Mighty Tracker: Latest news from MightyPix and milestones for 2024-26

Eva Vilella
On behalf of many people…
(see next slide)

4th Mighty Tracker Workshop at Liverpool

2–4 Jul 2024
126 Mount Pleasant, Lecture Theatre 113
Europe/London timezone

https://indico.cern.ch/event/1403159/overview

- Overview
- Timetable
- Contribution List
- Registration
- Participant List
- Videoconference

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The workshop will be held at Liverpool

It will start on **Tuesday 2nd July** in the morning and will end on **Thursday 4th July** in the afternoon.

The workshop will be held **in-person on the University campus in the Liverpool city centre**. The room is **Lecture Theatre 113 at 126 Mount Pleasant** (map). Remote attendance (via zoom) will be arranged for those who cannot travel, but attendance in person is highly encouraged.

Registration is now open with deadline of 23rd June. You are kindly asked to register quickly and indicate whether you will be attending in person.

A workshop dinner will be held on Wednesday 3rd. Participants are expected to pay directly for their dinner. Further information will be provided at a later date.

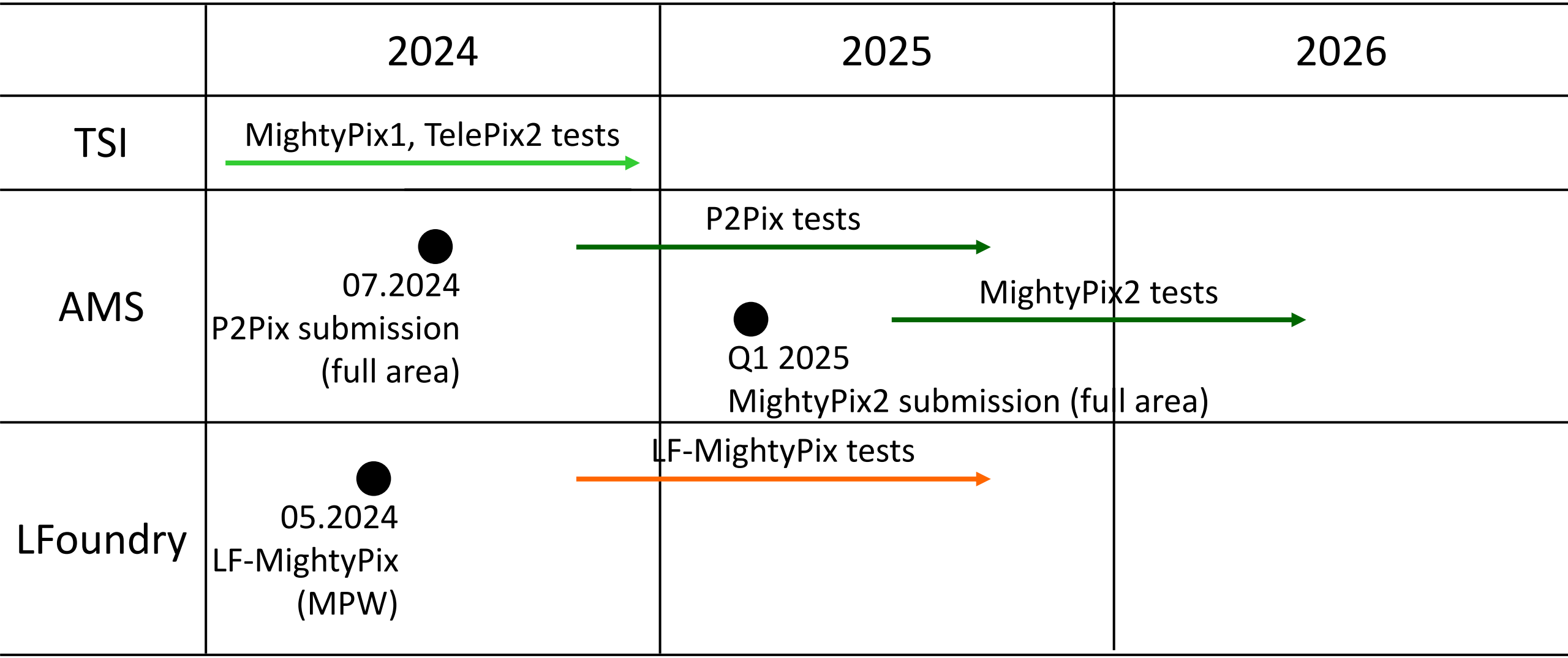
There is no registration fee, but registration is required for everyone attending to determine the number of participants (size of the room) and participation to the workshop dinner.

