Vertex Detector Discussion Meeting
6-7 May 2024, DESY
https://indico.desy.de/event/43834/

(probable) Other projects using TPSCo 65 nm

Jerome Baudot

- Expected TPSCo 65 nm submissions
- Experiments (with MAPS)
- Specifications
- DRD3 guess work

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TPSCo 65 nm submission plan

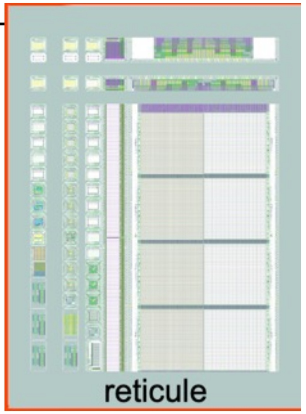
2024	2025	2026	2027	2028	2029	2030	2031

ER2 ER3 => ALICE/ITS3 { Significant R&D in previous MLR1 & ER1
Few R&D in ER2
None in ER3 (?)

MPR2 MPR3 … **<= R&D line 'supported' by CERN EP R&D WP 1.2**
under shared-budget model
but yet unclear decision making

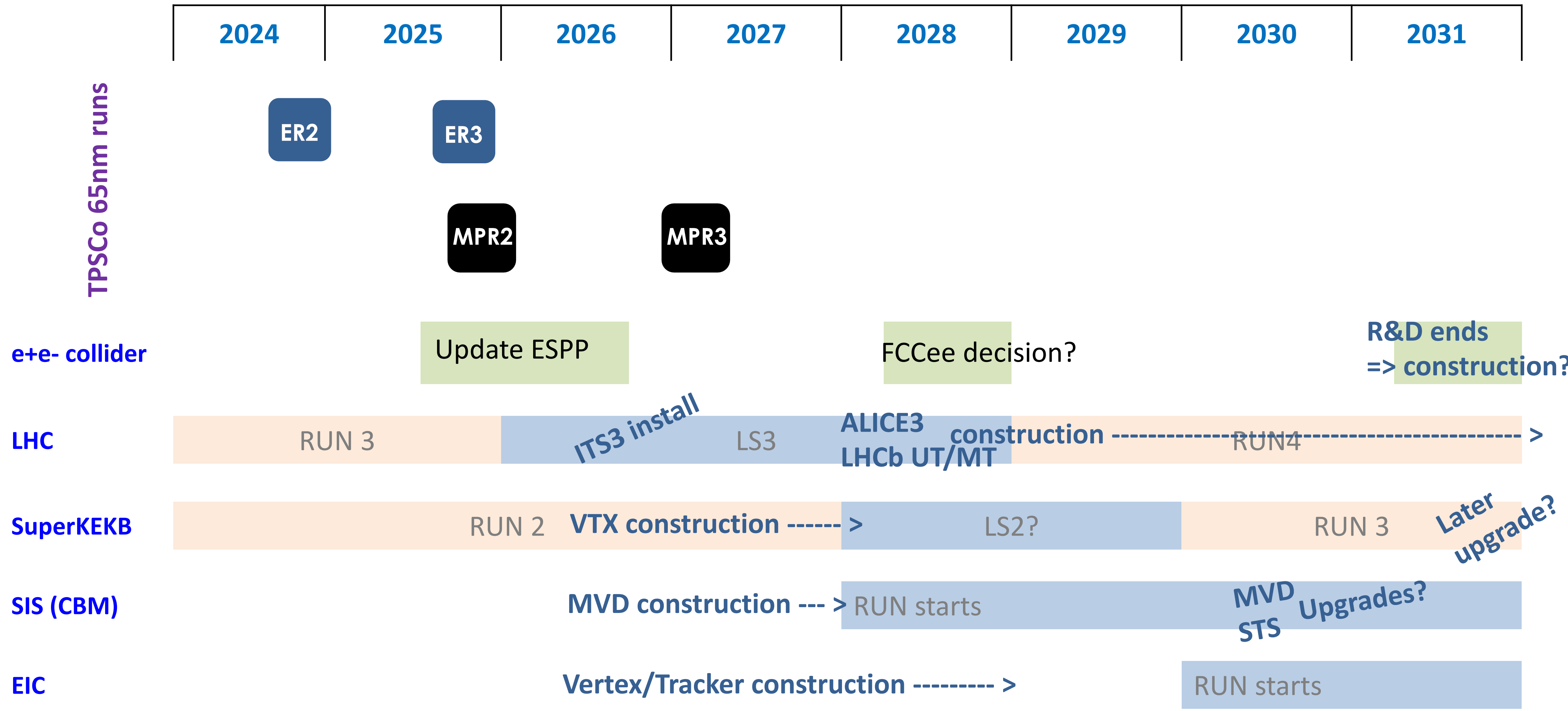
- MPR = Multi Project Run
- Maximal reticule size 32.5 x 25.5 mm^2 => allows
  - Chiplets (so far 1.5x1.5 mm2)
  - Stitched sensors
  - Large (mutli cm^2) prototypes

