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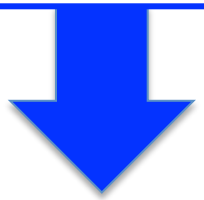
Biennale du LPNHE – Tirrenia 04/10/2016

Motivation

- La physique de la saveur, complémentaire au recherches directes de nouvelles physique, est plus que jamais d'actualité.
- La majorité des mesures sont actuellement limitées par l'erreur statistique, et pas par l'erreur systématique => il faut collecter une quantité de données encore plus grande
- Les paramètres de fonctionnement du LHC après le Run II impliquent une dose de radiation et un taux d'occupation trop élevés pour les sous-détecteurs actuels.

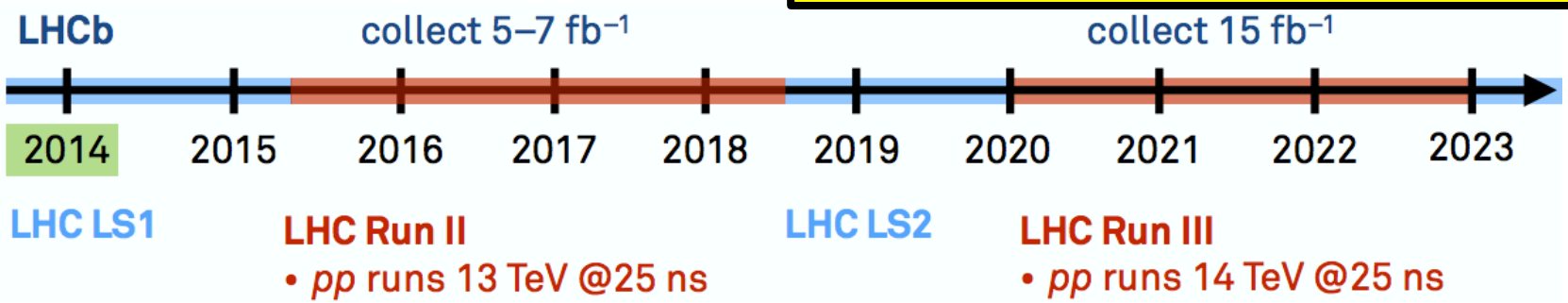


Upgrade du détecteur LHCb.

Timescale

LHCb UPGRADE

- replace/overhaul several sub-detectors: VeloPixel, Trackers (UT, ***SciFi***), RICH
- replace readout electronics: from 1 MHz to 40 MHz
- Full software trigger

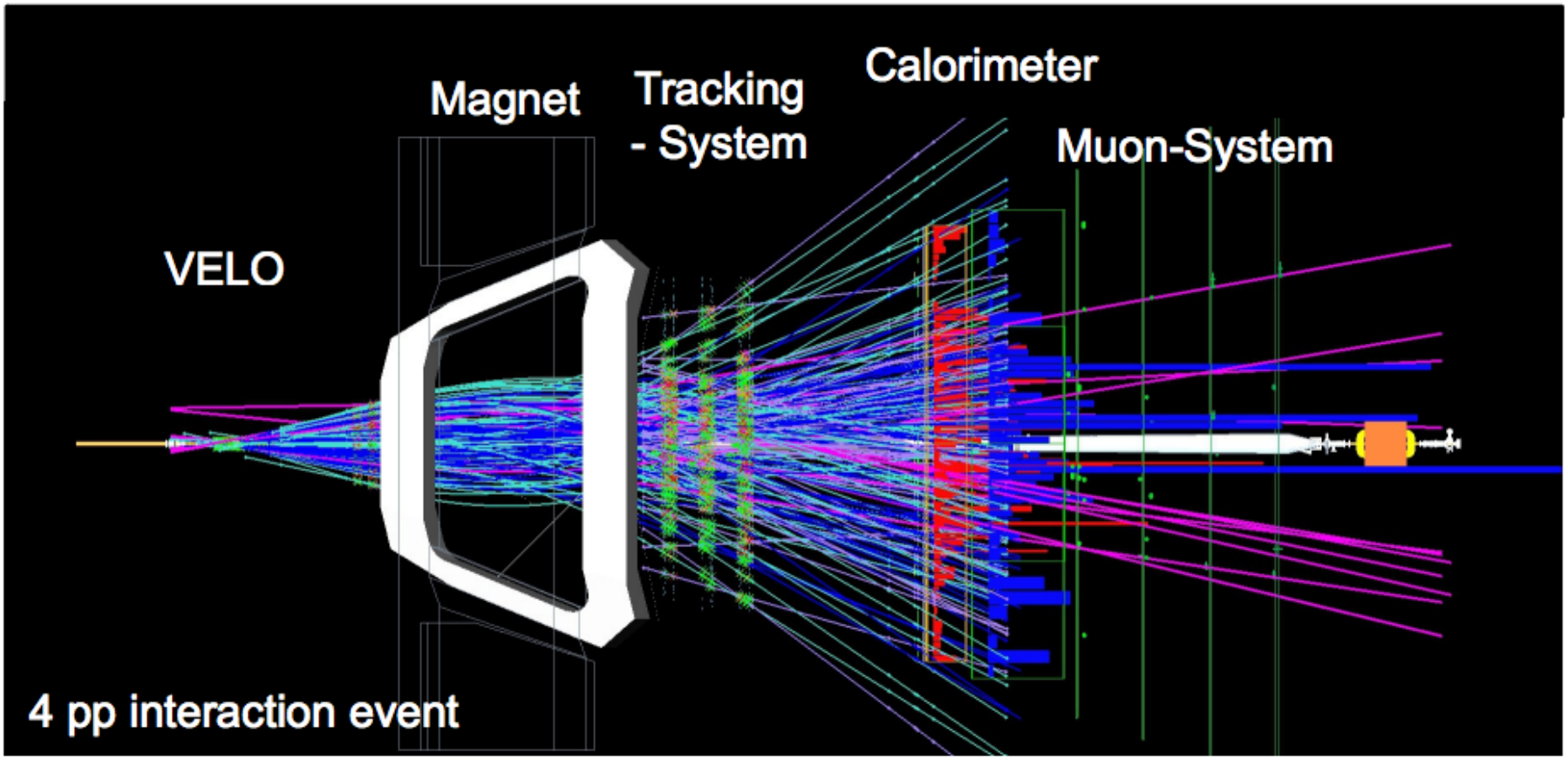


LHC running conditions		
Year	*2012*	***upgrade***
Energy	*8 TeV*	***13 - 14 TeV***
Bunch spacing	*50 ns*	***25 ns***
Colliding bunches		***2400***
Luminosity leveling	*$4x10^{32}$ cm^{-2} s^{-1}*	***$2x10^{33}$ cm^{-2} s^{-1}***
Pileup (interactions/bunch crossing)	*1.7*	***2.5 to 5***

Target: collect 50 fb^{-1} over 10 years after LS2

NB: C'est le seul upgrade prévu pour LHCb pour l'instant (discussions en cours sur le futur).

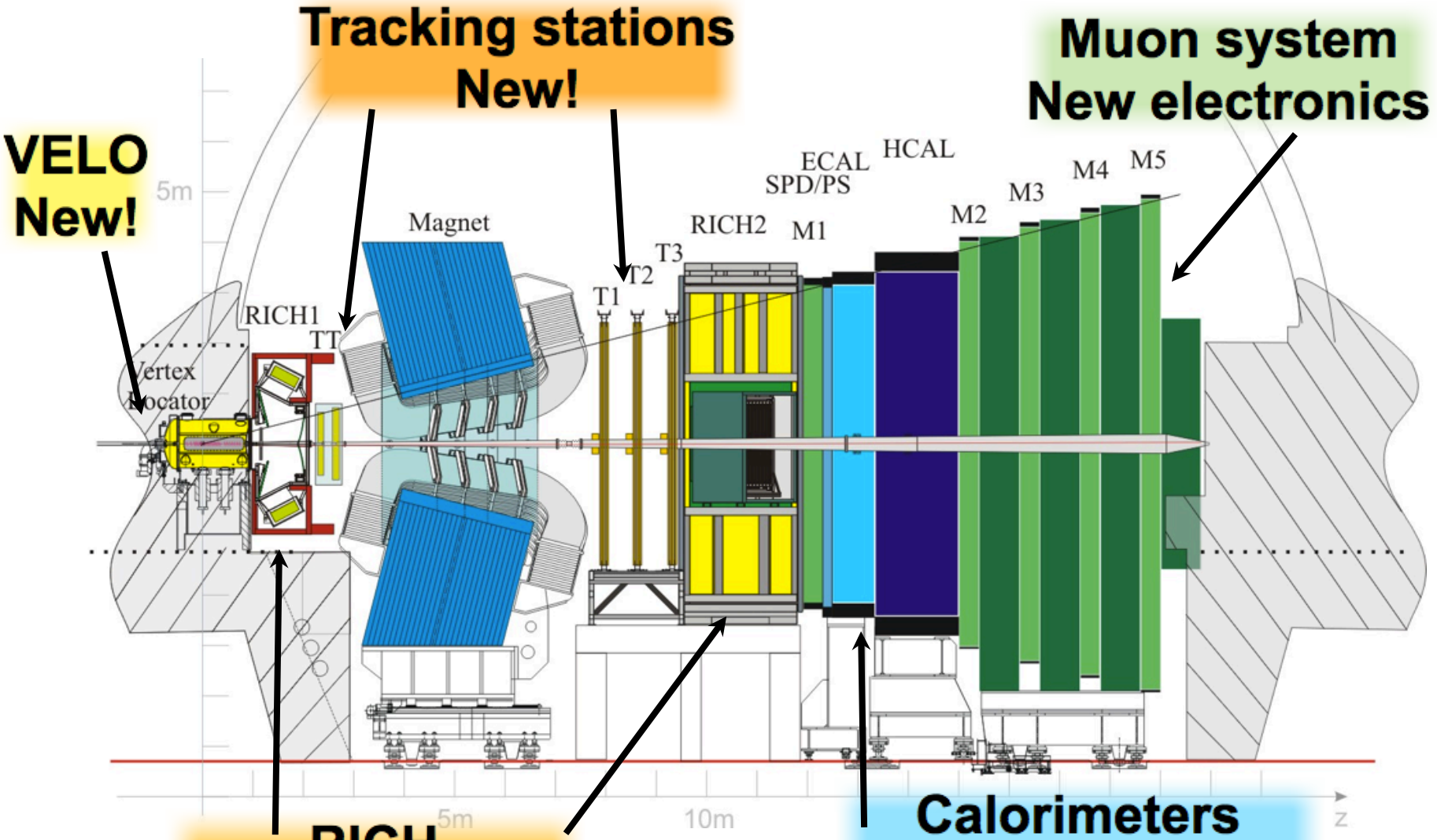
Occupancy in the upgrade era



Average pp interactions per bunch crossing m: 2 → 5

Average number of tracks in a bb event:72 → 180

LHCb upgrade: overview



LPNHE contribution to the upgrade

Since 2013.

Main development related to the new tracking detector (SciFi):

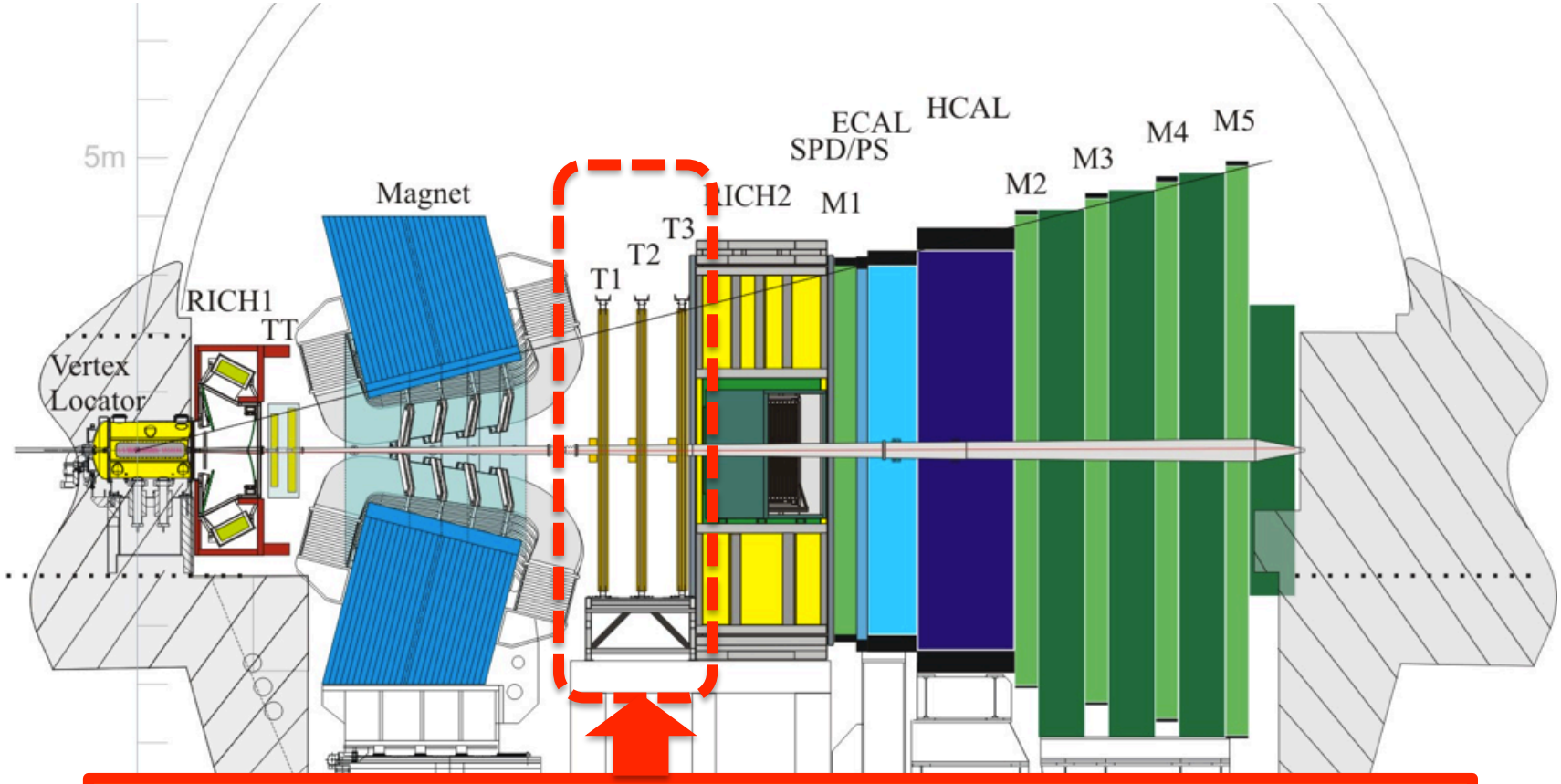
- ***electronics:*** Olivier Le Dortz responsable de l'acquisition backend du SciFi

- ***simulation of the tracker*** (geometry, detector design) ***and evaluation of its performances*** (pattern recognition)

Tracking activities are pursued also in the context of Run II.