Travel to Liverpool

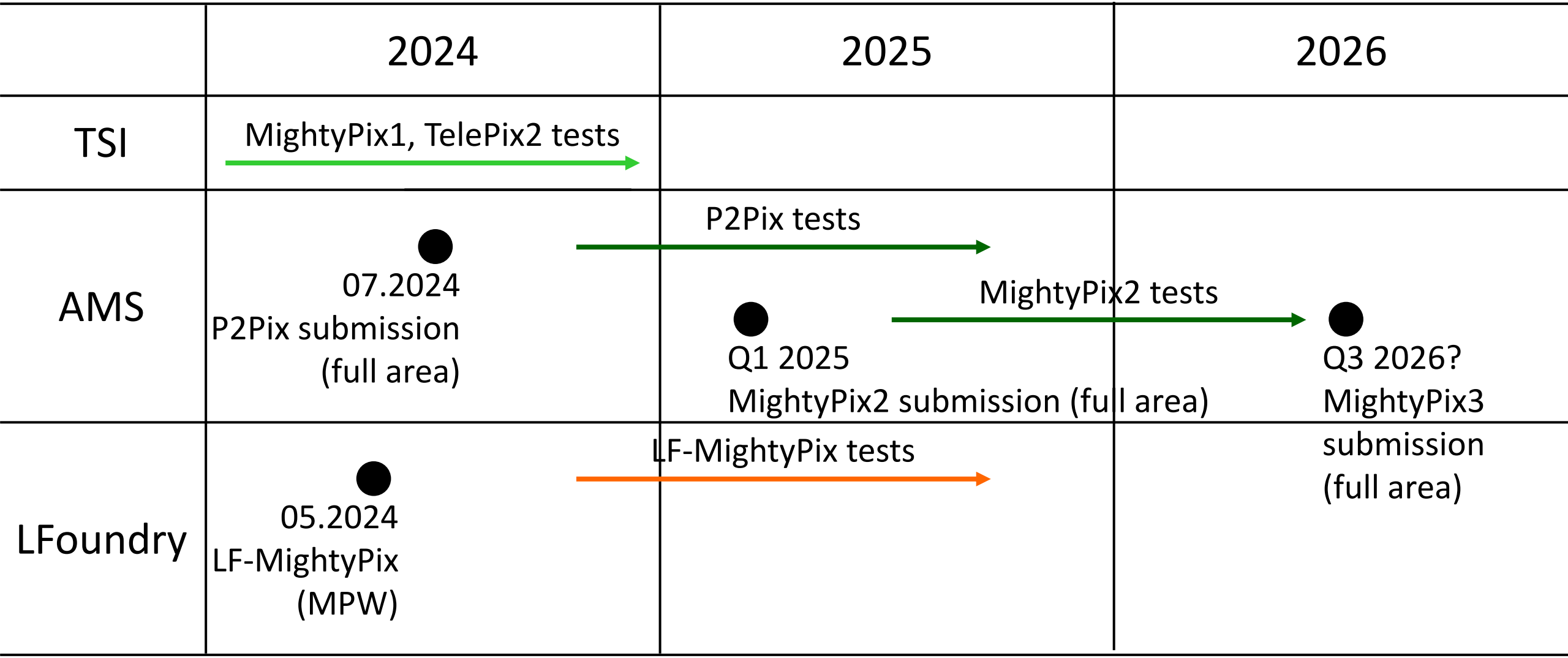
By train

Material that I will show today taken from last week's workshop… Many thanks to everybody who prepared slides

Timeline


2024
2025
2026
TSI
MightyPix1, TelePix2 tests
AMS
07.2024
P2Pix submission
(full area)
P2Pix tests
MightyPix2 tests
Q1 2025
MightyPix2 submission (full area)
LFoundry
05.2024
LF-MightyPix
(MPW)
LF-MightyPix tests

Timeline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MightyPix2 submission (full area)
MightyPix2 tests
Q3 2026?
MightyPix3
submission
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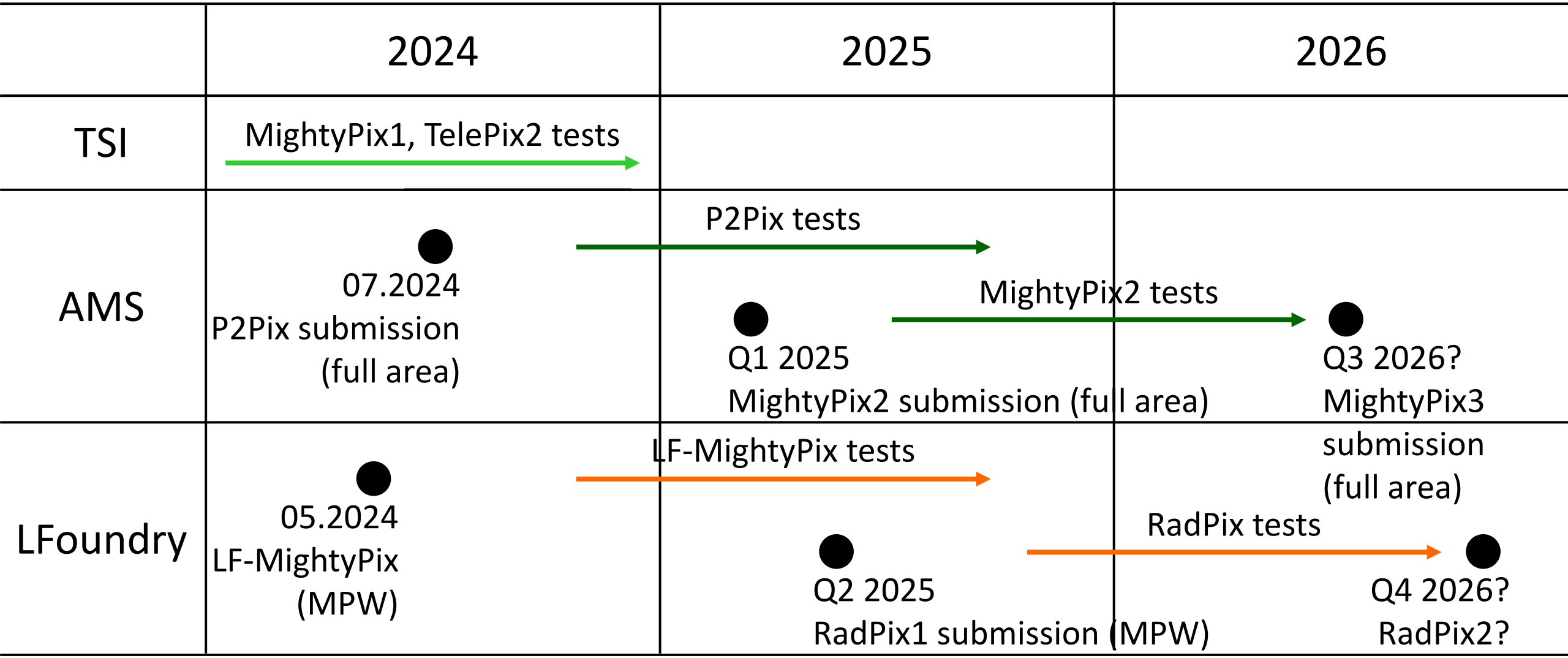
LFoundry
05.2024
LF-MightyPix
(MPW)
LF-MightyPix tests

