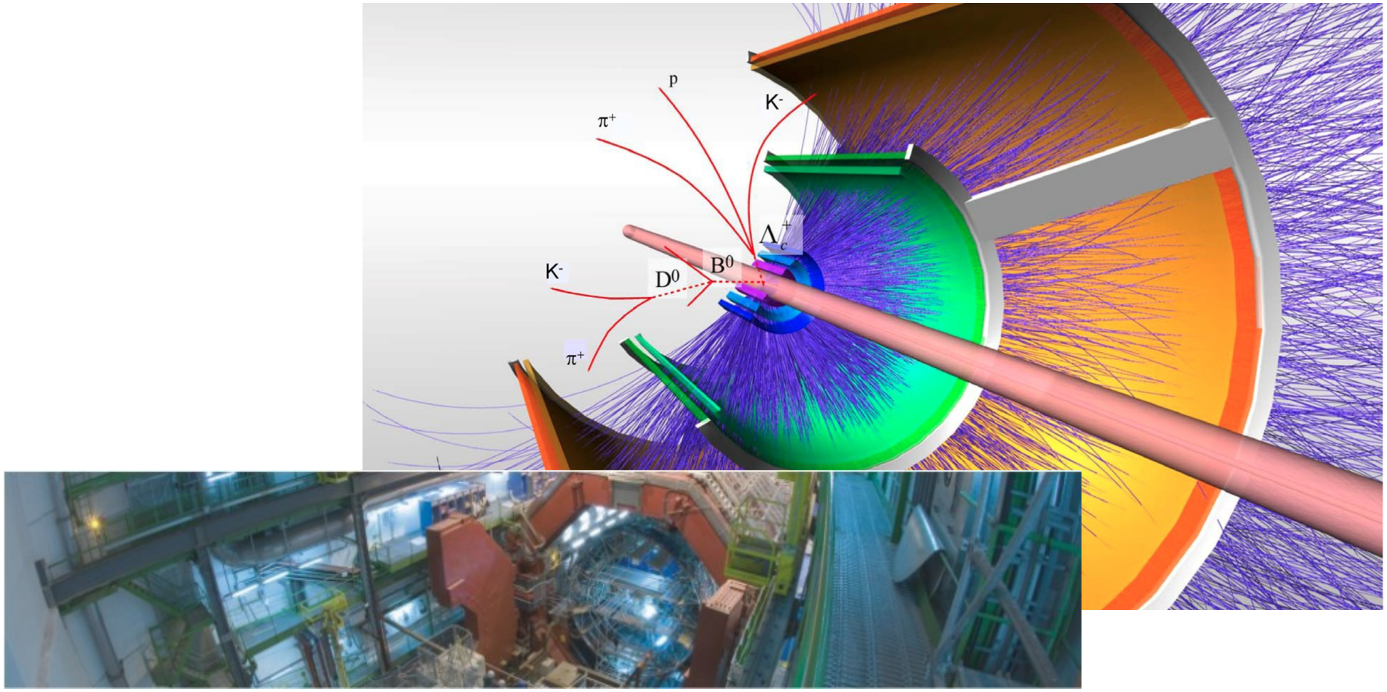
Antonin MAIRE – IPHC Strasbourg
Mon, 15 Nov 2019 – **GDR QCD 2019**

Towards a QCD+QGP physics at HL-LHC with ultra-low p_T detection :

ALICE ITS3 + “all-Si experiment”



IPHC
Institut Pluridisciplinaire
Hubert CURIEN
STRASBOURG

Foreword

1. - Apologies for my short stay here…

CONTACTS	Th/Exp	FIELD	1st approach	Discussion
Jean-Yves Ollitrault	Th	hydrodynamics	√	√
Derek Teaney	Th	fluctuations	√	TbD
Stefan Flörchinger	Th	hydrodynamics	√	TbD
Aleksas Mazeliauskas	Th	hydrodynamics	√	TbD
François Arléo	Th	CNM	√	√
Pol-Bernard Gossiaux	Th	charm	√	√
Stéphane Peigné	Th	CNM	√	√
François Gellis	Th	CGC	√	TbD
Grégory Soyez	Th	jets	√	TbD
Jacopo Ghiglieri	Th	EFT	√	TbD
Marlene Nahrgang	Th	fluctutations	TbD	…
Alice Ohlson	Exp	net quantum numbers	TbD	…
Francesco Noferini	Exp	TOF	TbD	…
Andre Stahl	Exp	CMS MTD	TbD	…
Emmanuel Sauvan	Exp	$e^{\pm}$ p, ATLAS	TbD	…
Cristinel Diaconu	Exp	$e^{\pm}$ p, ATLAS	TbD	…
You ?	…	…	…	…

2. - Thinking in progress…

look for contradictors
to forge one’s opinion

Outline

A. Basic unit : MAPS

B. ≥2021, Run 3 (*ITS2 reminder*)

C. ≥2026, Run 4 (*ITS3*)

D. ≥2031, Run 5 (*All-Si experiment*)

References

ITS2 :

ITS3 : 1) LHCc 2019-06 ALICE, M.Mager ITS3 + 2) EoI ITS3, ALICE-PUBLIC-2018-013

LS4+ : 1) EoI LS4+, arXiv:1902.01211 + 2) SQM 2019 L.Musa indico.cern.ch/e/755366/c/3428151/

*LHC direct alternative : * CMS MTD, 1) LoI CERN-LHCC-2017-027 + 2) TDR CERN-LHCC-2019-003*

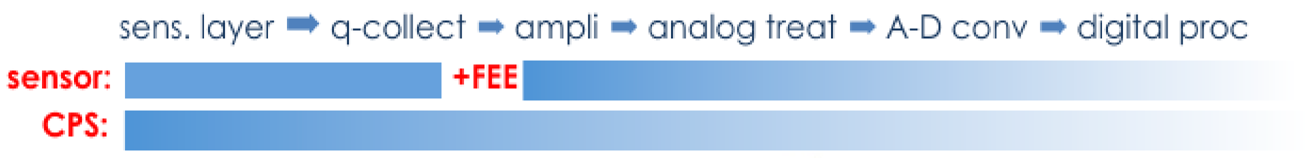
3) Seminar IPHC, Chang-Seong Moon : indico.in2p3.fr/e/19269/

** LHCb, EoI upgrade LS4, arXiv:1808.08865*

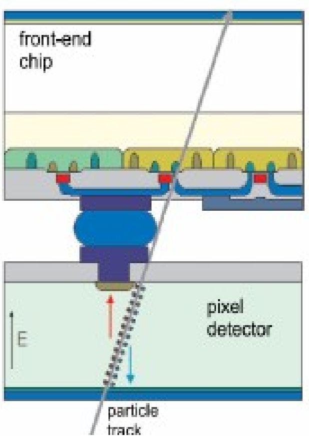
Part A – the basic tool

I.1 – Pixel detectors : Monolithic Active vs Hybrid techno.

Hybrid pixel sensor →
CMOS pixel sensor →

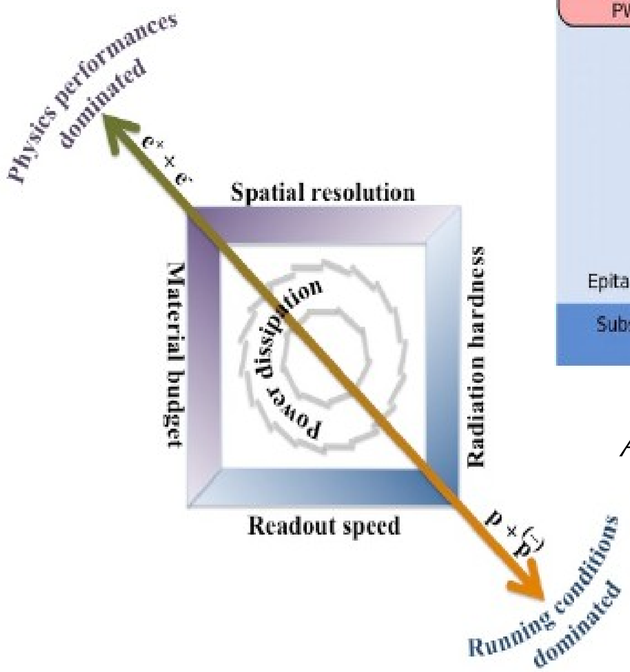


Hybrid pixel sensor

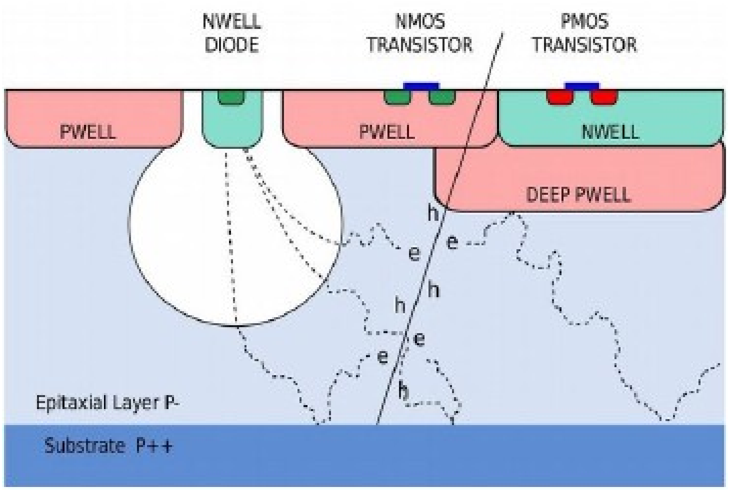


Advantages :

- faster readout
- better radiation-hardness
- …



CMOS pixel sensor

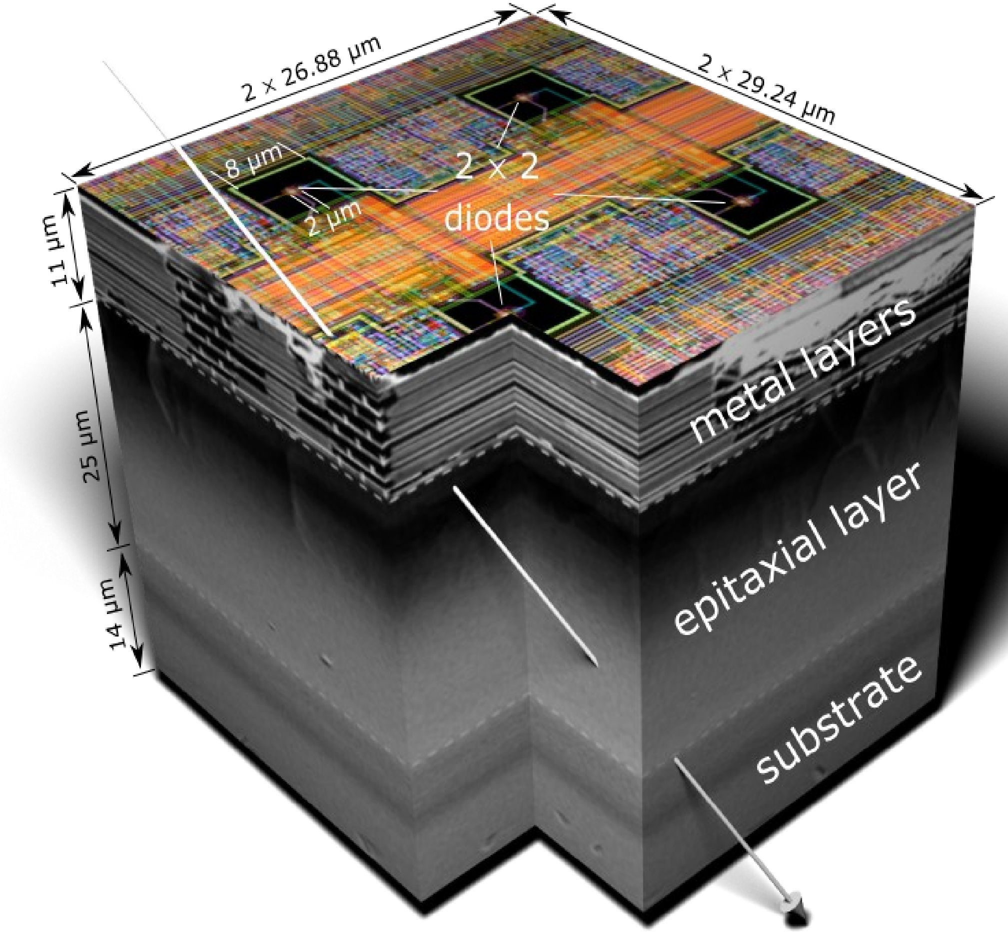


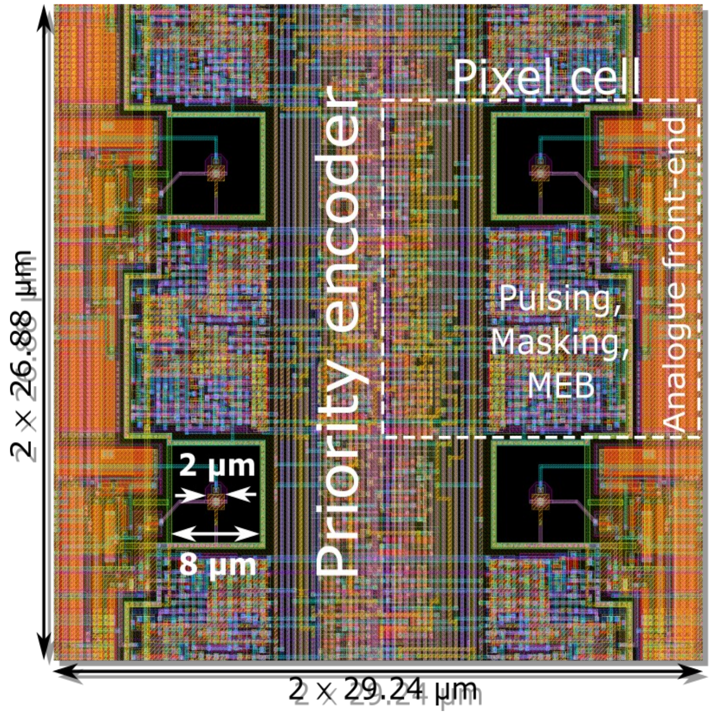
Advantages :

- thinner
- smaller pixel size accessible
- lower power consumption
- cheaper to produce
- …

I.2 – Pixel detectors : ALPIDE chip

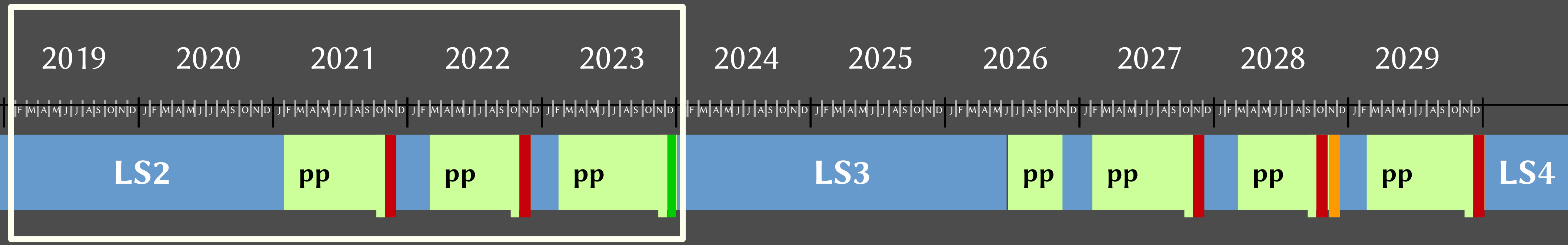
Sensor using
TowerJazz 0.18µm CMOS Imaging Process





