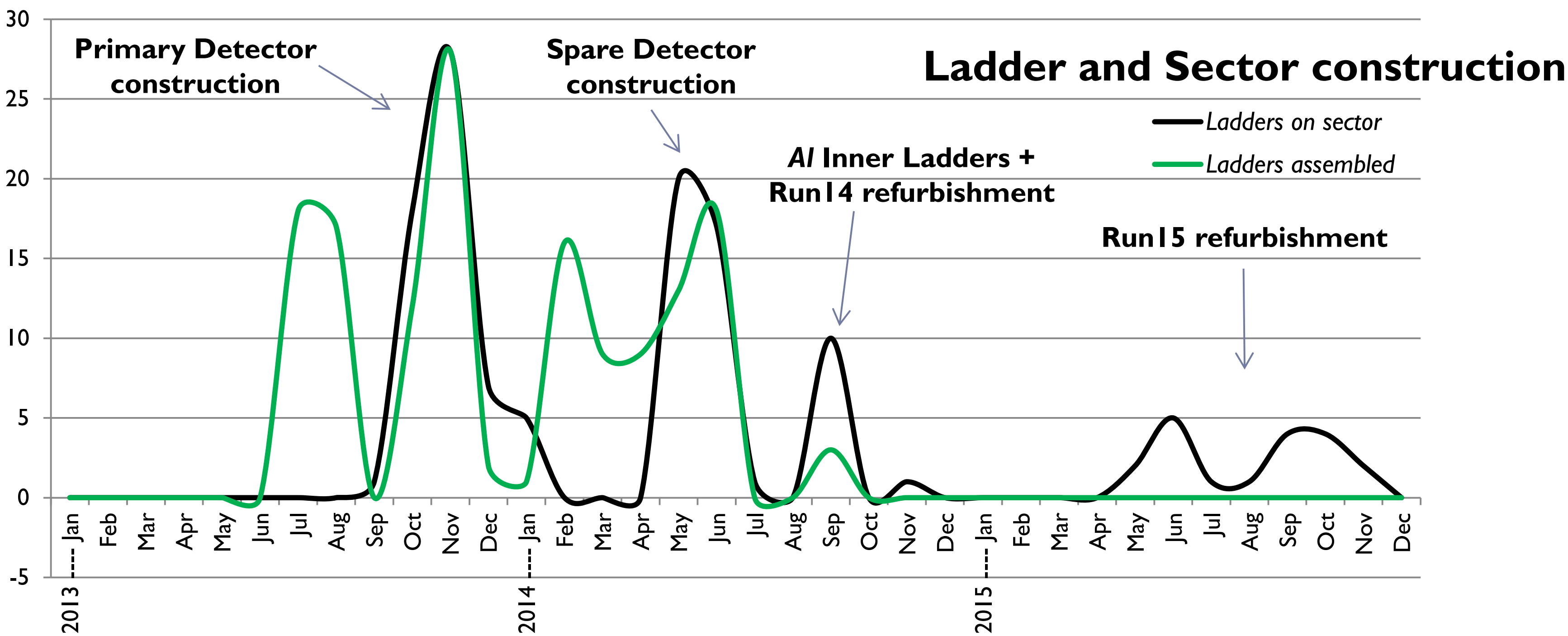


PXL inserted and cabled in STAR

PXL production timeline

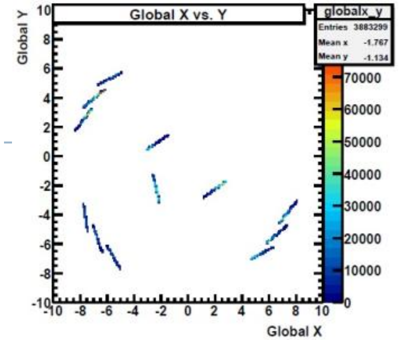
- Delivered:
  - **2014 Run:** Primary Detector, 2 *aluminum cable* inner ladders, others in *copper*
  - **2015-2016 Runs:** 2 detector copies, all inner ladders in *aluminum*
- Sector refurbishment:
  - After each STAR Run for *latch-up* induced damage
  - After power supply accident during 2015 Run installation

Overall stats	**#**
Assembled ladders	146
Installed on sectors	127
Ladder tests	~2000



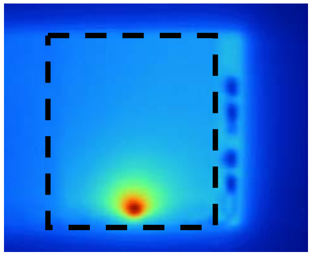
- Operations, Performance, Lessons Learned

2013 Engineering Run

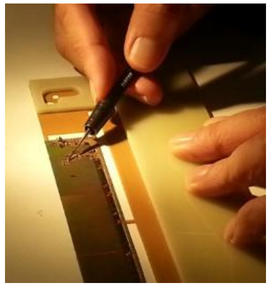


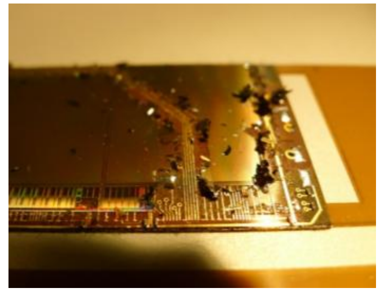
Engineering run geometry

- PXL Engineering Run assembly crucial to deal with a number of unexpected issues



Sensor IR picture

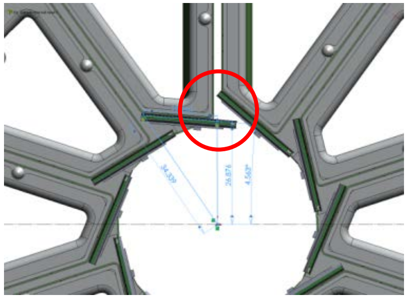




Flawed ladder dissection: searching for shorts

- Shorts between power and gnd, or LVDS outputs
- Adhesive layer extended in both dimensions to increase the portion coming out from underneath the sensors
- Insulating solder mask added to low mass cables

- Mechanical interference in the driver boards on the existing design.
- The sector tube and inner ladder driver board have been redesigned to give a reasonable clearance fit
- Inner layer design modification: ~ 2.8 cm inner radius

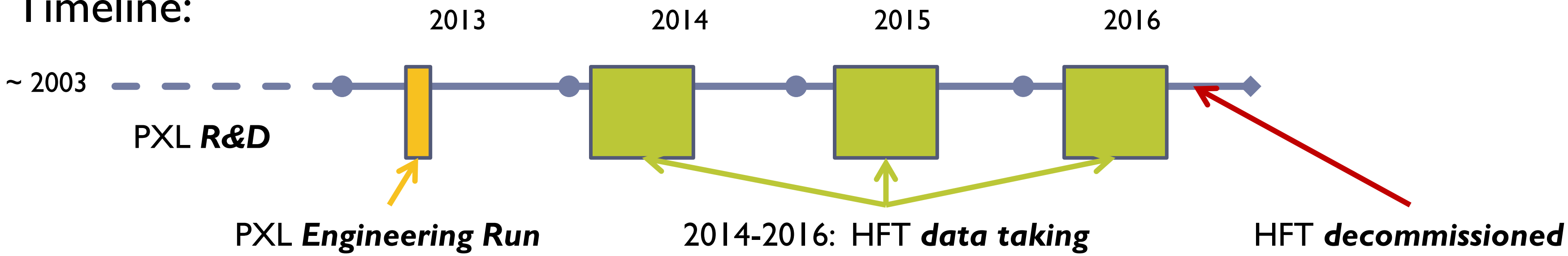


Inner layer design

- Limited capability to remotely control power and current limits
- After the engineering run added functionality to the Mass Termination Board:
  - remote setting of LU threshold and ladder power supply voltage + current and voltage monitoring

PXL data taking

- Timeline:

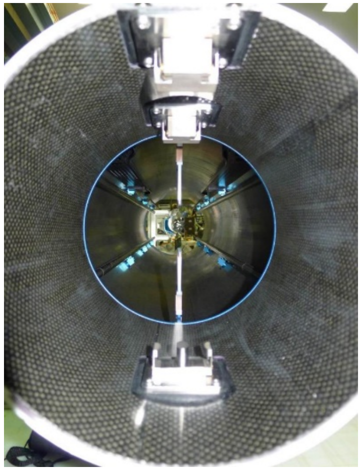


- PXL Operations
  - Hit multiplicity per sensor: up to 1000/inner-sensor, 100/outer-sensor
  - Dead time up to ~6%
  - Typical trigger rate: 0.8-1 kHz
  - Latch-up reset events: 2 latch-up/min
  - Periodic reset to clear SEUs

- Collected *minimum bias* events in the PXL acceptance:
  - 2014 Run: ~ 1.2 Billion Au+Au @ $\sqrt{s_{NN}}$ = 200GeV
  - 2015 Run: { ~ 1 Billion p+p; ~ 0.6 Billion p+Au } @ $\sqrt{s_{NN}}$ = 200GeV
  - 2016 Run: { ~ 2 Billion Au+Au; ~ 0.3 Billion d+Au } @ $\sqrt{s_{NN}}$ = 200GeV

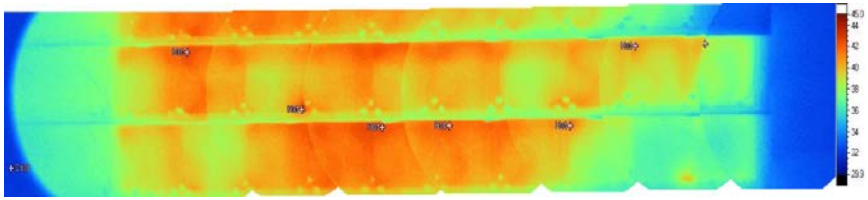
Operational Aspects

- Operational **latch-up protection and voltage control** limited the effect of LU-related sensor damage *(more later in this talk)*
- **Detector reset** on a 15 minute schedule limited SEU-related data corruption
- **Mechanics**
  - The detector halves maintained survey pixel positions after insertion and during operational heating and in the cooling airflow (10 m/s).
  - The rapid insertion and removal mechanism worked well, allowing removal and replacement operation of a 2nd detector in one day.
- **Air cooling** worked very well, typical variation in sensor temperature over the runs was within 1-2 degree C.



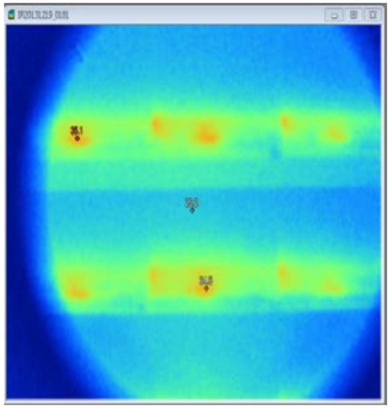
PXL Kinematic mounts

Sector vibration in the radial direction scales as:	$flow^2$
Sector vibration at full flow:	5 µm RMS
Sector DC displacement scales as:	$flow^2$
Sector moves in at full flow: **(Stable displacement)**	25 µm - 30 µm
Sector moves in when ladders powered: **(Stable displacement)**	3 µm - 8 µm



Composite IR image of PXL test ladders

IR image of production PXL ladders. Max ΔT is 12° C from ambient.



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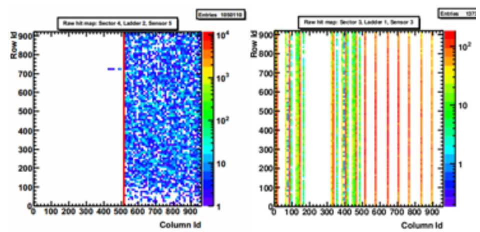
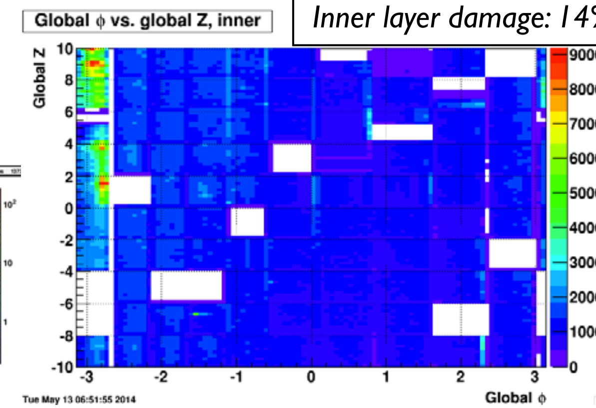
Operational issues: Latch-up damage

- Unexpected damage seen on 15 ladders in the STAR radiation environment in 2014 Run first 2 weeks
  - Digital power current increase
  - Sensor data corruption
  - Hotspots in sensor digital section
  - Correlated with *latch-up* events
  - Limited with operational methods



Inner layer damage: 14%

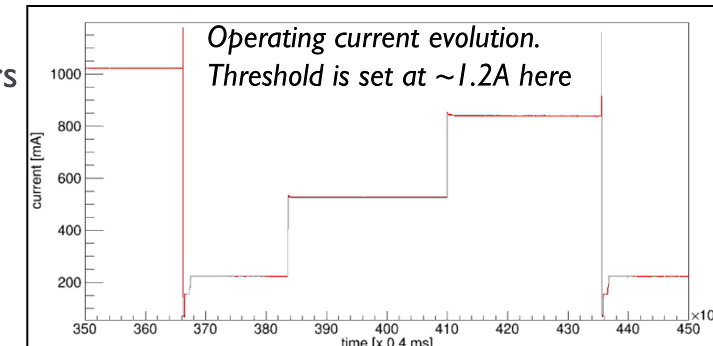


- Latch-up tests at *BASE facility* (LBL) to measure latch-up cross-section and reproduce damage
  - 50 μm & 700 μm thick, low and high resistivity sensors; PXL ladders
  - Irradiation with heavy-ions and protons