Timeline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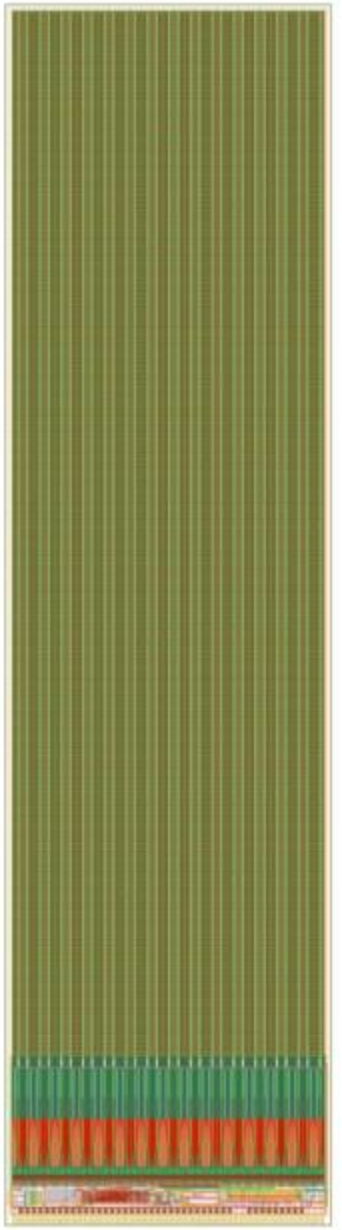
05.2024
LF-MightyPix
(MPW)
LF-MightyPix tests
Q2 2025
RadPix1 submission (MPW)
RadPix tests
Q4 2026?
RadPix2?

MightyPix specifications

Pixel size	< 100 µm x 300 µm
Efficiency	> 99.99%
Timing resolution	~ 3 ns
In-time efficiency	> 99% within 25 ns window
Radiation tolerance	$3x10^{14}$ 1 MeV n_{eq}/cm^2 (NIEL) & 40 MRad (TID)
Power	< 150 mW/cm^2
Data transmission	4 links of 1.28 Gb/s each
Compatibility with the LHCb readout system	