  => Combination under CERN control
  Through DRD7.6.a
- metal stack: 7+1 layers
- Process modification: possible but under CERN control
  - Through DRD7.6a



Perspective on experiments (with MAPS)

(Note: Mu3e not there)



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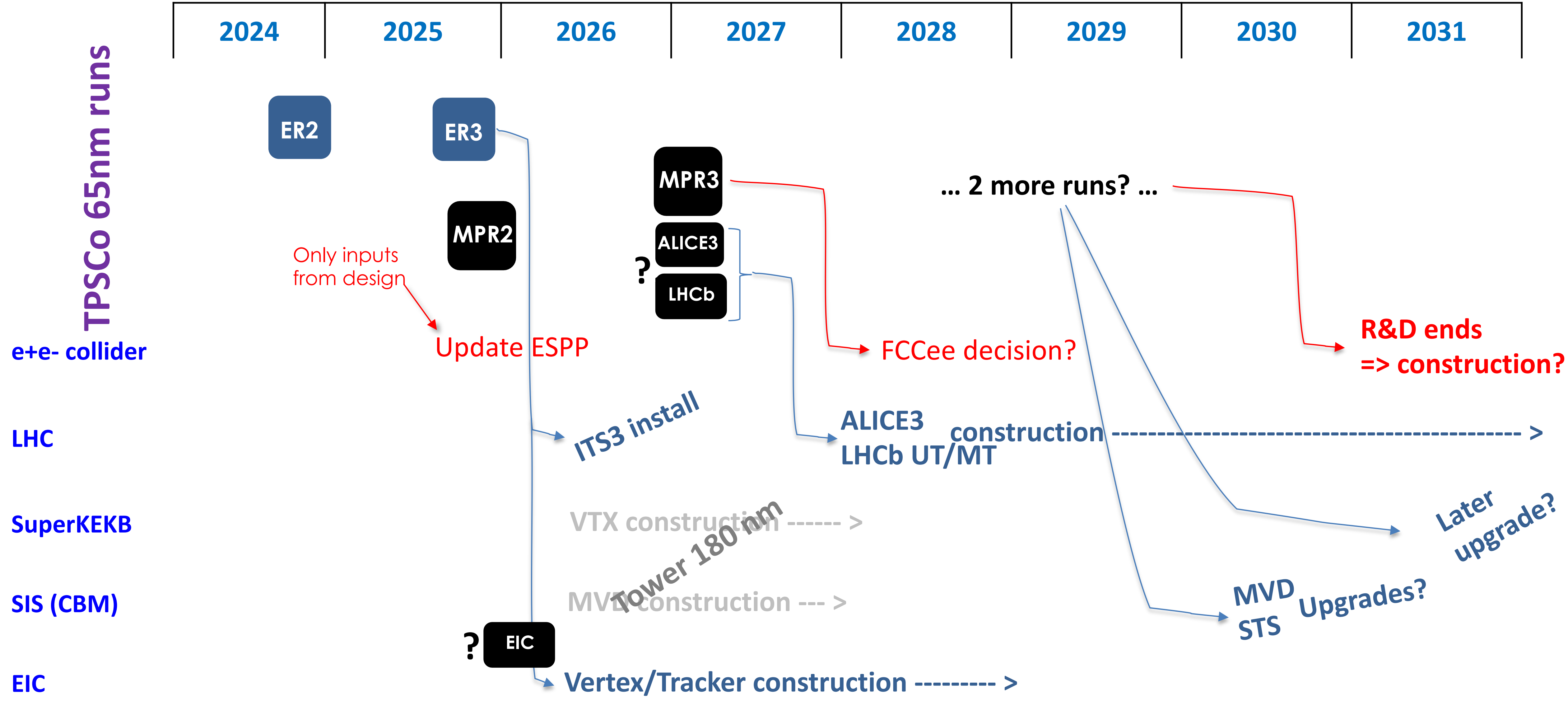