Latch-up phenomenon:
- Self feeding short circuit caused by single event upset
- Can only be stopped by removing the power

- Results and observations
  - Current limited latch-up states observed (typically ~300 mA)
  - Damage reproduced only with HI on PXL 50 μm thinned sensors

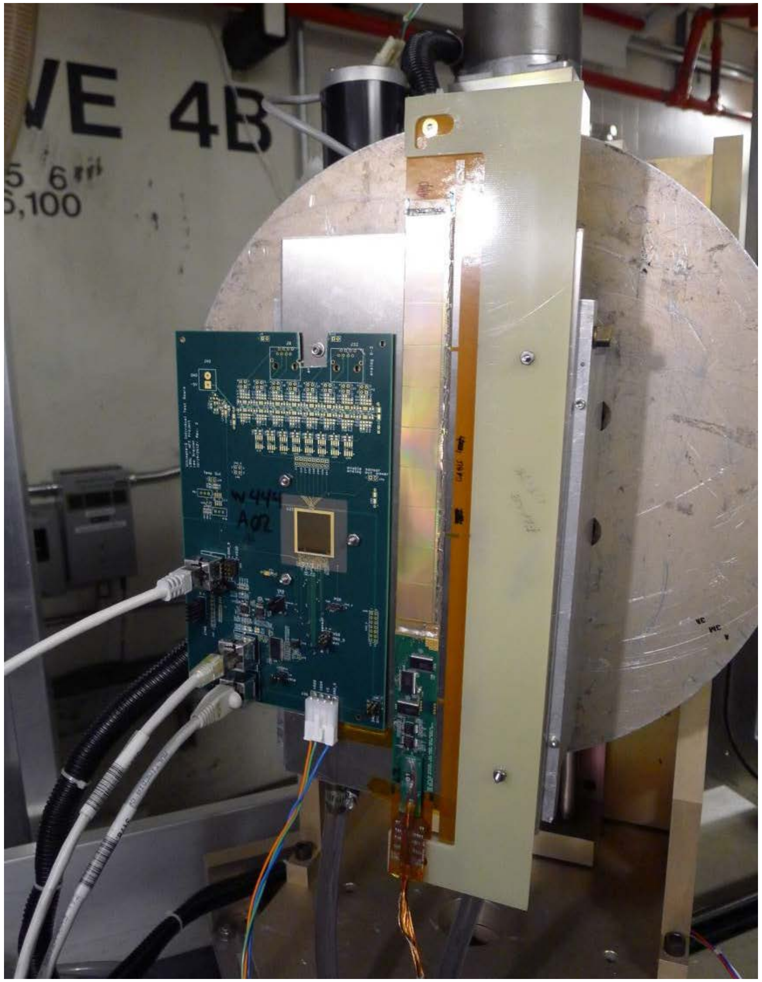
- Safe operations envelope implemented
  - Latch-up protection at 80 mA above operating current
  - Periodic detector reset to clear SEU



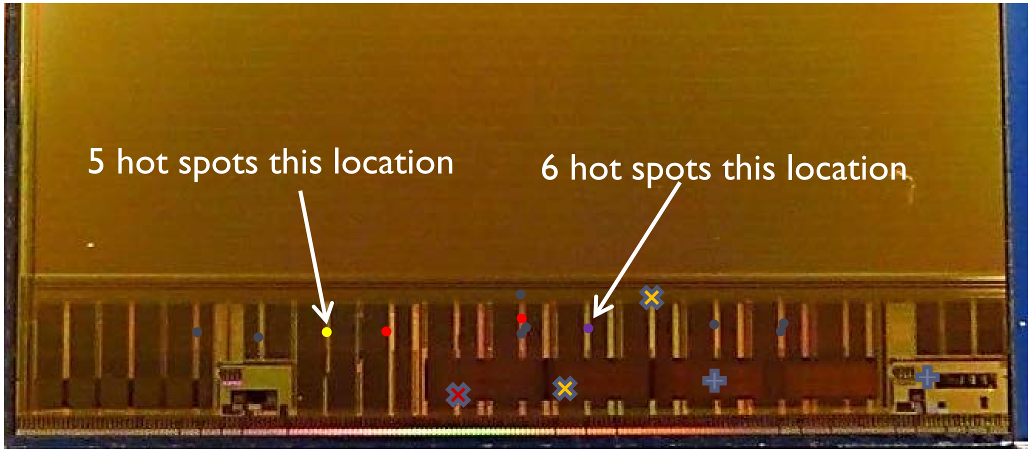
Operating current evolution. Threshold is set at ~1.2A here

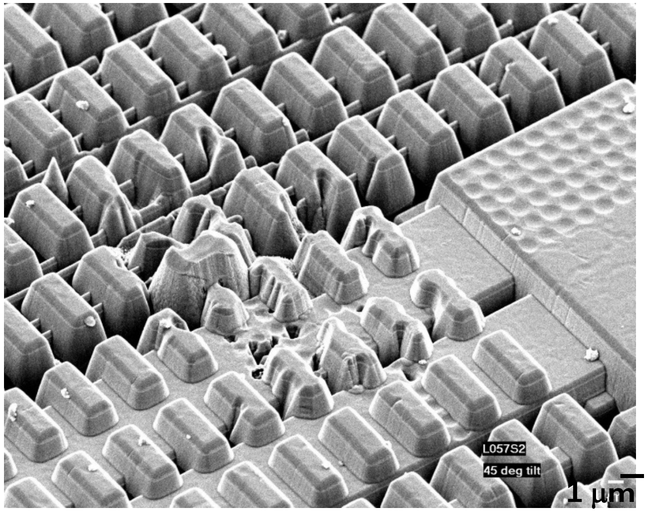
Latch-up test setup and damage analysis

Individual sensor test boards and ladders mounted on cooling plate



IR "hotspots" locating the damage tend to favor particular structures (isolated buffers with specific structure pitch)





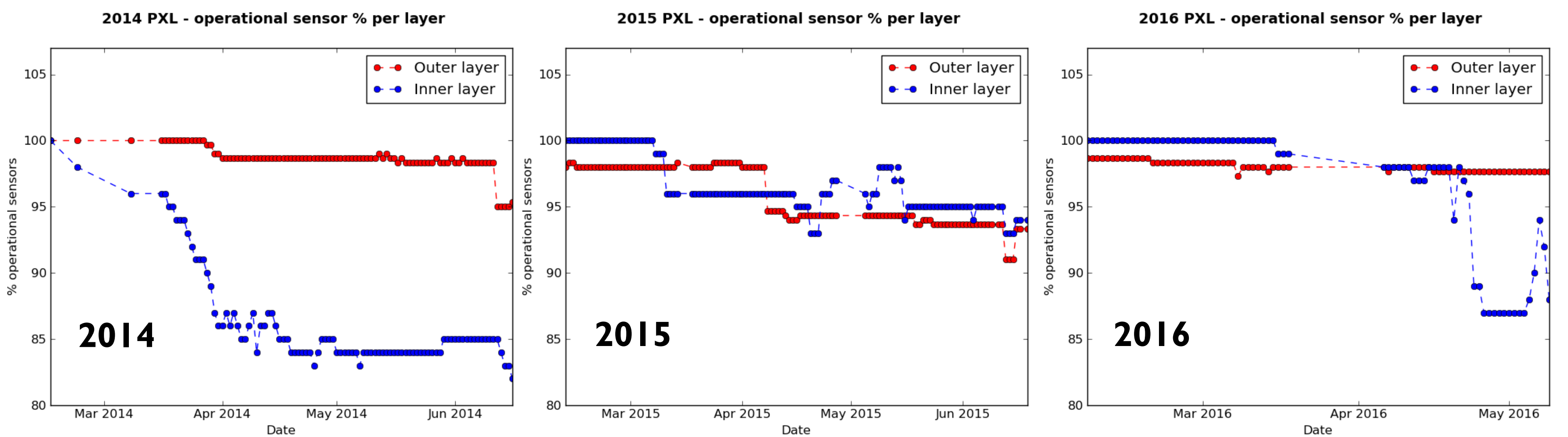
PXL sensor layers deconstructed (plasma etching technique) and viewed with SEM (@BNL Instrumentation Division)

The layers appear to be melted

Damage evolution

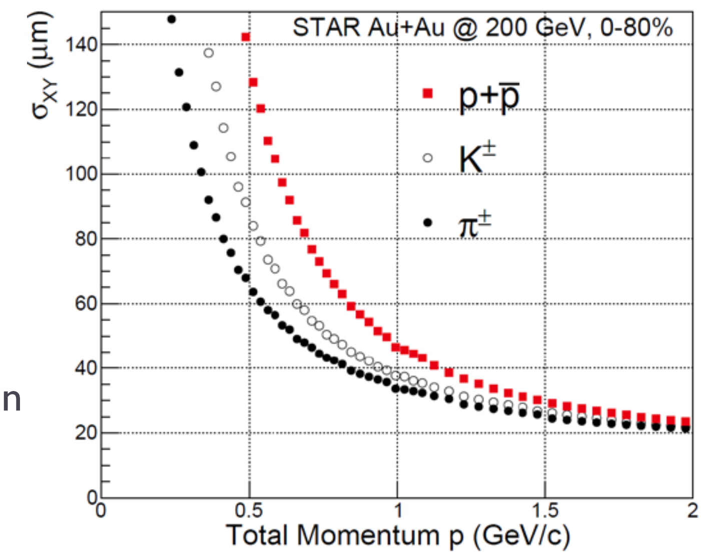
Run	Good sensors on Inner Layer		Good sensors on Outer Layer		*Comment*
	installation	**end of run**	installation	**end of run**	
2014	100%	82%	100%	95%	LU damage, most of it in the first 15 days of operations
2015	99%	94%	98%	96% *(93%)**	* = Lost control of an outer ladder (10 good sensors off)
2016	100%	95% *(87%)*[+]	99%	98%	[+] = Current instability on inner ladder (8 good sensors off)

Good sensor = sensor with >95% active channels and uniform efficiency



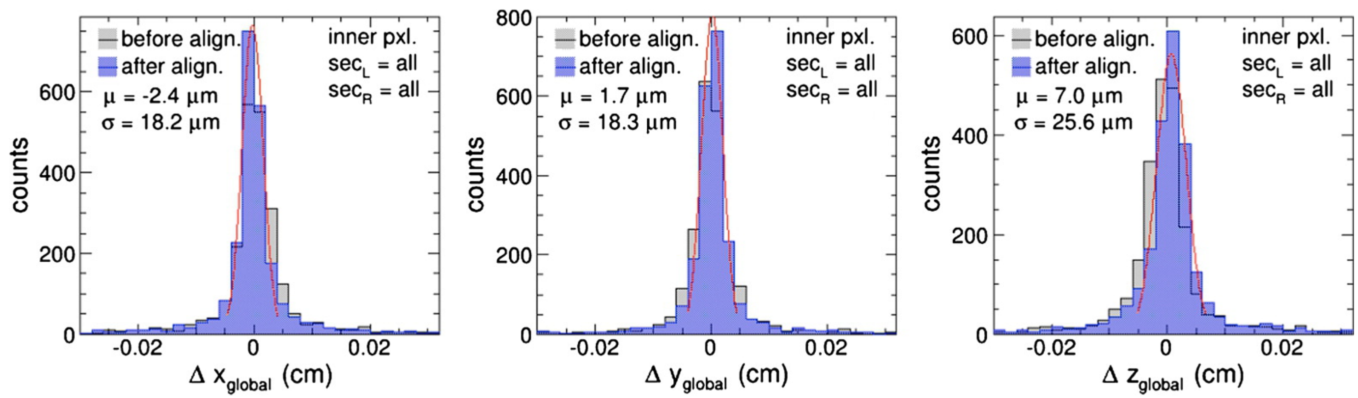
HFT Performance from 2014 data

- Distance of Closest Approach (DCA) resolution - design requirements exceeded
  - ~ 50 μm for 750 MeV/c Kaons
  - ~ 30 μm for p > 1 GeV/c



- Sensor detection efficiency:
  - 97.2% average estimated with cosmic rays before the Run

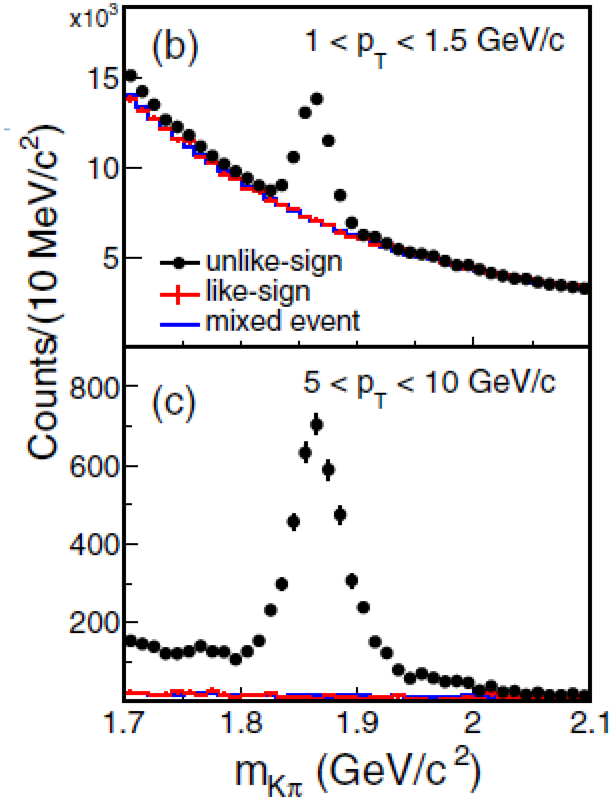
- Alignment
  - Residuals distribution after alignment shows σ ≤ 25 μm