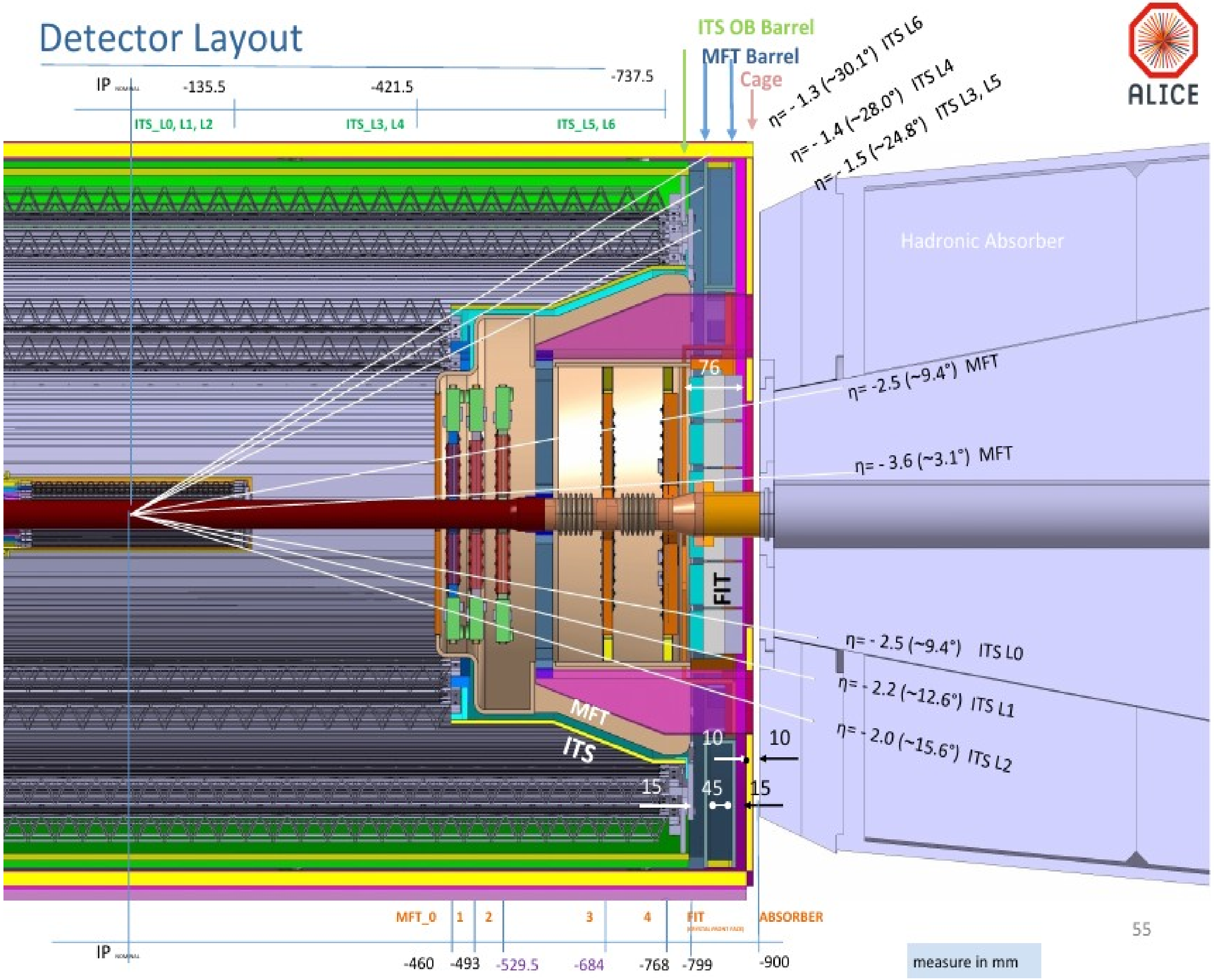
ALPIDE – 3D and 2D views of 2x2 pixels
(Here, in the 50-µm-thick version...)

Part B – ITS-2 = after LS2 (≥2021, Run 3)



LHC running plan

II.1 – ITS-2 + MFT : MAPS-based detector



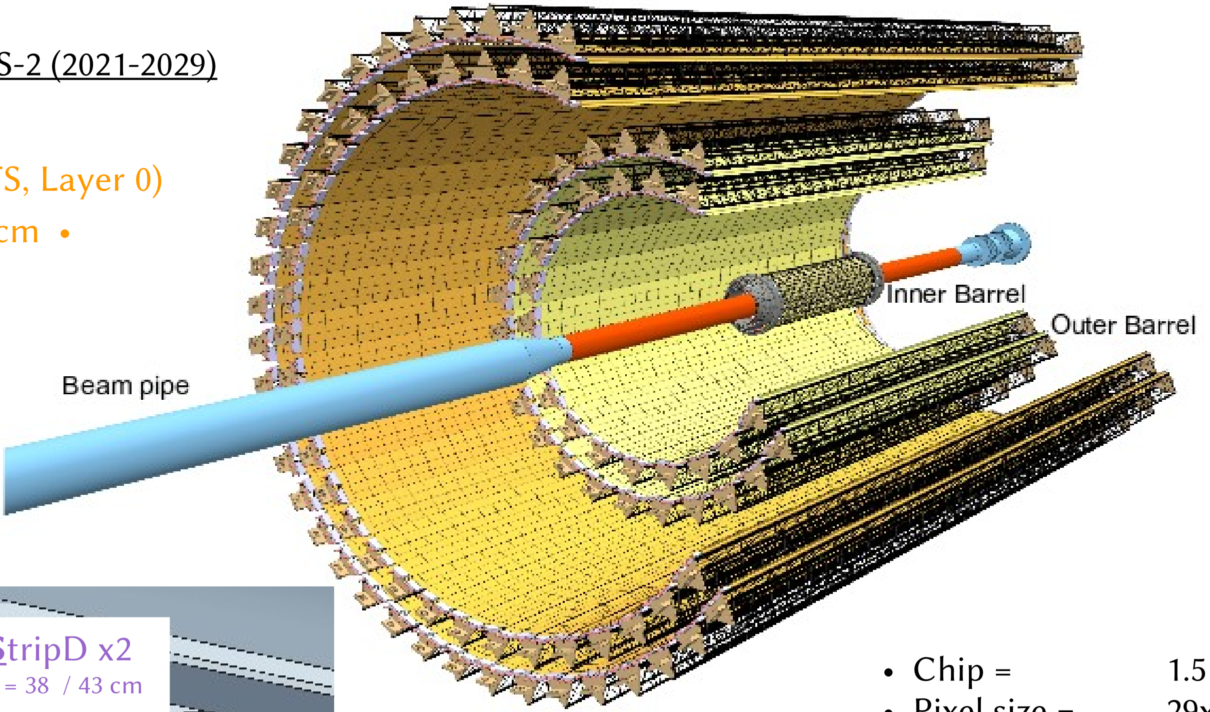
TDR ITS-2 Upgrade
- CERN-LHCC-2013-024

II.2 – ITS2 : ALICE upgrade ITS, few figures

ITS-2 (2021-2029)

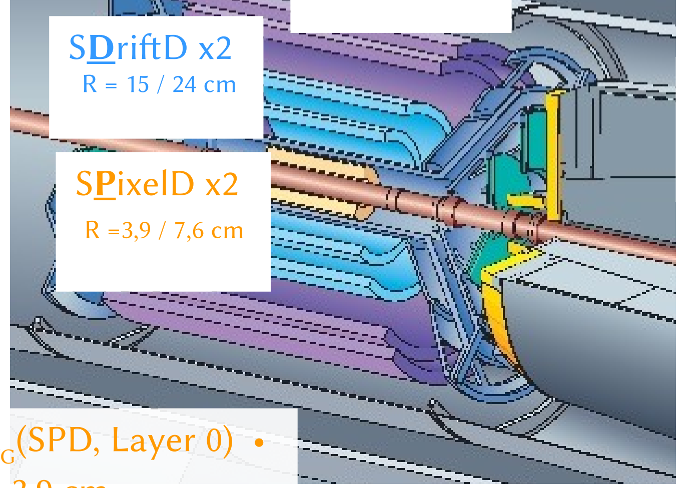
R_{AVG}(uITS, Layer 0) = 2.34cm •

Beam pipe : $R_{upgrade}$ 1.82 cm •



- 7 pixel-only layers
- 12.6 x10^9 pixels,
- ~ 10 m² in total
- 13.6 x10^6 CHF (0.18-µm CMOS technology by TowerJazz)

ITS-1 (2009-2018)



SStripD x2
R = 38 / 43 cm

SDriftD x2
R = 15 / 24 cm

SPixelD x2
R =3,9 / 7,6 cm

R_{AVG}(SPD, Layer 0) • = 3.9 cm

- Beam pipe : $R_{current}$ = 2.9 cm

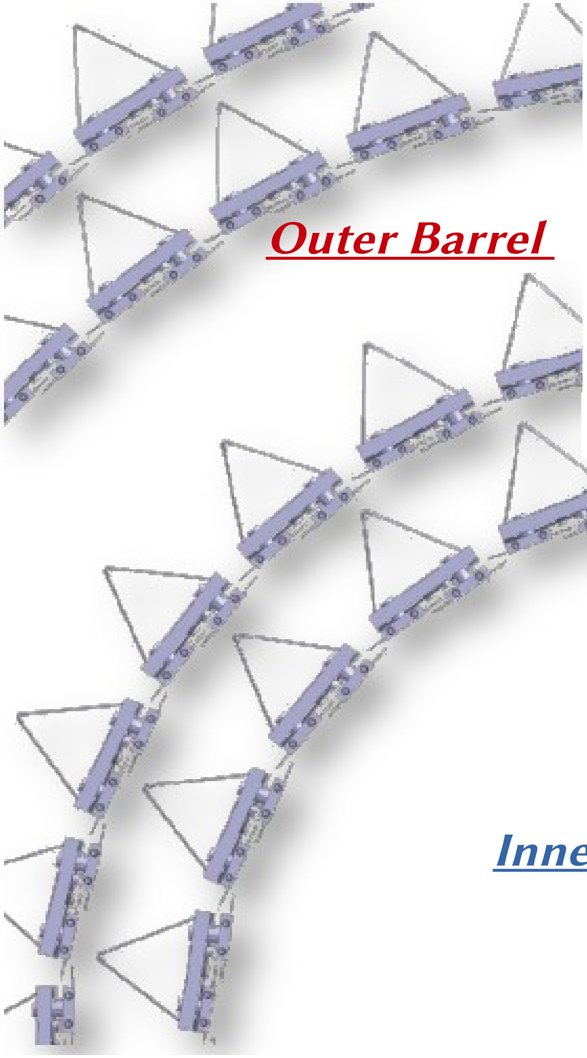
- Chip = 1.5 x 3 cm²
- Pixel size = 29x27 µm² (current SPD : 50 x 425 µm²)

Note :
No d*E*/dx information,
binary pixel readout “0/1”

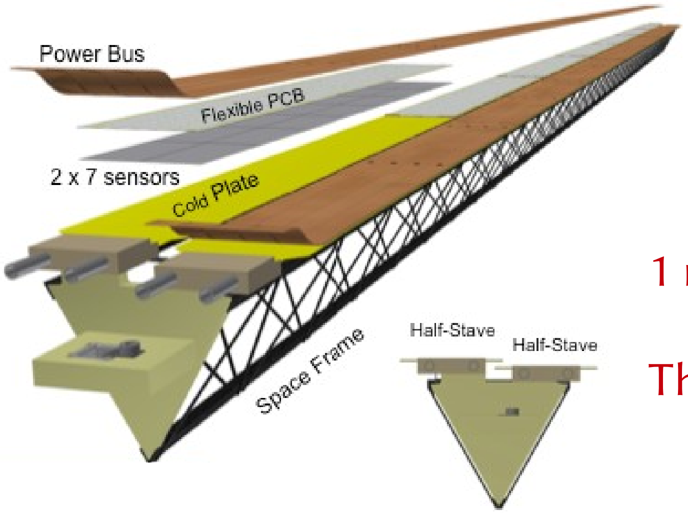
Unlike “past” ITS-1 with SDD, SSD…

Antonin.MAIRE@cern.ch – IPHC Strasbourg / GDR-QCD 2019

II.3 – ITS2 : “(half)-stave of modules of chips”

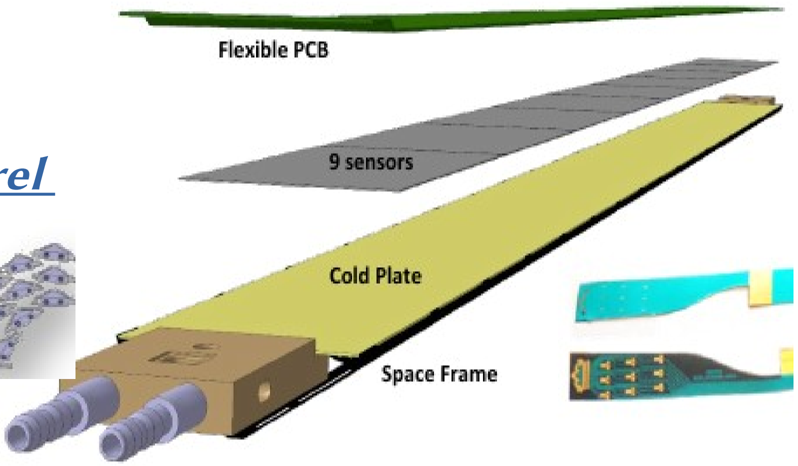


Outer Barrel



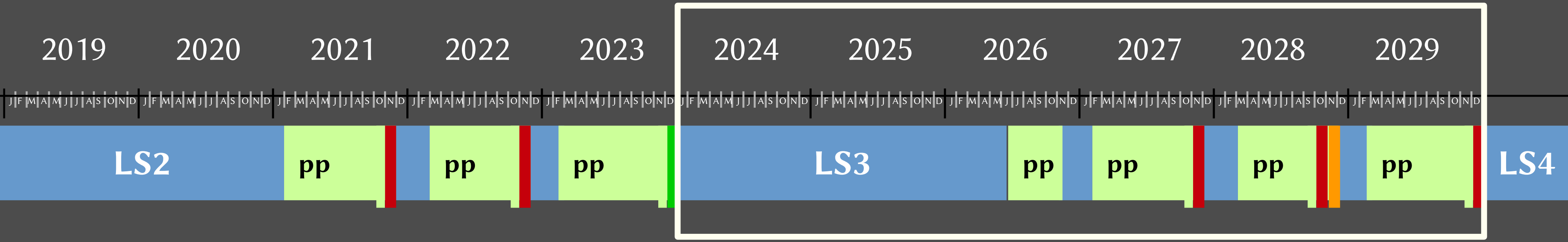
1 module = 2x7 chips
≈ 3 cm x 21 cm ,
Then, up to 7 modules to build half-stave