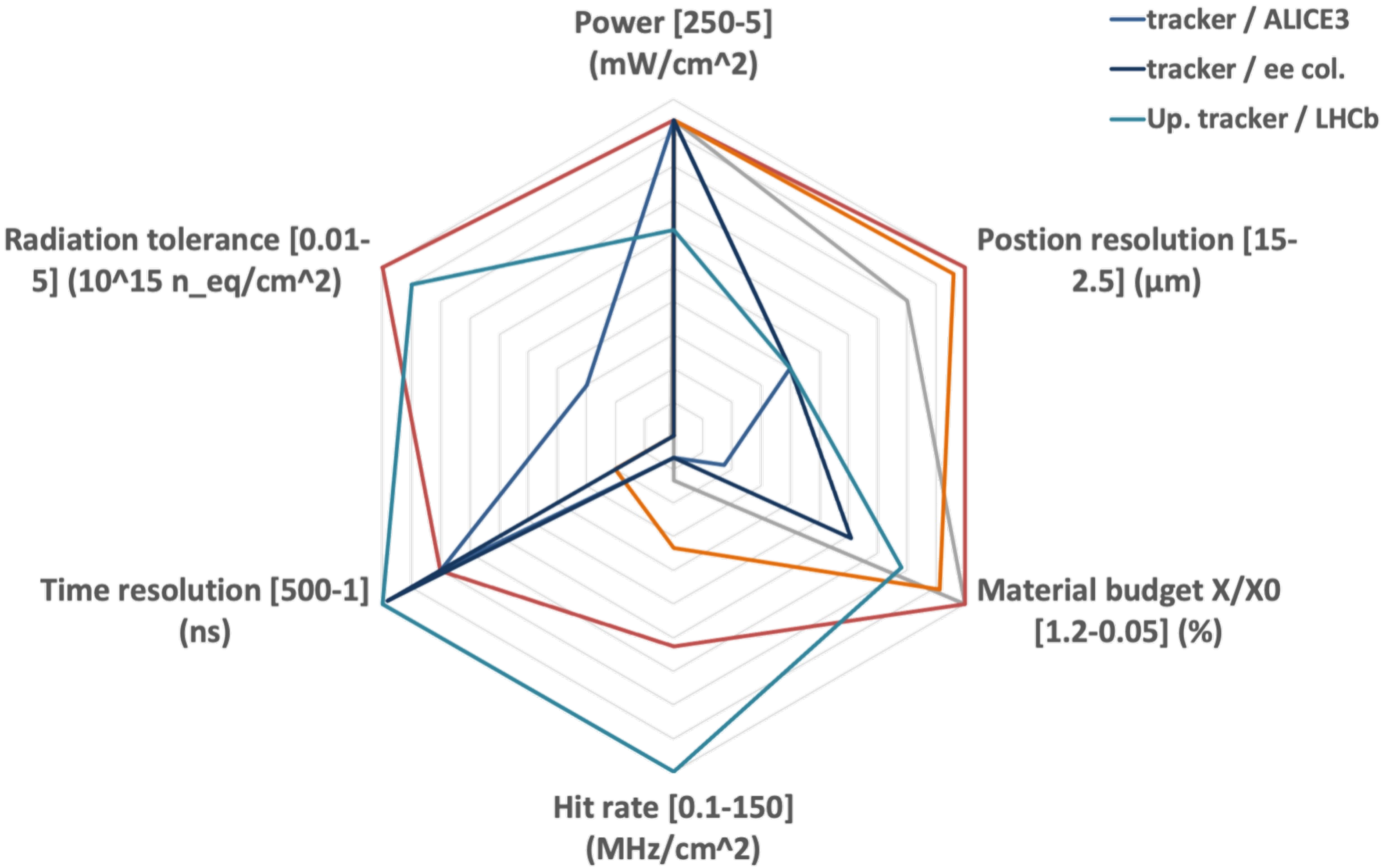
Specifications: numbers!

	CBM MVD	ALICE ITS3	Belle-II VXD	ALICE3 VTX	ALICE3 tacker	EIC tracker	LHCb UT	FCCee VTX	FCCee tracker
Sensor readiness	2026	2026	2026?	2030?	2027	2027?	2027	~2040	~2035
Total area (m^2)		10	1	0.15	5/57	?	4.5	~1	~50
Techno (nm)	TJ 180	TPSCo 65	TJ 180	TPSCo 65	TPSCo 65	TPSCo 65			
Spatial res. (µm)	**~5**	**~5**	< 10	**2.5**	10/10		O(10 µm)	**3**	~10
Pitch (µm)	27x29	22x22	<40x40	**10x10***	50x50		50x50	**15x15***	50x50
Mat. budget (%X0)	~0,3	**0.05**	**0.15**	**0.1**	1/1	0.05-0.55	<1	**0.15**	**<<1 ?**
Hit rate (MHz/cm²)	**15-70**	9	**100** triggered	**94**	1.7/0.06	?	**160** 20Gb/s	O(20)	<10
Time figure (ns)	5.10^3	5.10^3	~100	100	100/100	100 (?)	**O(1)**	10^2-10^3	10^2-10^3
Trigger rate (kHz)	-	-	30	-	-	500	-	-	-
Power (mW/cm²)	<100	**20 (matrix)**	200	70	**20/20**		100-300	**20**	50?
Rad.hard. (kGy) **(n_{eq}/cm²)**	30 /year < 10^{14} /y.	3 $3x10^{12}$	100 $5x10^{13}$	3000 **$10x10^{15}$**	50/2 10^{14}/5.6x 10^{12}	- 10^{15}	**2400** **$3x10^{15}$**	20 $5x10^{11}$	20 $5x10^{11}$
nb of layers			5-6	3	4/4	5 + 5d	3-4	3x2	
bunchX (ns)		25	4			10			

* Assuming binary output

Specifications: the graph

Pay attention to axis scales,
not very robust!