HFT Physics achievements

- Physics of D-meson production
  - High significance signal
  - Nuclear modification factor R_{AA}
  - Collective flow v_2

Sample: ~900 M
Au+Au collisions
$\sqrt{s_{NN}}$ = *200GeV*



- $D^0 \rightarrow K + \pi$
  - Significance $S/\sqrt{S+B} \sim 220$
- $D_S^{\pm} \rightarrow \phi(K^+ + K^-) + \pi^{\pm}$
  - Significance $S/\sqrt{S+B} \sim 25$
- ***NEW!!!* First measurement of Λ_c baryons in HI collisions**
  - $\Lambda_c^{\pm} \rightarrow p^{\pm} K^{\mp} \pi^{\pm}$ $c\tau \sim 60\mu m$ BR = 5 %
  - Experimentally challenging to measure in heavy-ion collisions
    → Combinatorial background is greatly suppressed
  - Significance: $S/\sqrt{S+B} \sim 5.2$ (10-60% centrality, p_T: 3–6 GeV/)
  - Λ_c/D^0 ratio compatible with baryon-to-meson ratios of light hadrons

STAR PXL Project: Strengths and Weaknesses

Project paper: *"The STAR MAPS-based PiXeL detector" submitted to NIM A (arXiv:1710.02176)*

Strengths

- Sensor and Readout System developments strictly coupled
- Engineering run, crucial for the program
- ~Full control on the production

⟶ **Success!** { Performance exceeded expectations; Access the charm domain }

Weaknesses

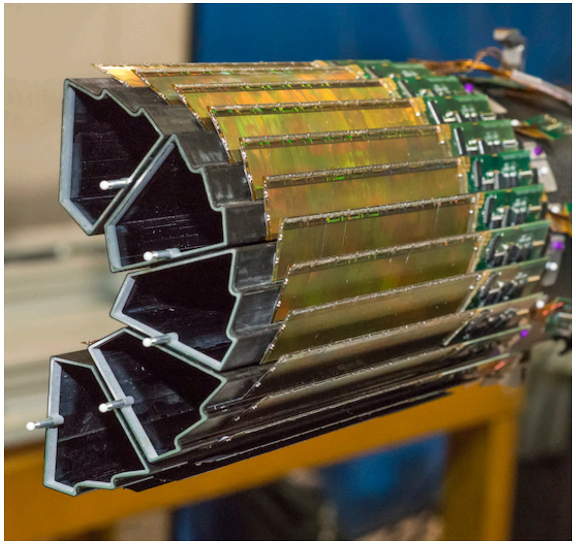
- Untested technology in a collider environment
- Short (3-year) physics program
- Sensor too slow to access the bottom domain

⟶ **Future:** ALICE ITS Upgrade, sPHENIX MVTX

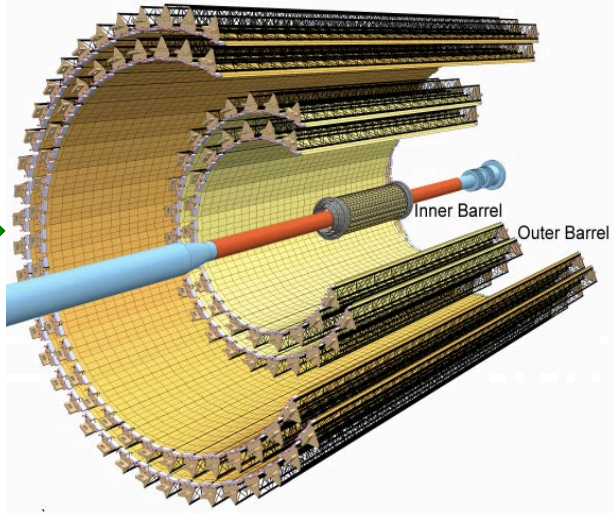
Evolution of MAPS-based Vertex Detector

2014-2016 | 2021+

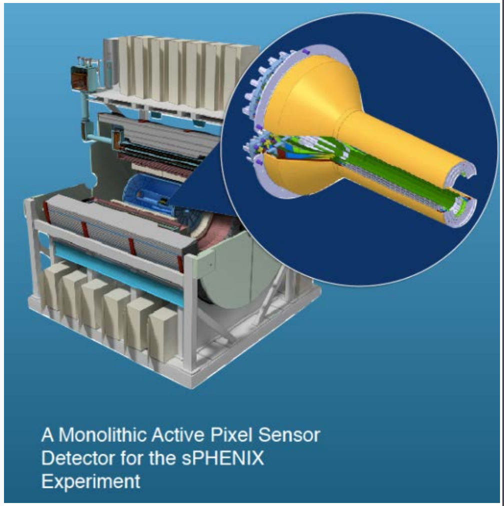
STAR HFT/PXL (Current)



ALICE ITS Upgrade



sPHENIX MVTX



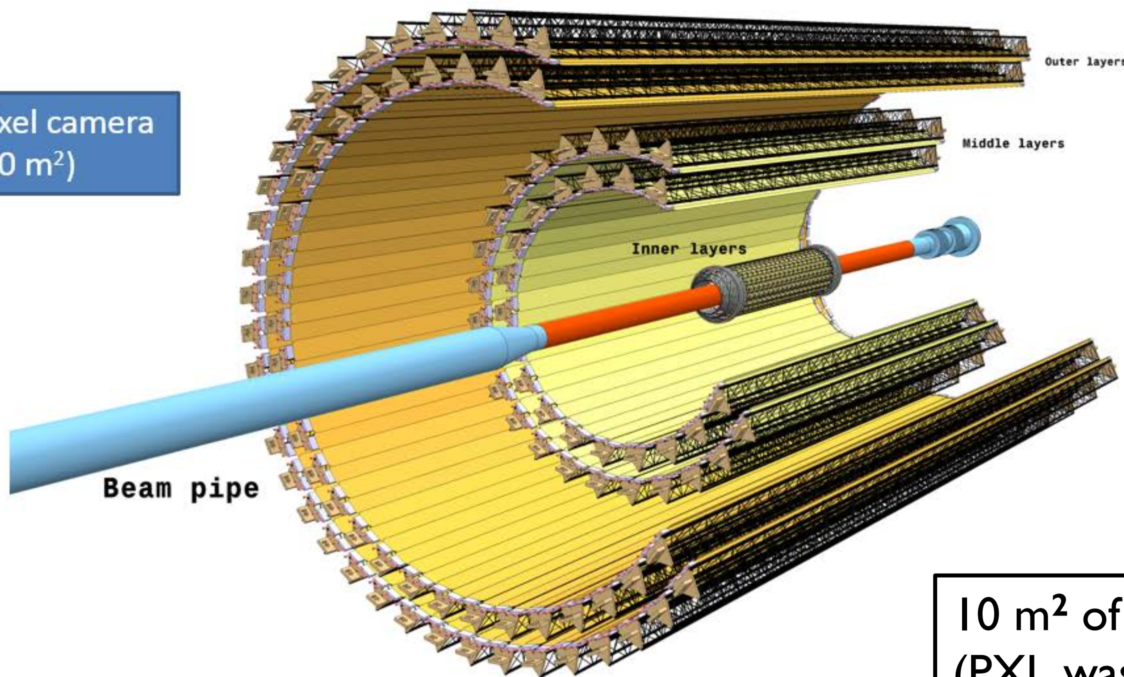
Integration time: **186 μs**
Thickness first layer: 0.4%X_0

Integration time: **<20 μs**
Thickness first layer: 0.3%X_0

Next generation MAPS detector used for ALICE ITS Upgrade and for sPHENIX MVTX:
Thin MAPS detector with much shorter integration time
-> Significantly reduced background hits -> Much improved tracking efficiency

@LHC: ALICE ITS Upgrade From HybridPixels/Drifts/Strips to MAPS

12.5 G-pixel camera
(~10 m^2)



10 m^2 of silicon
(PXL was 0.16 m^2)

7-layer barrel geometry based on MAPS

r coverage: 23 – 400 mm

η coverage: |η| ≤ 1.22
for tracks from 90% most luminous region

3 Inner Barrel layers (**IB**)

4 Outer Barrel layers (**OB**)

Material /layer : 0.3% X_0 (IB), 1% X_0 (OB)

7

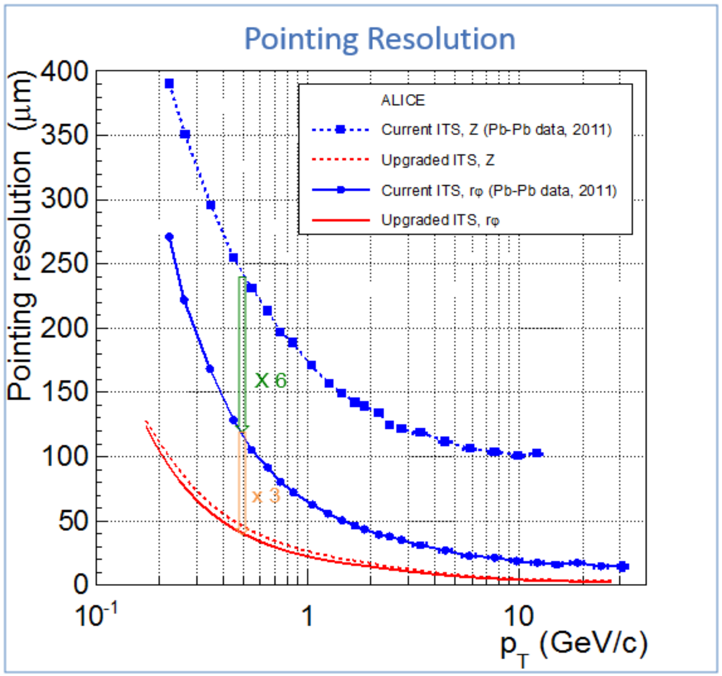
http://iopscience.iop.org/0954-3899/41/8/087002/

Upgraded ITS Performance

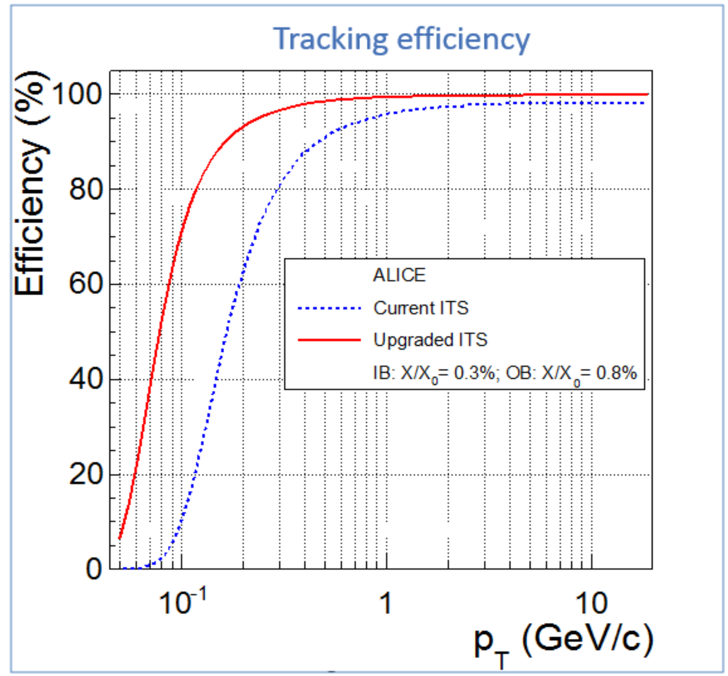
Performance of new ITS (MC simulations)

ALICE

Impact parameter resolution



Tracking efficiency (ITS standalone)



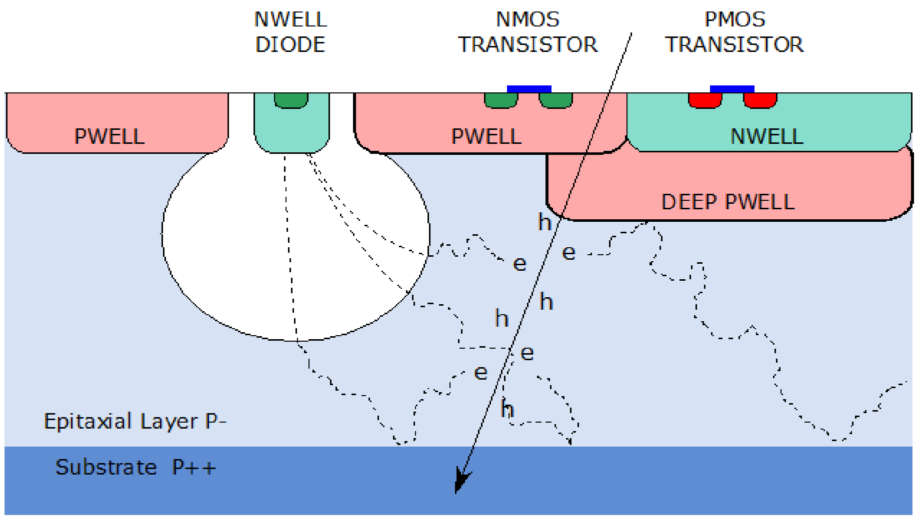
Existing ITS:	Hybrid pixels, drift, strips	X/X0 ≥1% /layer	~120 µm @ 500MeV/c
ITS Upgrade:	All layers are MAPS sensors	X/X0 ~0.4% /layer	~40 µm @ 500MeV/c