Inner Barrel



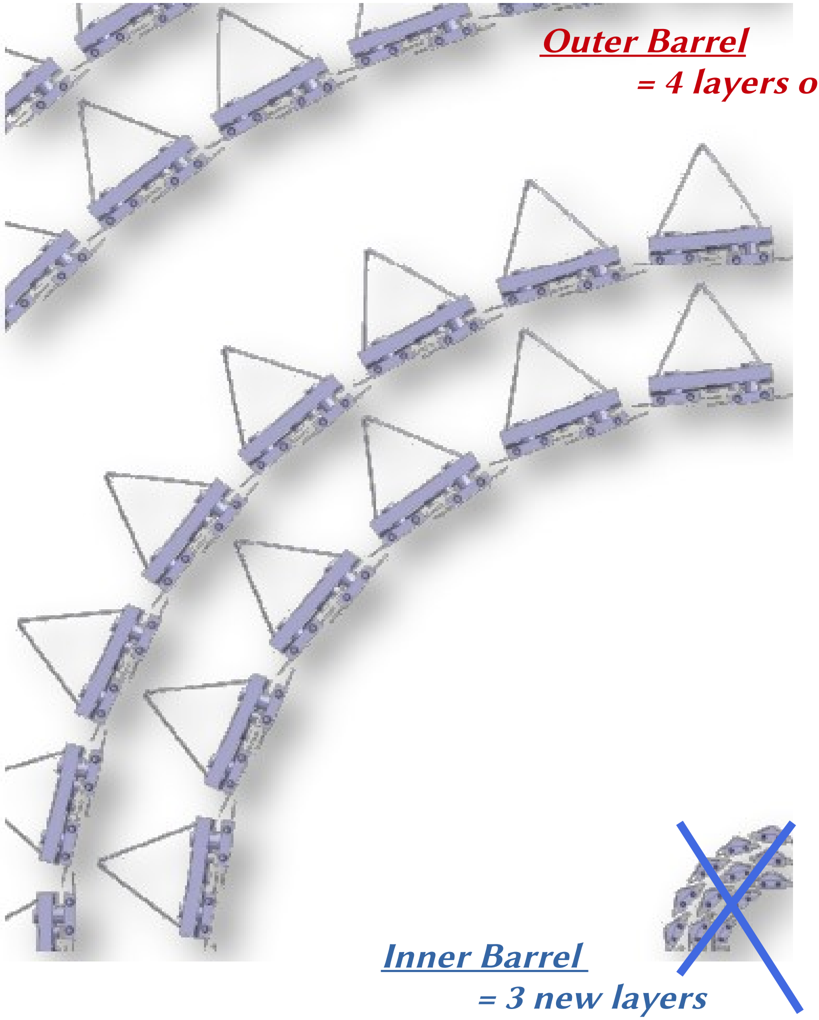
1 module
= 9 chips in a raw,
≈ 1.5 cm x 27 cm
directly put on stave

Part C – ITS-3 = after LS3 (≥2026, Run 4)



LHC running plan

III.1 – ITS-3 : first expression of interest



Outer Barrel
= 4 layers of ITS2 kept !

Inner Barrel
= 3 new layers

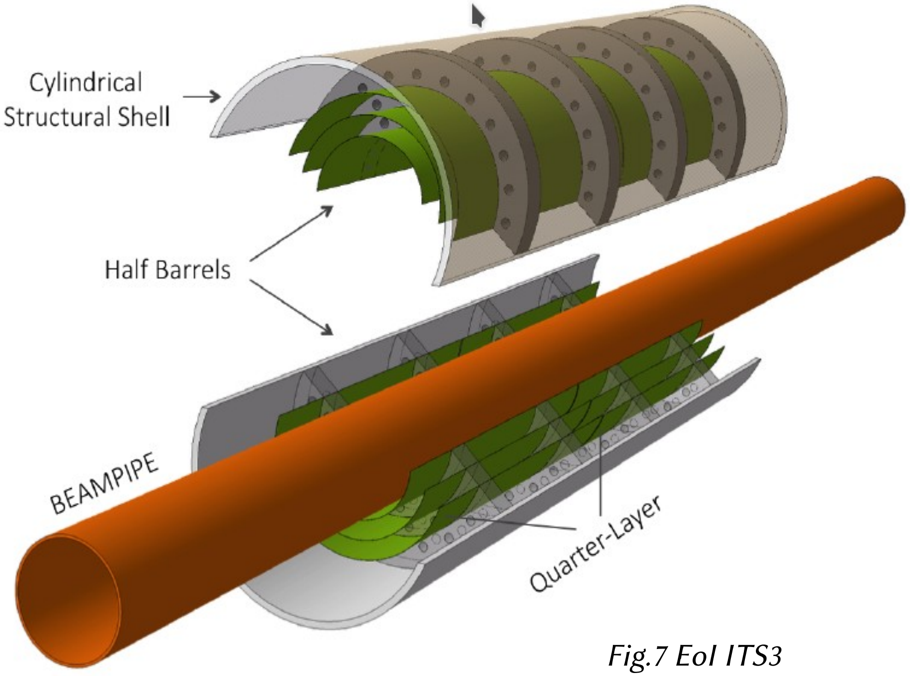


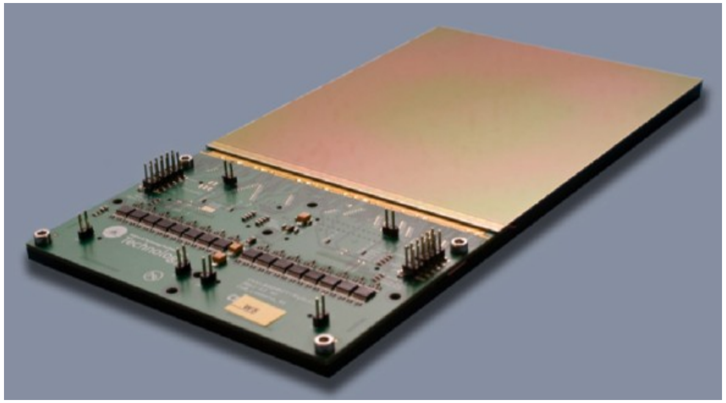
Fig.7 EoI ITS3
ALICE-PUBLIC-2018-013

III.2 – ITS-3 : key foreseen features, “closer + lighter”

Keys :

(**1**) - shrinked beam pipe ($r_{\text{beam pipe}}$ = 1.6 cm)
⟶ inner most layer at r_{L0} = 1.8 cm

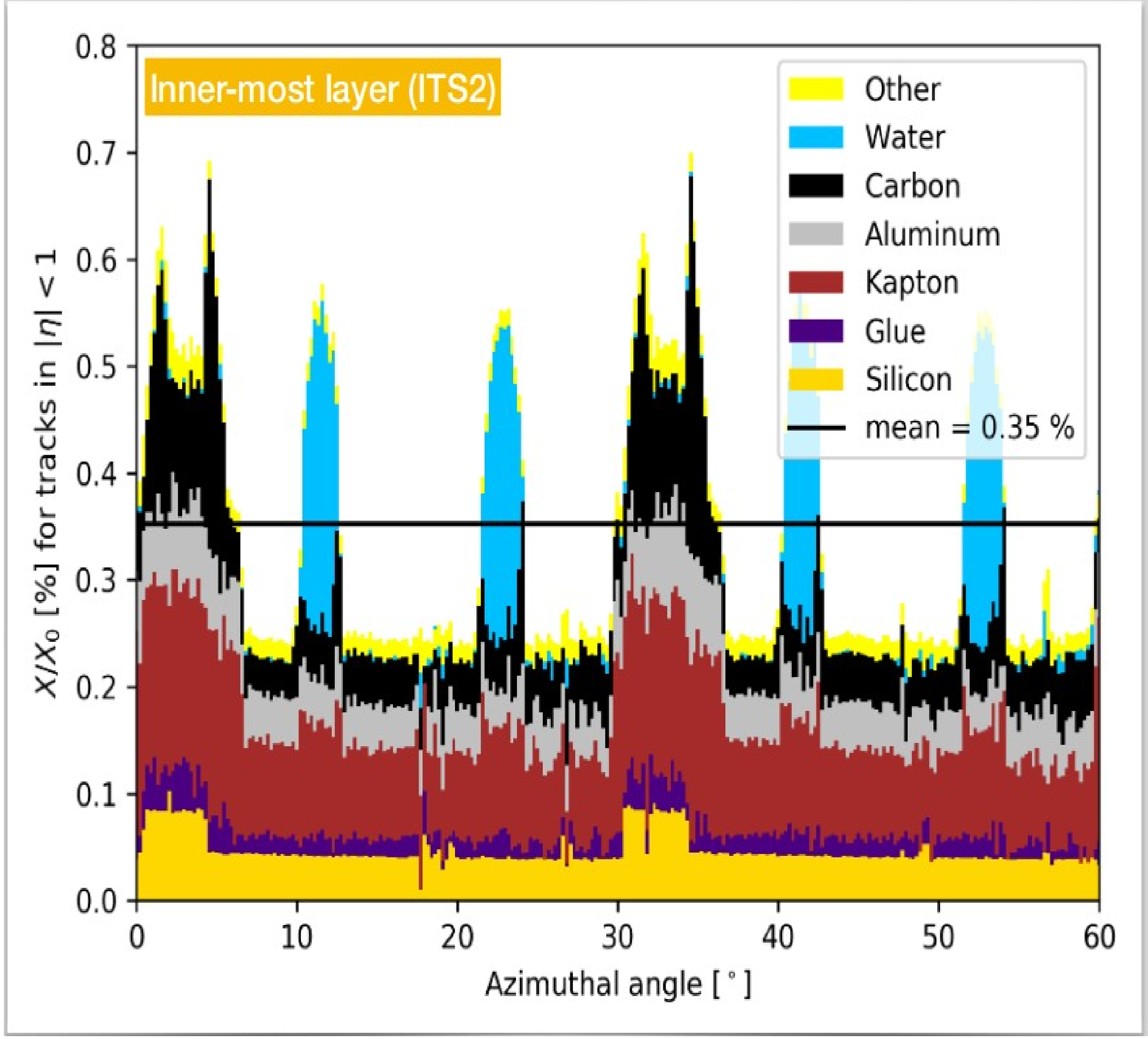
(**2**) - reticle-size sensor (O[15x10 cm²]) + (**3**) - ultra-thin Si CMOS (20-µm thick)
⟶ circuitry pushed to periphery (*stitching*), ~no extra services required
⟶ can be curved
⟶ homogeneous 0.05% X/X° per layer