<= greyish: where we stand

<= reddish: vertex requirements

<= blueish: tracker requirements

Do we need as many sensors as experiment?

Specifications: the graph

Pay attention to axis scales,
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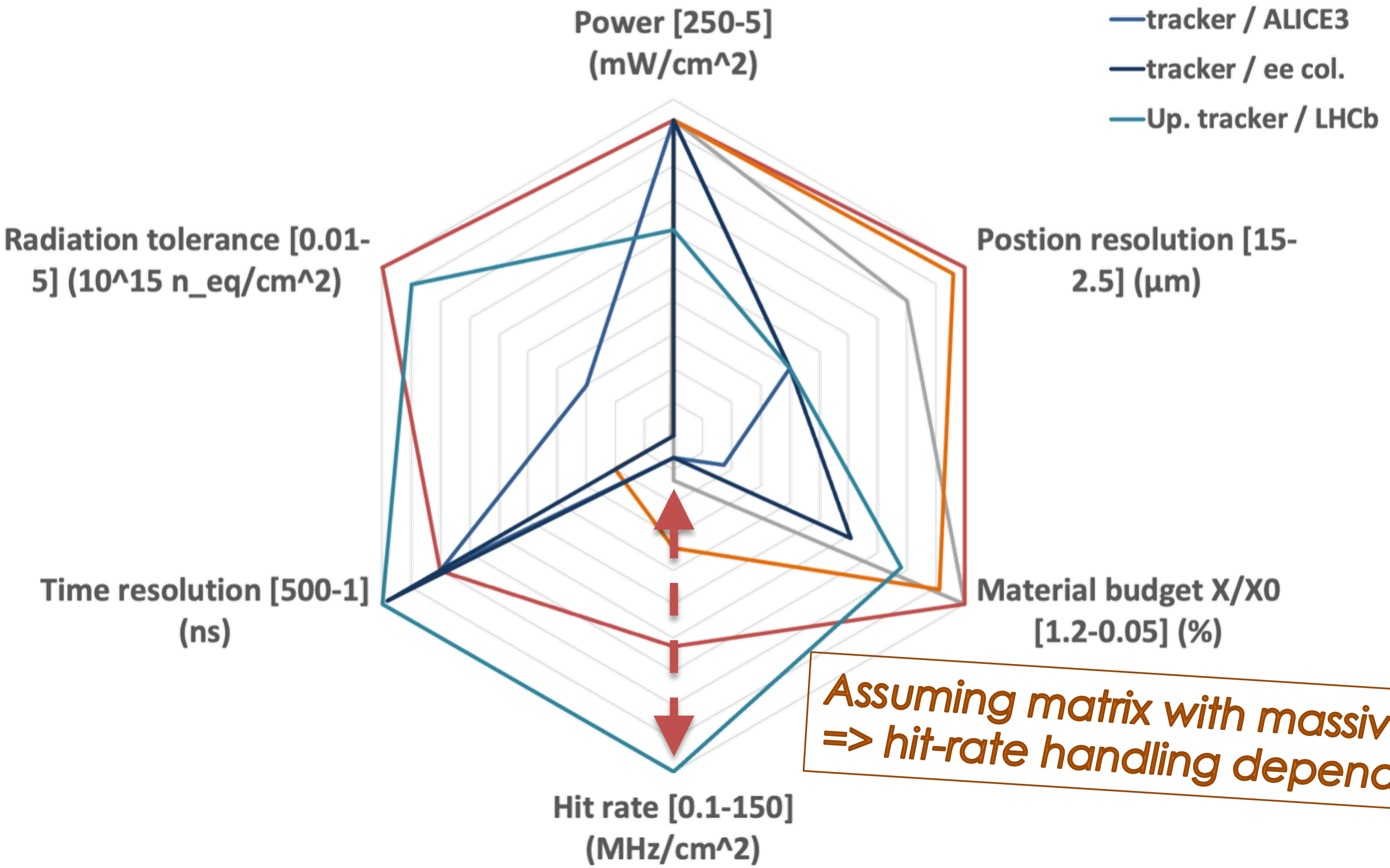

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Do we need as many ~~sensors~~ as experiment?
matrices

Assuming matrix with massive parallel read-out
=> hit-rate handling depends on periphery