Physics Goals: Improve charm meson study - Access charm baryons, bottom hadrons

ITS Pixel Chip – technology choice

ALICE

CMOS Pixel Sensor using TowerJazz 0.18µm CMOS Imaging Process



ALPIDE sensor *(developed at CERN)*

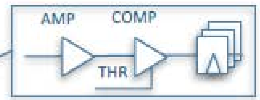
- ~28 µm pitch
- Integration time: < 20 µs
- Trigger rate: 100 kHz
- Read out up to 1.2 Gbit/s
- Power: 40 mW/cm^2
- Priority encoder - sparsified readout
- Rad. Tolerant: 700krad - 10^{14} 1MeV n_{eq}/cm^2

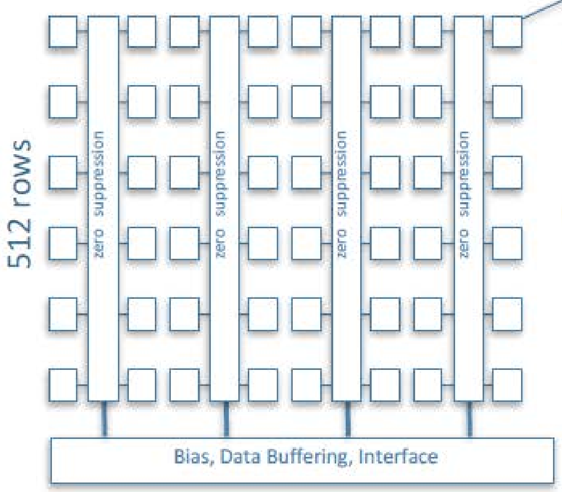
- High-resistivity (> 1kΩ cm) p-type epitaxial layer (20µm - 40µm thick) on p-type substrate
- Small n-well diode (2-3 µm diameter), ~100 times smaller than pixel => low capacitance
- Application of (moderate) reverse bias voltage to substrate can be used to increase depletion zone around NWELL collection diode
- Quadruple well process: deep PWELL shields NWELL of PMOS transistors, allowing for full CMOS circuitry within active area

ALPIDE Architecture

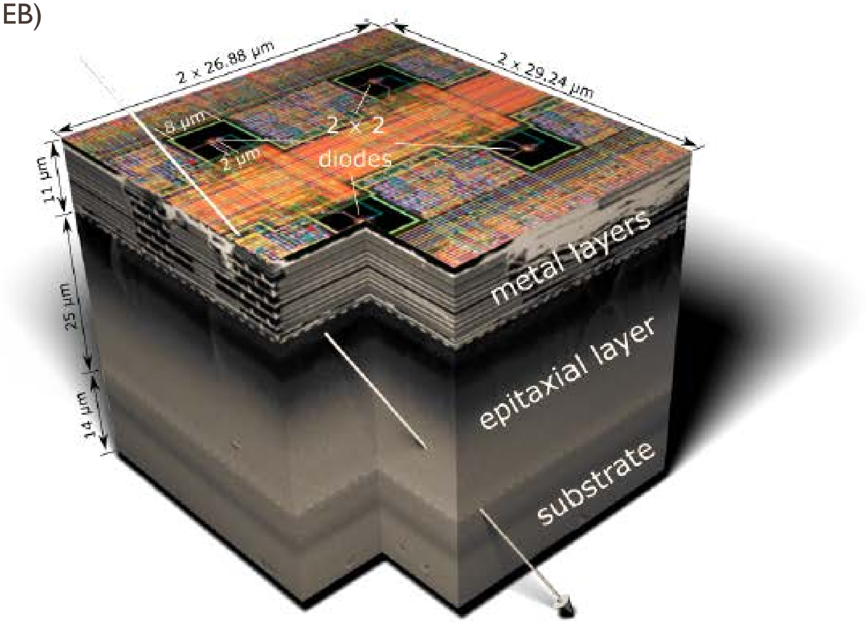
Priority Encoder (AE-RD)
1024 pixel columns
(32 regions x 16 double-columns)

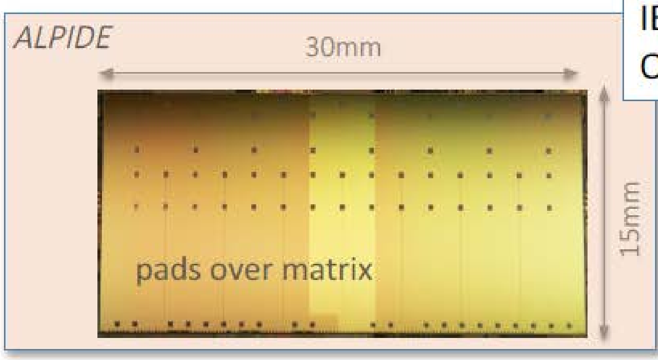
In pixel:
- Amplification
- Discrimination
- 3 hit storage registers (MEB)





external trigger
or
Continuous



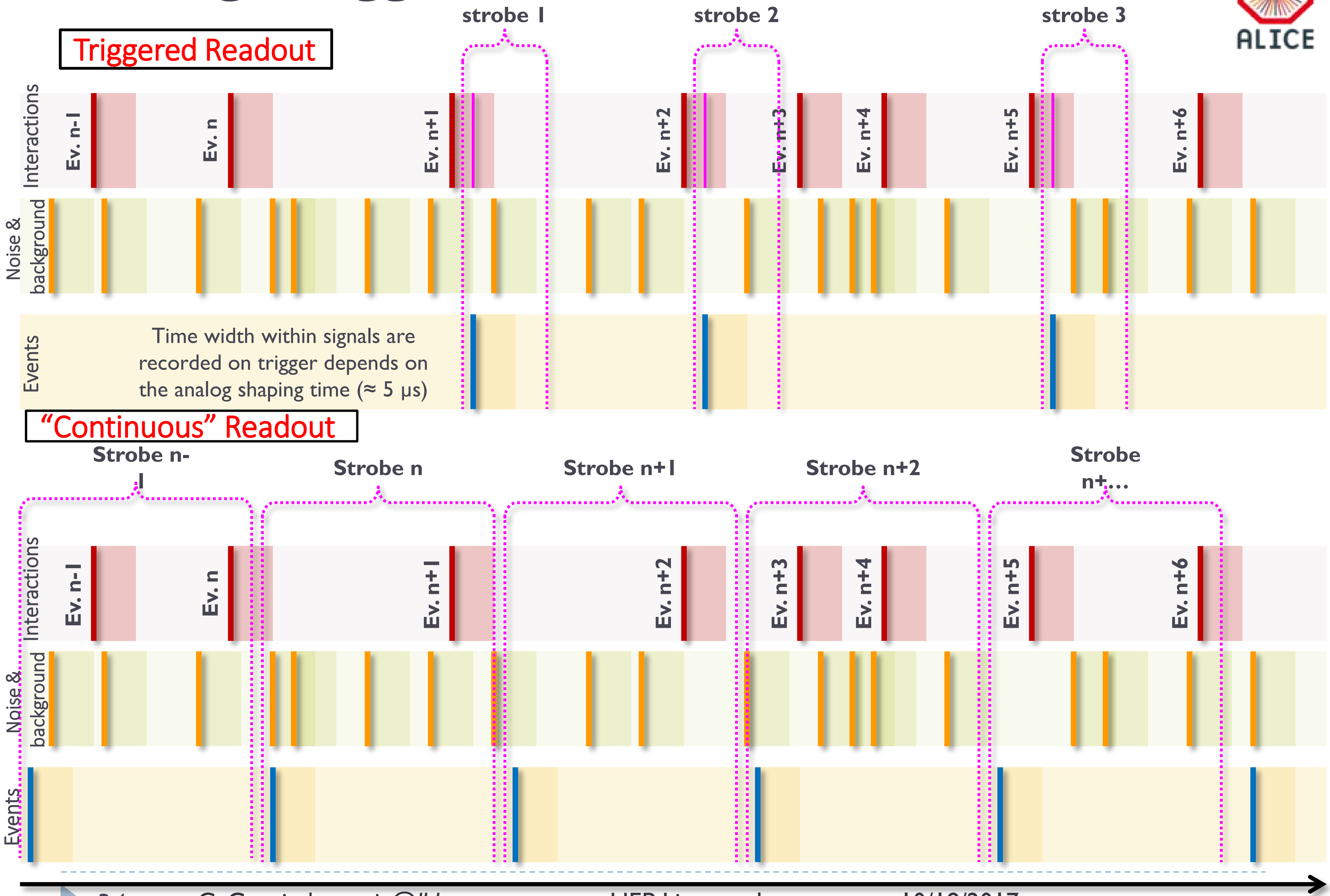


IB: 50µm thick
OB: 100µm thick

Power: 40 mW/cm^2
Trigger rate: 100 kHz
Integration time:
Read out up to 1.2 Gbit/s.

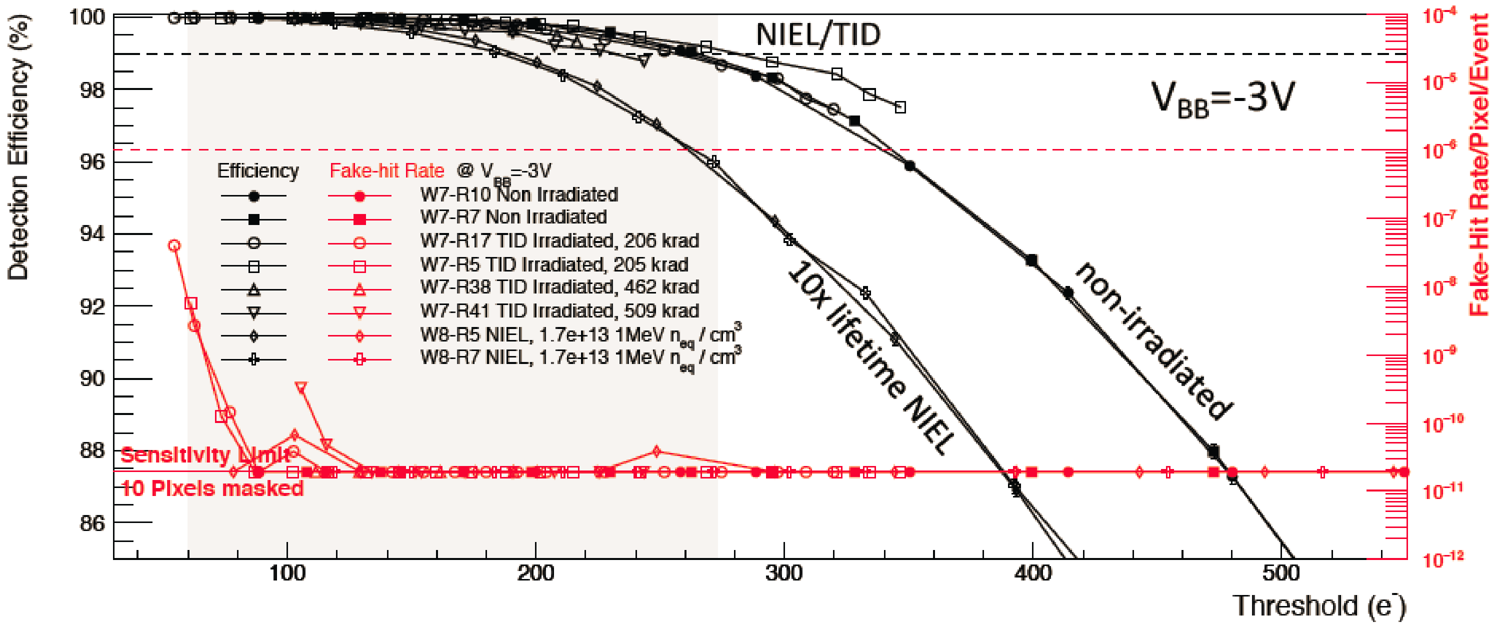
130,000 pixels / cm^2 27x29x25 µm^3
spatial resolution: ~ 5 µm (3-D)
Max particle rate: 100 MHz / cm^2
fake-hit rate: ~ 10^{-10} pixel / event
power : ~ 300 nW /pixel