X-ray detector 13.9 x 12 cm² TowerJazz 0.18-µm

Silicon Genesis: 20 micron thick wafer

III.3 – ITS-3 : skimming material budget of ITS-2

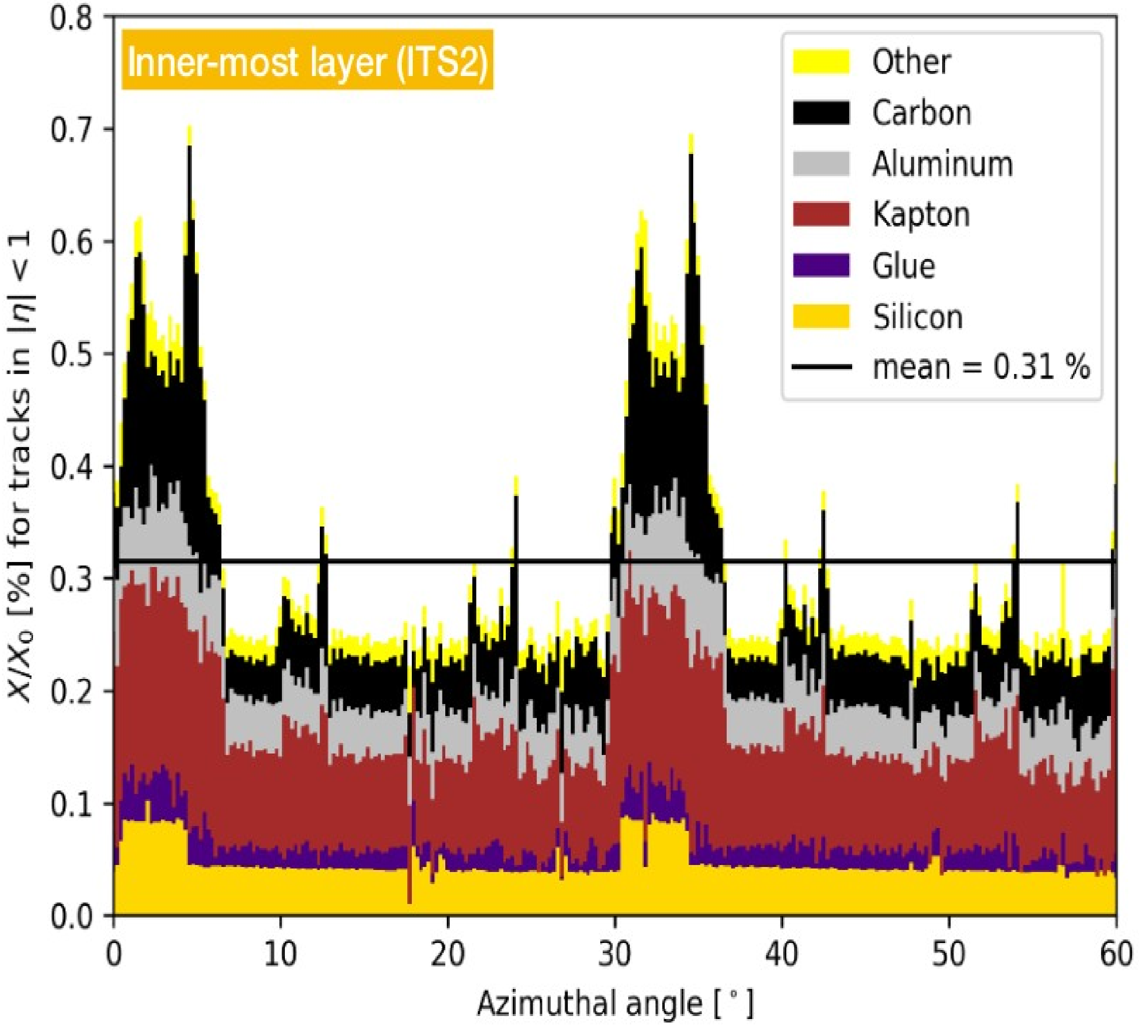


➡ Si only 1/7th of total material

➡ irregularities due to overlaps + support/cooling

LHCc 2019-06 ALICE, M.Mager ITS3

III.3 – ITS-3 : skimming ITS-2



➡ Si only 1/7th of total material

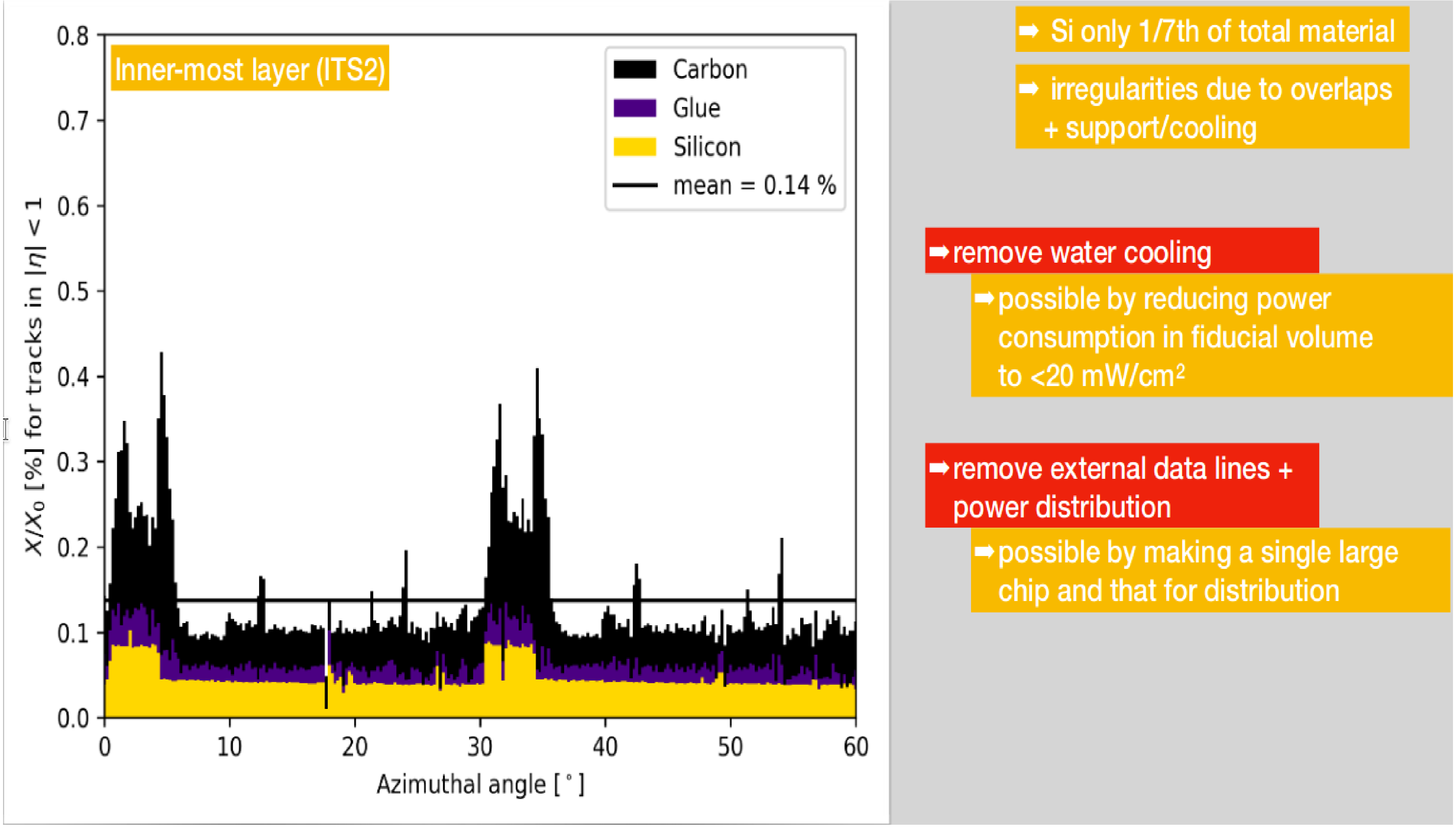
➡ irregularities due to overlaps + support/cooling

➡ remove water cooling

➡ possible by reducing power consumption in fiducial volume to <20 mW/cm²

LHCc 2019-06 ALICE, M.Mager ITS3

III.3 – ITS-3 : skimming ITS-2



➡ Si only 1/7th of total material

➡ irregularities due to overlaps + support/cooling

➡ remove water cooling

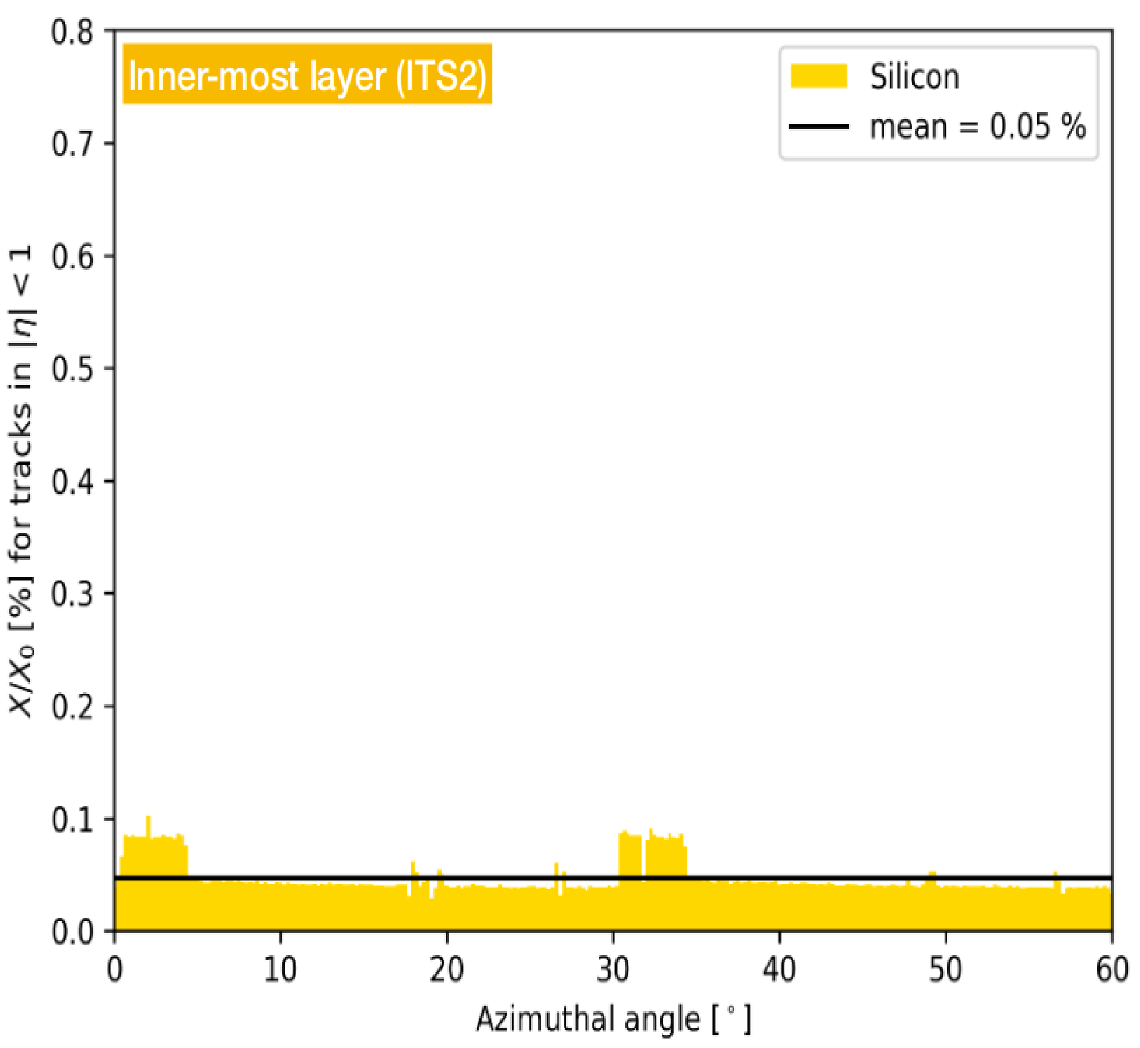
➡ possible by reducing power consumption in fiducial volume to <20 mW/cm^2

➡ remove external data lines + power distribution

➡ possible by making a single large chip and that for distribution

LHCc 2019-06 ALICE, M.Mager ITS3

III.3 – ITS-3 : skimming ITS-2



- ➡ Si only 1/7th of total material
- ➡ irregularities due to overlaps + support/cooling

- ➡ remove water cooling
  - ➡ possible by reducing power consumption in fiducial volume to <20 mW/cm^2
- ➡ remove external data lines + power distribution
  - ➡ possible by making a single large chip and that for distribution
- ➡ move mechanical support outside acceptance
  - ➡ benefit from increased stiffness by rolling Si wafers

LHCc 2019-06 ALICE, M.Mager ITS3

III.4 – ITS-3 : 5.3 kCHF up to 2025

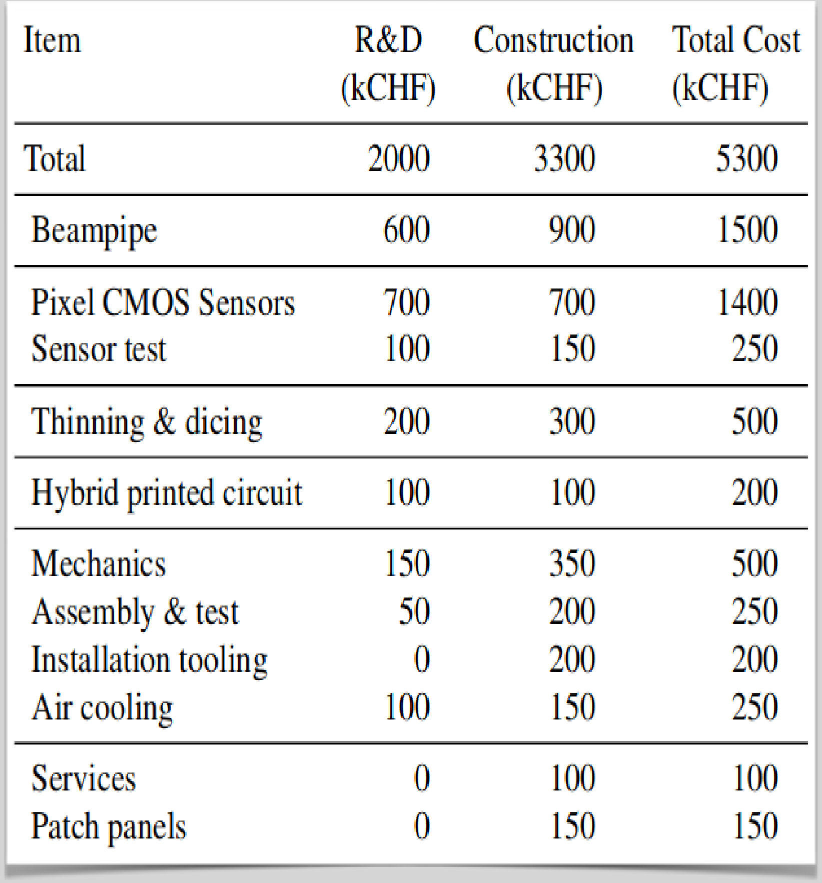
R&D 2020-2023

- ➡ Wafer thinning+bending
  - ➡ 2019: contact to industry
  - ➡ 2019-2020: first prototypes with ALPIDE chips and wafers
  - ➡ later: continue with specific prototypes
- ➡ Stitched sensor development
  - ➡ 2019-2020: technology test structures
  - ➡ 2020-2022: prototyping chips
  - ➡ 2022-2023: full-scale prototype + final chip

Technical Design Report 2022

Construction 2024-2025

Cost breakdown



Item	R&D (kCHF)	Construction (kCHF)	Total Cost (kCHF)
Total	2000	3300	5300
Beampipe	600	900	1500
Pixel CMOS Sensors	700	700	1400
Sensor test	100	150	250
Thinning & dicing	200	300	500
Hybrid printed circuit	100	100	200
Mechanics	150	350	500
Assembly & test	50	200	250
Installation tooling	0	200	200
Air cooling	100	150	250
Services	0	100	100
Patch panels	0	150	150

NB: ~40% is R&D

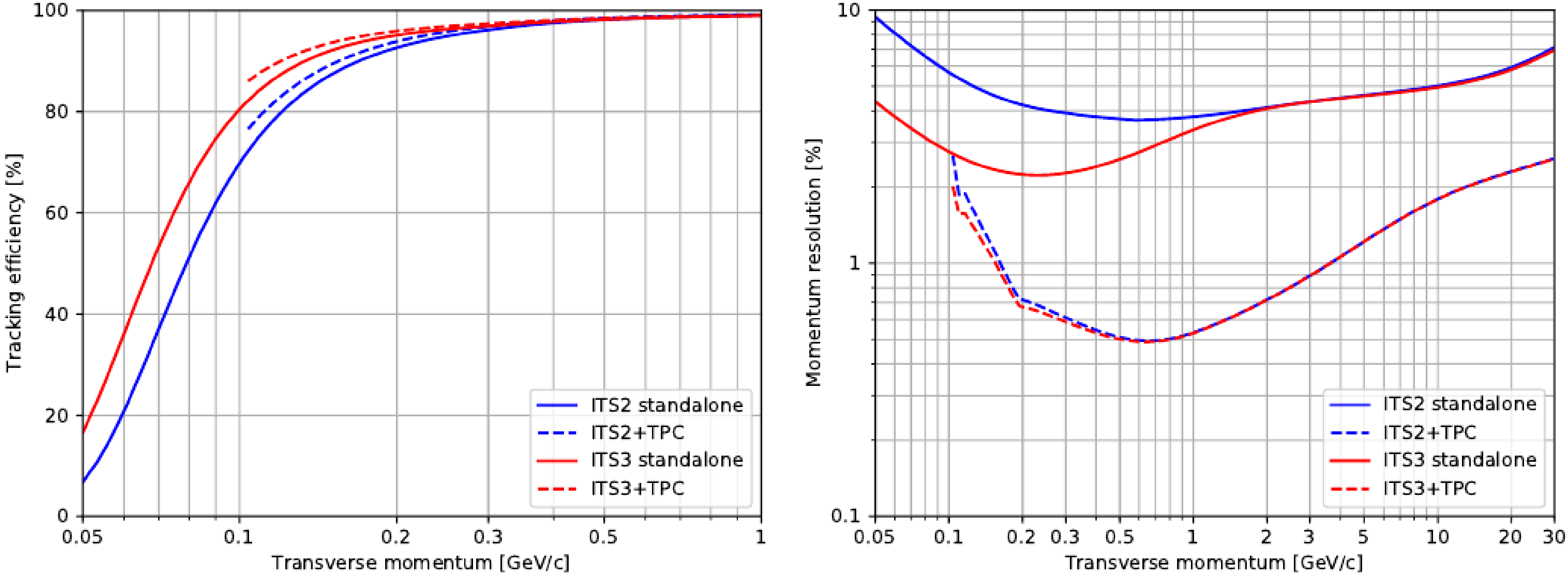
LHCc 2019-06 ALICE, M.Mager ITS3

III.5 – ITS-3 : synoptic table

	ITS1 (SPD = 2 inner)	ITS2 (3 inner)	ITS3 (3 inner)
Beam pipe inner radius/thickness	3.0 cm/0.09 cm	1.82/0.08 cm	1.6/0.05 cm
First-layer radius	3.9 cm	2.3 cm	1.8 cm
X/X° per layer	1.1 %	0.35 %	0.05%
|η| coverage	> 1.4	> 2.0	> 2.0
Number of Sensors per layer	80+160	108+144+180	2 to 4
Technology	Hybrid pixels	CMOS	CMOS
Trigger ?	yes	no	Not foreseen
Pixel size rφ x z	≈ 50x425 μm^2	≈ 30x30 μm^2	≈ 10x10 μm^2
Intrinsic resolution rφ / z	12 μm / 100 μm	5 μm / 5 μm	3 μm / 3 μm
Readout frequency Pb-Pb	< 3 MHz > 300 ns (SPD)	< 50-100 kHz > 20-10 μs	≈ ≤ 200 kHz ≈ ≥ 5 μs
Power dissipation in the pixel matrix	≈ 550-736 mW/cm^2 i.e. liquid cooled	~40 mW/cm^2, i.e. liquid cooled	~7 mW/cm^2, i.e. air flow

III.6 – ITS-3 : why would you invest into it ?