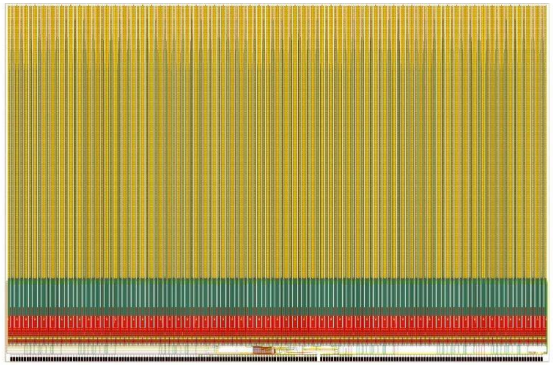
MightyPix1

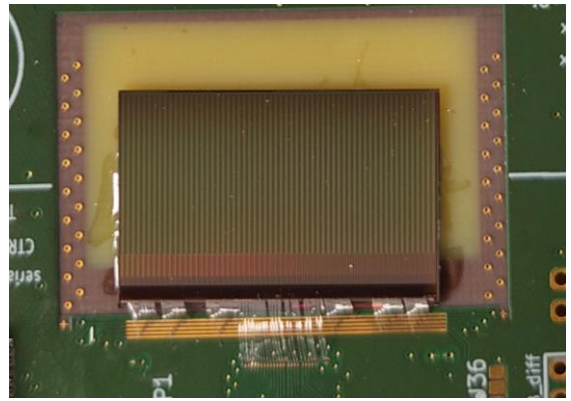
First HV-CMOS sensor chip dedicated to the Mighty Tracker	
Technology	TSI 180 nm
Chip size	0.5 cm x 2 cm (prototype size) ¼ of final MightyPix size → ¼ width, full column length
Pixel size	50 µm x 165 µm
Readout electronics	CMOS amplifier & CMOS comparator
First prototype compatible with LHCb readout system • Runs with LHC clock at 40 MHz • Uses lpGBT protocol • Meets TFC and ECS requirements	



TelePix2

HV-CMOS sensor chip for fast-timing beam telescope	
Technology	TSI 180 nm
Chip size	1.3 cm x 2 cm (prototype size)
Pixel size	25 µm x 165 µm
Readout electronics	CMOS amplifier & CMOS comparator (same as MightyPix1)
High digital power consumption (~1.5 W)	



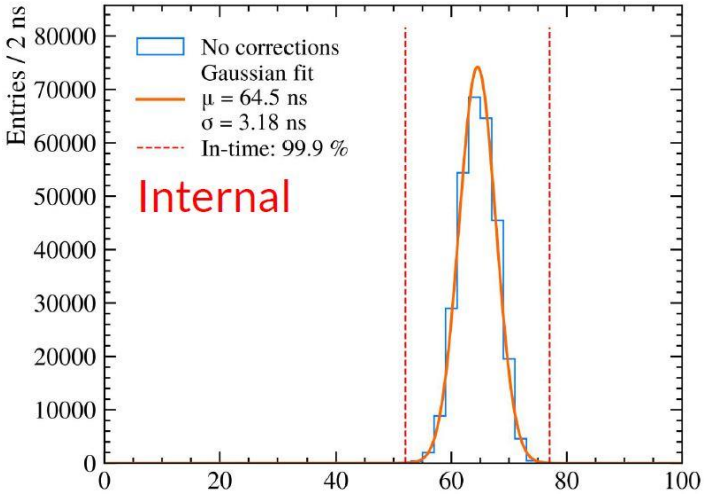


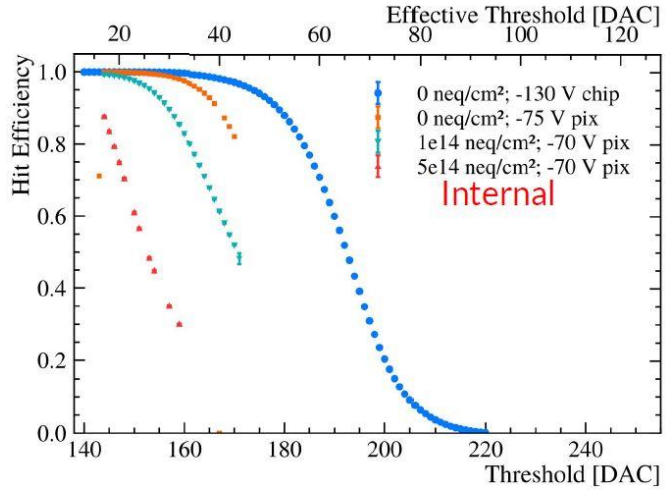
Evaluation

- **MightyPix1 lab measurements**
  - Time resolution fulfills specifications
  - Design mistakes already been corrected for LF-MightyPix
  - Trying to reproduce data rate simulations

See Mary's slides for nice pictures and plots

- **TelePix2 test beam in March**
  - Unirradiated → fulfills in-time efficiency without any corrections
  - Irradiated → high leakage current (insufficient cooling) limited HV biasing
  - Pixel rings were used for HV





- **TelePix2 'express' test beam in May**
  - Study HV-bias dependency
  - Unirradiated samples only

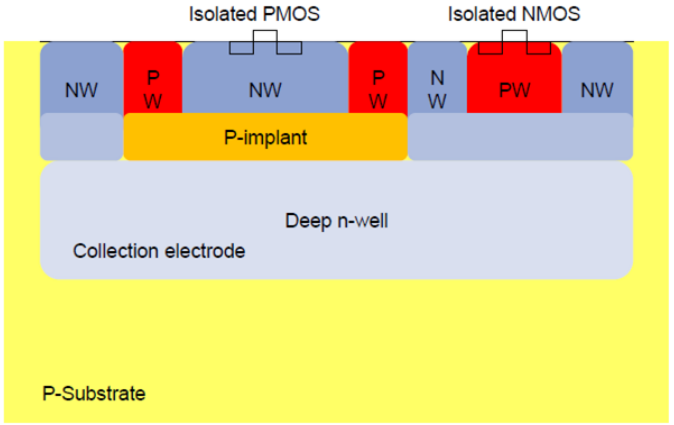
- **TelePix2 lab measurements**
  - TelePix2 and MightyPix1 have similar time resolution