Specifications: the graph

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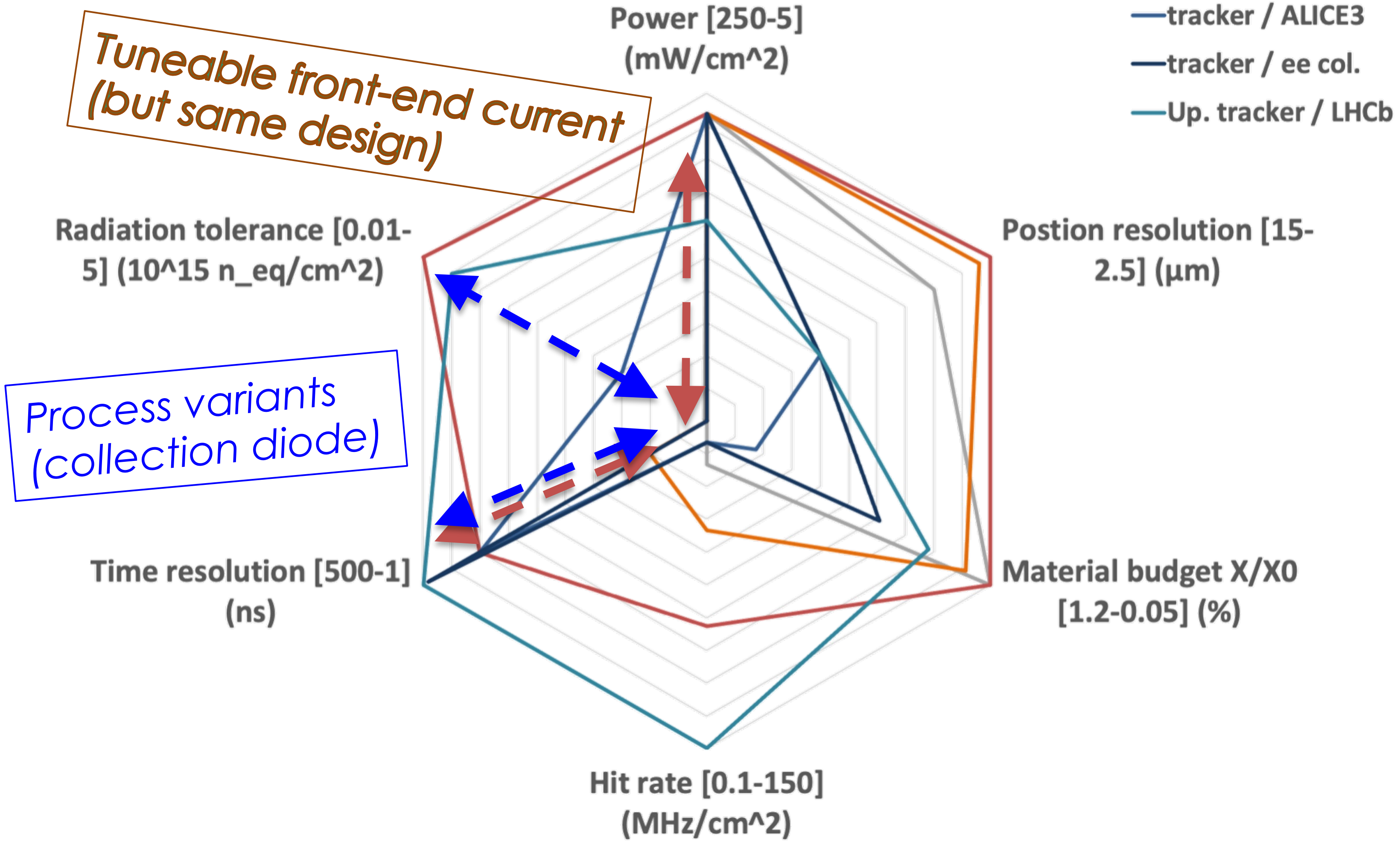

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Do we need as many ~~sensors~~ as experiment?
matrices
with tuneable front-end and process variants