Fig.12, EoI ITS-3, ALICE-PUBLIC-2018-013

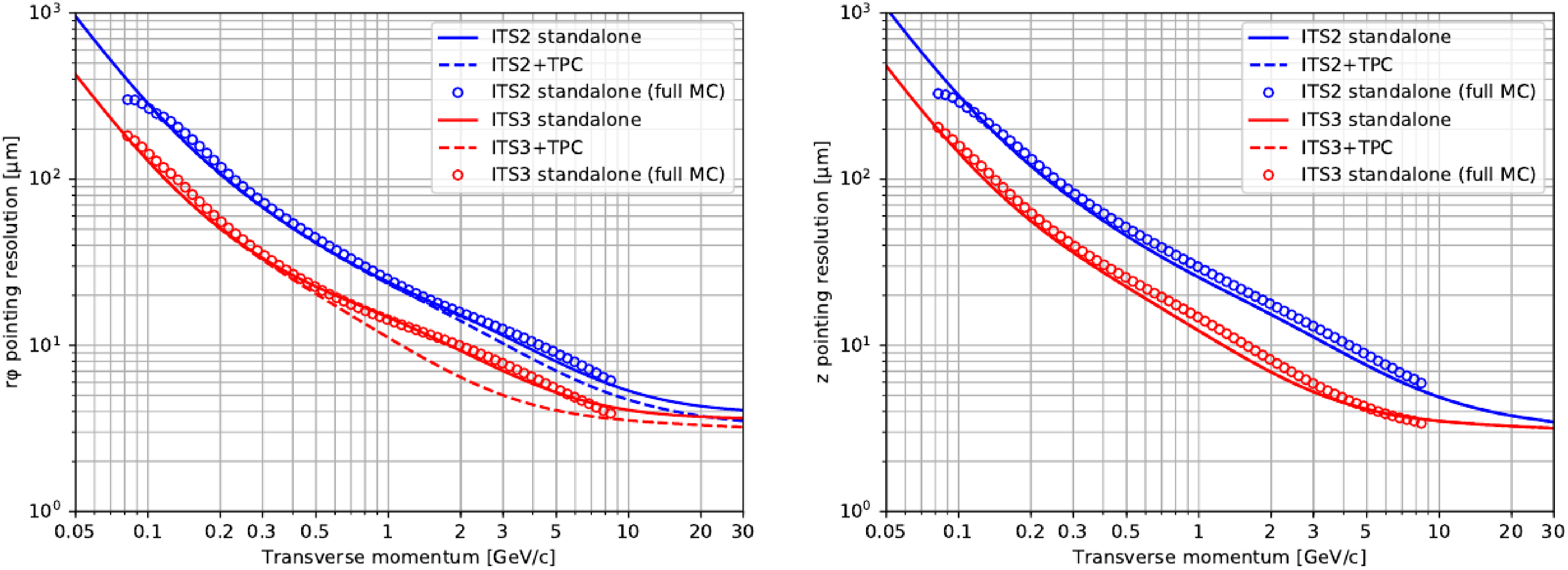


Pb-Pb 0-10% $\sqrt{s_{NN}}$ = 5.5 TeV

(Fast MC tracking tool...)

III.6 – ITS-3 : why would you invest into it ?

Fig.11, EoI ITS3, ALICE-PUBLIC-2018-013



Pb-Pb 0-10% $\sqrt{s_{NN}}$ = 5.5 TeV

Antonin.MAIRE@cern.ch – IPHC Strasbourg / GDR-QCD 2019

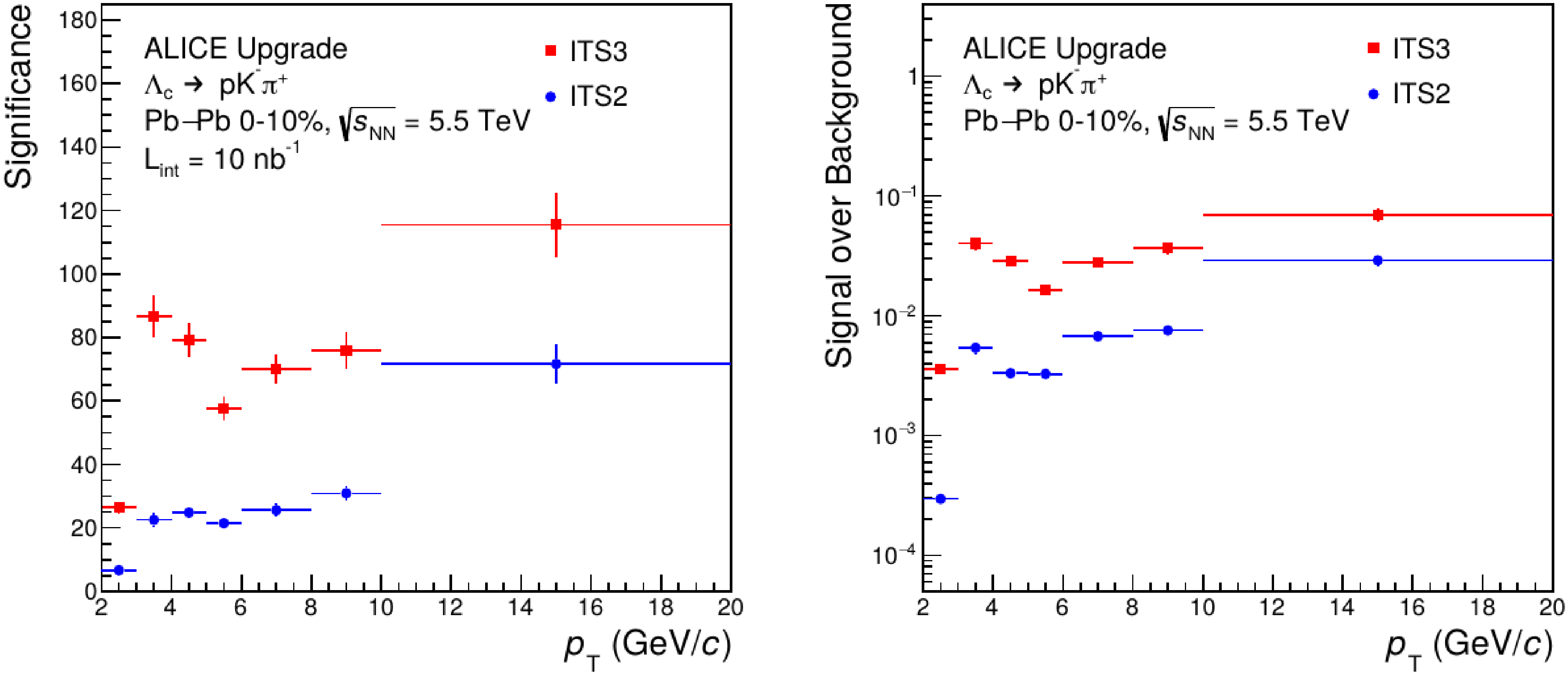
Part D – why all that ?

LHC running plan

IV.1 – ITS-3 : why would you invest into it ?

Fig.13, EoI ITS3, ALICE-PUBLIC-2018-013

Λ_C^+ (m = 2.286 GeV/c^2 / $c\tau$ = 60 µm)



See also QM 2019, G.-M. Innocenti for ITS-1 Pb-Pb or pp physics of Λ_C^+ …

IV.2 – ITS*n* : admittedly… but, in more concrete terms, “why” ?

ALICE :

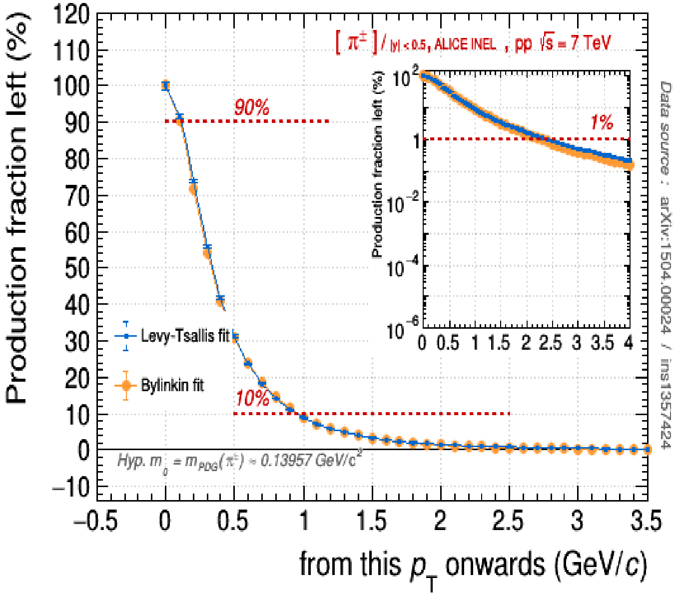
- for “low p_T charmed hadrons and baryons (Λ_C^+ to Ω_{CCC}^{++})”
- for “thermal radiation by the QGP via vitual photons (low-mass e^+e^- $m_{ee} < 2$ GeV/c)” !

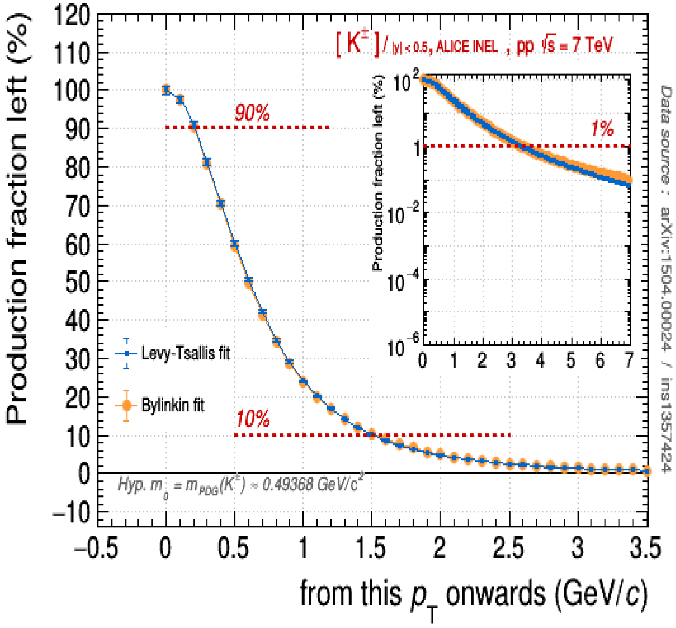
(Wo)man on the HEP street : “Seriously, that’s your physics case to be sold ?!”

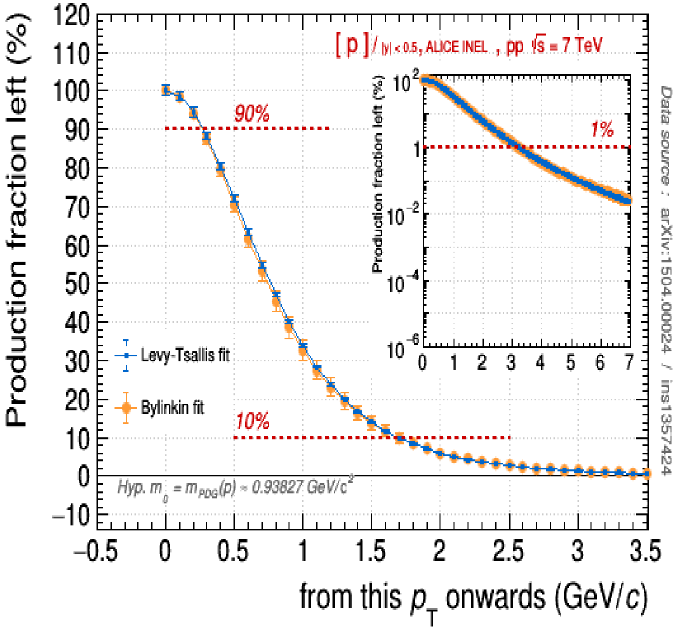
⟶ Consider them as litmus tests :
if one is able to do those two type of measurements,
then you can do many things on top of that.

= Focus given to “ultra low p_T” detection threshold (≥ 20-50 MeV/*c*),
i.e. push the logic of “scrutinise what is yet abundant” far to the end
in contrast to CMS/ATLAS strategy to fight for the “unseen/rarity”

IV.3 – ITS*n* : why low p_T ? Simple examples of π,K,p





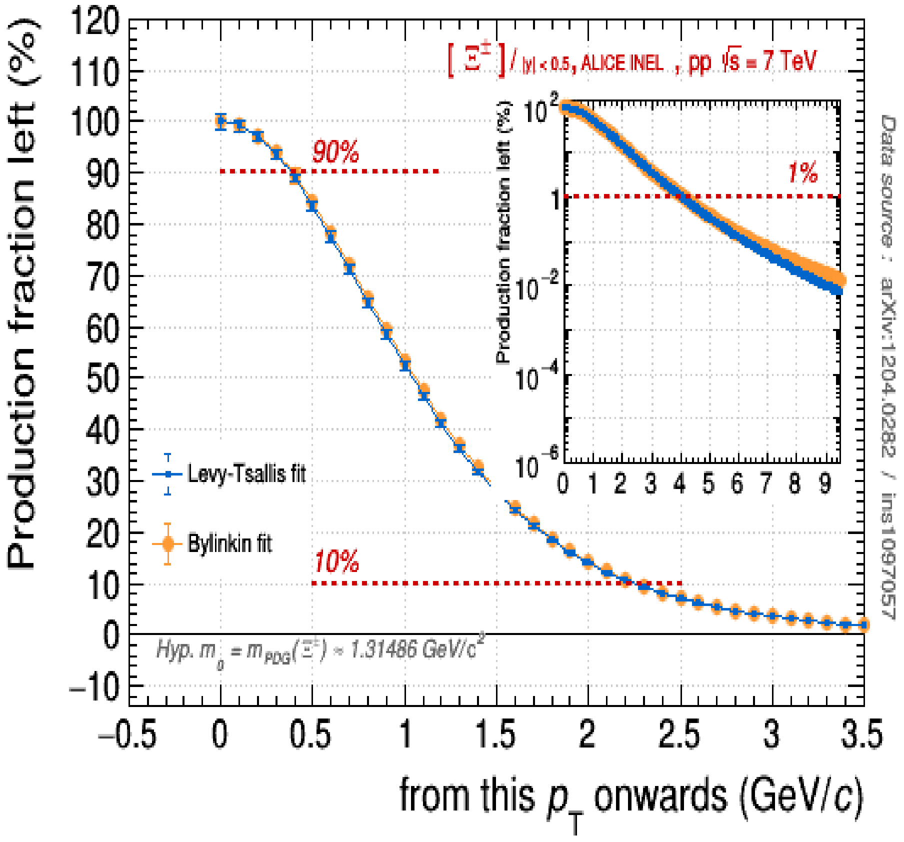


If your $\pi^+(u\bar{d})$ / $K^+(u\bar{s})$ / p(*uud*) measurements start above 0.0, 0.1, 0.2 … GeV/c,
you miss *x*% of the total d*N*/d*y* in pp.