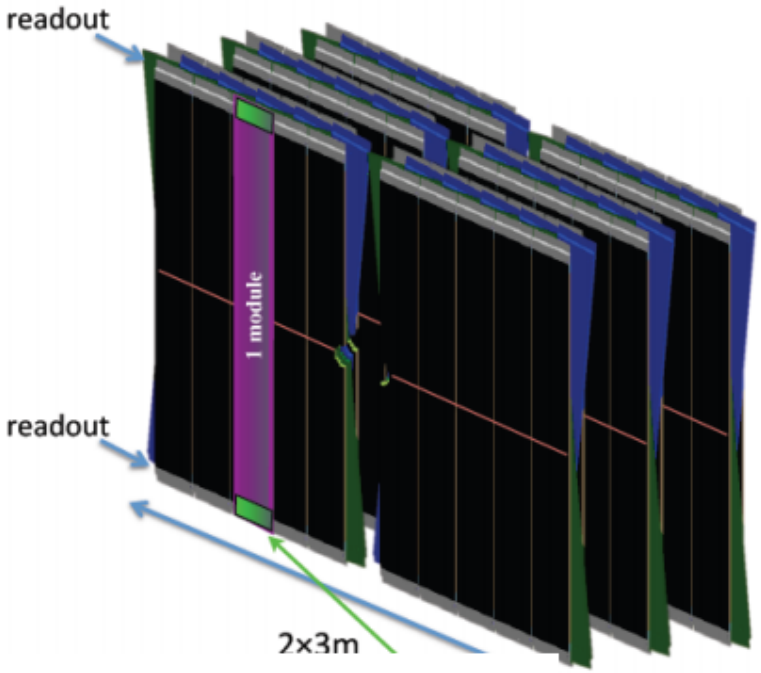
The SciFi detector

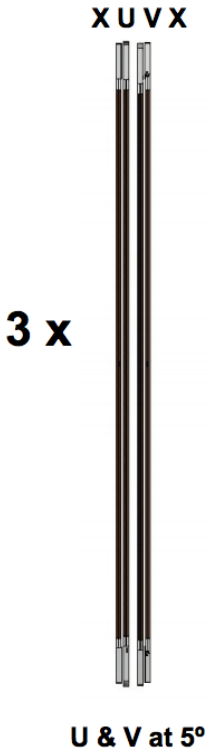
Il est ou le SciFi?

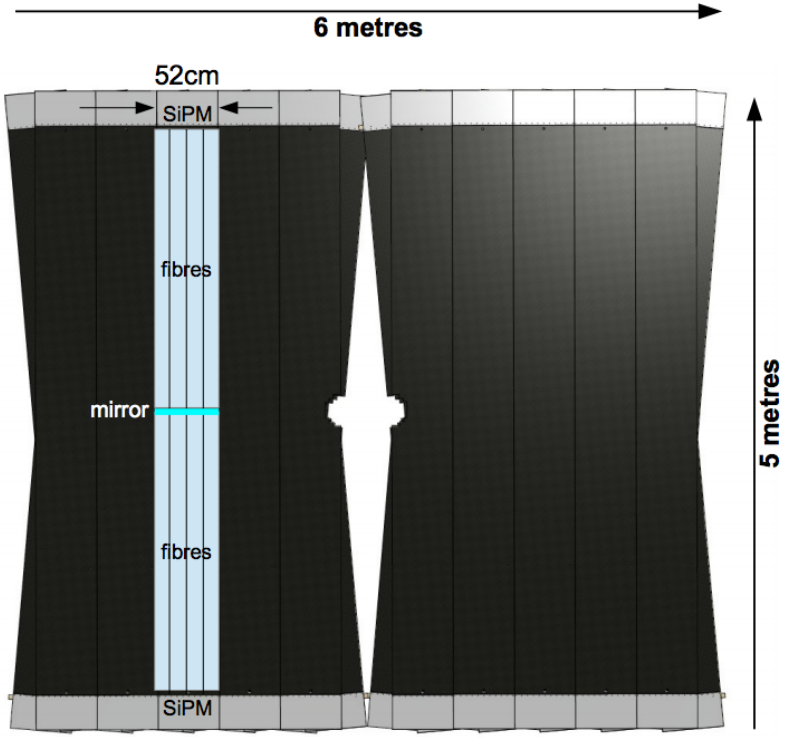


Le Scintillating Fiber tracker (SciFi) va remplacer les stations de tracking après l'aimant

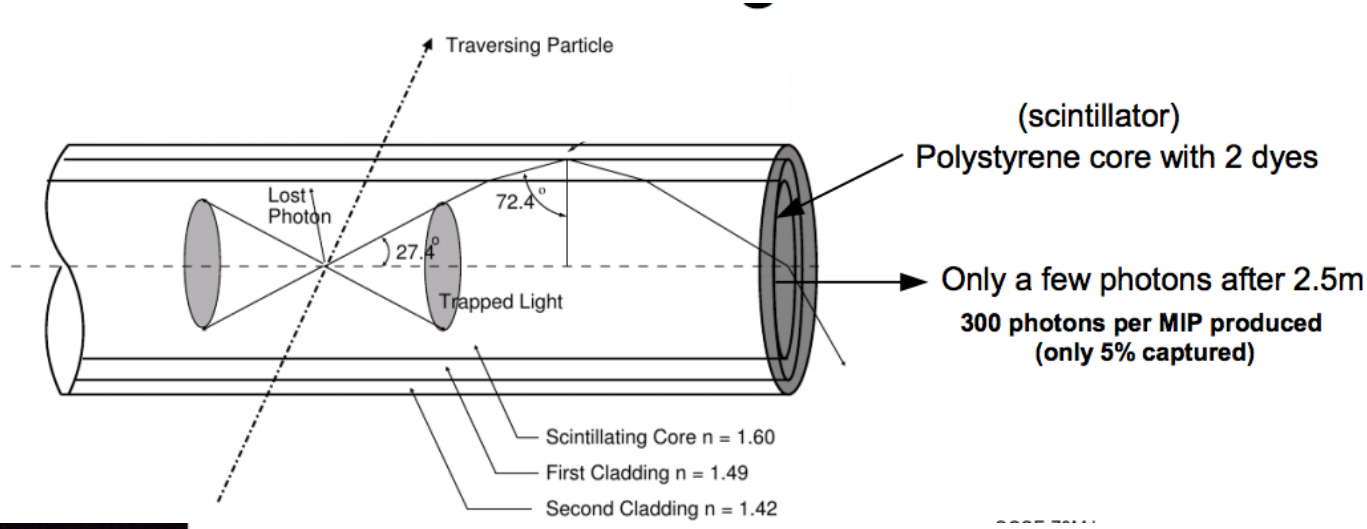
Planes and modules

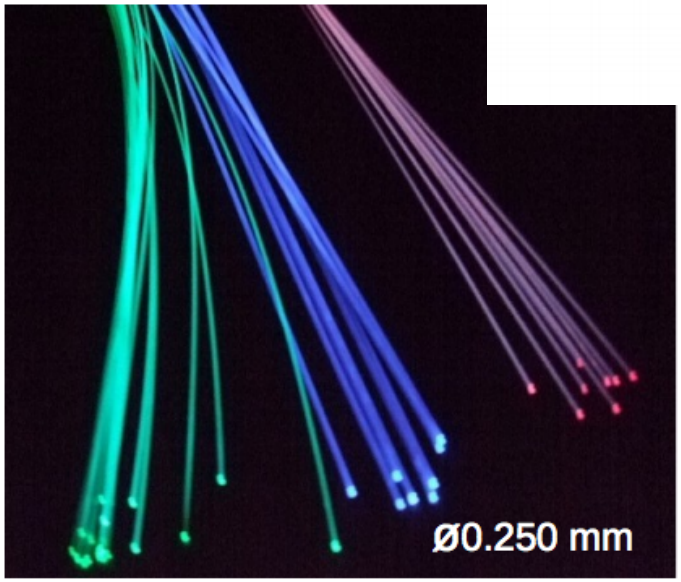






Fibres

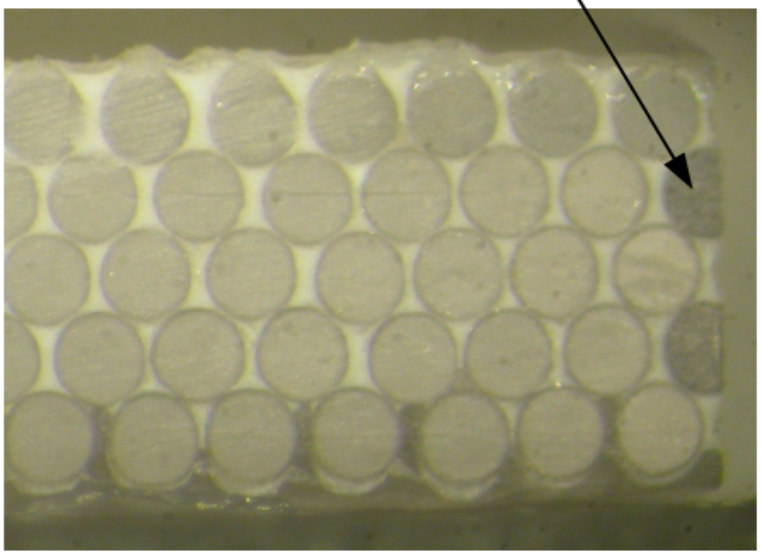




Scintillating fibres

-fast decay time (2.8ns)
-good light yield and attenuation length

Cutting will create dead fibres on the edges



Silicon PhotoMultipliers

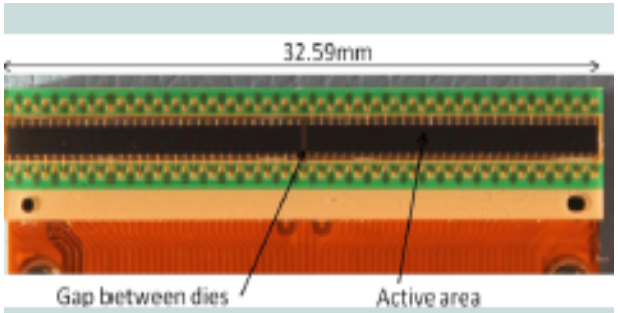
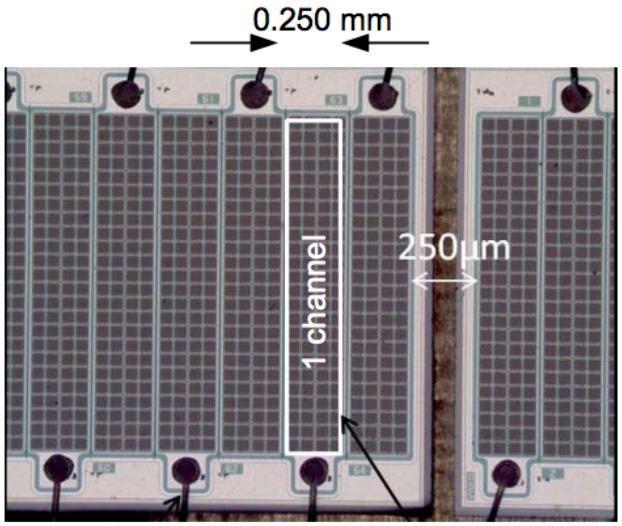


Figure : Hamamatsu SiPM

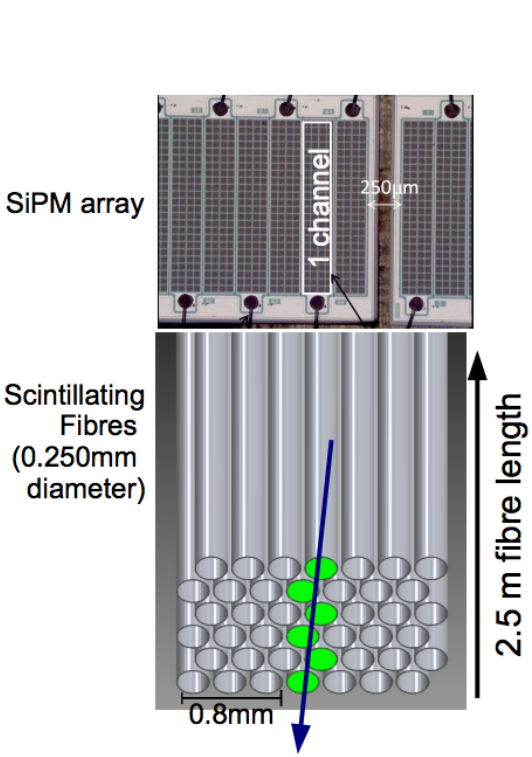


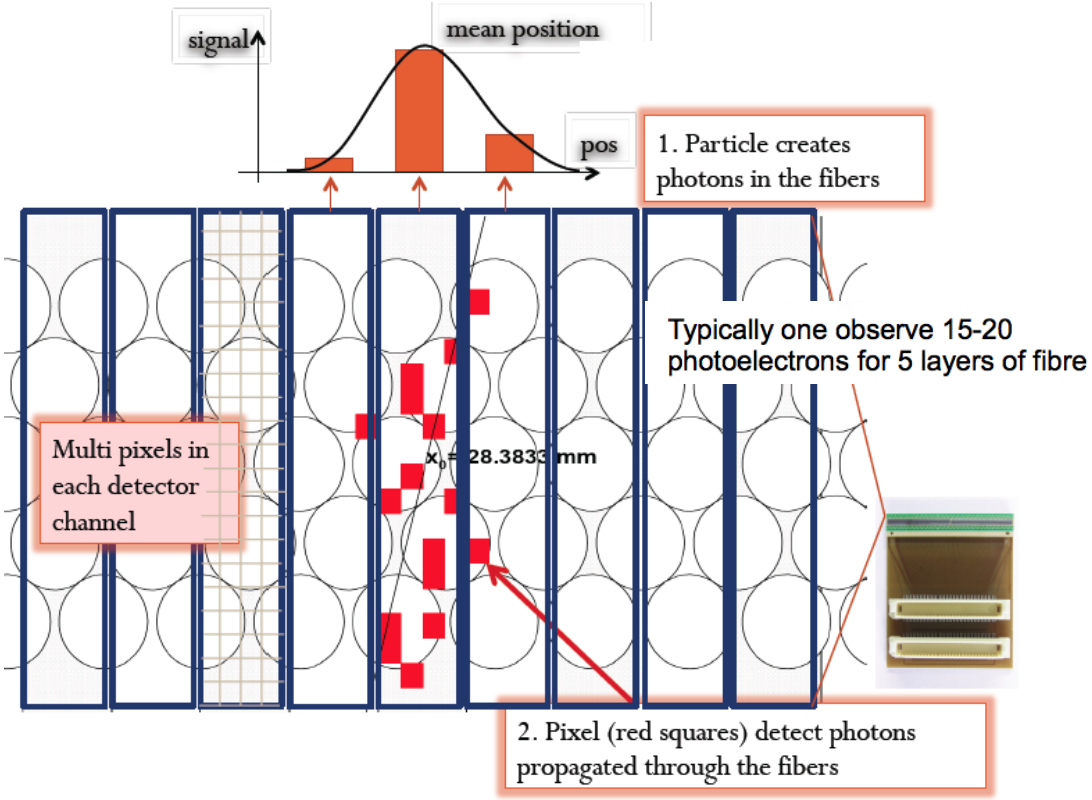
An array of pixelated silicon photomultipliers