Specifications: the graph

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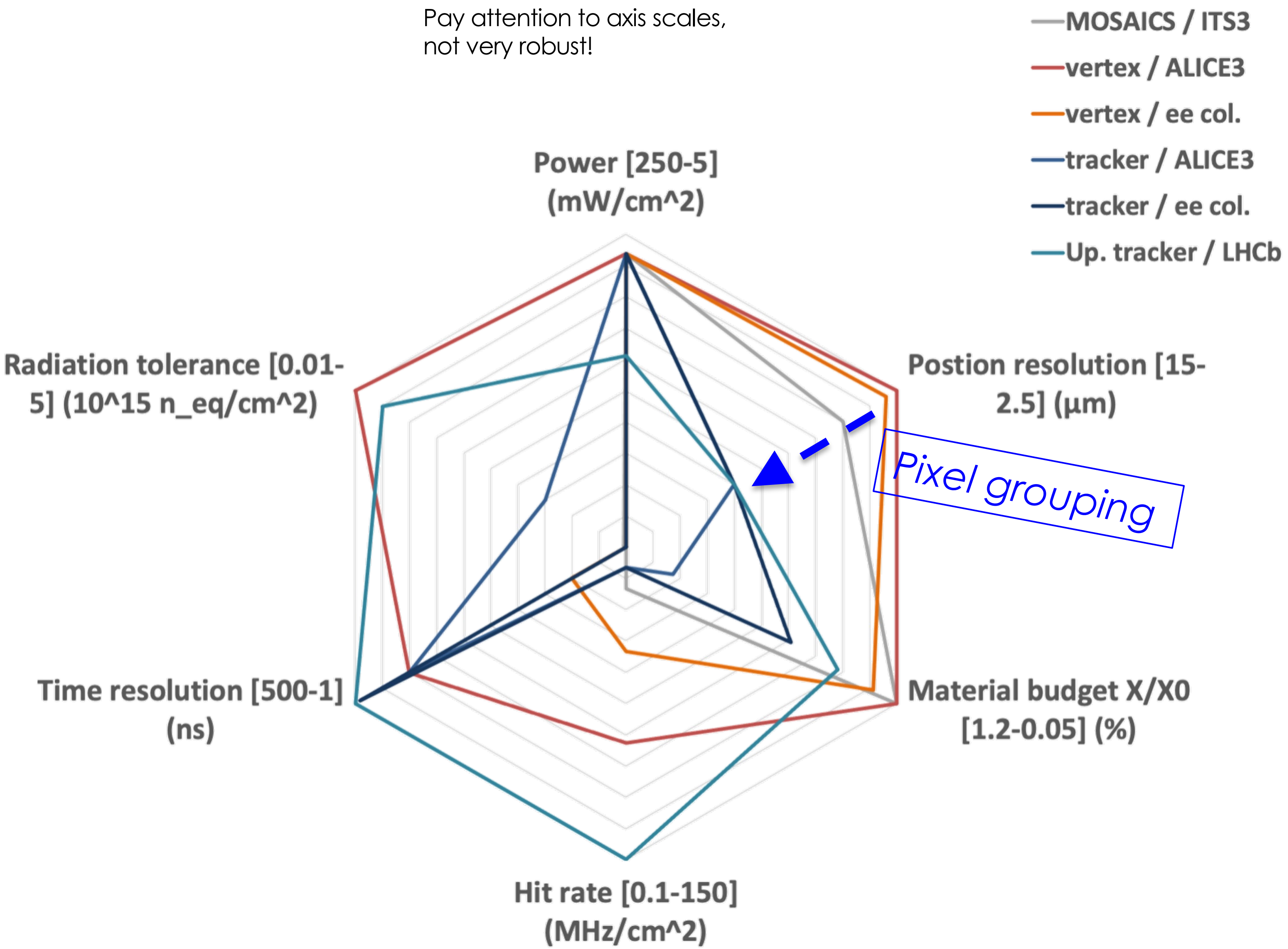

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Do we need as many ~~sensors~~ as experiment?
matrices
with tuneable front-end
and process variants
and switchable pixel group