For a given particle type of interest,
can you claim a "precision measurement" if you indeed miss *x*% of production ?
⟶ yes or no ? to be decided, case by case, but…

__NB__ : ALICE arXiv:1504.0024 = $h^{\pm}$ > 0.15 GeV/*c* // $\pi^{\pm}$ > 0.1 GeV/*c* / $K^{\pm}$ > 0.2 GeV/*c*, p > 0.3 GeV/*c*…

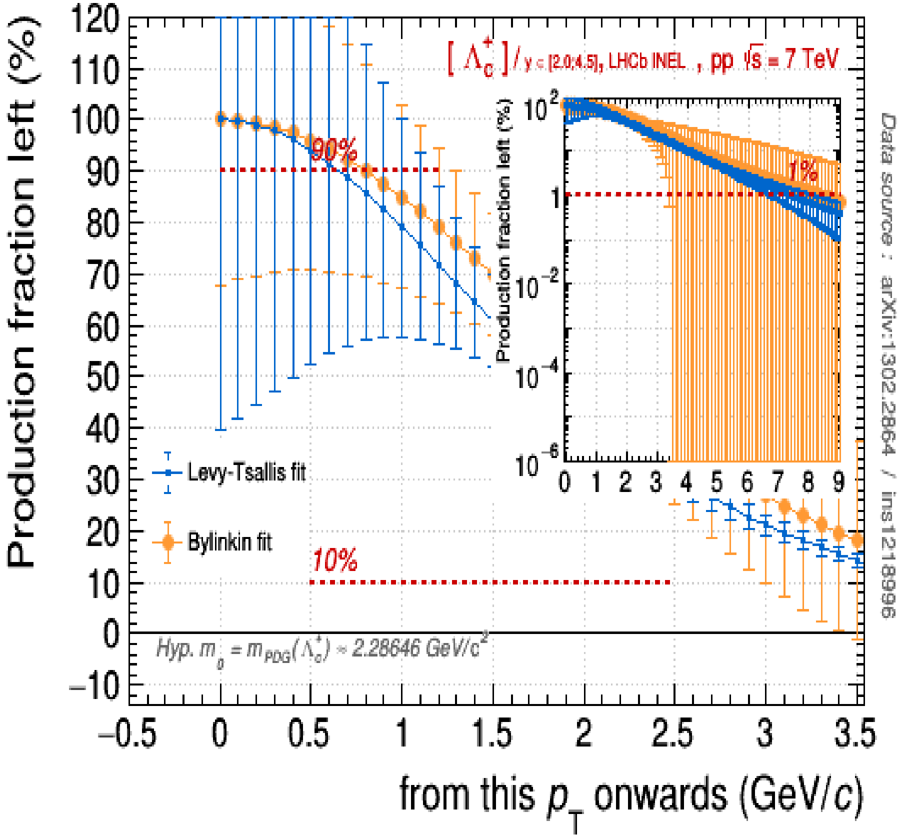
IV.4 – ITS*n* : why low p_T ? Example $\Xi^{\pm}$



If your Ξ^-(*dss*) measurement starts above 0.0 / 0.6 / 1.2 GeV/c, you miss x% of the total d*N*/d*y* in pp

NB : ALICE arXiv:1204.0282, Ξ > 0.6 GeV/c in |y| < 0.5

IV.5 – ITS*n* : why low p_T ? Example of Λ_C^+

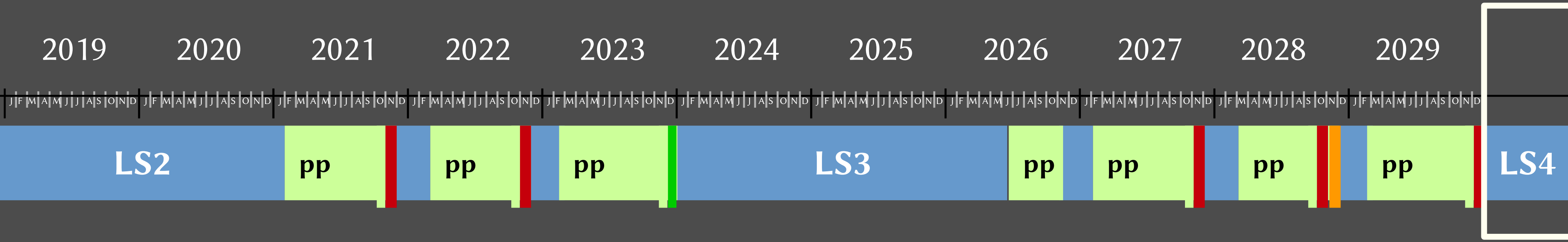


If your Λ_C^+(*udc*) measurement starts
above 0.0 / 1.0 / 2.0 GeV/c,
you miss x% of the total d*N*/d*y* in pp

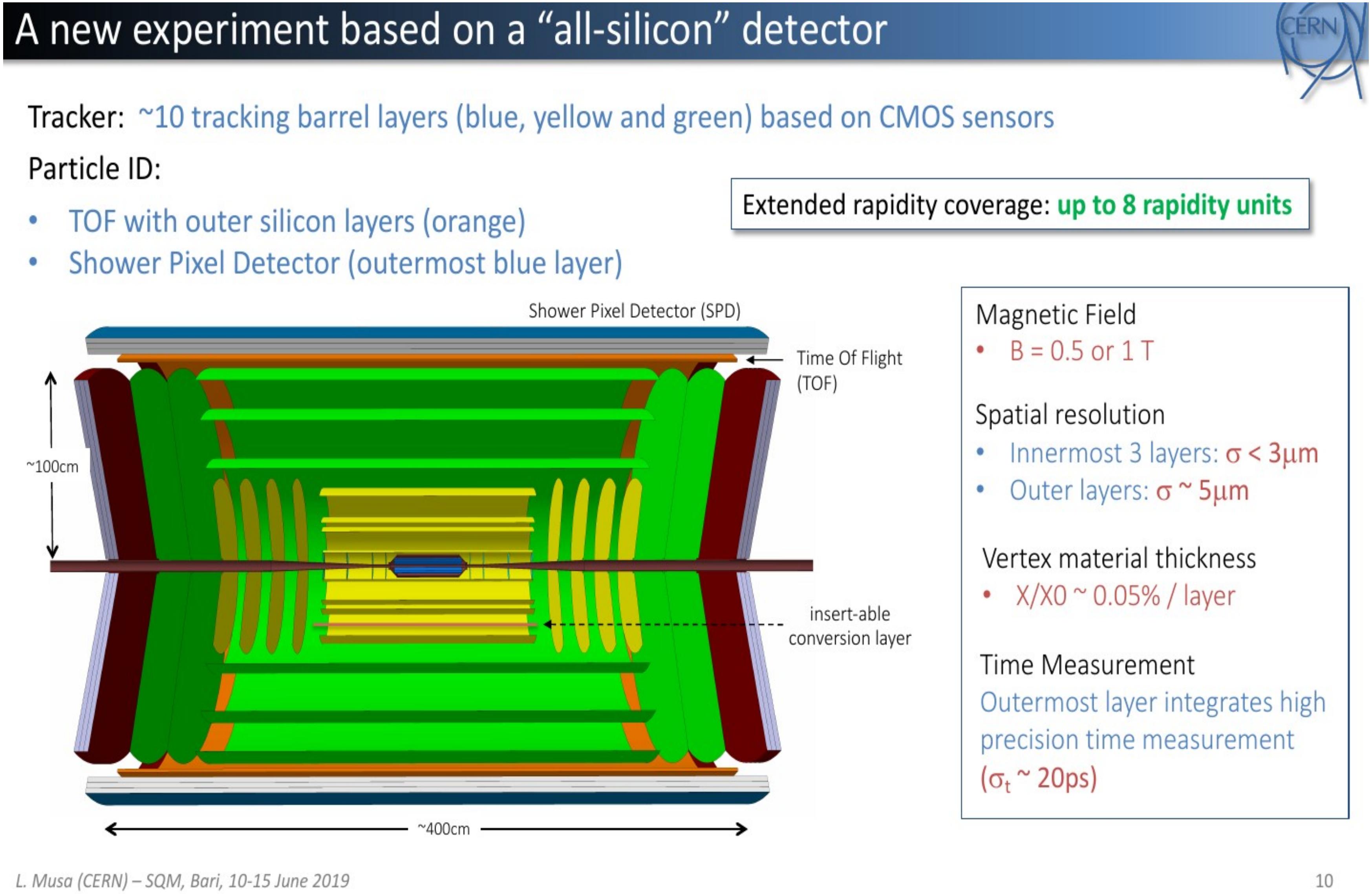
NB :

LHCb pp arXiv:1302.2864, Λ_C^+ > 0.0 GeV/c
ALICE pp arXiv:1712.09581, Λ_C^+ > 1.0 GeV/c

Part E – All-Si = after LS4 (≥2031, Run 5)



V.1 – All-Si : “LS4+” = “ITS4” = “ANGHIE”



A new experiment based on a “all-silicon” detector

Tracker: ~10 tracking barrel layers (blue, yellow and green) based on CMOS sensors

Particle ID:

- TOF with outer silicon layers (orange)
- Shower Pixel Detector (outermost blue layer)

Extended rapidity coverage: **up to 8 rapidity units**

Magnetic Field

- B = 0.5 or 1 T

Spatial resolution

- Innermost 3 layers: $\sigma < 3\mu m$
- Outer layers: $\sigma \sim 5\mu m$

Vertex material thickness

- X/X0 ~ 0.05% / layer

Time Measurement

Outermost layer integrates high precision time measurement ($\sigma_t \sim 20$ps)

L. Musa (CERN) – SQM, Bari, 10-15 June 2019

10

EoI A Next Genreration lhc heavy-ion Experiment LS4+, arXiv:1902.01211
+ SQM 2019 L.Musa Indico.cern.ch/e/755366/c/3428151/

V.2 – All-Si : LHC alternative options possibly on the table

In Run 4+5, beware CMS opportunities...

CMS MTD = "pile-up tagger", *Fig 1.5 + Fig 5.23 - TDR CERN-LHCC-2019-003*

a) CMS cool extra-things after LS3 :

- very large η coverage as well (|η| < 4)
- unique calorimetry ($\mathrm{PbW0_4}$ EmCal + HCAL SiPM sampling)

NB : all this, really expensive (quite more than the All-Si exp...),

but ~funded already

b) Assuming (*i*) material budget could be ~bearable for our "low-p_T" purpose

(plan : < 20 % X/X° cumulated on the whole tracker for HL-LHC Vs ≈ 30-40% X/X° currently),

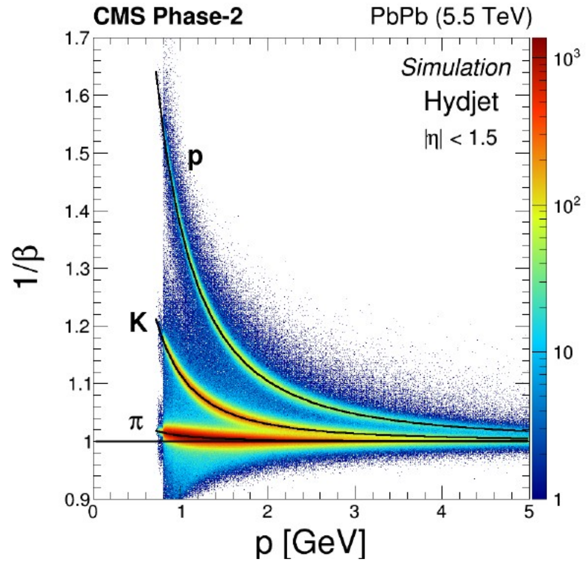
CMS with pile-up tagger MTD

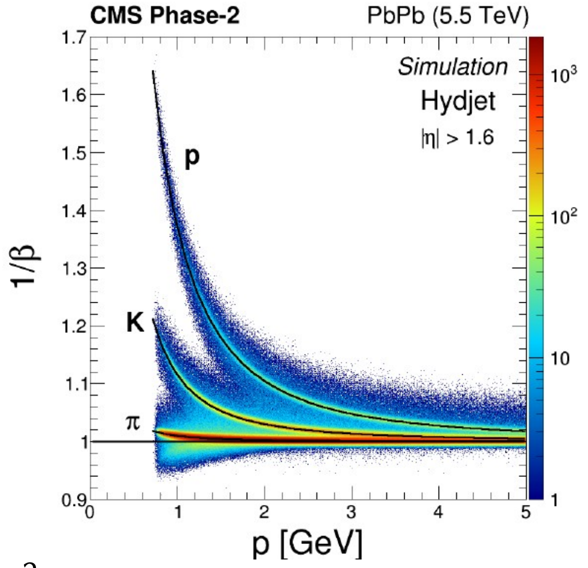
(LGAD in endcap or SiPM in barrel ⟶ $\sigma_{\text{time stamp}} \approx 30$ ps),

in (*ii*) any or low (?) pile-up condition (= Pb-Pb)

+ preferentially (*iii*) moderate B field,

MTD = a TOF detector...





⟶ Decisive but open questions :

- influence of pile-up (pp) / running time negociated within CMS in (very) low pile-up ?
- running with (B field < 3.8 T) Vs max. number of hysteresis cycles authorised for the CMS magnet ?

V.3 – All-Si : LHC alternative options possibly on the table

In Run 5, beware LHCb opportunities...

LHCb, EoI upgrade LS4, arXiv:1808.08865

a) Profiting from boost for forward geometry,
→ LHCb will remain a serial heavy-flavour tagger...
Sitting forward makes life easier than at mid-rapidity in that respect

b) Readout/tracking/PID capabilities likely to work by then
in all systems (pp, p-O, Ar-Ar, Xe-Xe, ...)
and under any event activity (Pb-Pb 0-5%)...

V.4 – All-Si : some physics cases (GT03 input after 1st discussions…)

- **Évolution de la température au long de la collision AA** : accessible avec la radiation thermale de photons virtuels émis au fil de l'avancement de la collision, sous forme de di-électrons de basses masses ($0 < m_{e+e-} < 2$ GeV/c^2).
- **Nature de la transition de phase et des degrés de liberté dans le QGP** : mesures des moments d'ordres supérieurs (m_n, $n \in [2;6]$) de la production nette, intégrée en p_T, de baryons ($\bar{p}$–p, …), de l'étrangeté (K^+-K^-, $\bar{\Lambda}$-Λ, …) à $\mu_B = 0$ (Sec. 3.3 in [4]) ; cela quantifie les fluctuations événement par événement de nombres quantiques globaux, donnant accès à des comparaisons directes avec les prédictions *ab initio* de la QCD sur réseau vis-à-vis des transitions de phases (déconfinement et symétrie chirale) [5].