Evaluation

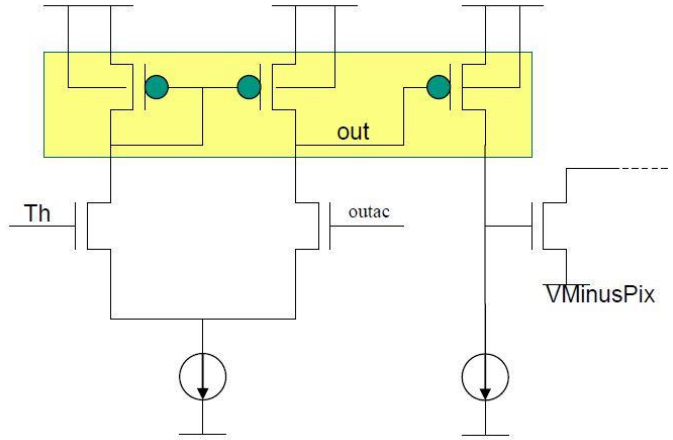
- **TelePix2 test beam in December (planned)**
  - Goal is to measure efficiency of irradiated TelePix2 at high HV-bias with proper cooling
  - Neutron irradiation (Ljubljana) → $1x10^{14}$, $5x10^{14}$ and $1x10^{15}$ 1 MeV n_{eq}/cm^2
  - Proton irradiation (Bonn) → $1x10^{12}$ → $1x10^{14}$ 1 MeV n_{eq}/cm^2

MightyPix2 – AMS design and submissions

- **TSI discontinued the 180 nm HV-CMOS process in 2023**
- **Alternative: TSI designs can be produce by AMS**
  - Small design translation
  - P2Pix submission to AMS in 07.2024, which LHCb can use to learn
  - P2Pix is based on TelePix and MuPix (similar to MightyPix, except for the digital periphery)
- **Issue: AMS cannot offer deep p-well layer on short notice**
  - Pixels cannot have CMOS comparator
  - P2Pix will be fabricated without p-implant
  - P2Pix will use nMOS comparator
  - Question if nMOS comparator is good enough for the Mighty Tracker (timing?)
  - It might be possible to have the p-implant in MightyPix2

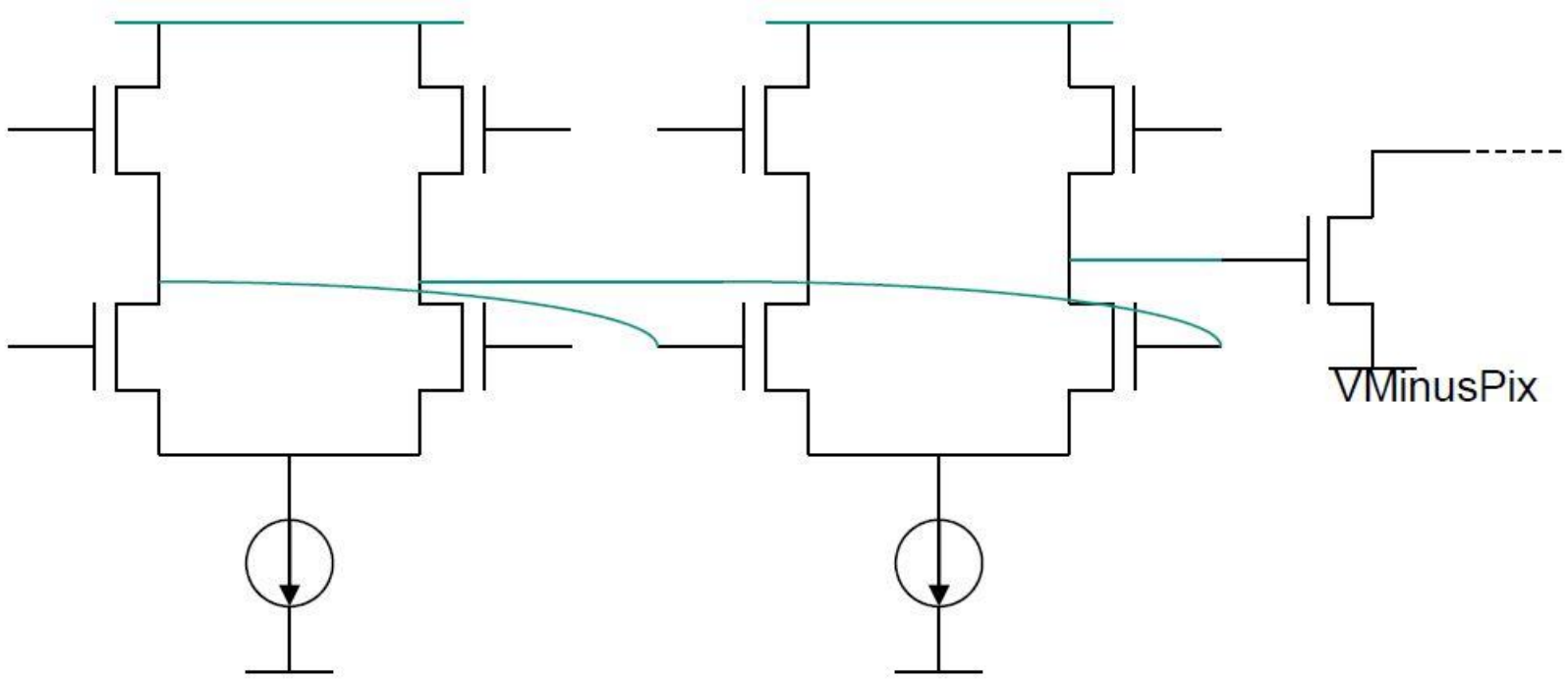


CMOS comparator



MightyPix2 – AMS design and submissions

- **nMOS comparator**
  - Used in previous chips (*e.g.* ATLASPix3)