Specifications: the graph

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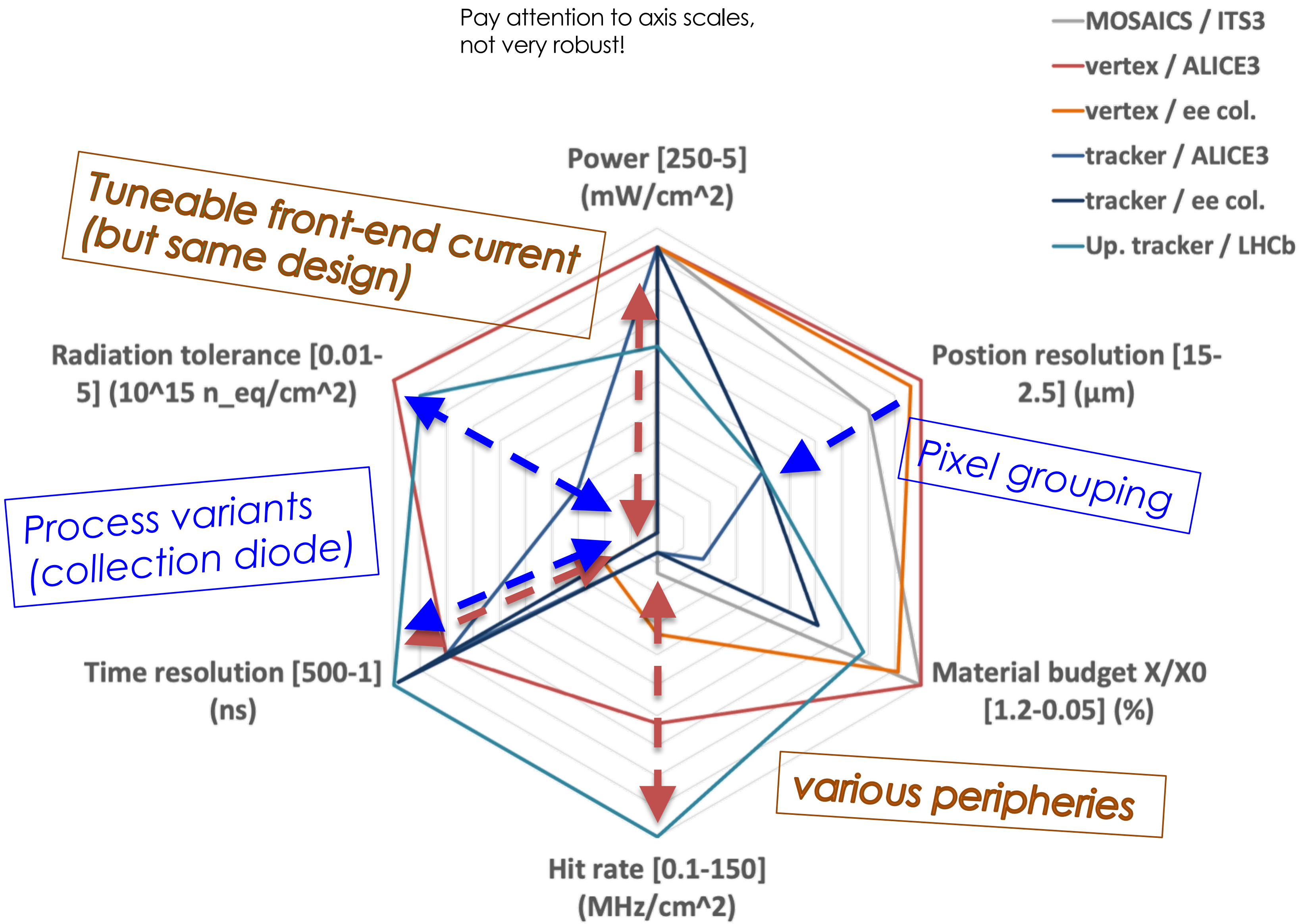

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Do we need as many ~~sensors~~ as experiment?
matrices
with tuneable front-end
and process variants
and switchable pixel group

Not 6 but 2-3 is wise

Aside from the Vertex project

- ALICE 3
  - On-going brainstorming group => Convergence toward SINGLE SENSOR for vertex & middle tracker & outer tracker

- LHCb, Belle II, FCCee
  - Interested in tracker
  - *Some specs strongly differ*

- Long term stuff
  - Intrinsic amplification
  - Timing (10-100 ps)

- **Chiplets in MPR2**

  1st sizeable sensor in MPR3?

- **Large proto-sensor for tracker in MPR2**
  - Main common features
    - Position resolution <10 µm
    - Low power 20-50 mW/cm^2
  - Differentiating features
    - Time merit <25 ns or < 100 ns
    - Hit rate 10 to 200 MHz/cm^2
    - NIEL fluence 10^{11} to 10^{16} n_{eq}/cm^2
  - Optional: time resolution 10-100 ps
  - Realisation:
    - *Powerful matrix with adapted perf in periphery*
    - Pitch 25 to 30 µm => 50 µm readout (4x 25 µm pixels)
    - ALICE-3 considers 10 µm pitch
    - In-pixel digitisation => time-walk correction / improved position res.
    - TDC outside matrix
    - Asynchronous read-out architecture => 25 ns stamping

1 or 2 such projects?

Tower 180 nm still kicks strongly!

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ER MIMOSIS-2 — ER MIMOSIS-3 => CBM / MVD

ER OBELIX-1 — ER OBELIX-2 => Belle II / VTX

Can still taught us a lot

=> MALTA

MPR QP2 — MPR QP3 … => R&D line organised by IPHC-C4Pi

- MPR = Multi Project Run
- Maximal reticule size 31 x 25 mm^2
- metal stack: 6 layers
- Process modification: possible but under CERN control
  - Through DRD7.6a

Expectations for DRD3 – WG1/WP1

(My own extrapolations)

- Timeline
  - 21 May: ZOOM kick-off meeting
    https://indico.cern.ch/event/1414293/
    => call for projects
  - Reception of proto-projects
    –
  - 17-21 June: 1st DRD3 week at CERN
    https://indico.cern.ch/event/1402825/
  - WP1 convenors work with community
    => consolidated projects
  - September: we have a plan!