V.5 – All-Si : some physics cases (GT03 input after 1st discussions…)

- **Hydrodynamique aux limites relativistes** : à $y \approx 0$, un tel détecteur doit offrir la possibilité de mesure des harmoniques de Fourier pour les hadrons non-identifiés, $v_n(h^\pm)$, jusqu'à des p_T faiblement relativistes, $p_T < 0{,}05$ GeV/c *($\beta^{\pi\pm} \approx 0{,}34$).* Repousser les limites basses de la mesure correspond à une avancée majeure pour la compréhension du *bulk* (à $|\eta| < 0.8$, $\sqrt{s_{NN}}$ O(TeV), 10 % de la production $h^\pm$ est situé entre [0 ; 0,2] GeV/c, 70 % entre [0 ; 0,5] GeV/c) ; cela permet une mesure sans extrapolation aux bas p_T et de suivre l'entrée de l'hydrodynamique d'un secteur non-relativiste vers celui relativiste (comportement d'abord linéaire puis quadratique des $v_n(h^\pm)$ avec les p_T croissants).
- **Interactions entre les partons durs et les constituants du milieu** :
  - modifications intra-jets (*jet shapes, jets structures,* reconstruits à l'aide des particules chargées) avec des incertitudes systématiques fortement réduites (<2-5%) grâce à une forte granularité et un accès aux traces qui composent les jets jusqu'à des bas p_T^{trace}.
  - di-jets étiquetés en saveurs (reconstruction complète des mésons lourds dans les jets) en vue de mesures sur les pertes d'énergie du charme et de la beauté.
- **Quarks lourds (c,b) face à la collectivité** :
  - section efficace totale du charme pour p_T>0 et y < 3-4 [mésons et baryons : $D^0(c\bar{u})$, $D^+(c\bar{d})$, $D_S^+(c\bar{s})$, $\Lambda_C^+(udc)$ et quarkonia $c\bar{c}$ [η_C, J/ψ, ψ(2S), χ_{Cj} …]
  - exploration des baryons (multi-)charmés (et étranges en surcroît) [$\Lambda_C^+(udc)$, $\Xi_C^+(usc)$, $\Xi_C^0(dsc)$, $\Omega_C^0(ssc)$, $\Xi_{CC}^{2+}(ucc)$, … , $\Omega_{CCC}^{2+}(ccc)$] et des baryons beaux [$\Lambda_B^0(udb)$, …]. L'objectif est notamment de tester les mécanismes de recombinaison des quarks charmés et leur sensibilité au milieu (hydrodynamisation, équilibration chimique, thermalisation / coefficients de transport). Un tel objectif exige une augmentation drastique de la significance du signal reconstruit et de la précision spatiale (paramètre d'impact des traces, notamment) pour reconstruire des topologies de désintégration de plus en plus complexes, allant typiquement de 2 à 6 corps.

Conclusion

Now +10-year horizon = blur ?

→ future of QCD/QGP physics = via precision measurements for sure.

No escape.

ALICE choice : roadmap paved with LS2 upgrades (≥2021)

with a stress given to :

i) PID and low p_T ($0 < p_T < 10$ GeV/c)

ii) flavour mapping (Light/Heavy Flavours : differences ? Similarities ?)

Such a physical roadmap = proposed to be extended with ITS3 (≥2026), in order to bridge a gap towards an all-Si experiment (≥2030)

NB: such an all-Si experiment could also play on other experimental grounds if people want it so, complementing the “ALICE-like perspectives” for such a lightweight experiment

(*e.g.* ∃ some BSM searches at low-p_T, R&D very close to e+e- experiments, …)

Appendices

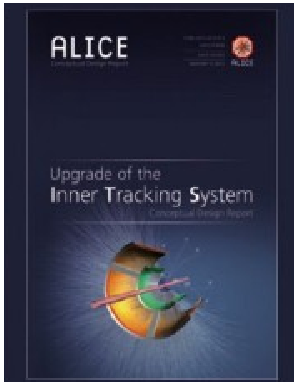
A.1 – Beyond LS2 : TDRs for run 3+4 detectors


ALICE
Upgrade of the
ALICE Experiment
Letter of Intent

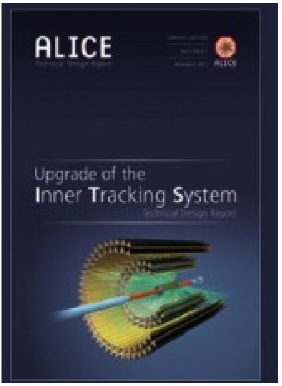
CERN-LHCC-2012-012


ALICE
Upgrade of the
Time Projection Chamber
Technical Design Report

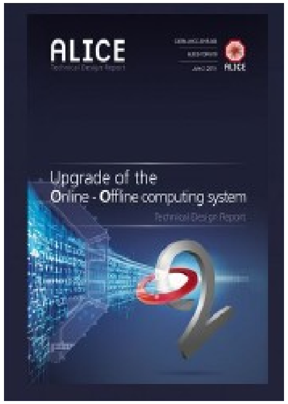
CERN-LHCC-2013-020


ALICE
Upgrade of the
Inner Tracking System
Conceptual Design Report

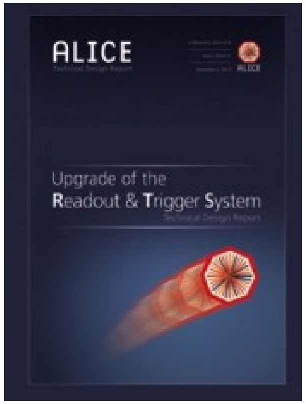
CERN-LHCC-2012-005


ALICE
Upgrade of the
Inner Tracking System
Technical Design Report

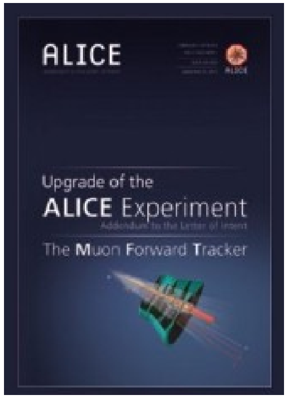
CERN-LHCC-2013-024


ALICE
Upgrade of the
Online - Offline computing system
Technical Design Report

CERN-LHCC-2015-006


ALICE
Upgrade of the
Readout & Trigger System
Technical Design Report

CERN-LHCC-2013-019


ALICE
Upgrade of the
ALICE Experiment
Addendum to the Letter of Intent
The Muon Forward Tracker

CERN-LHCC-2013-014


ALICE
Muon Forward Tracker
Technical Design Report

CERN-LHCC-2015-001

B.1 – ANGHIE : In2p3 prospectives, GT03 contribution

<table>
<tr><th></th><th colspan="3">ITS-2 [3]</th><th colspan="3">ITS-3 [6]</th><th colspan="3">ANGHIE [8]</th></tr>
<tr><td>Période LHC</td><td colspan="3">Run III + IV (2021-29)</td><td colspan="3">Run IV (2026-29)</td><td colspan="3">≥ Run V (>2030)</td></tr>
<tr><td>Nombres de couches</td><td colspan="3">3+<i>4</i></td><td colspan="3">3 (+<i>4 ITS-2</i>)</td><td colspan="3">$\mathcal{O}$(3+<i>7</i>)</td></tr>
<tr><td>R_{tube}</td><td colspan="3">1,82 cm</td><td colspan="3">1,6 cm</td><td colspan="3">1,6 ou 2,9[2]</td></tr>
<tr><td>r_{L0} / r_{L1} / r_{L2} … r_{Last} (cm)</td><td colspan="3">2,3 / 3,2 / 3,9 … <i>39,3</i></td><td colspan="3">1,8 / 2,4 / 3,0 … <i>39,3</i></td><td colspan="3">1,8 / … ≈ <i>100</i></td></tr>
<tr><td>Champ magnétique $B_{\text{solénoïde}}$</td><td colspan="3">0,2 ou 0,5 T</td><td colspan="3">0,2 ou 0,5 T</td><td colspan="3">0,2 à 1 T</td></tr>
<tr><td>Matière par couche (x/X_0)</td><td colspan="3">0,3 % à <i>0,8 %</i></td><td colspan="3">0,07 % à <i>0,8 %</i></td><td colspan="3">0,05 % à <i>0,5 %</i></td></tr>
<tr><td>Taille d'un pixel (µm^2)</td><td colspan="3">≈ 30 x 30</td><td colspan="3">≈15 x 15 (+ <i>30</i> x <i>30</i>)</td><td colspan="3">≈10 x 10 (+ <i>30</i> x <i>30</i>)</td></tr>
<tr><td>Résolution temporelle</td><td colspan="3">≥ 2-5 µs</td><td colspan="3">2-5 µs</td><td colspan="3">≤ 1 µs</td></tr>
<tr><td>Résolution spatiale</td><td colspan="3">5 µm</td><td colspan="3">5 µm</td><td colspan="3">≈ 3-5 µm</td></tr>
<tr><td>Couverture en η</td><td colspan="3">$|\eta| < 2{,}0$ à <i>1,3</i></td><td colspan="3">$|\eta| < 2{,}0$ à <i>1,3</i></td><td colspan="3">$|\eta| < 4{,}0$</td></tr>
<tr><td rowspan="2">$\varepsilon_{tracking}\left(p_T\left(h^{\pm}\right)=X\ GeV/c\right)$</td><td>1</td><td>0,1</td><td>0,05</td><td>1</td><td>0,1</td><td>0,05</td><td>1</td><td>0,1</td><td>0,05</td></tr>
<tr><td>98 %</td><td>60 %</td><td>10 %</td><td>98 %</td><td>75 %</td><td>20 %</td><td>98 %</td><td>75 %</td><td>20 %</td></tr>
<tr><td>Coûts totaux (R&D + Constr.)</td><td colspan="3">≈ 10 MCHF</td><td colspan="3">5,3 MCHF</td><td colspan="3">≈ 80-100 MCHF</td></tr>
<tr><td>Nb d'instituts / Nb de pays</td><td colspan="3">30 / 16</td><td colspan="3">30 / 16</td><td colspan="3">(>399 signataires)✋</td></tr>
</table>

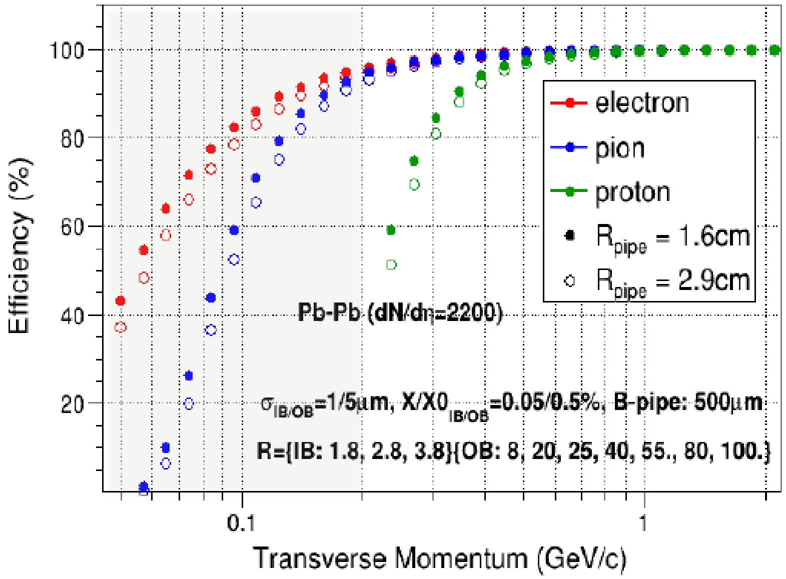
SQM 2019 L.Musa Indico.cern.ch/e/755366/c/3428151/

B.2 – ANGHIE : tracking efficiencies

Operation at reduced B field for tracking low p_T particles

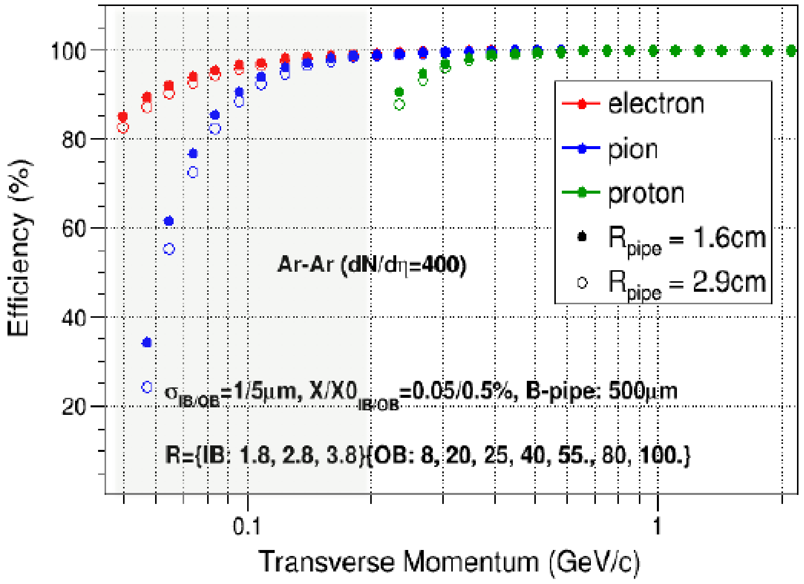
Pb-Pb (dN/dη = 2200), B = 0.2 Tesla

R. Shahoyan - 2018



dN/dη = 440, B = 0.2 Tesla

R. Shahoyan - 2018



Efficiency requiring that all particles reach the outermost layer at 1m (10 layers)

⇨ optimization possible (e.g. using only layers up to 40cm)

⇨ improvement for lower dN/dη

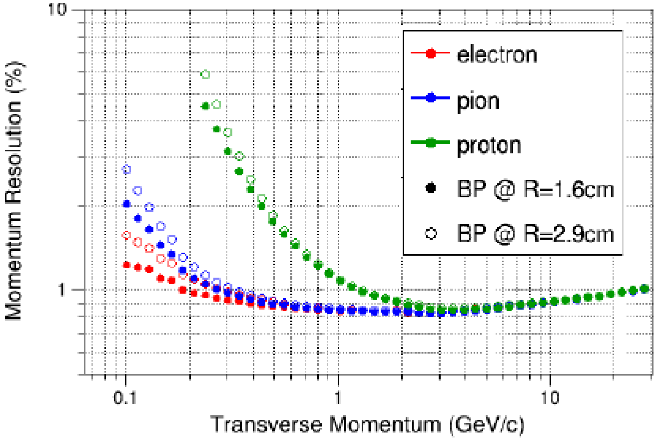
Further layout optimization possible!