-fast signals
-high photon detection efficiency (40+%)
-compact channel size

Figure : The SiPM flex cable

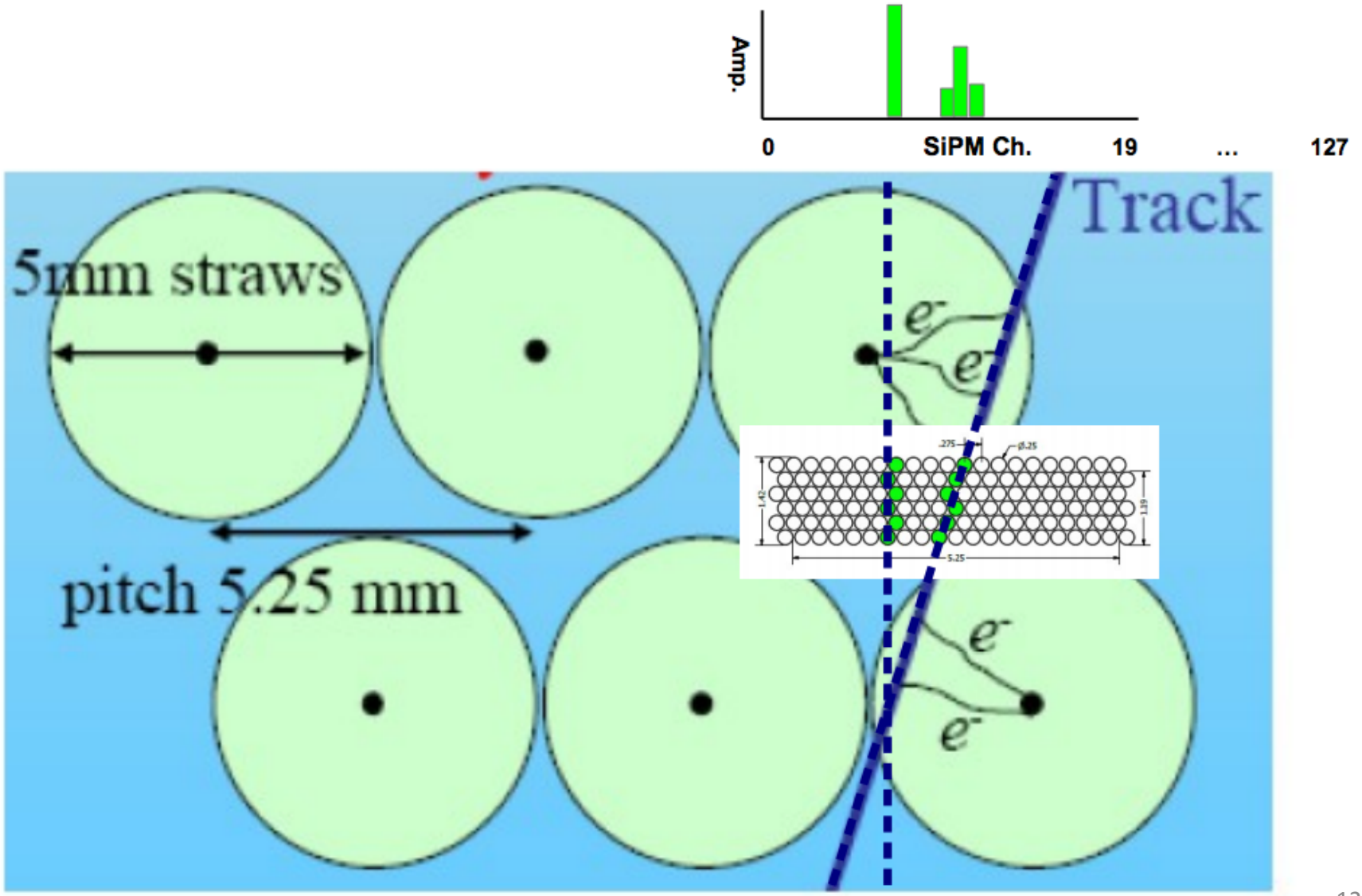
Caractéristiques principales





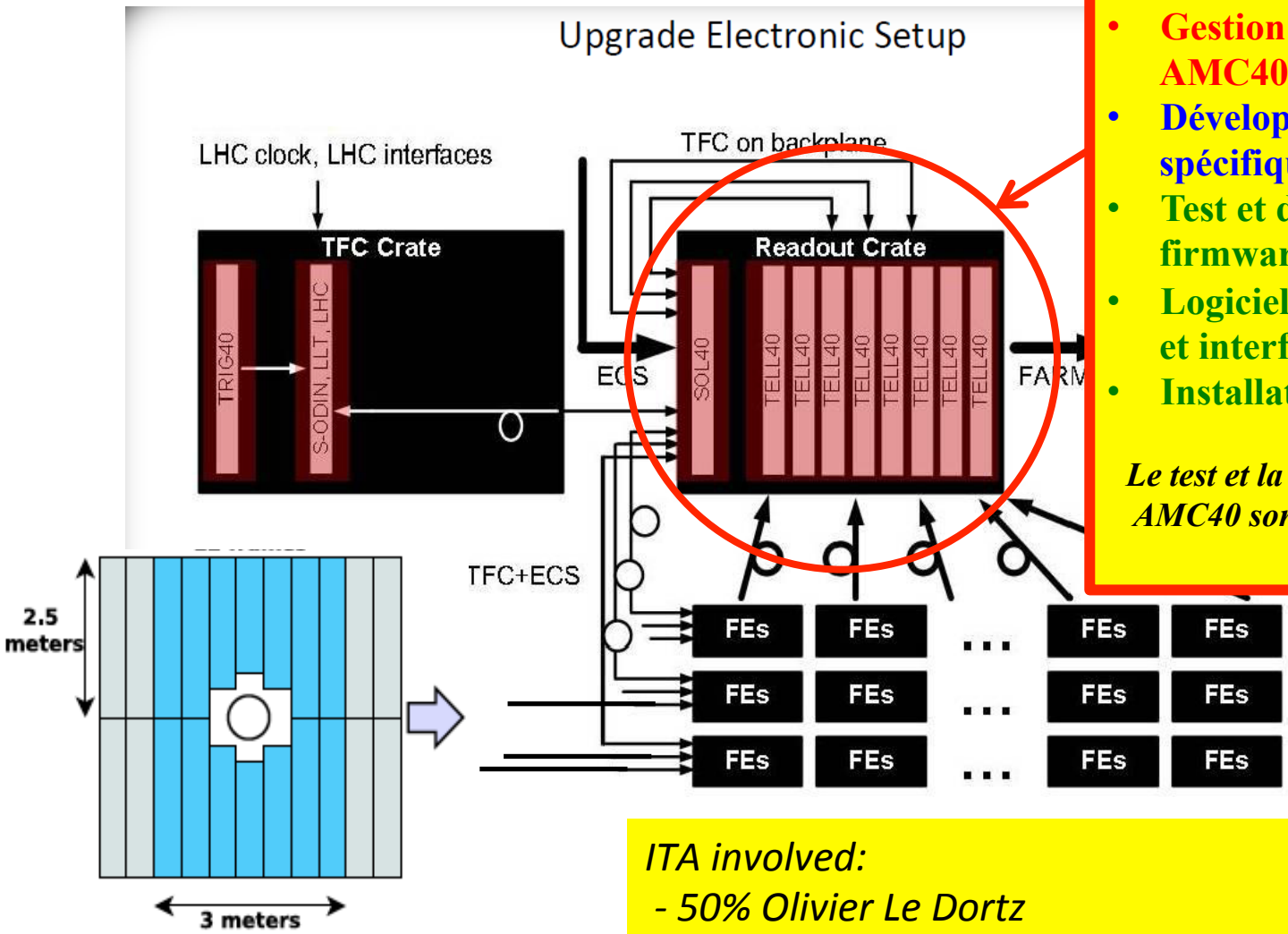
- Made up of ***3 stations***, each station with ***4 layers*** (x, u, v, x), each layer divided into ***10 (12) fiber modules.***
- ***Scintillating fibers: 250 µm diameter, 2.5m long***, arranged in multiple planes for improved light collection.
- ***Mirror at the center*** (beam pipe height) to collect reflected light.
- Multi-channel Silicon photo-multipliers (***SiPM 128 channels in a 32mm array***), ***16 SiPM per module.***
- ***40MHz front-end electronics***.
- Dead material in the acceptance minimized through ***readout at borders***.
- Whole acceptance covered (no IT/OT as today)

Comparaison avec le detecteur actuel



SciFi: le projet electronique du LPNHE

See Olivier's presentation!



Prise en charge de l'électronique de back-end SciFi:

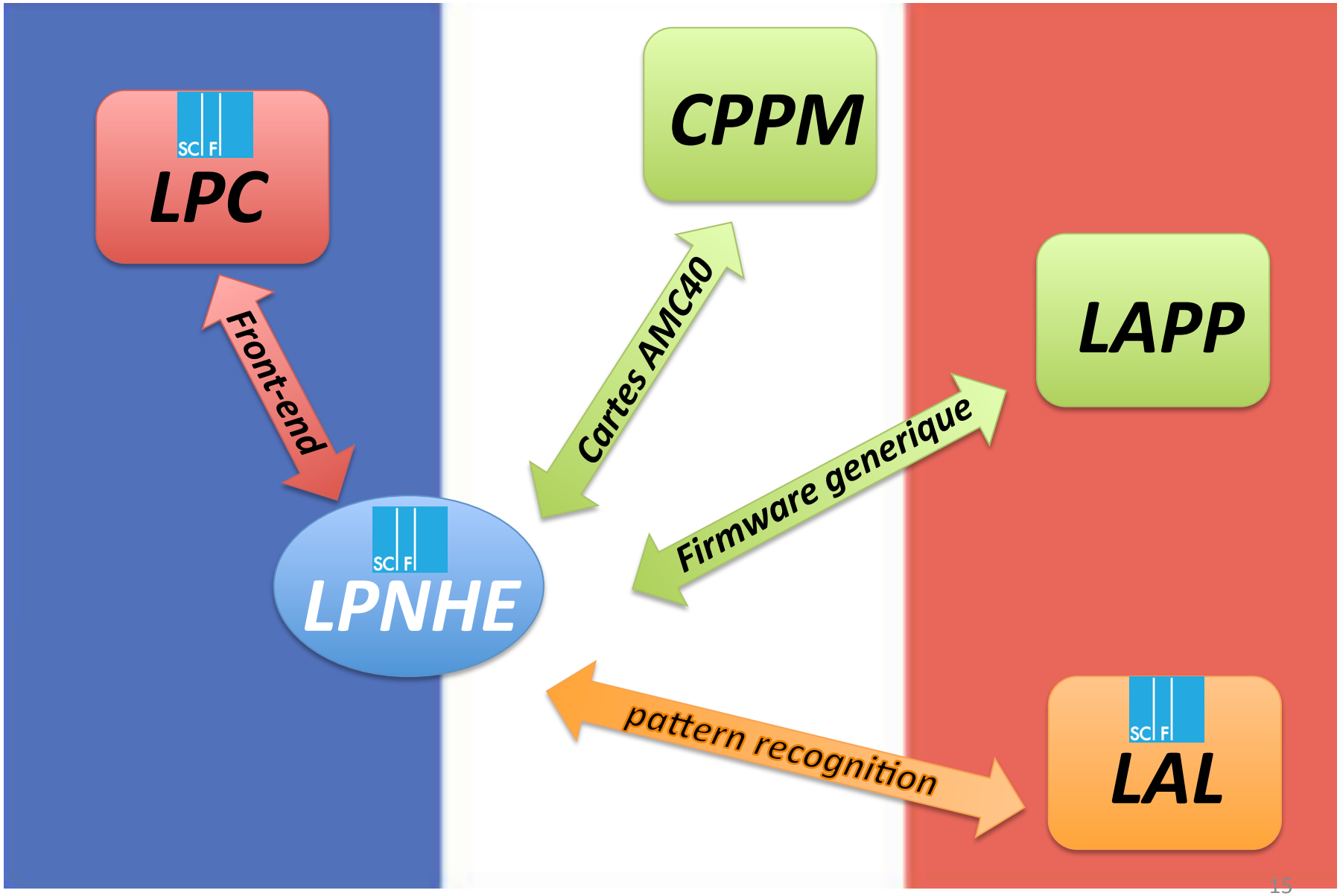
- **Gestion de l'achat des cartes AMC40 en format PCIexpress.**
- **Développement d'un firmware spécifique, si nécessaire.**
- **Test et déploiement du firmware.**
- **Logiciel de pilotage des cartes et interface avec la DAQ.**
- **Installation et commissioning.**

Le test et la qualification hardware des AMC40 sont sous la responsabilité du CPPM

ITA involved:
- 50% Olivier Le Dortz
- 45% Diego Terront => Eduardo Sepulveda

La collaboration SciFi

Implication dans le panorama français

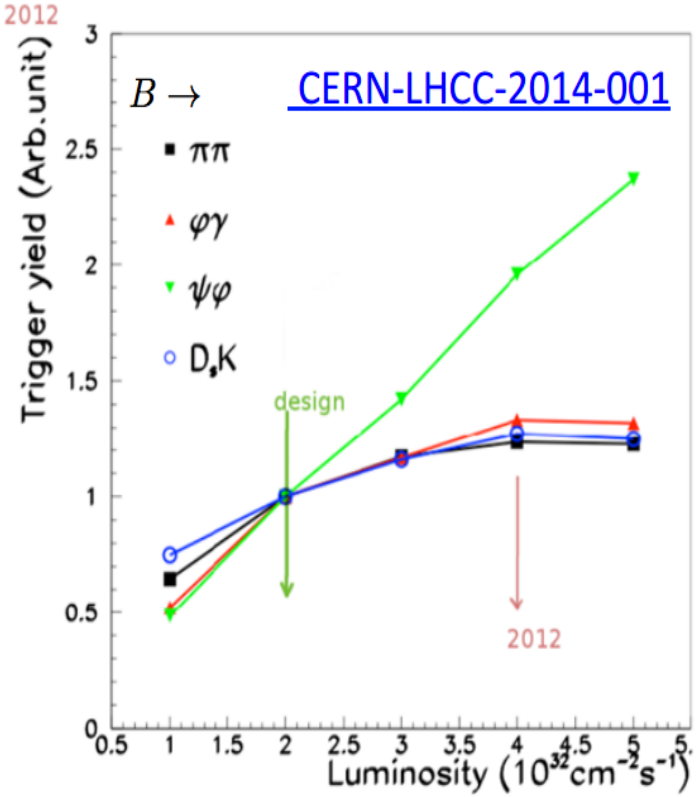


The trigger and the tracking

Beyond the limits: the trigger

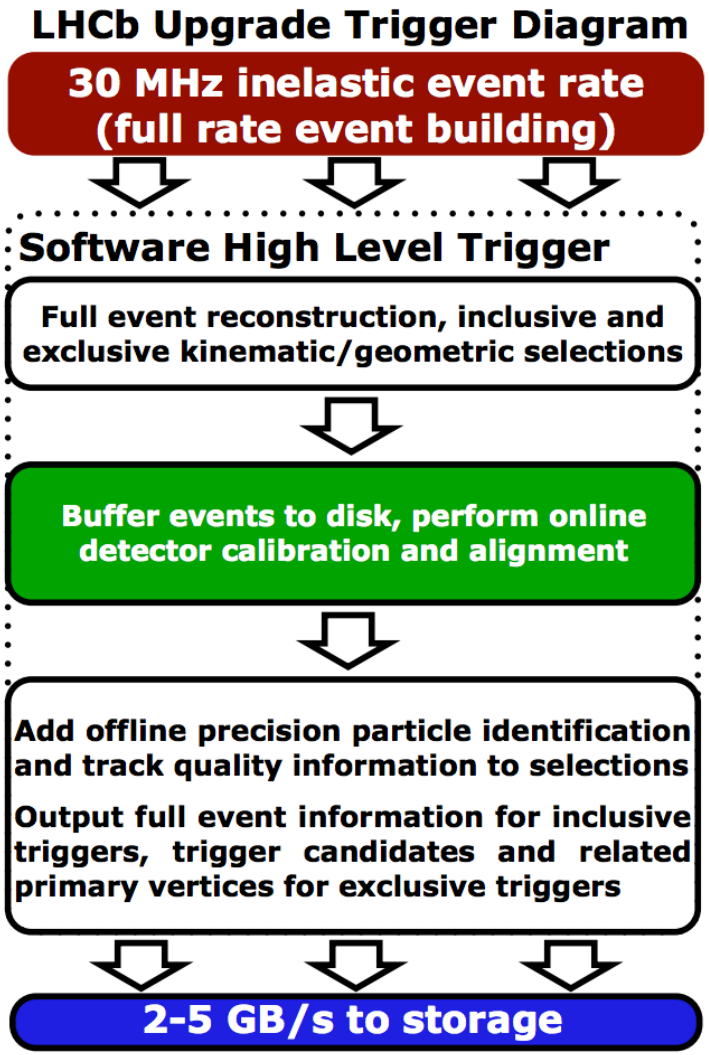
Expected luminosity four times higher: $2x10^{33}$ cm^{-2} s^{-1} (=> 5 fb^{-1} /year)

Hadronic channels saturate due to energy cuts in the hardware trigger



Need to move from 1 MHz to 40 MHz read-out rate (i.e. reading at the collision frequency of the LHC!)