Timing: Triggered & "Continuous" Readout



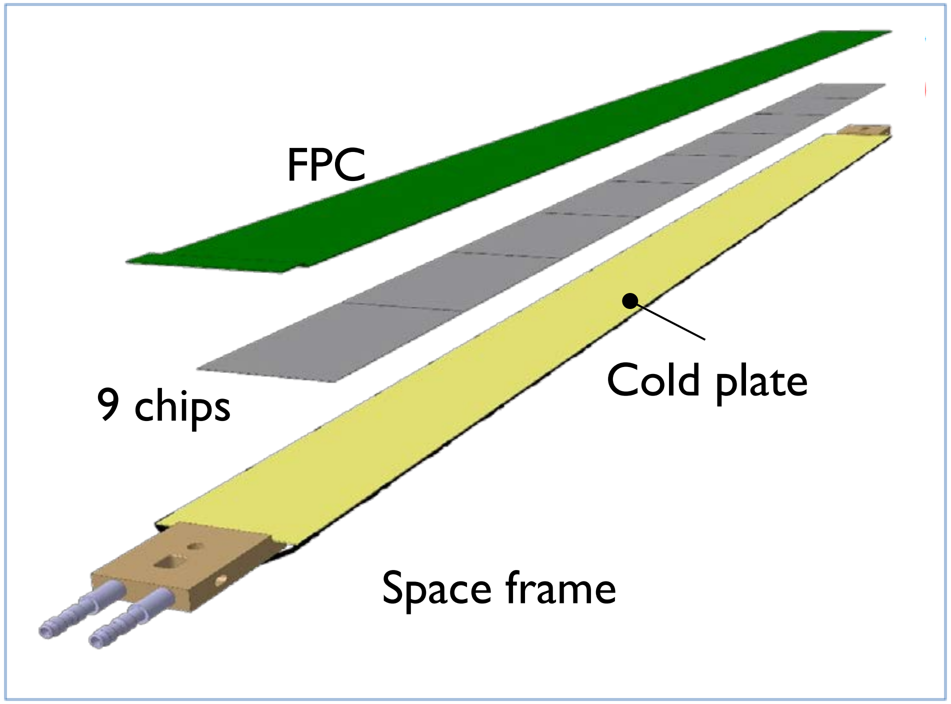
ALPIDE performance

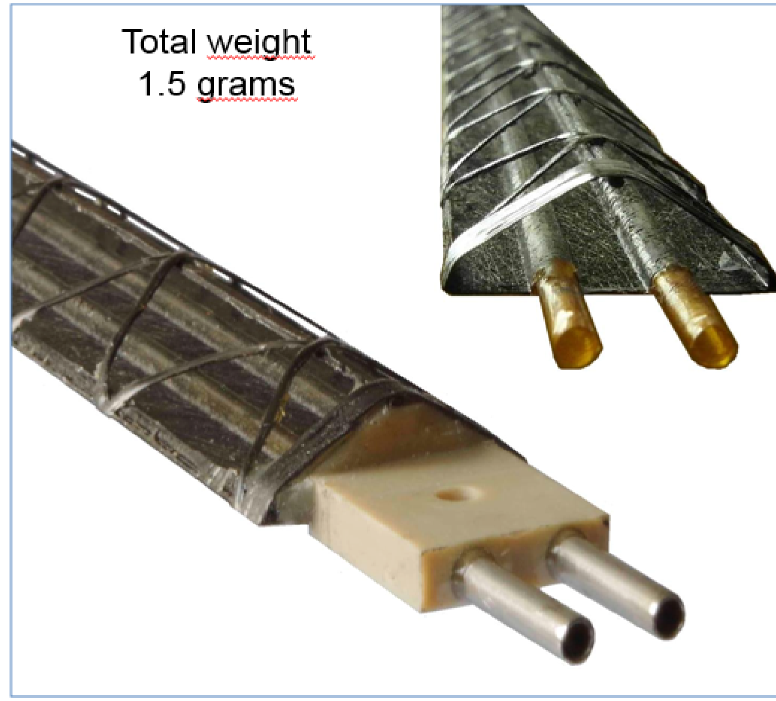
Detection Efficiency and Fake-Hit Rate



- Big operational margin with only 10 masked pixels (0.002%)
- Chip-to-chip fluctuations negligible
- Non-irradiated and NIEL/TID chips show similar performance
- Sufficient operational margin after 10x lifetime NIEL dose

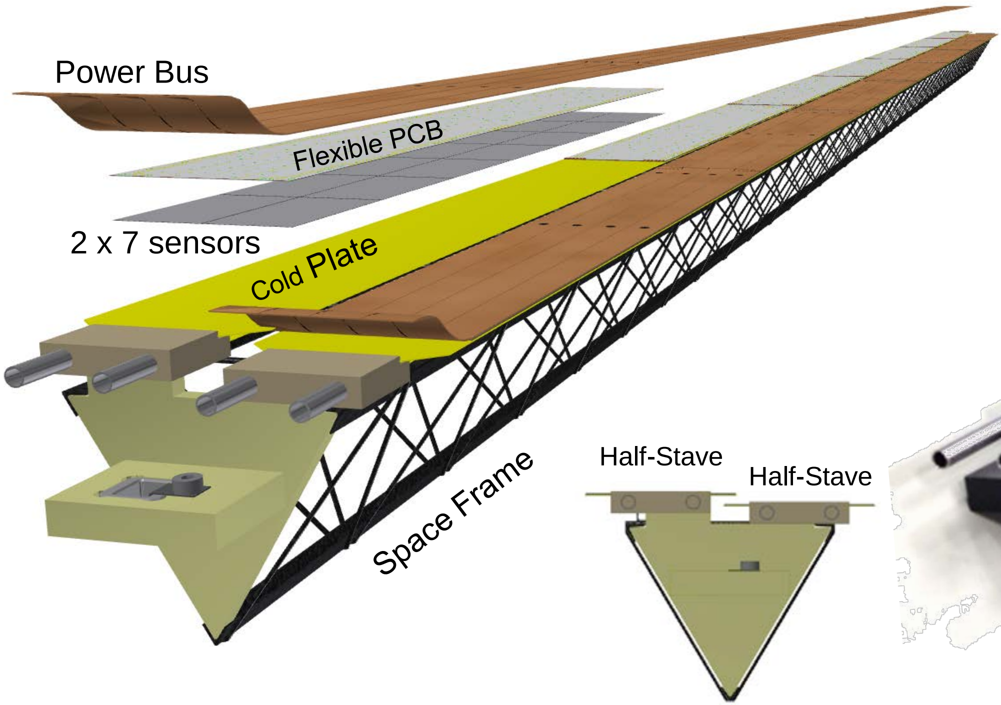
New ITS Layout - Inner Barrel Stave





<Radius> (mm): 23,31,39	Length in z (mm): 290
Nr. of staves: 12, 16, 20	Nr. of chips/stave: 9
Nr. of chips/layer: 108, 144, 180	Material thickness: ~ 0.3% X_0
Power density: < 100 mW/cm^2	Throughput (@100kHz): < 80 $Mb/s \times cm^{-2}$

ITS Outer Barrel



Outer Barrel (OB)

<radius> (mm): 194, 247, 353, 405

Nr. staves: 24, 30, 42, 48

Nr. Chips/layer: 6048 (ML), 17740(OL)

Power density < 100 mW / cm^2

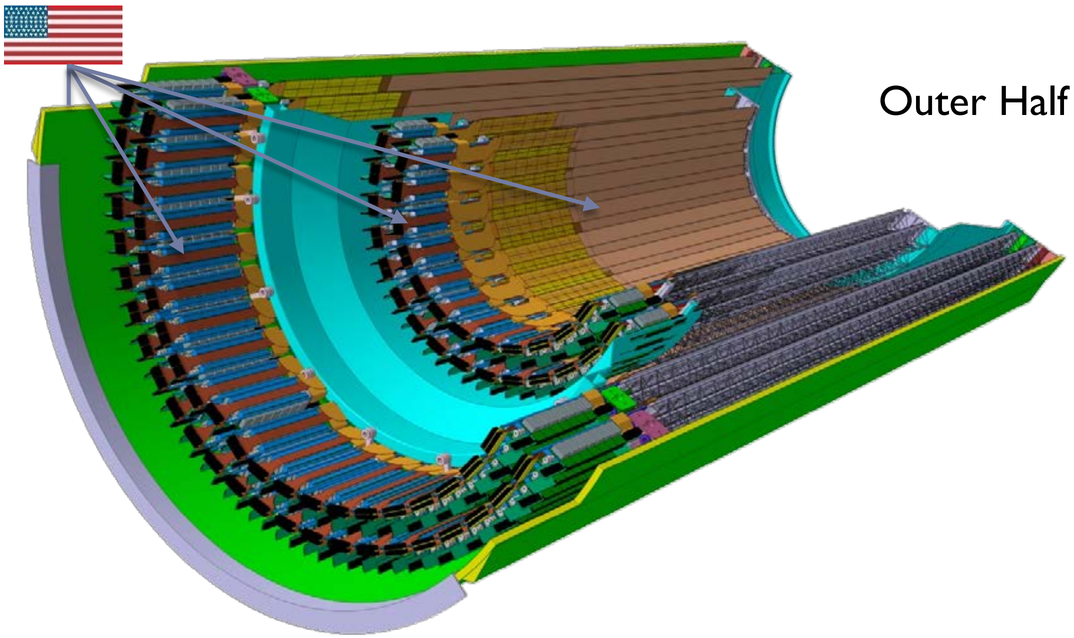
Length (mm): 900 (ML), 1500 (OL)

Nr. modules/stave: 4 (ML), 7 (OL)