MightyPix2 – AMS design and submissions

- **Simulated results – A comparative study**

	TW	MC @1.5k	Curr comp	Curr amp		Amplitude	C	ENC	T
CMOS	9.2ns	9n	2u	6u	84x84	1.8	182fF		0C
NMOS	**8.8ns**	**8.3n**	3.5u	6u	84x84	493m	215fF-8f		0C
Res	9.9ns	7.5n	3.5u	6u	84x84	580m	215fF+18f		0C
PMOS	8.6n	8.26n	3.5u	6u	84x84	800m	215fF-8f		0C
BigFast	18n	NN	2u	2x15u	200x200	1.8	374f-100f		0C
NMOS Optimized lay	**8.4ns**	**8.0n**	3.5u	6u	84x84	517mv	215fF-18f = 197fF		0C
PMOS with **1.8v** gate Optimized lay Vminus 730mV	8.3n (8.6n pfb)	**6.17n 6.12n* (840mV) 6.4n with pos fb**	3.5u	6u	84x84	800m	215fF-18f = 197fF		0C
Res optimized **1.8v**	**9n**	**6.6n**	3.5u	6u	84x84	545m 2.1 -520m	215+6f		0C

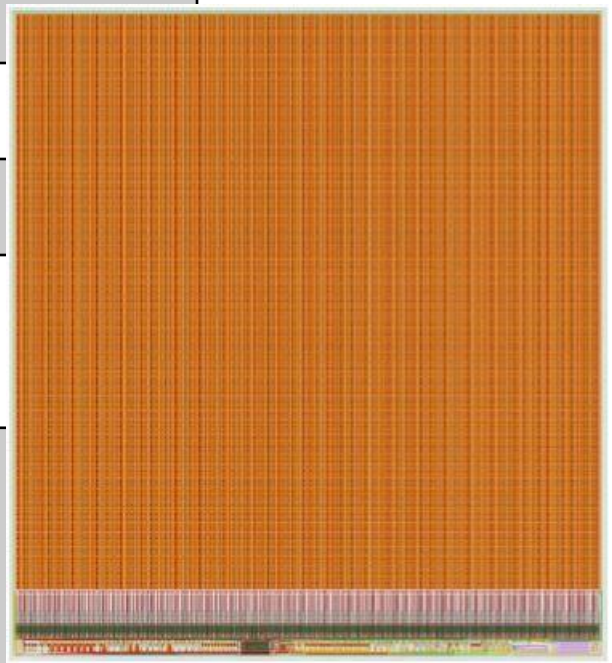
MightyPix2 – AMS design and submissions

- **Plans moving forward**
  - Test nMOS comparator in P2Pix
  - If results are good, suggestion to use nMOS comparator in MightyPix2
  - Even though if p-implant is possible with AMS, MightyPix2 might re-use circuits from P2Pix (including nMOS comparator) if they perform good enough in measurements

P2Pix

Production chip for P2 experiment in Mainz	
Technology	AMS 180 nm
Chip size	2 cm x 2.2 cm (production size)
Pixel size	84 µm x 84 µm
Readout electronics	CMOS amplifier & nMOS comparator

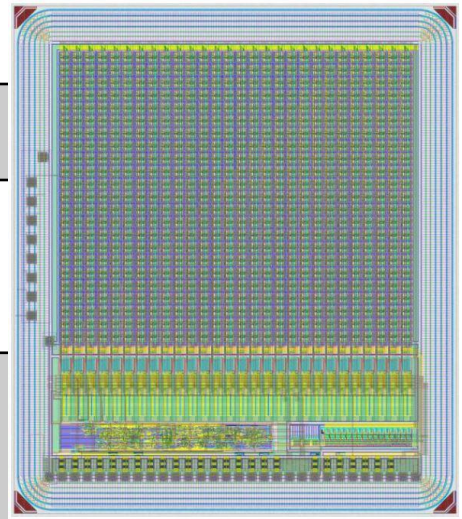
- MuPix based digital periphery (no lpGBT protocol or TFC & ECS commands either)
- Up to 2 ns timing resolution
- Use this chip to evaluate AMS performance before MightyPix2 subbmission