The new trigger paradigm

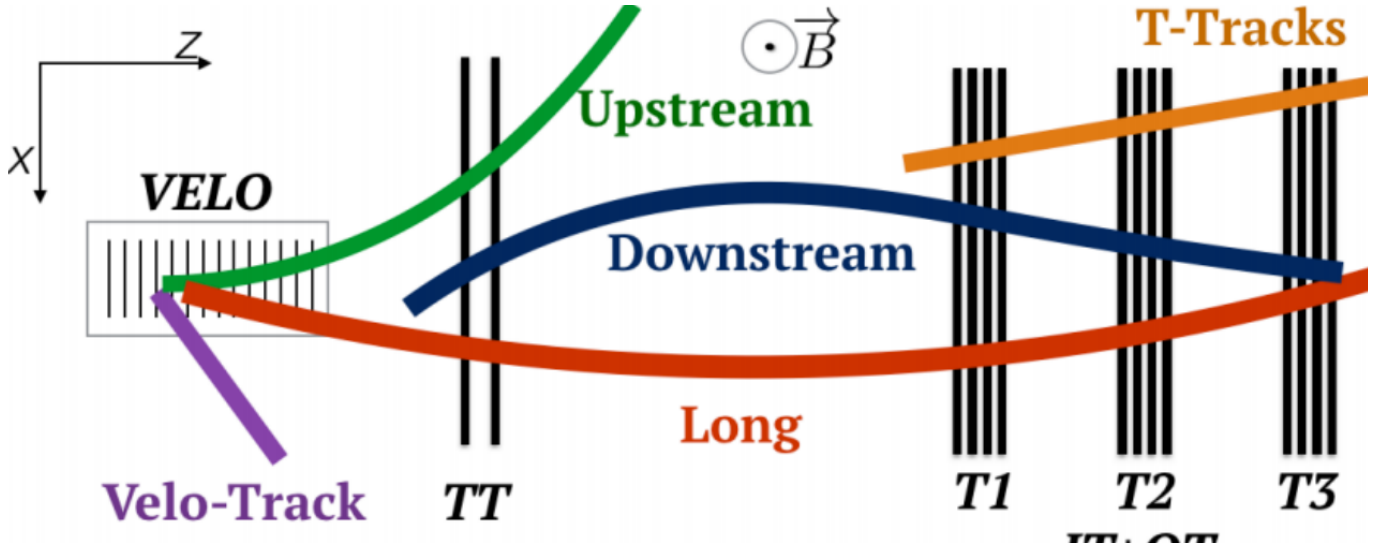


Full software trigger: driving criteria

- **Much more information at trigger level needed to categorize the more complex event topology**
- Essential to be able to:
  - Have the same tracking sequence online as online
  - Perform the real-time alignment and calibration
- Challenging time constraints for reconstruction:
  - Single CPU timing budget for reconstruction to be $\mathcal{O}(10)$ ms
- To be studied the possibility to optimized the reconstruction as a function of the decay channels

Run II used as test bench!

Tracking reconstruction



Several algorithms reconstructiong tracks traversing part or the whole detector

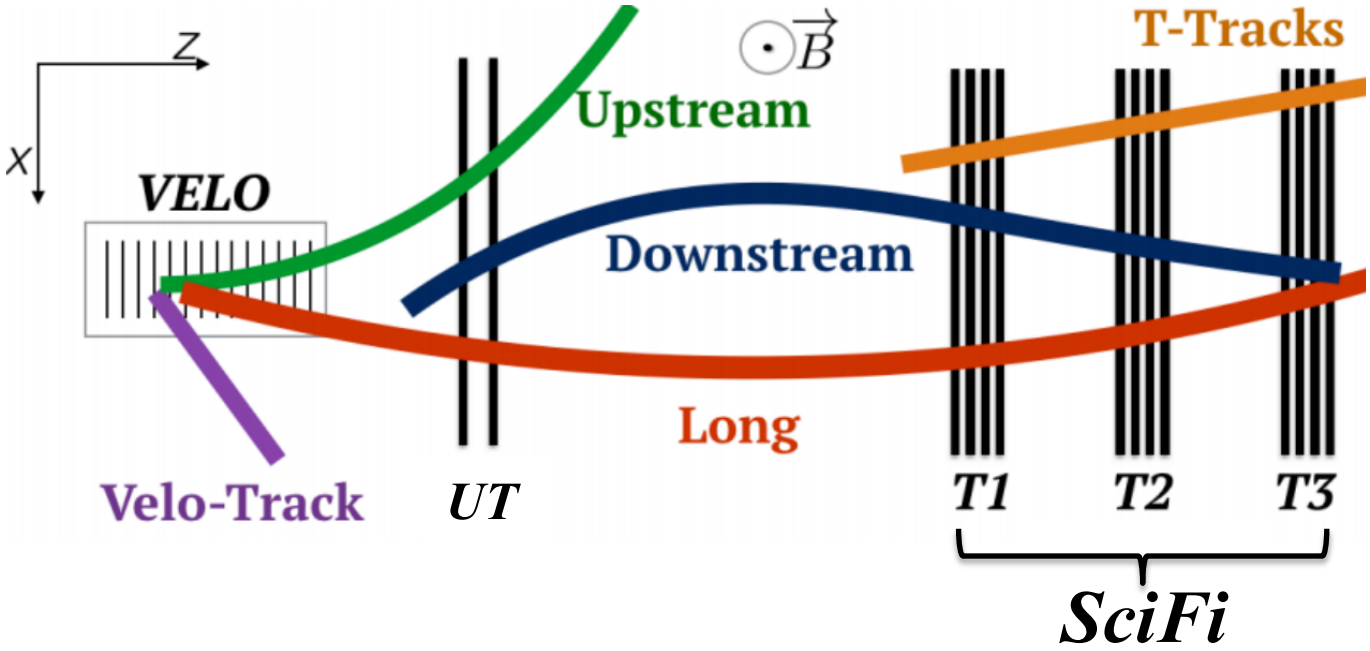
Challenges in the upgrade:

- **events with larger occupancy**
- **strong time constraints in order to be run at the trigger level**
- **need to keep excellent performances**

Activités du LPNHE en simulation

- **Implémentation de la géométrie du SciFi** pour la simulation et la reconstruction.
  - Toujours en évolution dans cette phase de projet.
  - Maintenance du package FTDet prise en charge par le LPNHE.

- **Pattern recognition for a stand-alone tracking (*SEEDING*)**:
  - Reconstruit les traces seulement avec les hits dans le SciFi (no velo, no UT)
  - Nécessaire, par exemple, pour la reconstruction des K_S
  - Implémentation et études de ses performances (efficacité, ghost rate, timing, …)



Comparaison avec la géométrie simplifiée

L'une des premières études: après l'implementation détaillée de la géométrie du détecteur pour le TDR (« New ») il a fallu comparer les performances par rapport à la géométrie approximative utilisée par les études précédentes (« Old ») où, par exemple, il n'y avait pas de segmentation en modules et donc de régions mortes.

Etudes pour le TDR

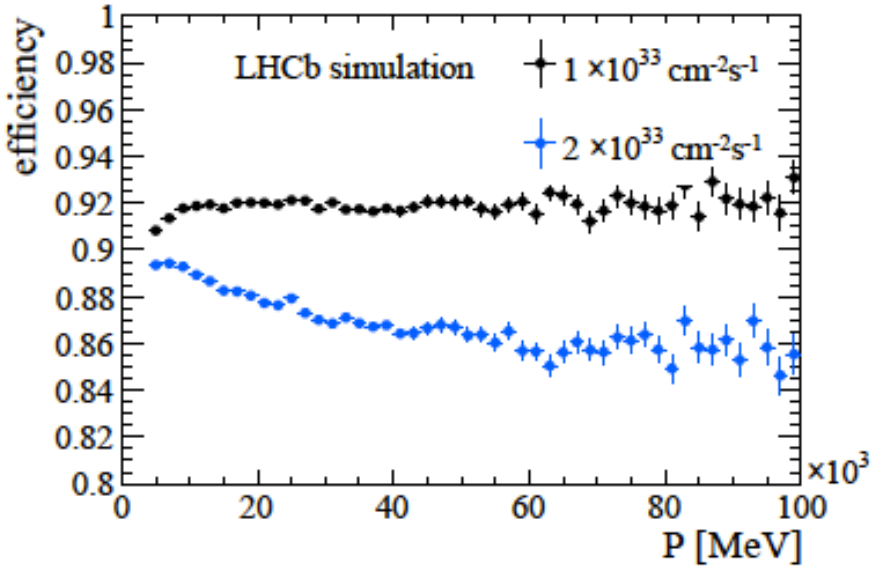
Geometry	MC Sample	Track category	tracks/event	efficiency
`New`	$\nu = 3.8$	long + from B	4.75	92.9 %
	$\nu = 3.8$	long + from B + $p > 5$ GeV	3.95	96.0 %
	$\nu = 7.6$	long + from B	4.81	92.0 %
	$\nu = 7.6$	long + from B + $p > 5$ GeV	3.81	95.3 %
`Old`	$\nu = 3.8$	long + from B	4.81	93.8 %
	$\nu = 3.8$	long + from B + $p > 5$ GeV	4.00	96.6 %
	$\nu = 7.6$	long + from B	4.82	93.0 %
	$\nu = 7.6$	long + from B + $p > 5$ GeV	4.01	96.1 %

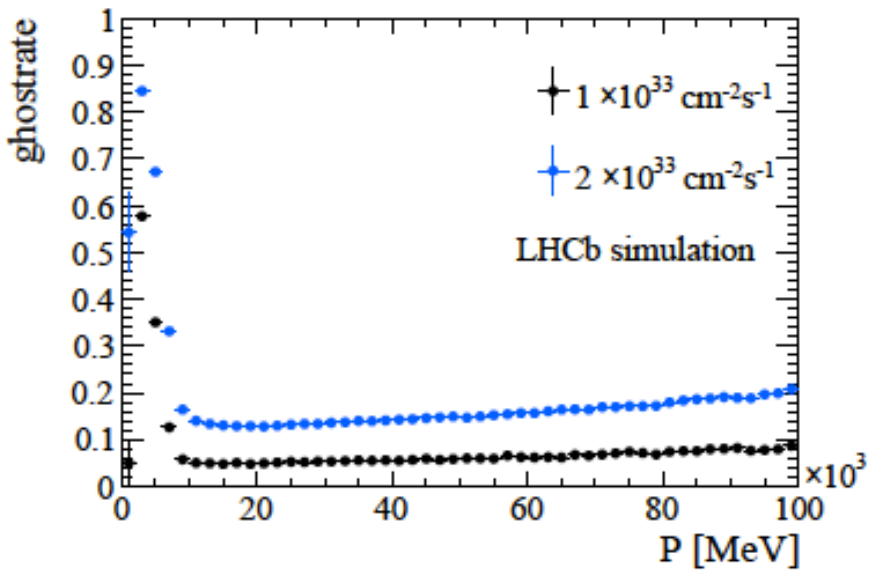
Table 12: Number of tracks from B daughters per event and `Forward` reconstruction efficiency using $B_s^0 \to \phi\phi$ events for both low and high luminosity for the new and old geometry.

Etudes de performance pour le TDR

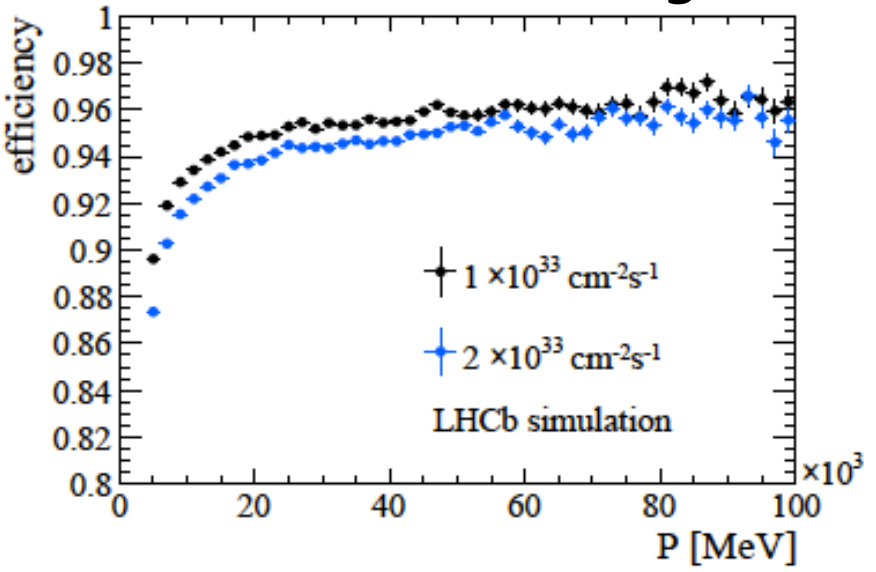
Etudes pour le TDR

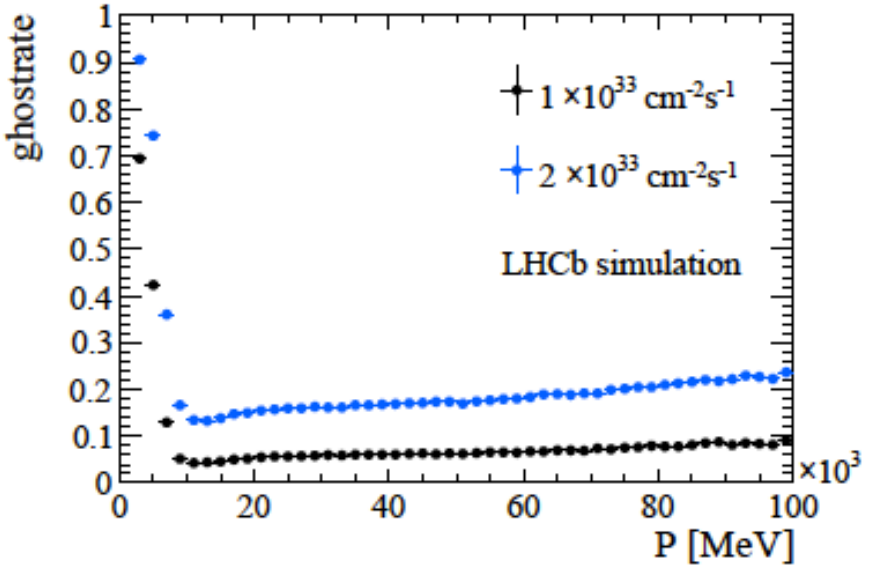
Seeding





Forward tracking





Estimation de l'angle stéréo optimal

Design of the detector

Algorithm	Stereo angle	Ghost rate	Track category	Efficiency	Clones
`Forward Tracking`	5°	18.9 %	long	88.1 %	2.8 %
			long + $p > 5$ GeV	94.1 %	1.4 %
	4°	20.5 %	long	88.4 %	3.0 %
			long + $p > 5$ GeV	94.0 %	1.5 %
	3°	22.9 %	long	88.2 %	3.1 %
			long + $p > 5$ GeV	93.7 %	1.5 %
	2°	26.8 %	long	87.6 %	3.2 %
			long + $p > 5$ GeV	93.0 %	1.6 %
`SeedingXLayers`	5°	6.6 %	Strange + T + TT	75.3 %	6.7 %
			Strange + T + TT + $p > 5$ GeV	92.0 %	5.2 %
	4°	5.1 %	Strange + T + TT	75.5 %	7.9 %
			Strange + T + TT + $p > 5$ GeV	91.9 %	6.1 %
	3°	3.7 %	Strange + T + TT	75.7 %	9.5 %
			Strange + T + TT + $p > 5$ GeV	91.8 %	7.7 %
	2°	2.4 %	Strange + T + TT	75.7 %	12.1 %
			Strange + T + TT + $p > 5$ GeV	91.2 %	10.1 %

Table 15: Performances of tracking algorithms for $B_s^0 \to \phi\phi$ events using the new geometry for $\nu = 3.8$ and for various stereo angles.