Material thickness: ~ 1% X_0

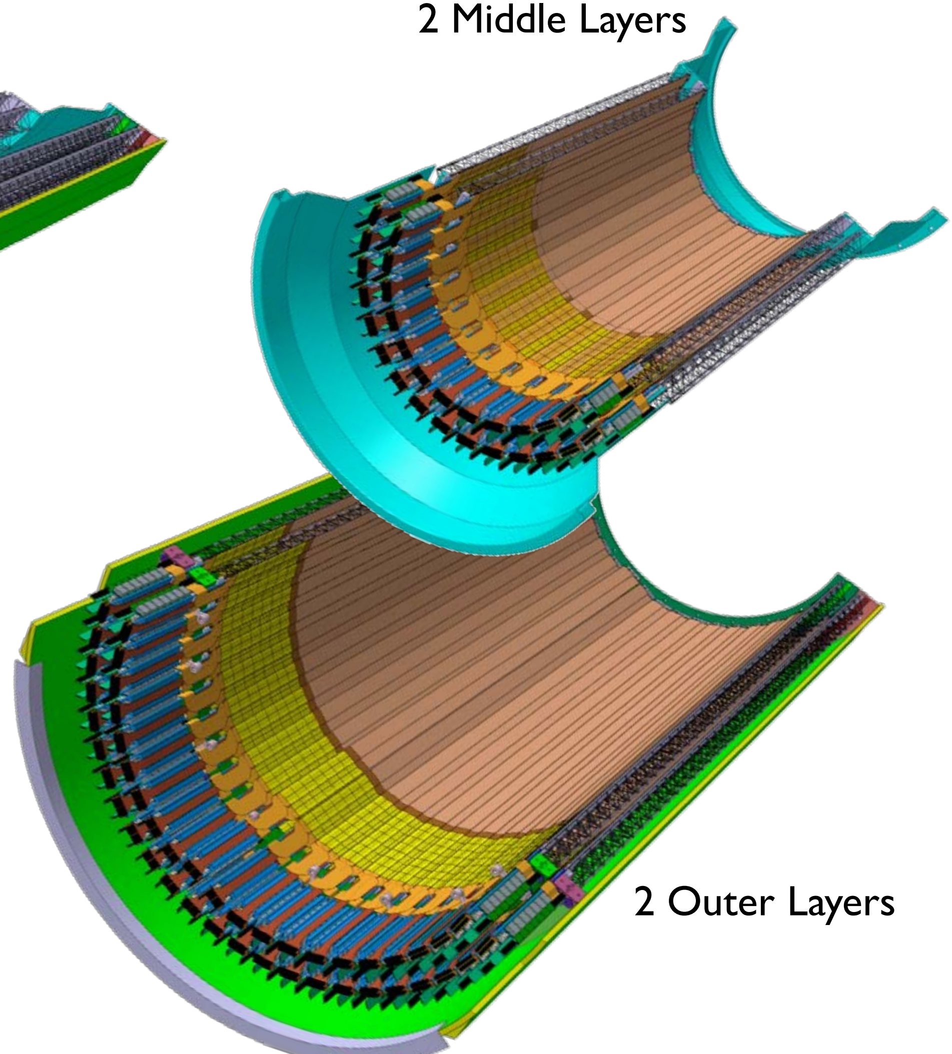
Throughput (@100kHz): < 3Mb/s × cm^{-2}

ITS Outer Detector Barrel

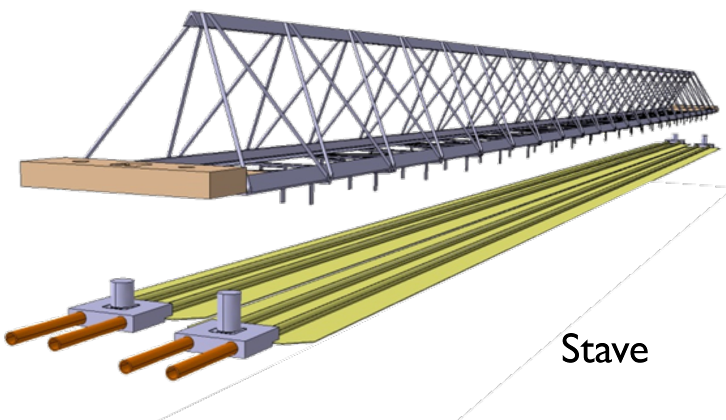


Outer Half Barrel

2 Middle Layers

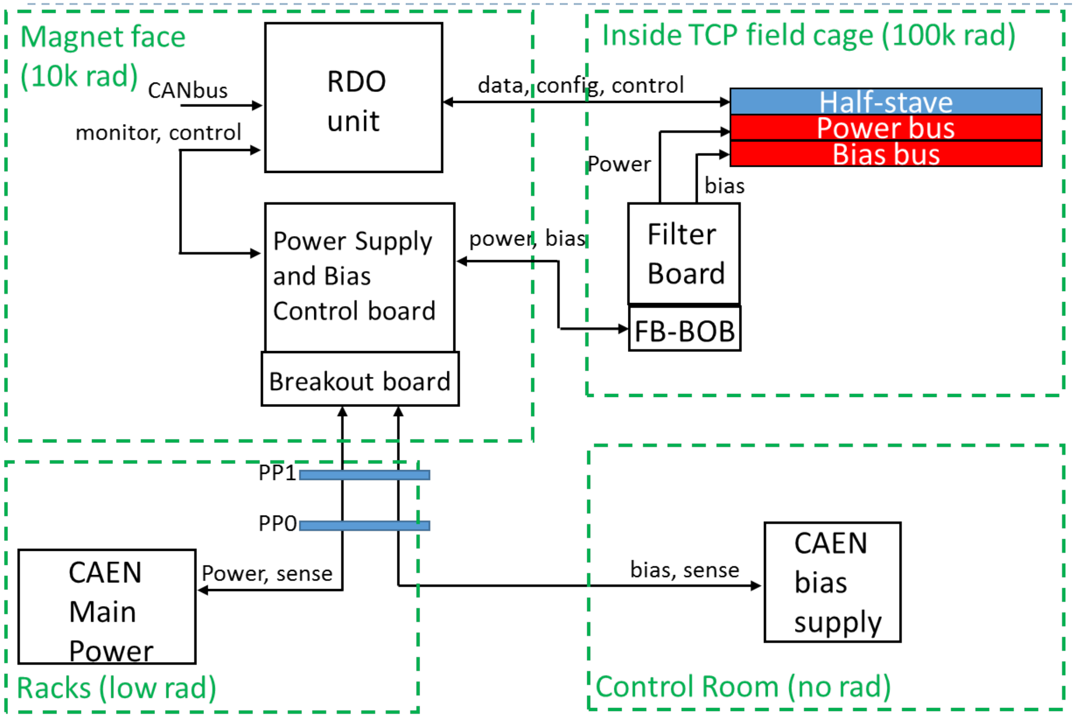


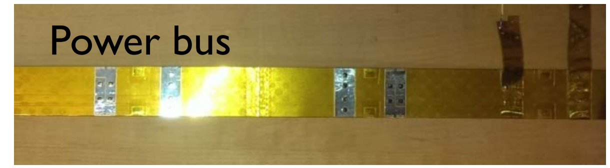
2 Outer Layers

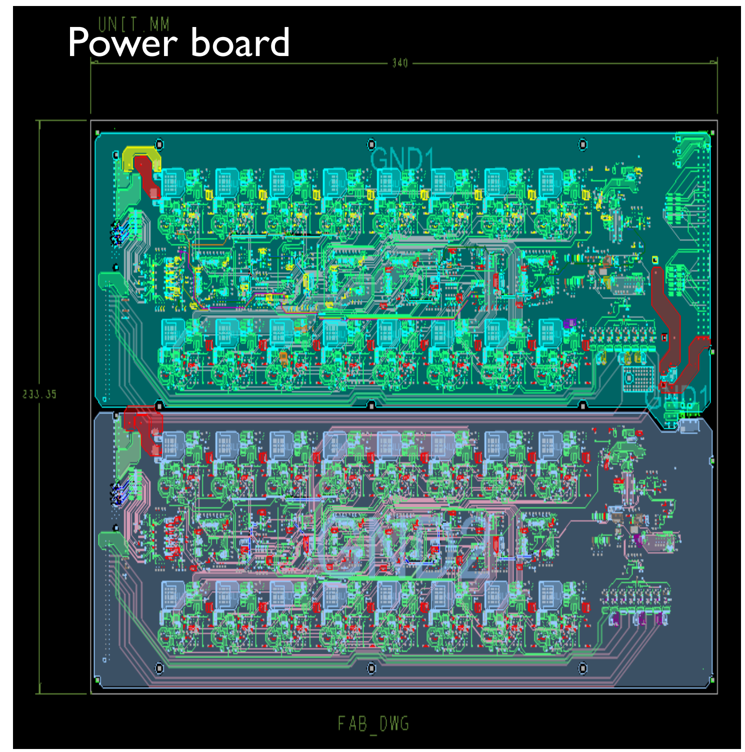


Stave

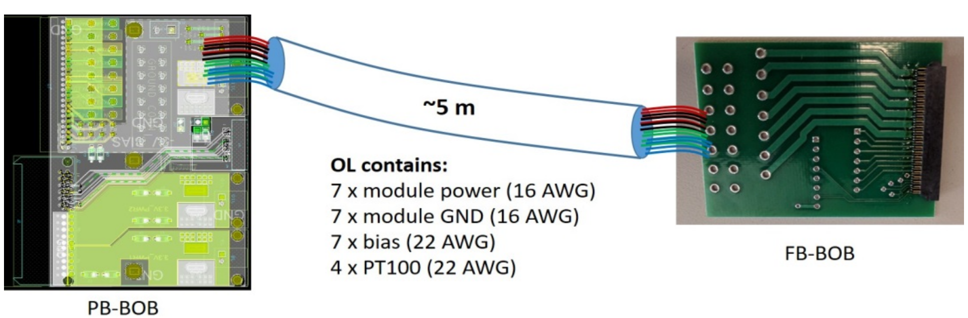
ITS Upgrade @ LBL - Power System







Break-out Boards and Cables



Other activities:

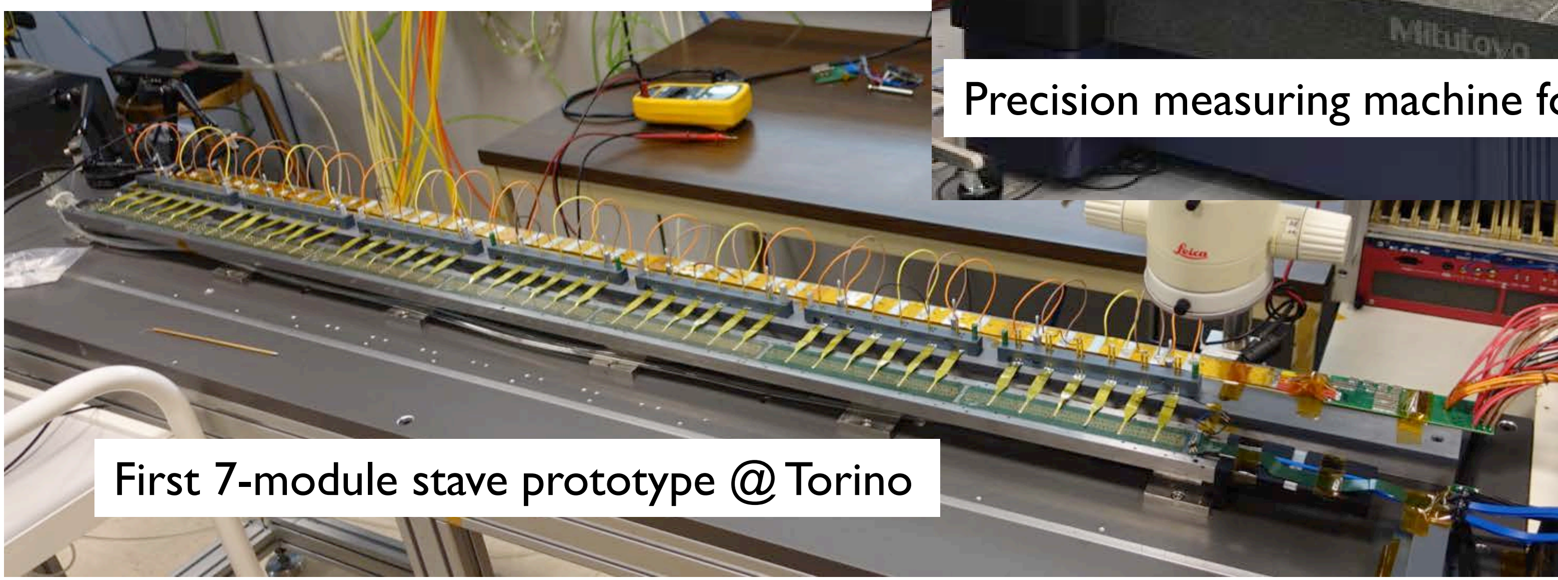
- Irradiation tests for components
- SEL, SEU tests for ALPIDE

ITS Upgrade @ LBL - Stave Assembly

ALICE

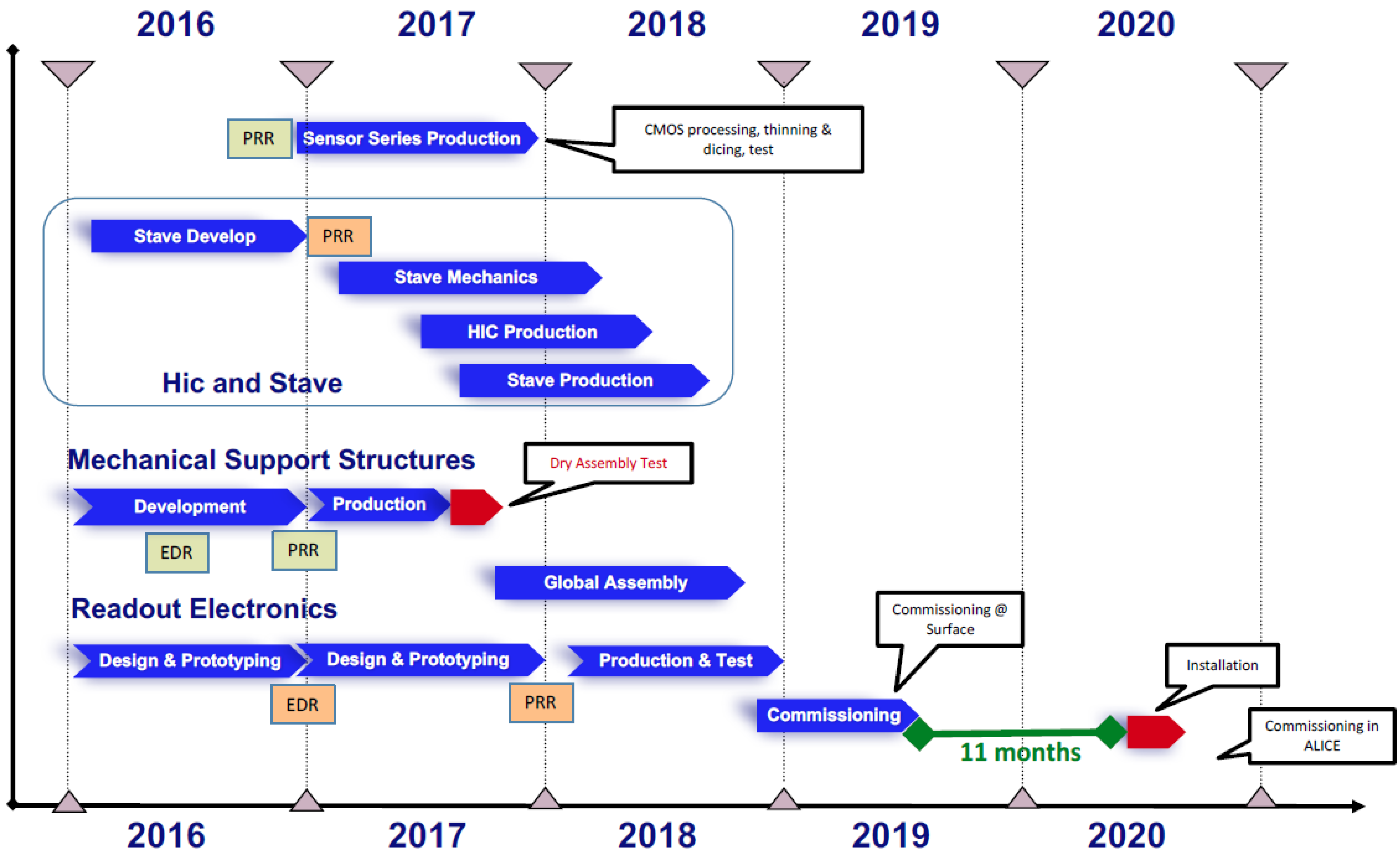
- Middle Layer Staves
  - 54 staves to assemble:
    - Modules + space frame + cooling plate + power bus
  - 1 stave = 2 half-staves * 4 modules
  - Starting soon