SQM 2019 L.Musa Indico.cern.ch/e/755366/c/3428151/

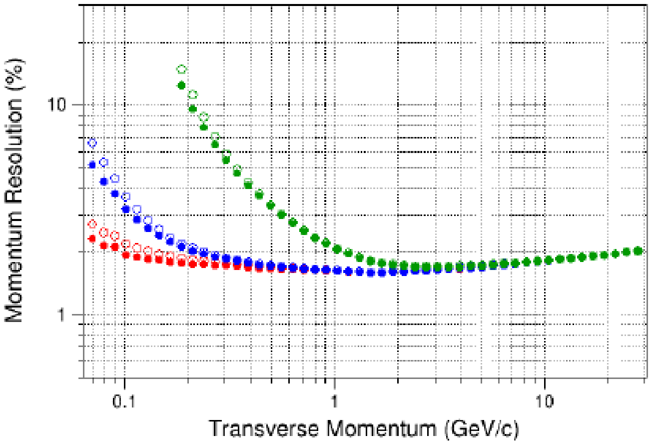
B.3 – ANGHIE : momentum resolution

Compared to ALICE in Run3, same performance at high p_T, some improvement at very low p_T

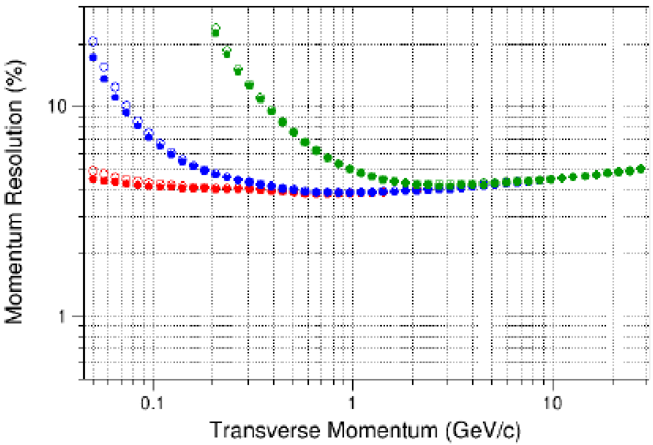
B = 1 T


R. Shahoyan - 2018

B = 0.5 T


R. Shahoyan - 2018

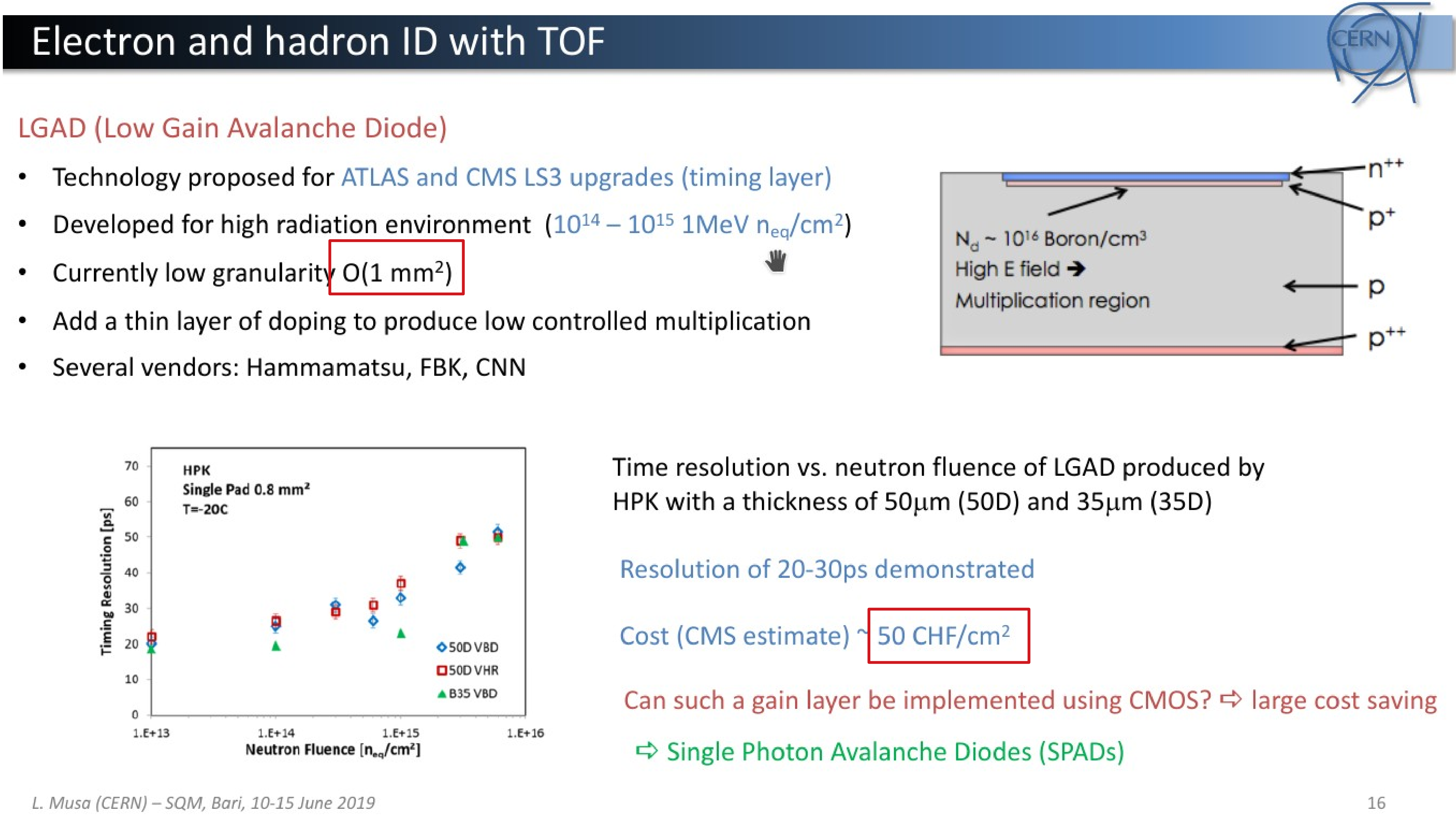
B = 0.2 T


R. Shahoyan - 2018

momentum resolution for 1GeV/c pions: ≈ 0.8% (1 T), ≈1.6% (0.5 T), ≈ 4% (0.2 T)

SQM 2019 L.Musa Indico.cern.ch/e/755366/c/3428151/

B.4 – ANGHIE : Particle Identification



Electron and hadron ID with TOF

LGAD (Low Gain Avalanche Diode)

- Technology proposed for ATLAS and CMS LS3 upgrades (timing layer)
- Developed for high radiation environment ($10^{14} – 10^{15}$ 1MeV n_{eq}/cm^2)
- Currently low granularity O(1 mm²)
- Add a thin layer of doping to produce low controlled multiplication
- Several vendors: Hammamatsu, FBK, CNN

Time resolution vs. neutron fluence of LGAD produced by HPK with a thickness of 50µm (50D) and 35µm (35D)

Resolution of 20-30ps demonstrated

Cost (CMS estimate) ~ 50 CHF/cm²

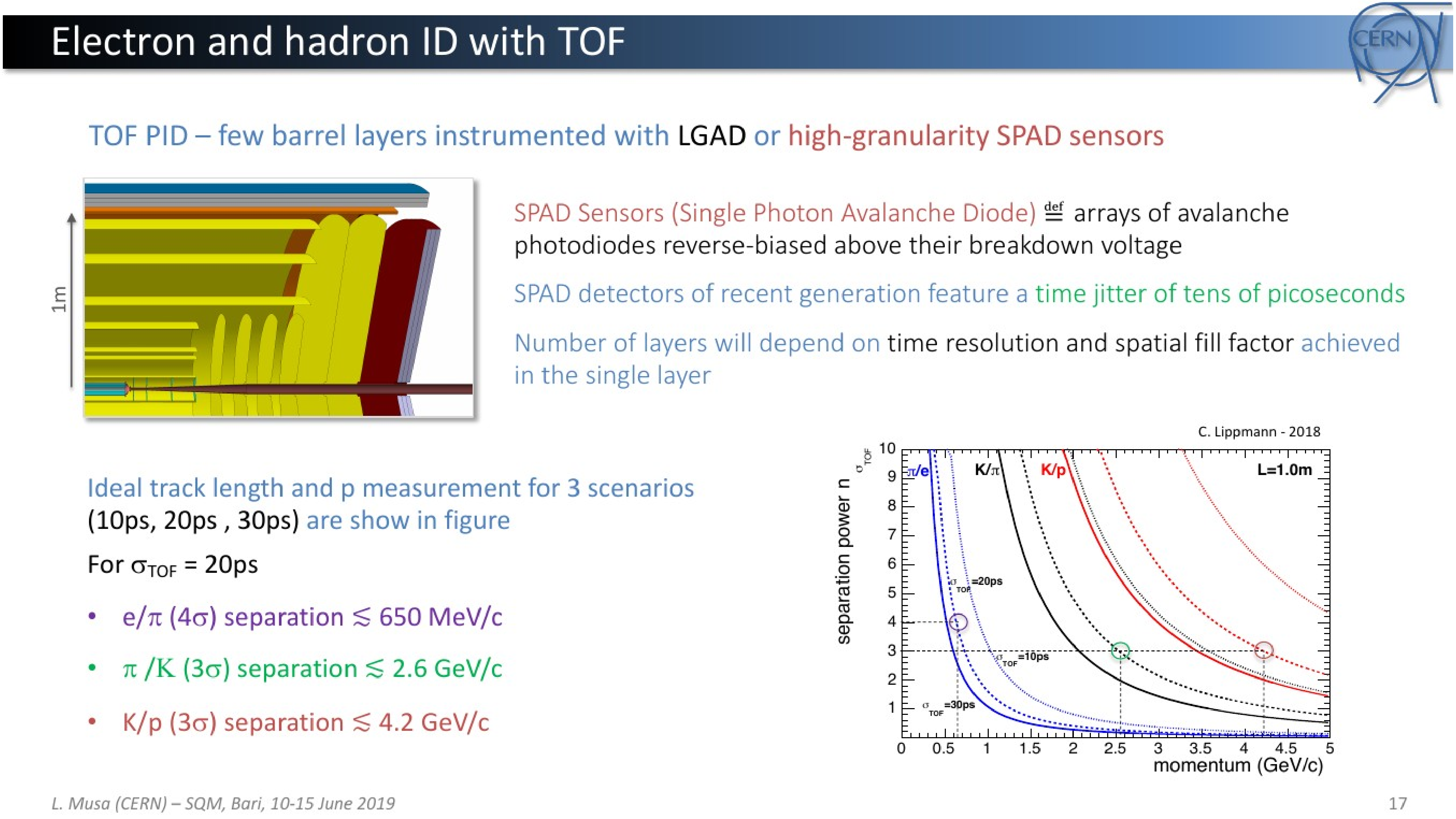
Can such a gain layer be implemented using CMOS? ➪ large cost saving

➪ Single Photon Avalanche Diodes (SPADs)

L. Musa (CERN) – SQM, Bari, 10-15 June 2019

SQM 2019 L.Musa Indico.cern.ch/e/755366/c/3428151/

B.5 – ANGHIE : TOF



Electron and hadron ID with TOF

TOF PID – few barrel layers instrumented with LGAD or high-granularity SPAD sensors

SPAD Sensors (Single Photon Avalanche Diode) $\stackrel{\text{def}}{=}$ arrays of avalanche photodiodes reverse-biased above their breakdown voltage

SPAD detectors of recent generation feature a time jitter of tens of picoseconds

Number of layers will depend on time resolution and spatial fill factor achieved in the single layer

Ideal track length and p measurement for 3 scenarios (10ps, 20ps , 30ps) are show in figure

For σ_{TOF} = 20ps

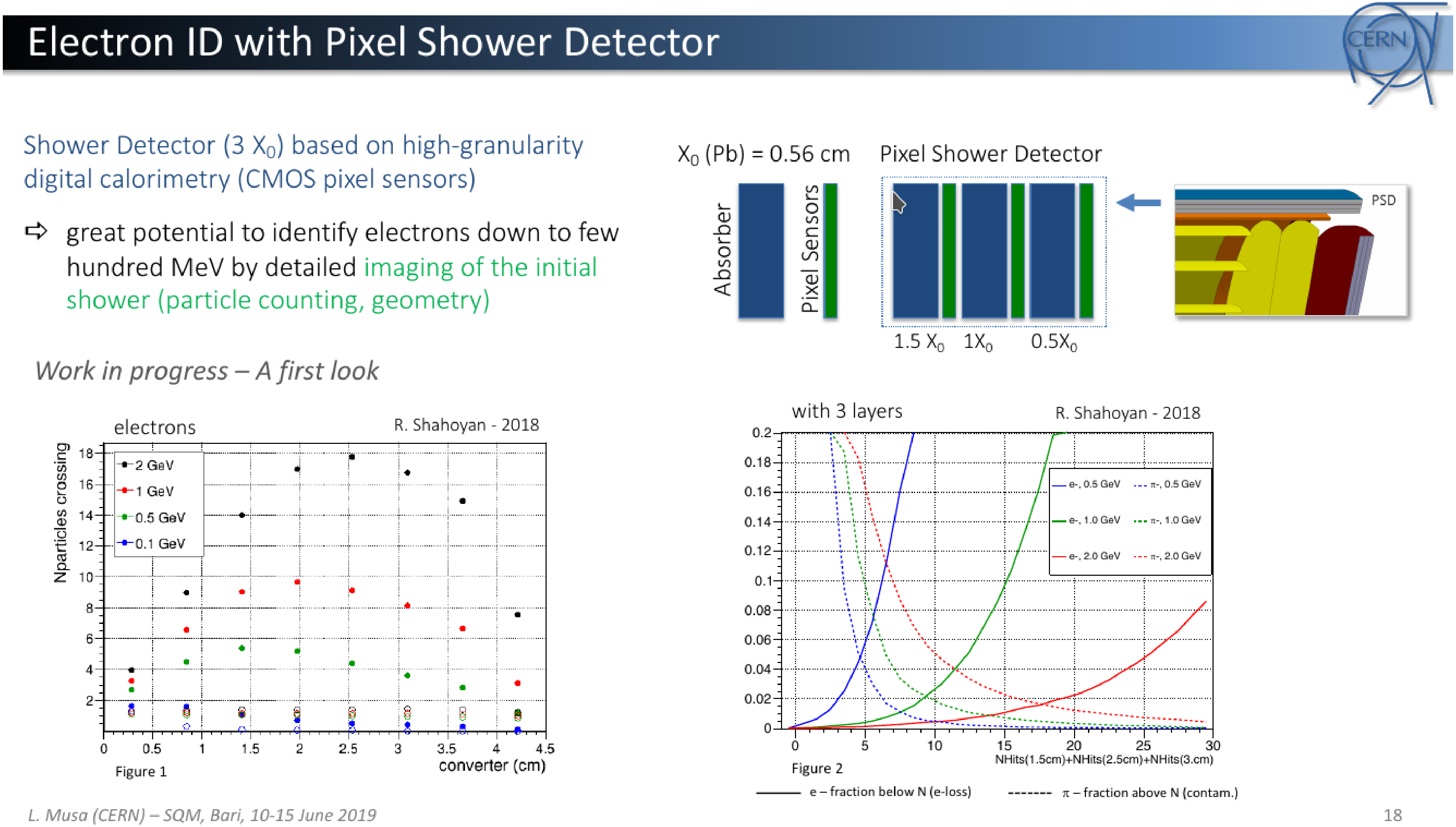
- e/π (4σ) separation ≲ 650 MeV/c
- π /K (3σ) separation ≲ 2.6 GeV/c
- K/p (3σ) separation ≲ 4.2 GeV/c

C. Lippmann - 2018

L. Musa (CERN) – SQM, Bari, 10-15 June 2019

17

B.6 – ANGHIE : electron pre-shower, PSD…



Electron ID with Pixel Shower Detector

Shower Detector (3 X_0) based on high-granularity digital calorimetry (CMOS pixel sensors)

⇨ great potential to identify electrons down to few hundred MeV by detailed imaging of the initial shower (particle counting, geometry)

Work in progress – A first look

Figure 1

Figure 2

—— e – fraction below N (e-loss) - - - - π – fraction above N (contam.)

L. Musa (CERN) – SQM, Bari, 10-15 June 2019

18