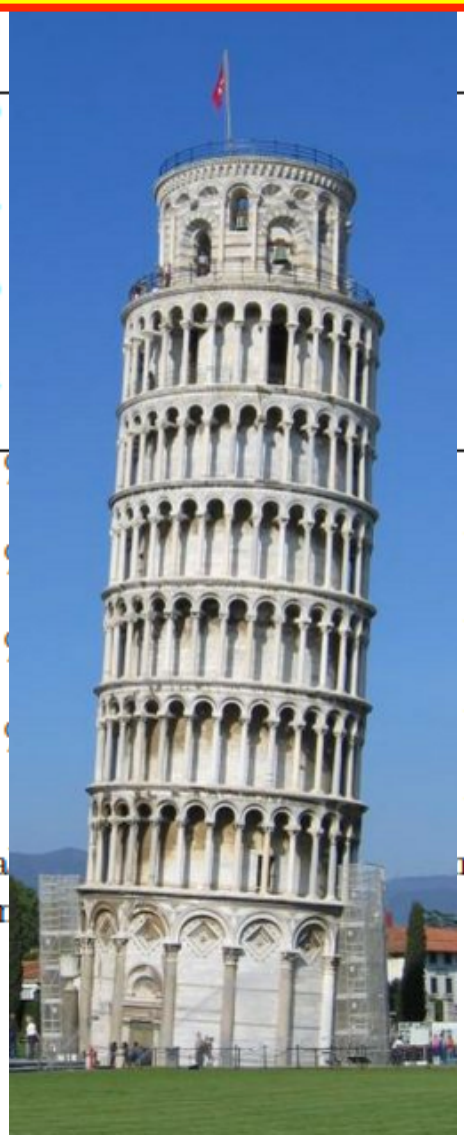
Estimation de l'angle stéréo optimal

And the winner is: 5°!
(C'est peut être pas par hasard…)

Design of the detector

Algorithm	Stereo angle	Ghost		Efficiency	Clones
`Forward Tracking`	5°	18.9		88.1 %	2.8 %
				94.1 %	1.4 %
	4°	20.5		88.4 %	3.0 %
				94.0 %	1.5 %
	3°	22.9		88.2 %	3.1 %
				93.7 %	1.5 %
	2°	26.8		87.6 %	3.2 %
				93.0 %	1.6 %
`SeedingXLayers`	5°	6.6		75.3 %	6.7 %
			$p > 5$ GeV	92.0 %	5.2 %
	4°	5.1		75.5 %	7.9 %
			$p > 5$ GeV	91.9 %	6.1 %
	3°	3.7		75.7 %	9.5 %
			$p > 5$ GeV	91.8 %	7.7 %
	2°	2.4		75.7 %	12.1 %
			$p > 5$ GeV	91.2 %	10.1 %

Table 15: Performances of tracking a … nts using the new geometry for $\nu = 3.8$ and for various stereo ar…



TDR seeding

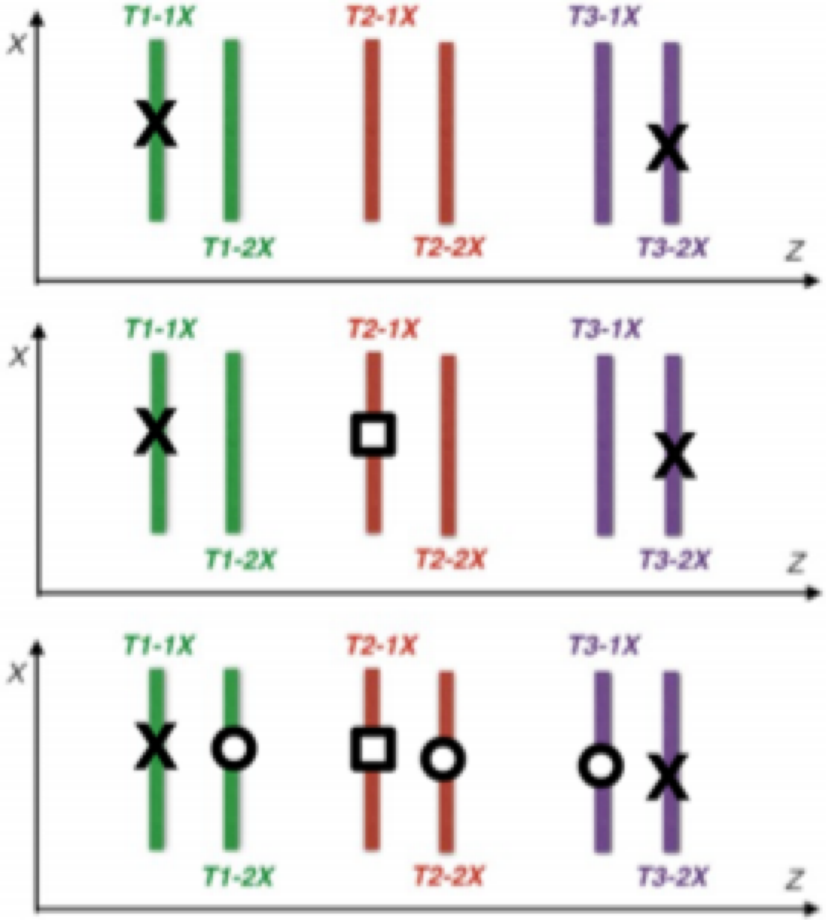
First implementation of the seeding for the SciFi

A pattern recognition algorithm in a two steps approach:

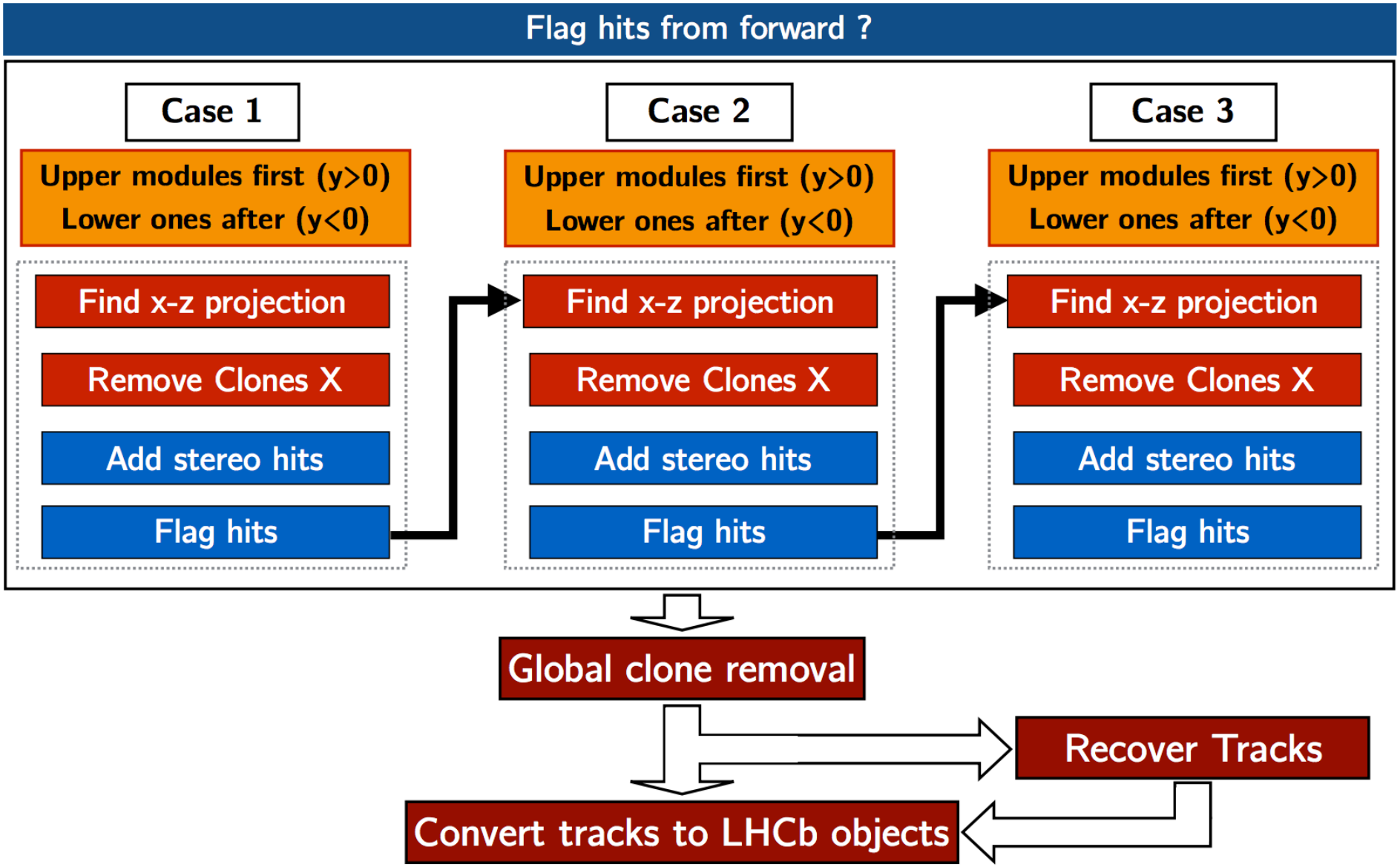
1) reconstruct the x-z projection of a track
   (3 cases to account for detector inefficiencies)
2) add hits from stereo layers

Provided preliminary performances for the TDR.

Put in evidence the need of improvements.

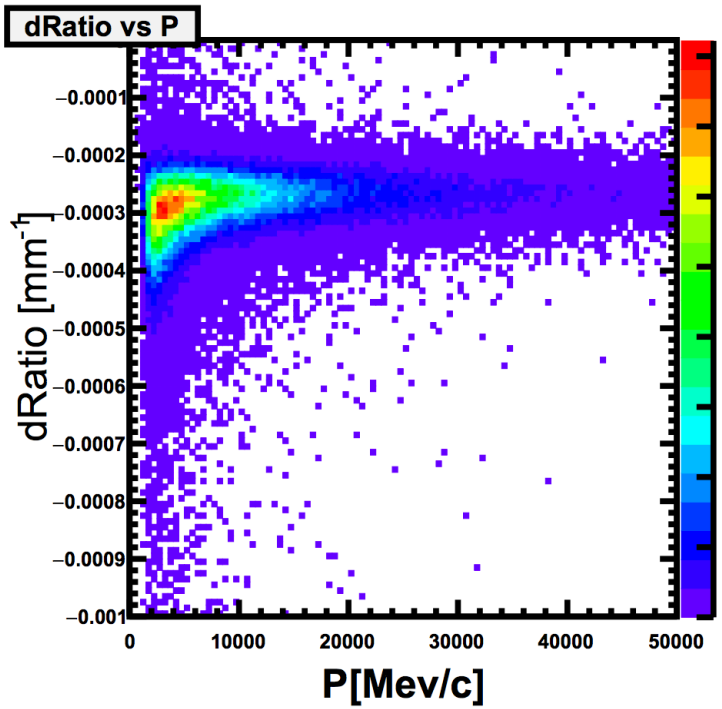


Hybrid seeding



Improvements with respect to the TDR

- **New track model**: from parabolic to 3rd order polynomial (*dRatio*)
- **Stereo hits treatment**: not only used to complete the x-z projection but to apply requirements reducing the ghost rate
- Implementation of a **software level**
  Y-segmentation: less hits on a track are permitted only where you expect detector inefficiency (beam hole)
- **Progressive cleaning of the tracking environment**: allows to relax search windows for low momentum tracks and so higher hit efficiency
- **Better implementation of the clone removal**
- **Track recovery routine for low momentum tracks**



$$B_y(z) \simeq B_0 + B_1(z - z_0)$$

$$\texttt{dRatio} = \frac{B_1}{3B_0}$$

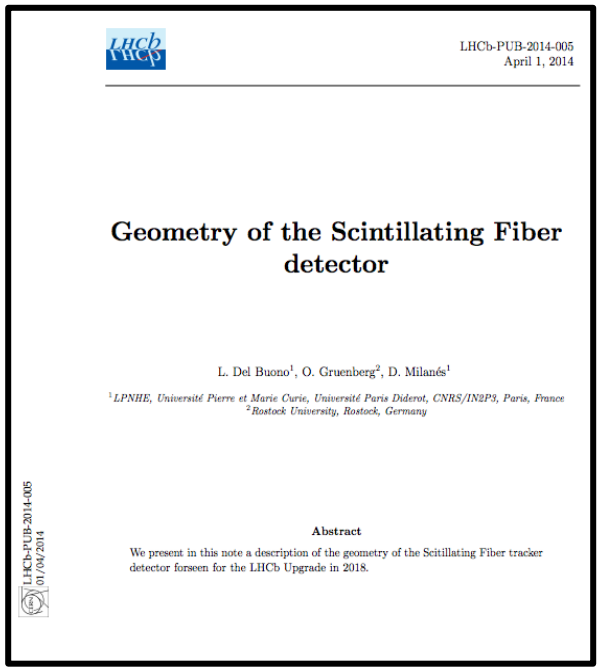
$$\begin{aligned} x_{track}(z) &= a_x + t_x \cdot dz + c_x \cdot dz^2 \cdot (1 + \texttt{dRatio} \cdot dz) \\ y_{track}(z) &= a_y + t_y \cdot dz \end{aligned}$$

TDR vs Hybrid seeding

Machine speed $n\cdot$ 2.8 GHz Xennon	Sample	Algorithm	Avg. time $[\frac{ms}{evt.}]$	Min. time $[\frac{ms}{evt.}]$	Max. time $[\frac{ms}{evt.}]$
2.76	1	`Forward Tracking Best`	29.95	0.11	612.1
		`TDR Seeding`	72.75	0.15	1770.0
		`Hybrid Seeding`	23.53	0.24	589.4