LF-MightyPix

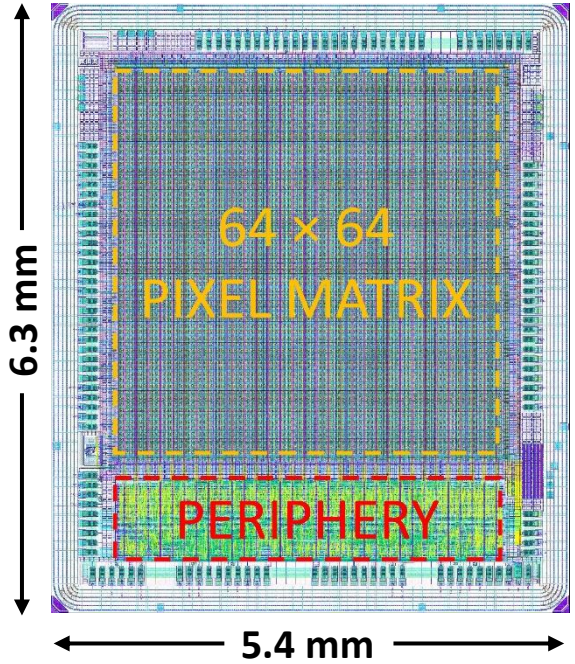
Test chip with improved LHCb digital periphery in backup technology	
Technology	LFoundry 150 nm
Chip size	4 mm x 3.5 mm (prototype size)
Pixel size	100 µm x 100 µm
Readout electronics	nMOS amplifier & CMOS comparator

- Runs with LHC clock at 40 MHz
- Uses lpGBT protocol
- Meets TFC and ECS requirements (improved TFC receiver)
- I2C for slow control
- Data transmission @ 1.28 Gbps/640 Mbps/320 Mbps
- Reduced hit data per hit from 64 to 48 bits
- Double Data Rate serialiser
- Chip ring from RD50



RD50-MPW4 – Design

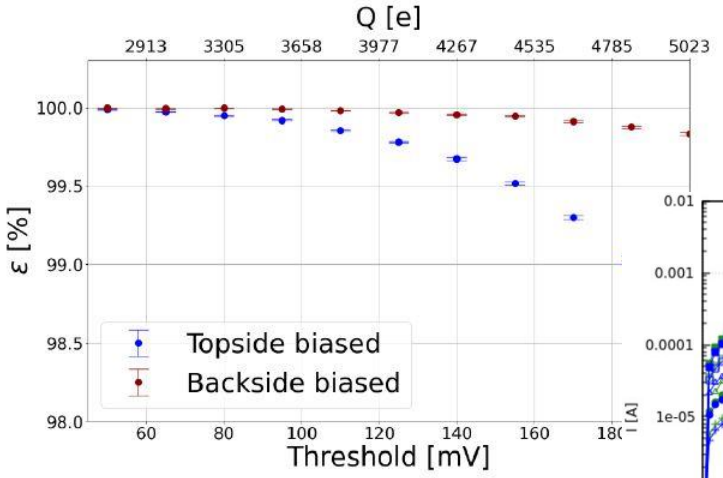
- **Significant improvements**
  - For high breakdown voltage and high radiation tolerance
  - Multiple ring structure around the chip edge
  - Substrate backside-biasing to high voltage
- **Fabrication details**
  - 150 nm High Voltage CMOS LFoundry (LF15A)
  - P-type substrate with nominal 3 kΩ·cm high resistivity
  - 280 µm thin
  - Backside processed via third party (Ion Beam Services)
- **Chip contents**
  - Pixel matrix with FE-I3 style readout
    - 64 x 64 pixels
    - 62 µm x 62 µm pixels with large collection electrode
  - Digital periphery (I2C slow control, data transmission)
  - Tests structures (e-TCT, DLTS)