Precision measuring machine for assembly



First 7-module stave prototype @ Torino

ITS Upgrade Current Schedule

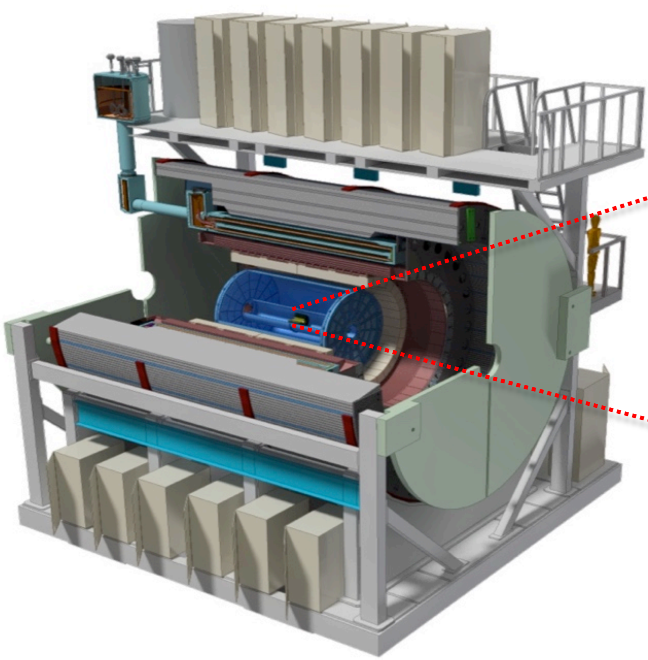


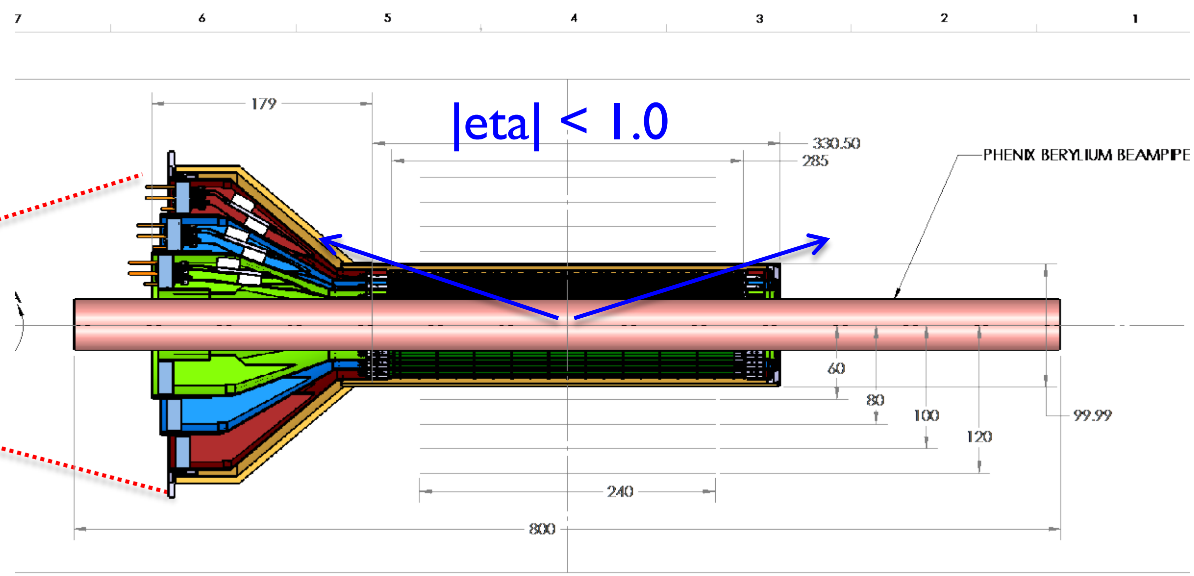
ITS Upgrade Talk @ QuarkMatter17, February '17

@RHIC: MAPS Vertex Detector (MVTX) for sPHENIX

sPHENIX: next-generation heavy-ion experiment on jets and Upsilons at RHIC
- detailed in NSAC long range plan 2015
- received first approval in Sept. 2016, inner tracker detectors not included in the baseline

MVTX brings new **heavy flavor** physics program to sPHENIX
- open bottom production at mid-rapidity over a broad momentum at RHIC





R = 2.3, 3.1, 3.8cm
L = 27.1cm

Physics-driven Detector Requirements

Physics goal: Access and study open bottom physics at RHIC

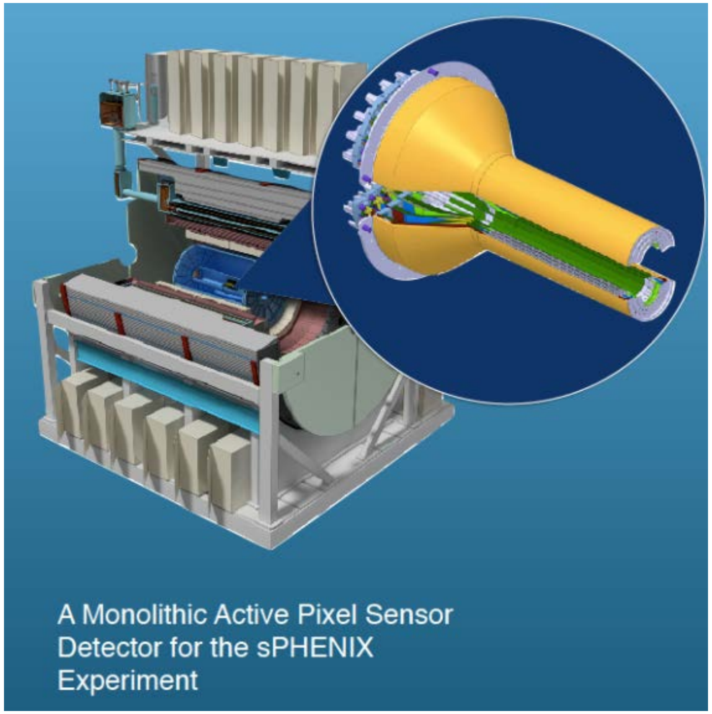
↓

Design goals: Reduce background hits, improve tracking efficiency

↓

Item	Requirements
Acceptance	Vertex $|z| < 10$ cm, $|\eta| < 1$, full azimuthal coverage
Event rate	Matching the sPHENIX DAQ rate of 15 kHz event rate
DCA resolution	< 50 μm for charged pions at $p_T = 1$ GeV/c
Tracking efficiency	> 60% efficiency for charged pions at $p_T = 1$ GeV/c in central Au+Au collisions

sPHENIX MVTX Proposal



- Technology choice: **MAPS**
  - ALPIDE sensor meets the requirements for MVTX
  - Int. time <20μs, ~28μm pitch, pow. diss. 40mW/cm^2
- Detector layout based on: **ITS Inner Barrel**
- **Leverage the ITS Upgrade R&D for:**
  - Sensor design and production
  - Inner Barrel and Mechanics layout
  - Stave production & test
  - Power system design
  - Readout Units design
- **Specific R&D - Fabrication - Assembly for MVTX**
  - Develop data aggregation/formatting/DAQ interface
  - Adapt and integrate carbon fiber structures design, and fabricate
  - Adapt and fabricate Power System and Readout Units
  - Assemble the detector and integrate in sPHENIX

Proposed MVTX Tasks and Timeline

FY2016 FY2017 FY2018 FY2019 FY2020 FY2021 FY2022

sPHENIX baseline

CD-0 9/2016

CD-1

CD-2/3

Ready for Beam

ALICE ITS/IB Production

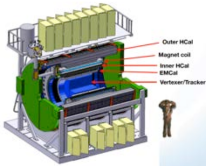
Key R&D

Readout R&D
Mechanics design

Mechanics
Integration
& Prototyping

Production

MAPS Prod. & QA By ALICE @CERN → IB Stave prod.&test @CERN; RU/CRU Prod. @US Carbon Structures @US → Detector Assembly & Test @LBNL → Installation @BNL



+2%

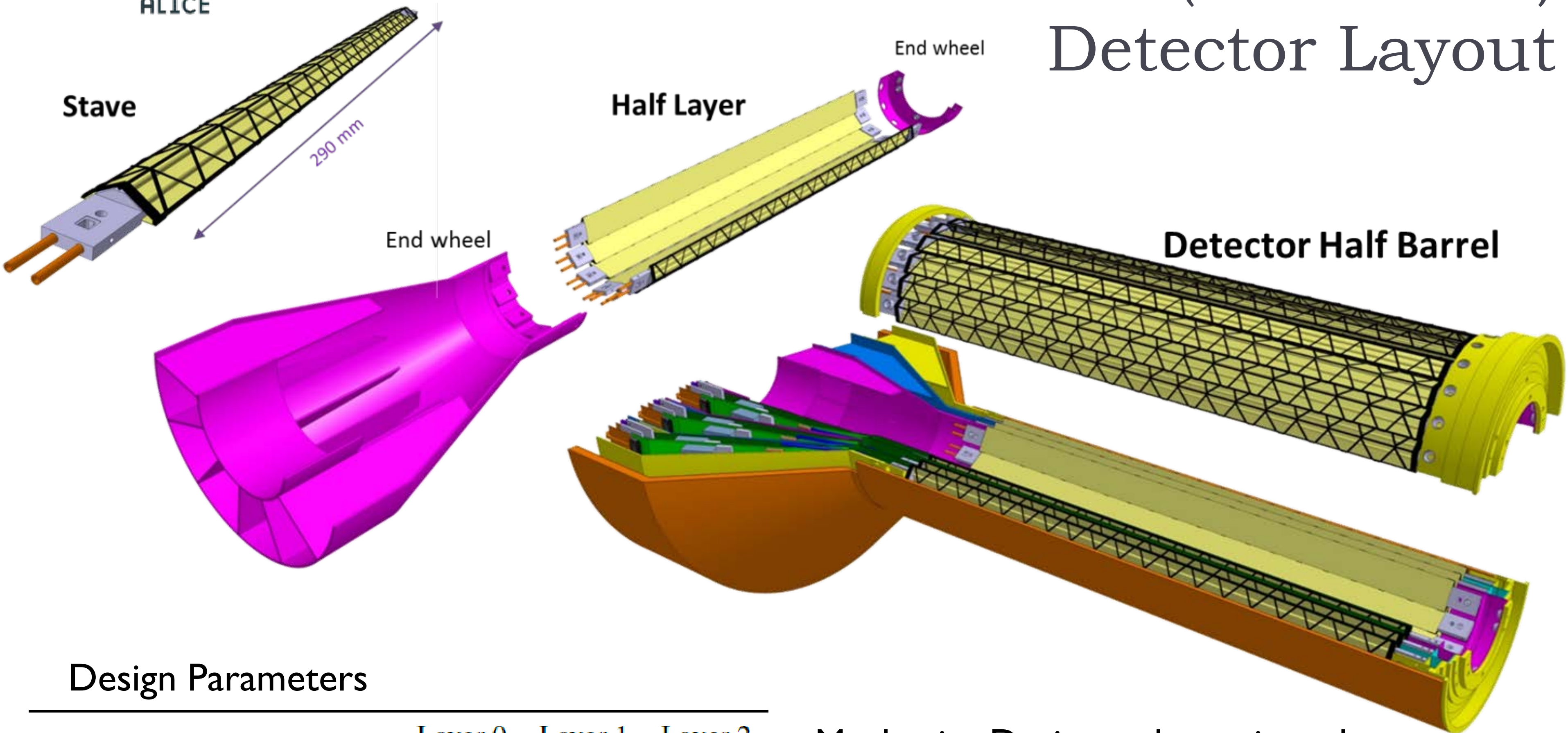
+50%

Aim to produce the staves following the ALICE production at CERN

- Produce MAPS chips and Stave Space frames for sPHENIX as part of ALICE production

…*from:* ALICE

MVTX (and ITS IB) Detector Layout



Design Parameters

	Layer 0	Layer 1	Layer 2
Radial position (min.) (mm)	22.4	30.1	37.8
Radial position (max.) (mm)	26.7	34.6	42.1
Length (sensitive area) (mm)	271	271	271
Active area (cm^2)	421	562	702
Number of pixel chips	108	144	180
Number of staves	12	16	20

Mechanics Design to be reviewed:

- Beam pipe clearance: 1.5 mm
  - sPHENIX Beam pipe radius: 20.9mm (ALICE: 19mm)
  - Innermost layer min. radius: 22.4 mm
- ITS Service barrel length: 2700 mm

Conclusions

- STAR PXL, first generation MAPS-based detector at a collider experiment, successfully completed the 3-year physics program at RHIC
  - Performance met design requirement, access open charm physics
  - 2013 Engineering Run, "permanent" construction phase, short duration program