Track type	*Sample 1*	
	`TDR Seeding` ϵ (*clone rate*)	`Hybrid Seeding` ϵ (*clone rate*)
hasT	(50.9 ± 0.1) (2.4) %	(65.7 ± 0.1) (0.0) %
long	(75.3 ± 0.1) (2.3) %	(90.3 ± 0.1) (0.0) %
long $P > 5\,\mathrm{GeV}/c$	(85.0 ± 0.1) (1.4) %	(93.1 ± 0.1) (0.0) %
long from B	(81.8 ± 0.2) (1.7) %	(92.1 ± 0.1) (0.0) %
long from B $P > 5\,\mathrm{GeV}/c$	(87.0 ± 0.2) (1.3) %	(93.6 ± 0.1) (0.0) %
long from B or D	(80.6 ± 0.2) (1.8) %	(91.8 ± 0.1) (0.0) %
long from B or D $P > 5\,\mathrm{GeV}/c$	(86.6 ± 0.1) (1.3) %	(93.4 ± 0.1) (0.0) %
UT +SciFi *strange*	(71.6 ± 0.1) (2.5) %	(89.7 ± 0.1) (0.0) %
UT +SciFi *strange* $P > 5\,\mathrm{GeV}/c$	(85.4 ± 0.2) (1.4) %	(93.3 ± 0.1) (0.0) %
noVELO +UT +SciFi *strange*	(72.2 ± 0.2) (2.4) %	(89.1 ± 0.1) (0.0) %
noVELO +UT +SciFi *strange* $P > 5\,\mathrm{GeV}/c$	(85.3 ± 0.2) (1.4) %	(93.1 ± 0.2) (0.0) %
ghost rate	(23.1 ± 0.1) %	(9.4 ±0.1) %
ghost rate (evt.avg)	12.0 %	4.9 %
hit purity	99.0 %	99.6 %
hit efficiency	96.0 %	97.82 %

Publications



LHCb-PUB-2014-005
April 1, 2014

Geometry of the Scintillating Fiber detector

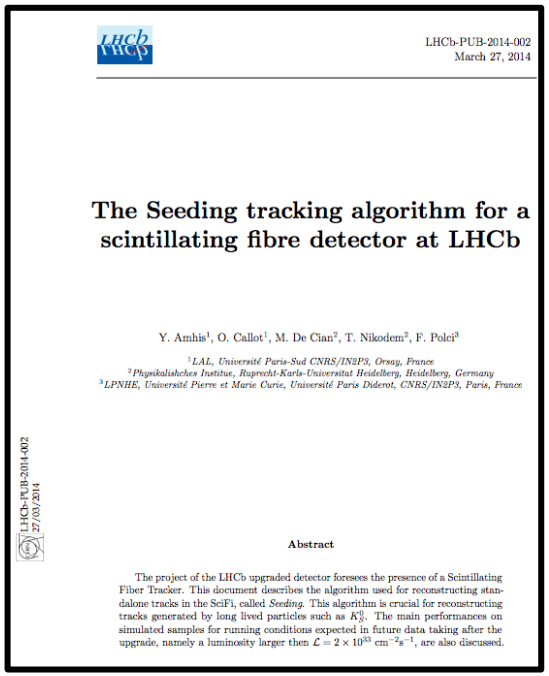
L. Del Buono[1], O. Gruenberg[2], D. Milanés[1]

[1]*LPNHE, Université Pierre et Marie Curie, Université Paris Diderot, CNRS/IN2P3, Paris, France*
[2]*Rostock University, Rostock, Germany*

LHCb-PUB-2014-005
01/04/2014

Abstract

We present in this note a description of the geometry of the Scitillating Fiber tracker detector forseen for the LHCb Upgrade in 2018.



LHCb-PUB-2014-002
March 27, 2014

The Seeding tracking algorithm for a scintillating fibre detector at LHCb

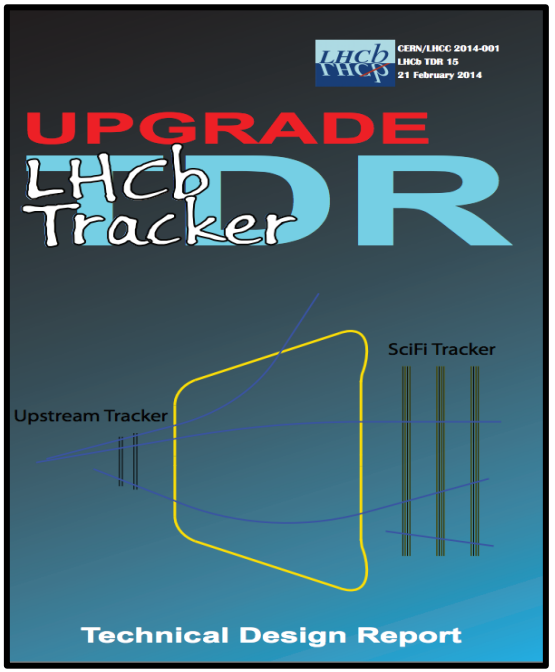
Y. Amhis[1], O. Callot[1], M. De Cian[2], T. Nikodem[2], F. Polci[3]

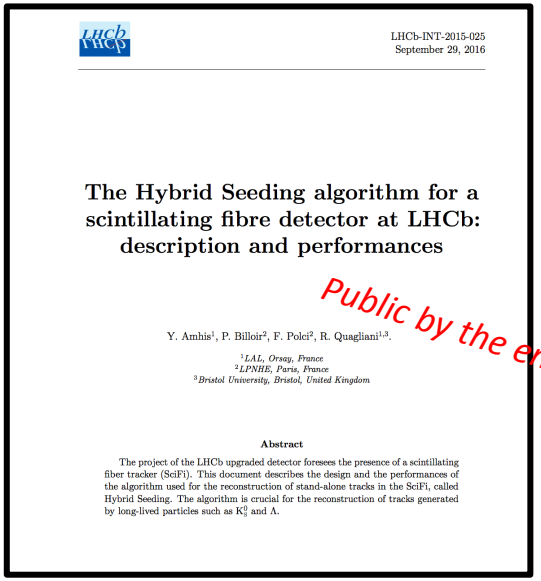
[1]*LAL, Université Paris-Sud CNRS/IN2P3, Orsay, France*
[2]*Physikalisches Institut, Ruprecht-Karls-Universitat Heidelberg, Heidelberg, Germany*
[3]*LPNHE, Université Pierre et Marie Curie, Université Paris Diderot, CNRS/IN2P3, Paris, France*

LHCb-PUB-2014-002
27/03/2014

Abstract

The project of the LHCb upgraded detector foresees the presence of a Scintillating Fiber Tracker. This document describes the algorithm used for reconstructing standalone tracks in the SciFi, called *Seeding*. This algorithm is crucial for reconstructing tracks generated by long lived particles such as K^0_S. The main performances on simulated samples for running conditions expected in future data taking after the upgrade, namely a luminosity larger then $\mathcal{L} = 2 \times 10^{33}$ cm^{-2}s^{-1}, are also discussed.





LHCb-INT-2015-025
September 29, 2016

The Hybrid Seeding algorithm for a scintillating fibre detector at LHCb: description and performances

Y. Amhis[1], P. Billoir[2], F. Polci[2], R. Quagliani[1,3].

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[2]*LPNHE, Paris, France*
[3]*Bristol University, Bristol, United Kingdom*

Abstract

The project of the LHCb upgraded detector foresees the presence of a scintillating fiber tracker (SciFi). This document describes the design and the performances of the algorithm used for the reconstruction of stand-alone tracks in the SciFi, called Hybrid Seeding. The algorithm is crucial for the reconstruction of tracks generated by long-lived particles such as K^0_S and Λ.

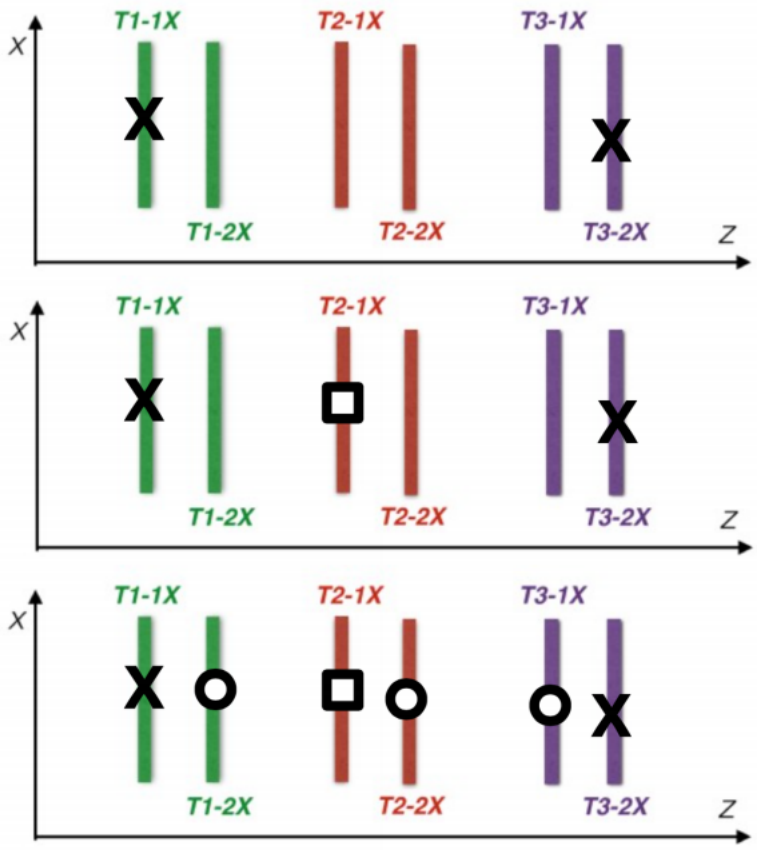
Public by the end of the year

What's going on now?

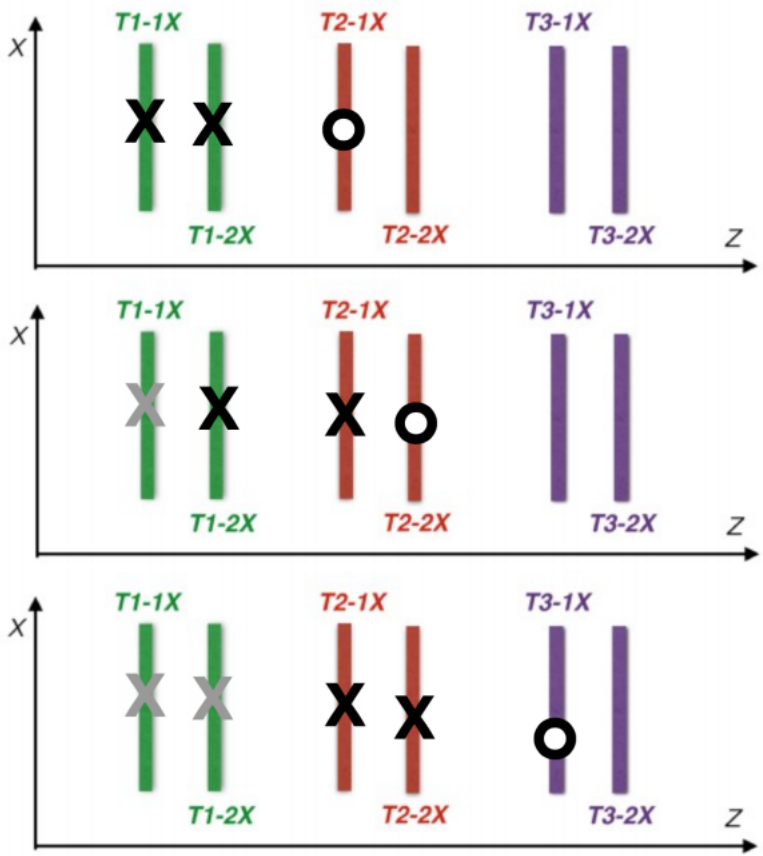
Alternative seeding

See Andrea Mogini's presentation on Friday.

Studies on-going to make the seeding faster



Hybrid seeding algorithm



Alternative seeding algorithm

Clustering studies

Interplay with electronics

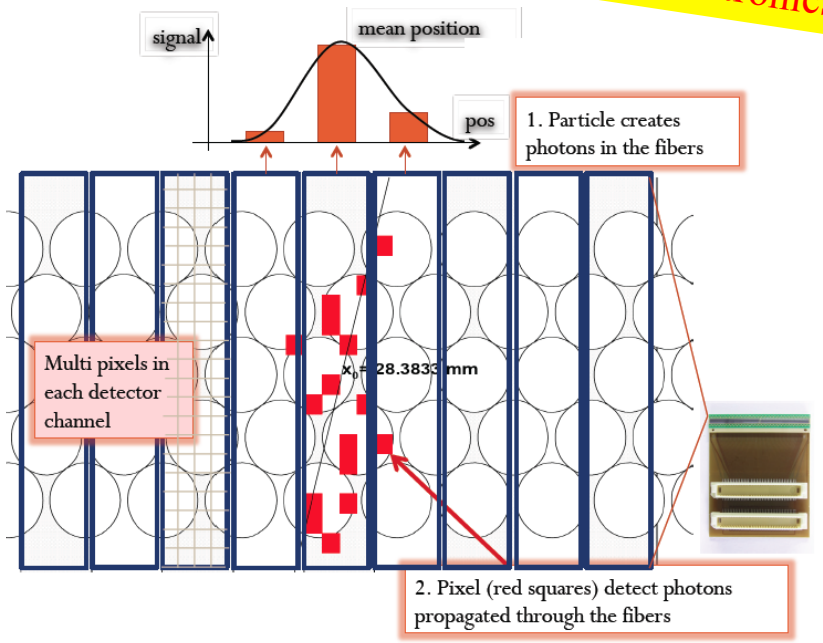
The clustering FPGA combines signal from different SiPM to identify the hit position.

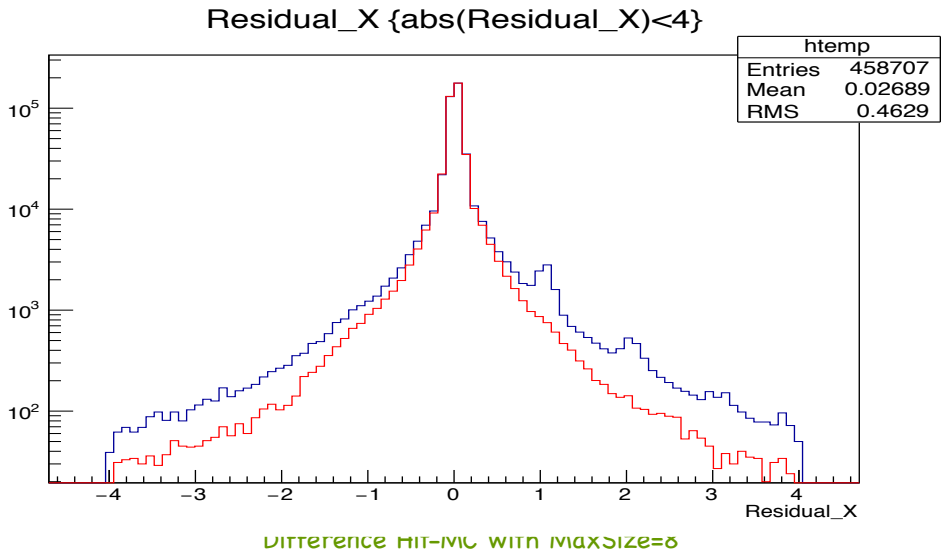
Two algorithms:

- "**standard**" (default option):
  - asymmetric building of clusters with size<8
  - shows parasitic peaks, due to asymmetric splitting of large clusters

- "**raw**" (proposed by LPNHE):
  - symmetric by construction.
  - if size>8, the cluster is eliminated or flagged
  - has less tails and a symmetric behavior

Check ongoing on feasibility of the implementation in the clustering FPGA.