- Projects
  - Research goals matching DRD3
  - Institutes with resources (kept within project)
  - Clear deliverables/milestone
  - Strong leadership

- **TPSCo 65 nm**
  2-3 large projects + chiplets
- **Tower 180 nm** (may fade away after 4 years)
  on-going experiment-oriented sensors
  + some dedicated R&D
- **LF 110 nm**
- **HV-CMOS**
- **IHP 130 nm**

(LF 110 nm, HV-CMOS, IHP 130 nm:) Less clear to me, probable mix of large projects + chiplets

Advertisement for PIXEL 2024 in Strasbourg 18-22 Nov.

Slides possibly useful for discussion

DRD3 WG1 general 'plan'

<table>
<tr><td colspan="2">DRD3 WG1 Monolithic CMOS</td><td colspan="4">Assess technology performance for each RG – handle technical solution options for strategic programs of LS4
time scale</td><td>Toward 4D-tracking for future colliders</td></tr>
<tr><td rowspan="4">Research Goals</td><td>Timeline</td><td>2024</td><td>2025</td><td>2026</td><td>2027</td><td>≳ 28</td></tr>
<tr><td>Technologies</td><td colspan="5">Foundry submissions and Milestonses (MS)</td></tr>
<tr><td>TPSCo (TJ) 65 nm</td><td>design MPW1.1</td><td>submit MPW1.1 mid-2025
design MPW1.2</td><td>evaluate MPW1.1
submit MPW1.2 Q4-2026</td><td rowspan="2">evaluate MPW1.2</td><td rowspan="2">design/submit/evaluate
MPW1.3-1.n
(possibly including in common submissions
ER designs for dedicated experiments)</td></tr>
<tr><td>TJ/TSI 180 nm, LFoundry 110/150 nm, IHP 130 nm</td><td>design MPW1.1
submit MPW1.1 Q4-2024</td><td>evaluate MPW1.1
design MPW1.2</td><td>submit MPW1.2 Q1-2026</td></tr>
<tr><td rowspan="2">RG1 Position precision</td><td>TPSCo (TJ) 65 nm</td><td colspan="2">electrode size/shape/pitch, process variants
12" ER splits, thin epitaxial layer, stitching
optimized for high channel density (low pitch)</td><td rowspan="8">MS1
establish position precision versus technology, channel configuration and readout mode
MS2
establish time precision versus technology, channel configuration
MS3
establish performance of readout variants for power consumption
MS4
establish radiation tolerance provide guidlenies for choice of substrates

select/merge MPW1.1 features
add new technology features

submit configurations for Vertex Detector, Central Tracking, Timing Layers, HGCAL</td><td rowspan="8">MS5
handle technical solutions for Vertex Detector (ALICE-3, LHCb-2, Belle-3, CMS/ATLAS)
1) high radiation tolerance/rate technlogies > 65 nm
2) high channel density, sitching TPSCo 65 nm

MS6
handle technical solutions for Central Tracking (ALICE-3, EIC, LHCb-2, Belle-3), Timing Layers (ALICE-3, ATLAS, CMS)
with stitching TPSCo 65 nm

MS7
handle technical solutions for low power w/o and w/ precision timing, at medium and high rates</td><td rowspan="8">merge RTs and various technology achievements in selected technologies,
extend all to stitching
implement 3D integration
consider finer nodes and new materials</td></tr>
<tr><td>TJ/TSI 180 nm, LFoundry 110/150 nm, IHP 130 nm</td><td colspan="2">electrode size/shape/pitch, wafer type/thickness, process variants
8" ER or MLM splits</td></tr>
<tr><td rowspan="2">RG2 Timing precision</td><td>TPSCo (TJ) 65 nm</td><td colspan="2">similar to RG1
optimized for fast signal collection speed and high S/N</td></tr>
<tr><td>TJ/TSI 180 nm, LFoundry 110/150 nm, IHP 130 nm</td><td colspan="2">similar to RG1
optimized for fast signal collection speed and high S/N
including gain layer option</td></tr>
<tr><td rowspan="2">RG3 Readout architecture common with DRD7</td><td>TPSCo (TJ) 65 nm</td><td colspan="2">digital/binary, synchronous/asynchronous
optimised to features of RG1 and RG2 at medium rates
power distribution and control in large size stitched matrix</td></tr>
<tr><td>TJ/TSI 180 nm, LFoundry 110/150 nm, IHP 130 nm</td><td colspan="2">digital/binary, synchronous/asynchronous
optimised to features of RG1 and RG2 at medium and high rates</td></tr>
<tr><td rowspan="2">RG4 Radiation tolerance</td><td>TPSCo (TJ) 65 nm</td><td colspan="2">process features in splits</td></tr>
<tr><td>TJ/TSI 180 nm, LFoundry 110/150 nm, IHP 130 nm</td><td colspan="2">variants of substrates (Cz, epitaxial), resistivity, p-type and n-type</td></tr>
</table>