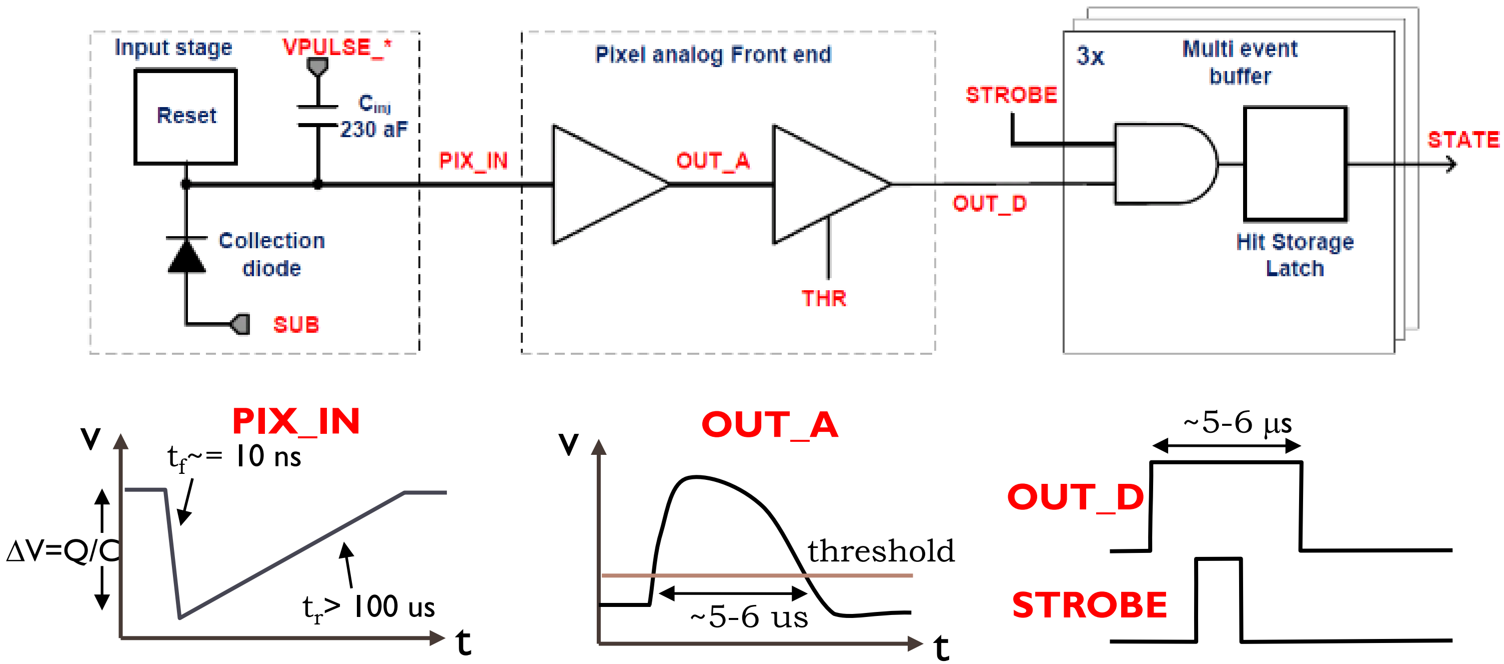
- MAPS technology proved to be suitable for vertex detector applications

- Next-generation MAPS sensor: ALPIDE
  - Shorter (x10) integration time
  - Higher radiation tolerance

- Next-generation MAPS-based vertex detectors:
  - ALICE ITS Upgrade @LHC *(now entering the production phase)*
  - sPHENIX MVTX @RHIC *(recently proposed)*
    - Reduced background hits, improved tracking efficiency → open bottom physics

Thank you for your attention!

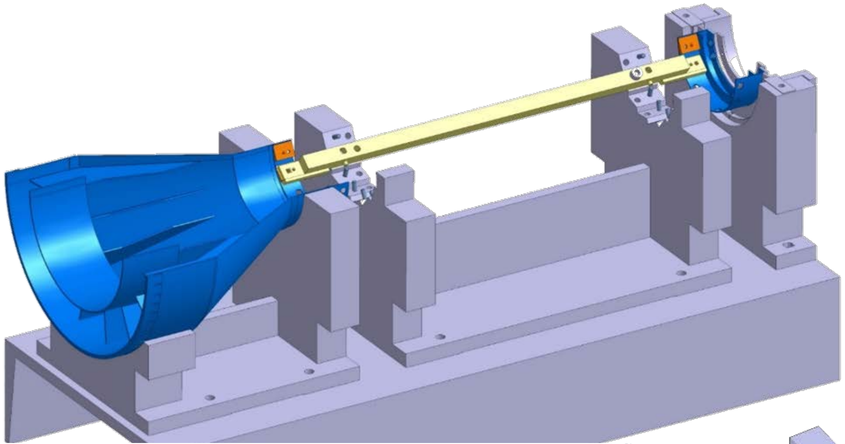
Pixel Architecture

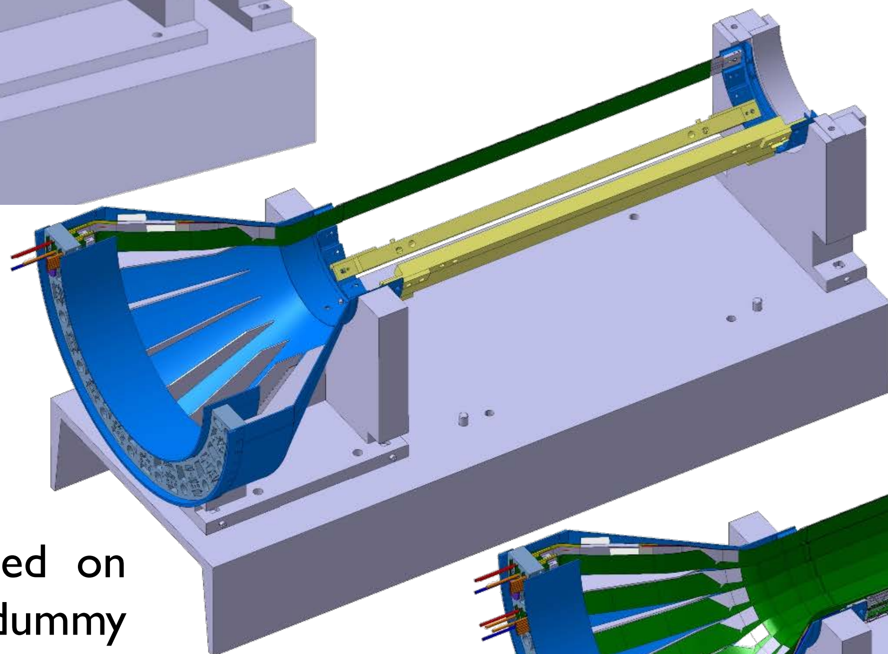


BERKELEY LAB Lawrence Berkeley National Laboratory

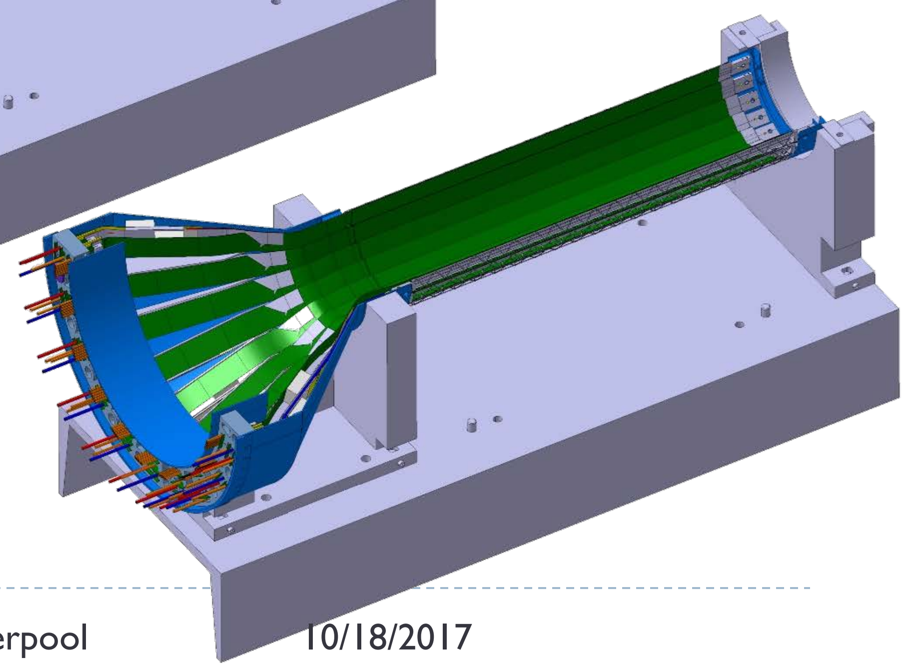
Stave assembly on the end-wheels

…*from:* ALICE





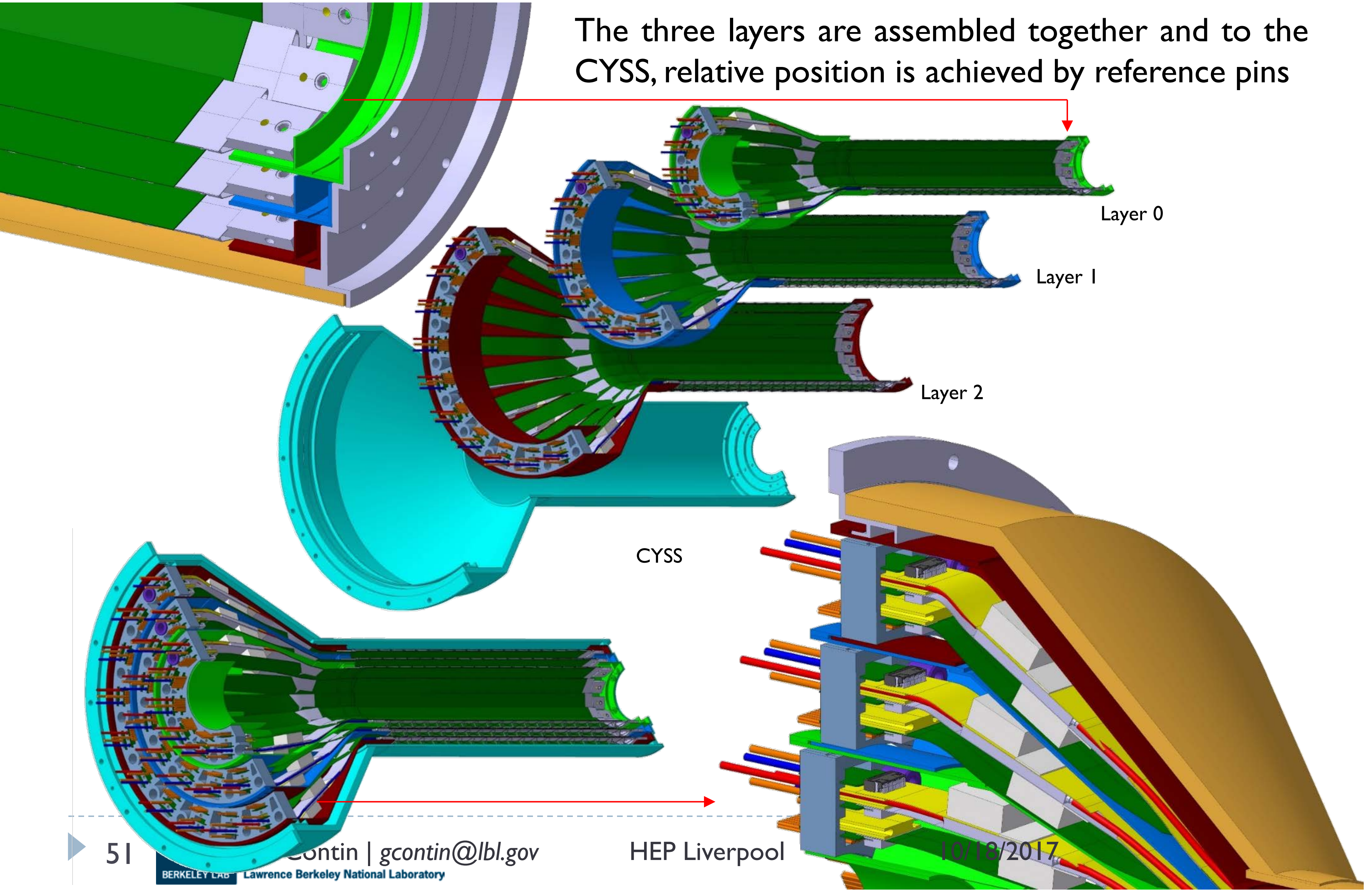
Ruby pads are glued to the EW by devoted jigs and dummy staves



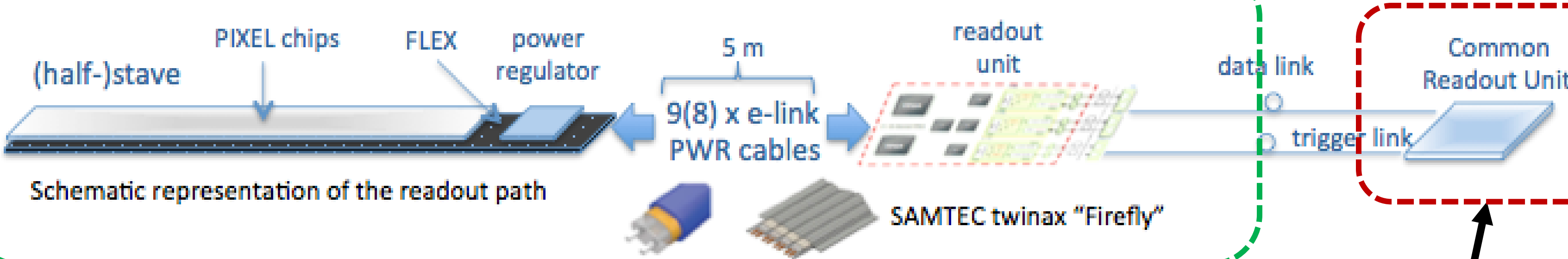
Staves are installed on the EW while dummy stave are removed

Layers assembly into Half-Barrel

The three layers are assembled together and to the CYSS, relative position is achieved by reference pins



Plans for MVTX Readout



Schematic representation of the readout path

From ITS

- Common Readout Unit options:
  - ALICE CRU
  - ATLAS FELIX
- Functionalities:
  - Data aggregation
  - Data formatting
  - Interfacing to RHIC triggering and clock
  - Interfacing to RHIC control
  - DAQ interface