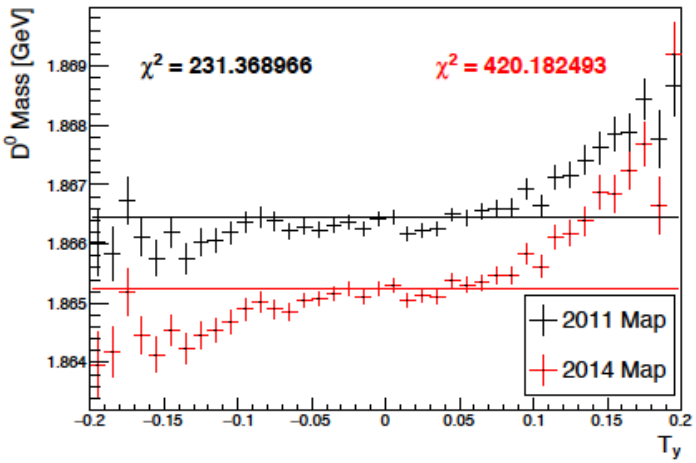


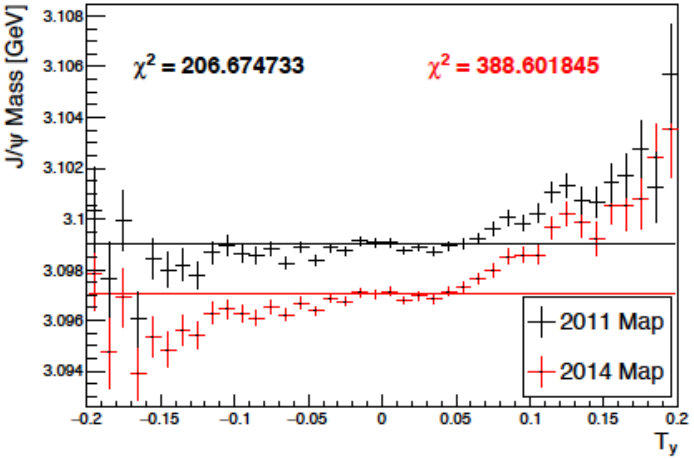
Field alignment

Potentially valid also in Run II

The present field map (LHCb-INT-2015-034) comes from:
simulation + global translation/rotation/scaling constrained by measurements in the central region (roughly: |x|<1500, |y|<1000, 3000<z<6000)

- *no guaranteed outside the measurement region*
- *some indication of biases for peripheral tracks*





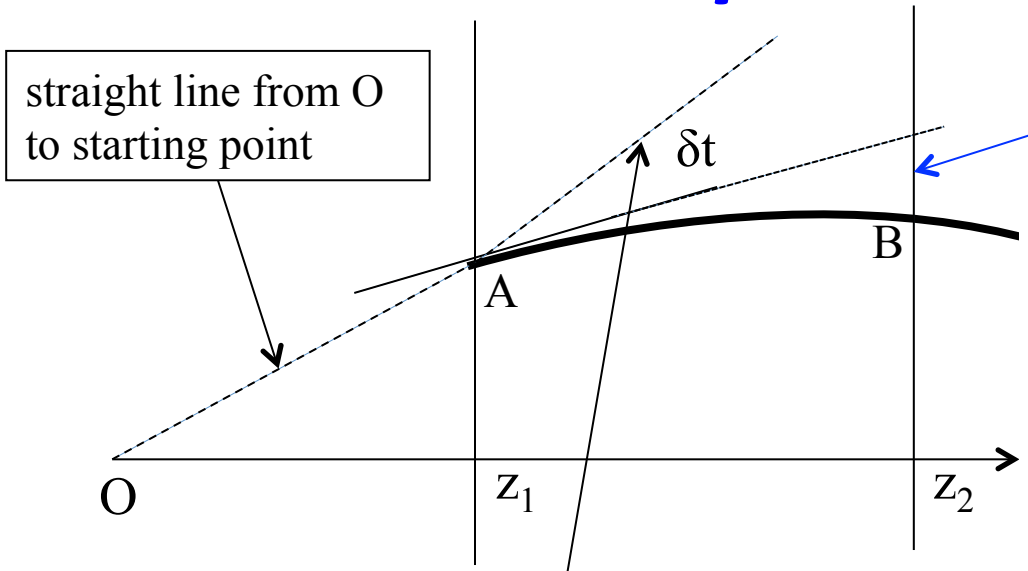
Can we use the alignment procedure to better constrain the field ?

If $\mathbf{B}_{perturb} = \mathbf{B}_{reference} + \Sigma\, \alpha_k \mathbf{P}_k(x,y,z)$
when extrapolating $(x_1, y_1, t_{x1}, t_{y1})$ at z_1 to $(x_2, y_2, t_{x2}, t_{y2})$ at z_2
then $(x_2, y_2, t_{x2}, t_{y2})_{perturb} - (x_2, y_2, t_{x2}, t_{y2})_{reference} = \Sigma\, \alpha_k (\delta x, \delta y, \delta t_x, \delta t_y)_k$

➔ the α_k may be included in a linearized alignment procedure in the same way as small translations/rotations.

Fast tracks extrapolation

Potentially valid also in Run II



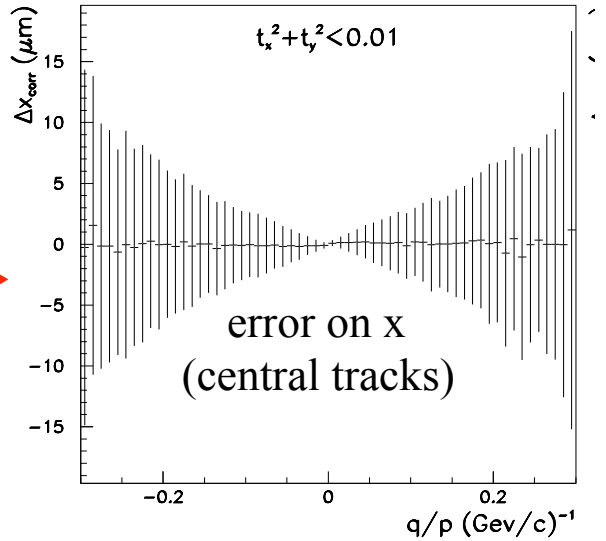
$$\Delta x = \Sigma\, C_{ijk}\, \delta t_x^{\,i}\, \delta t_y^{\,j}\, (q/p)^k$$

Similar expressions for Δy, Δt_x, Δt_y

Tabulate the coefficients as functions of x,y at z_1

include here the t_x deviation from 0 to z_1 as $q/p\ F(z_1)$ (F from a table) ➔ $|\delta t_x|$ and $|\delta t_x|$ are small

Quite acceptable in the zx plane after global correction of degree 7 in q/p



Conclusion

- *The LHCb upgrade ensures pursuing the flavor physics program at LHC*
- *The SciFi project is central in the upgrade*
- *The LPNHE group contributes to the SciFi via two activities:*
  - backend electronics
  - simulation
- *The simulation activity has an impact on the design of the detector (geometry, electronics) and a focus on the tracking algorithm*
- *Some solutions/ideas can be applied already in Run II*

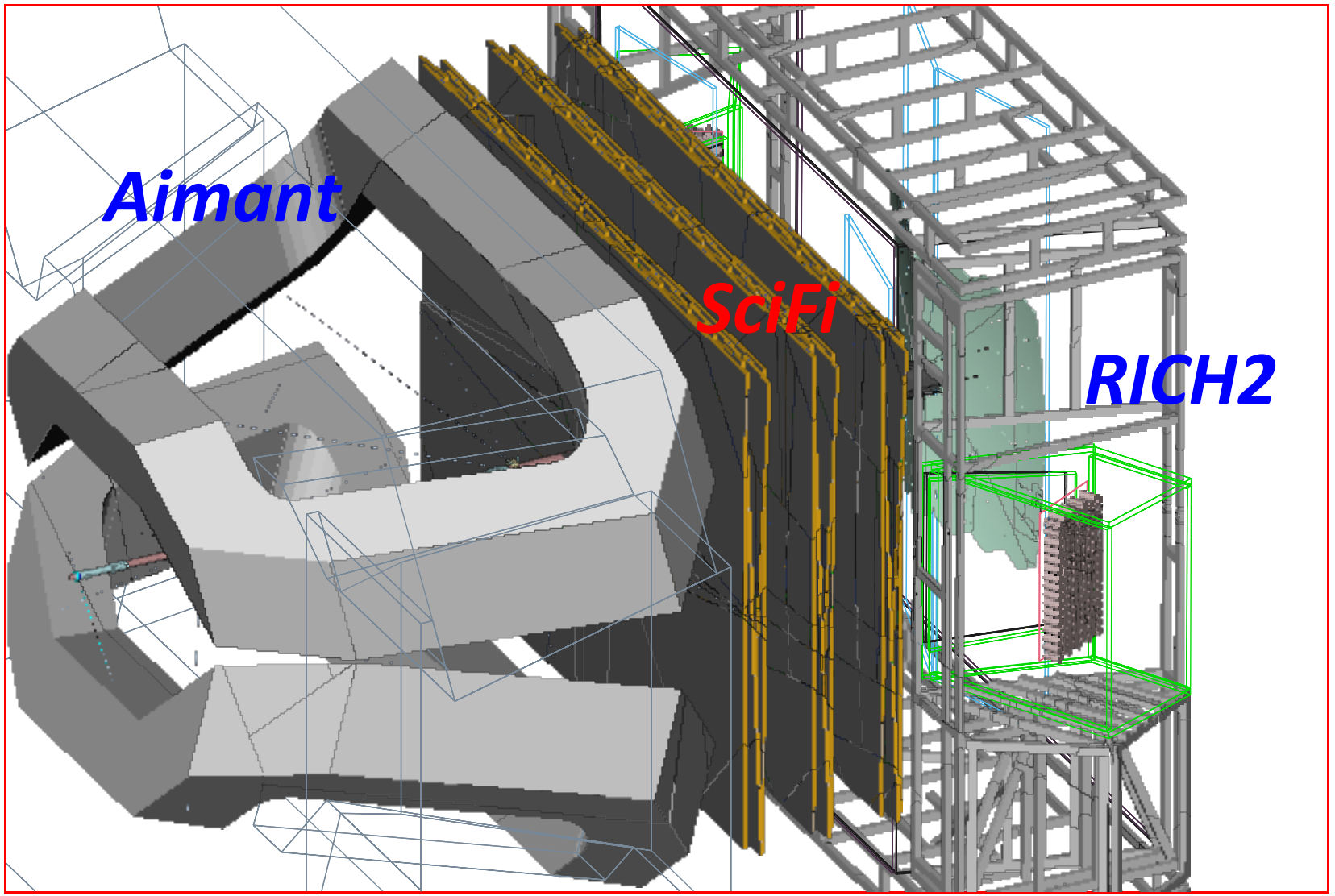
Potentiel de physique de l'upgrade

Framework TDR for the LHCb upgrade: Technical Design Report

		Erreurs statistiques			
		~3/fb	~8/fb	~50/fb	Theory
Type	Observable	LHC Run 1	LHCb 2018	**LHCb upgrade**	Theory
B_s^0 mixing	$\phi_s(B_s^0 \to J/\psi\,\phi)$ (rad)	0.05	0.025	**0.009**	~ 0.003
	$\phi_s(B_s^0 \to J/\psi\, f_0(980))$ (rad)	0.09	0.05	**0.016**	~ 0.01
	$A_{\rm sl}(B_s^0)$ (10^{-3})	2.8	1.4	**0.5**	0.03
Gluonic penguin	$\phi_s^{\rm eff}(B_s^0 \to \phi\phi)$ (rad)	0.18	0.12	**0.026**	0.02
	$\phi_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$ (rad)	0.19	0.13	**0.029**	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$ (rad)	0.30	0.20	**0.04**	0.02
Right-handed currents	$\phi_s^{\rm eff}(B_s^0 \to \phi\gamma)$	0.20	0.13	**0.030**	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	5%	3.2%	**0.8%**	0.2%
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.04	0.020	**0.007**	0.02
	$q_0^2\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	10%	5%	**1.9%**	$\sim 7\%$
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.14	0.07	**0.024**	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	14%	7%	**2.4%**	$\sim 10\%$
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ (10^{-9})	1.0	0.5	**0.19**	0.3
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	220%	110%	**40%**	$\sim 5\%$
Unitarity triangle angles	$\gamma(B \to D^{(*)}K^{(*)})$	7°	4°	**1.1°**	negligible
	$\gamma(B_s^0 \to D_s^\mp K^\pm)$	17°	11°	**2.4°**	negligible
	$\beta(B^0 \to J/\psi\, K_S^0)$	1.7°	0.8°	**0.31°**	negligible
Charm CPviolation	$A_\Gamma(D^0 \to K^+K^-)$ (10^{-4})	3.4	2.2	**0.5**	–
	ΔA_{CP} (10^{-3})	0.8	0.5	**0.12**	–

- Actuellement presque toutes les mesures sont limitées statistiquement.
- Incertitudes 10 fois plus petites après 10 ans d'upgrade: proches des erreurs théoriques.
- Le défi deviendra réduire les incertitudes systématiques.

Vue générale



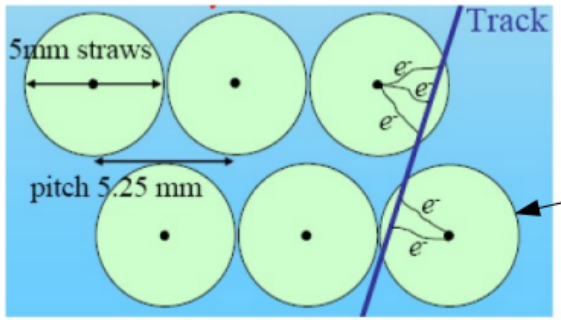
Limitation du detector actuel

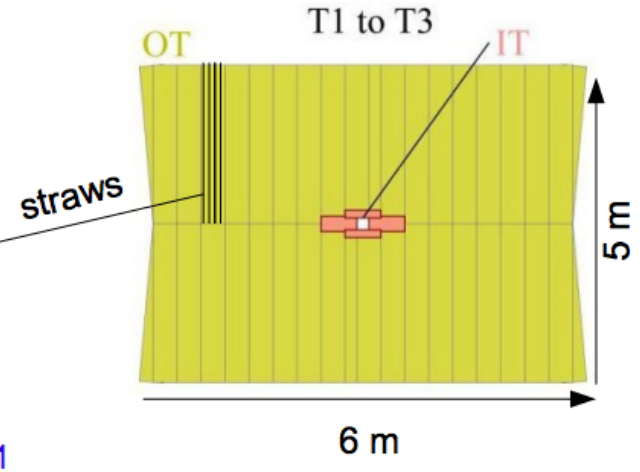
Detector Occupancy and Efficiency

Outer Tracker = 5 mm straw gas drift tubes (2.5m long)

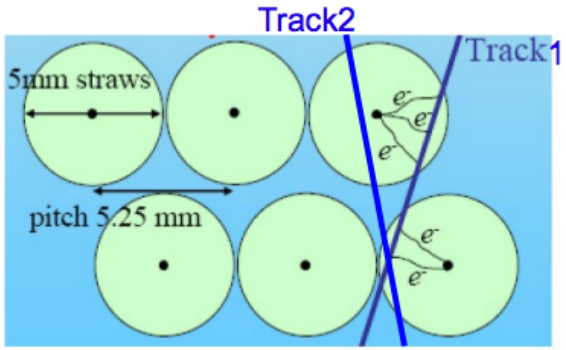
- Detector is insensitive to multiple tracks per tube (35ns drift time)

Good!!