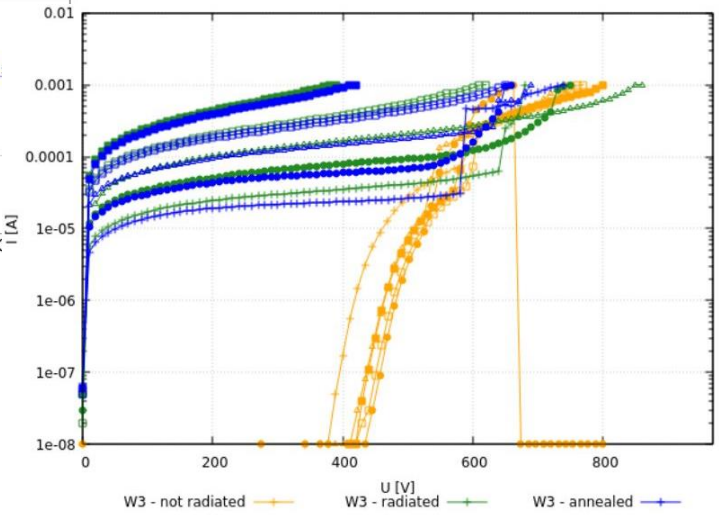


Chip delivered in Q1 2024
Evaluation is going very well

RD50-MPW4 - Evaluation

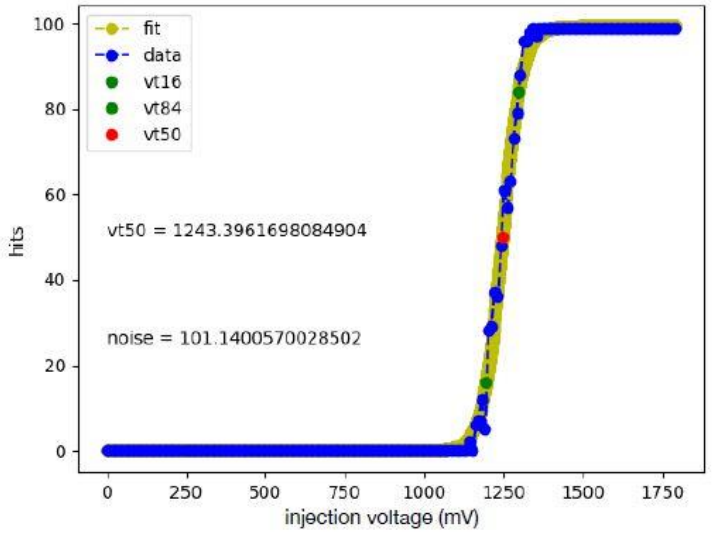
- **Test beam at DESY in April**
  - Unirradiated samples only
  - Topside and backside biased samples
  - High efficiency >99.99% achieved





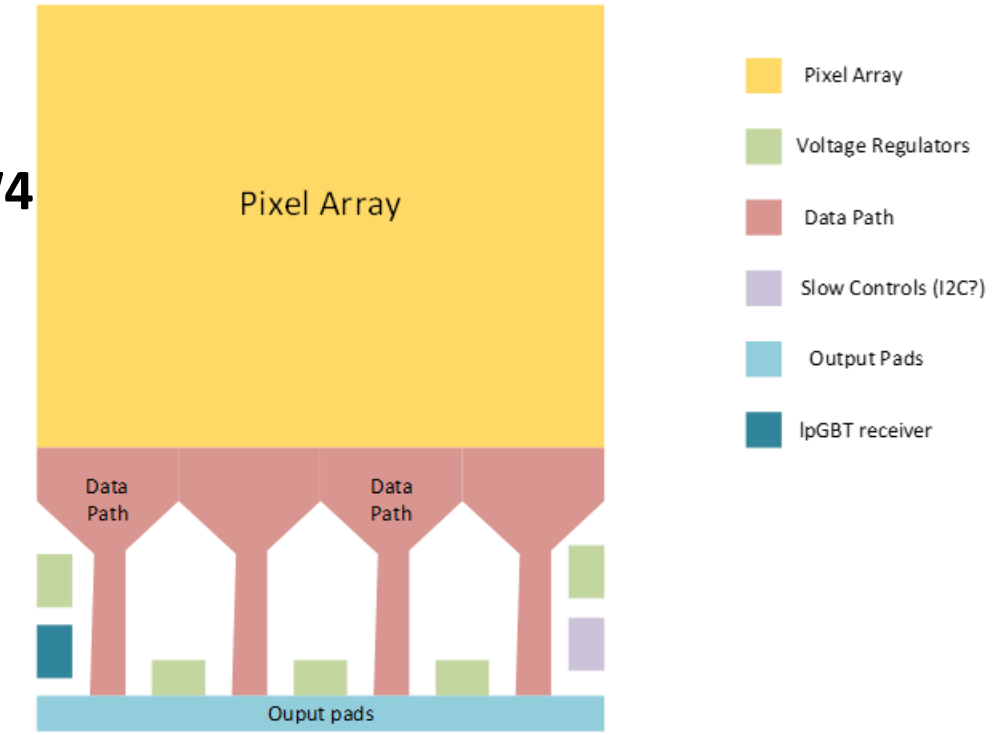
- **Irradiation campaign**
  - Neutron irradiation (Ljubljana) → $1x10^{14}$, $3x10^{14}$, $1x10^{15}$, $3x10^{15}$, $1x10^{16}$ and $3x10^{16}$ 1 MeV n_{eq}/cm^2
  - Samples can be biased to very high HV (room T)

- **Lab measurements with irradiated samples**
  - $3x10^{15}$ unprocessed sample (topside biasing only)
  - S-curve measurements show electronics are functioning
  - Test beam booked for September at DESY



From RD50-MPW4… to RadPix

- **UK designed HV-CMOS chip for LHCb**
  - Liverpool and RAL TD
- **Re-uses pixel matrix and chip rings from RD50-MPW4**
  - Attractive because designs are readily available and tested
  - Existing expertise
  - New pixel size (100 µm x 100 µm), meets LHCb specifications and will help reduce power consumption
  - Optimised front-end electronics (fast-timing, power consumption)
- **Re-uses digital periphery from LF-MightyPix1**
- **Integrate voltage regulators for serial powering**
  - Existing and tested IP blocks



Summary

- **New promising results towards meeting MightyPix specifications**
  - MightyPix1, TelePix2
- **New chips already submitted (or being submitted now)**
  - LF-MightyPix, P2Pix
- **Planned submissions**
  - MightyPix2, RadPix