BAD!!



Outer Tracker tracking efficiency decreases above 25% occupancy → 40% expected in the upgrade

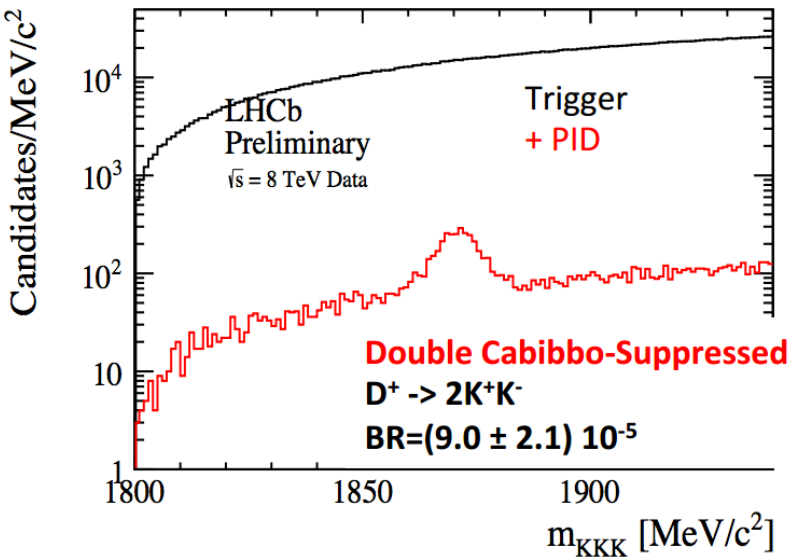
Beam bunch spacing will be 25ns in 2015+

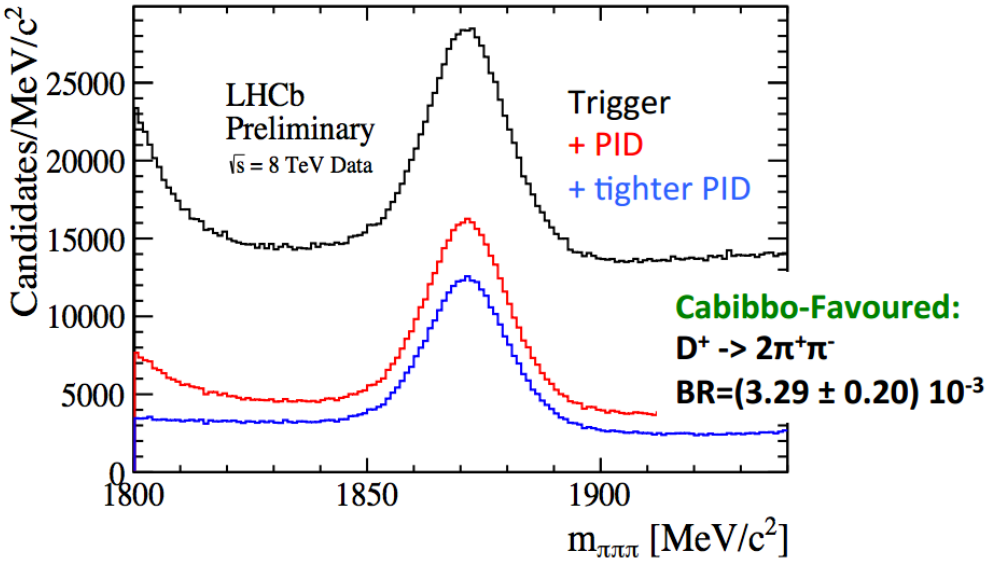
The trigger in the upgrade

Triggers will discriminate between different signal classes

Triggers today

Triggers in the future





- Same reconstruction as offline and complete alignment and PID calibration allows to apply a tighter selection on kinematics quantities
- RICH calibration allows to use hadron particle identification in selection, e.g. boost efficiency for Cabibbo suppressed decays while keeping the rate low by pre-scaling the Cabibbo favored counterpart

Comparison avec les autres experiences

***ECFA** (octobre 2013, Aix les Bains)*

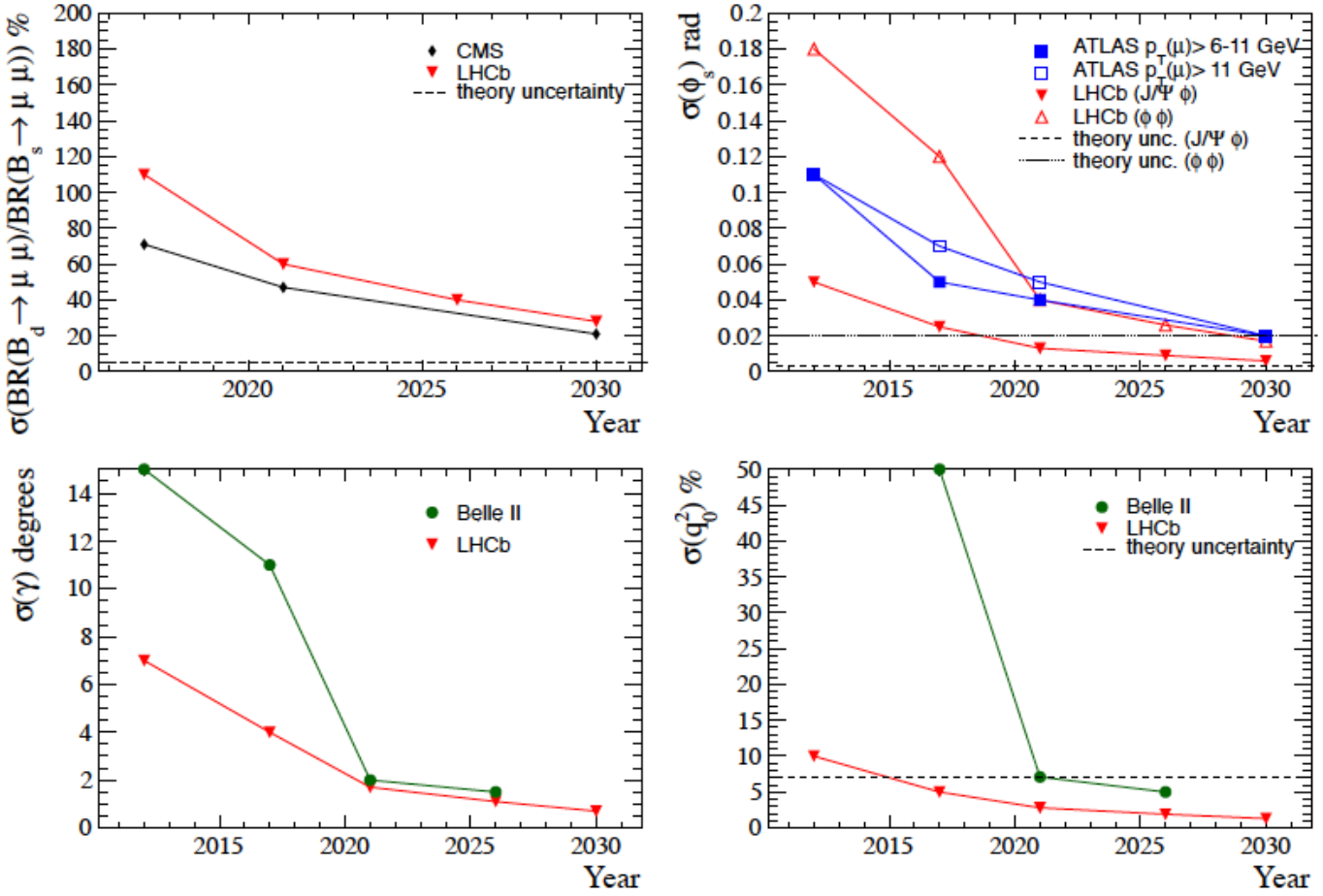
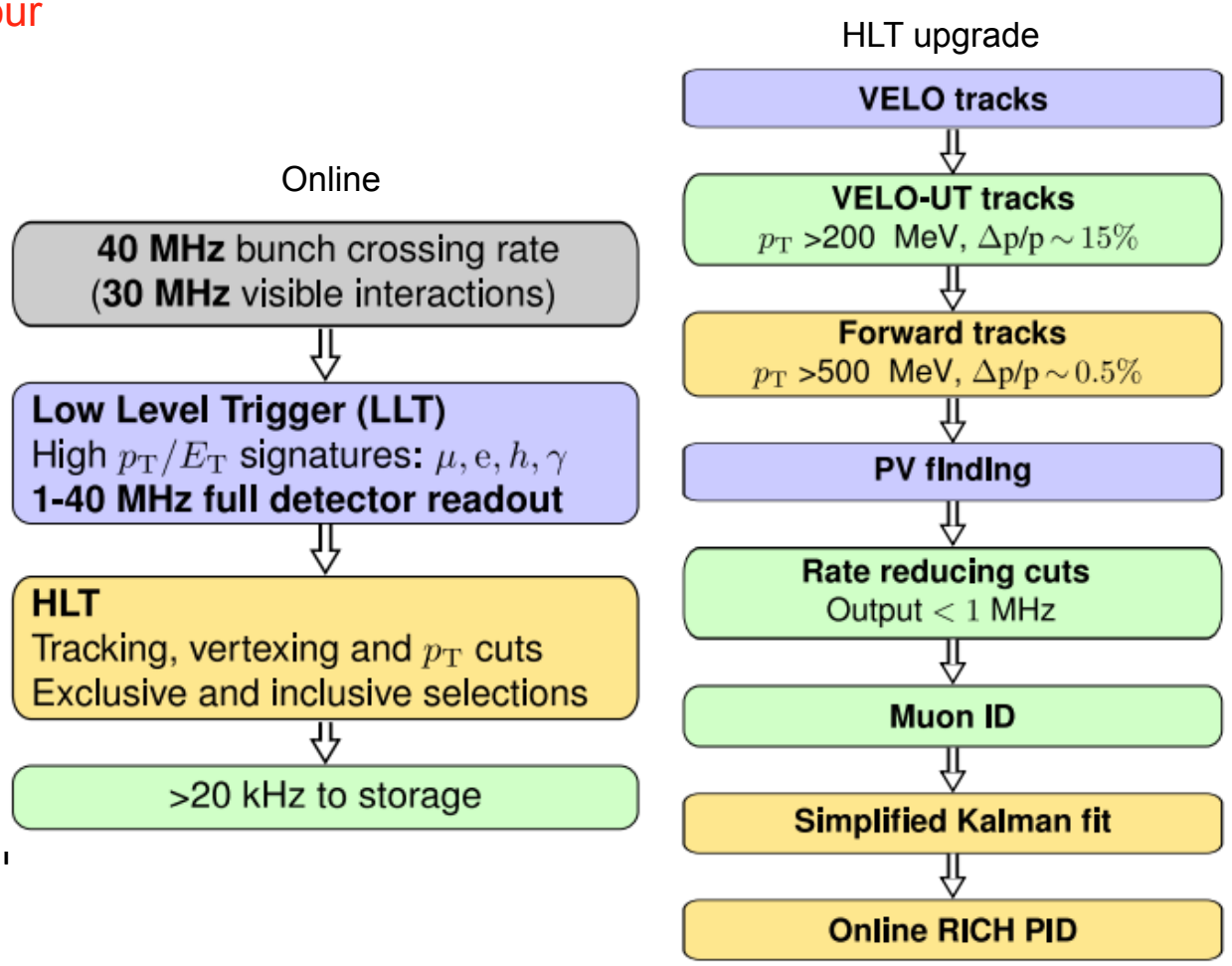


Fig. 2.1: Comparaison des précisions attendues pour les expériences ATLAS, CMS, LHCb et Belle-II pour $\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$, $\phi_s(B_s^0 \to J/\psi\phi)$ et $\phi_s(B_s^0 \to \phi\phi)$, l'angle γ et $q_0^2\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$. Une estimation des incertitudes théoriques est indiquée par les lignes pointillées. Les incertitudes théoriques dans le cas de l'angle γ sont négligeables.

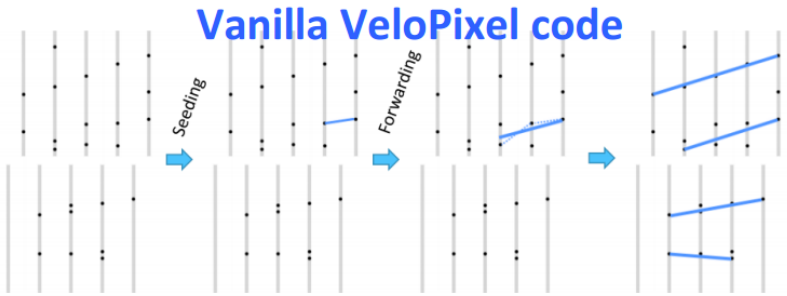
The trigger implications

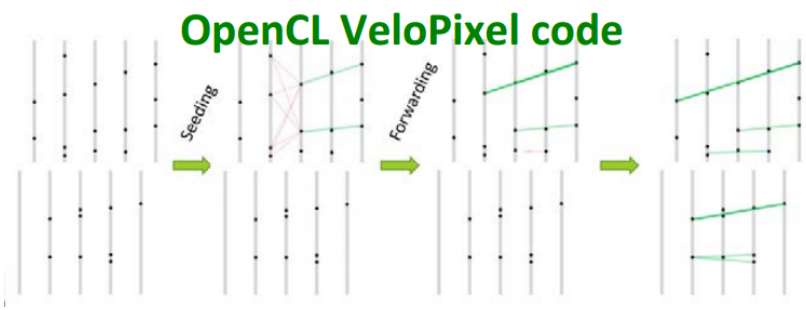
- To be improved to cope with our main limitations
  - Hardware trigger and data acquisition
  - Rate limited by bandwidth
- With higher luminosity...
  - Harder L0 separation. Chang to LLT
  - tighter cuts on E_T, p_T
  - bigger track multiplicity
  - much more data!
- It is needed
  - 5 kHz → 20kHz to storage
  - keep high efficiency on muon streams
  - improve gain on hadron streams



from C.Fitzpatrick, The upgrade of the LHCb trigger system, WIT2014

Parallelized VeloPixel (CPU vs GPU)





- **Idea**: building straight tracks in the Vertex detector
- Two steps:
  - **Seeding**: building a seed (or forming-track)
  - **Forwarding**: looking for a new hit to be add to the forming-track

Novelties:

- Each sensor is **processed in parallel**:
  - Seeding and forwarding performed 48 times
- Seeds are triplets
  - Only the **best triplets** is kept
- Saved first only the >=4hits tracks, then checked for 3-hits tracks
- Written in OpenCL: it can run CPU and GPU

Les couts pour l'in2p3

Tab. 5: Coût total de la contribution française à l'upgrade de LHCb. Le facteur utilisé pour convertir les euros en francs suisse est de 1,25. Les nombres sont en accord avec les valeurs qui sont données dans les TDRs publiés et en préparation. Elles incluent les composants de rechange et une marge pour imprévu au niveau de 15%.

		Coût [kCHF]
Calorimètres		1 286
	Front-end	339
	Controlleurs	58
	Liens optiques	323
	Cartes de lecture	566
Trajectographe à fibres		2 198
	ASIC	1 185
	Front-end	547
	14 Cartes de lectures	466
Low Level Trigger		343
	LLT-Calo	203
	LLT-Muon	117
	LLT-DU	22
Pré-série cartes de lecture		580
Projets communs (9.7%)		1 514
Complément R&D		250
Total		6 170

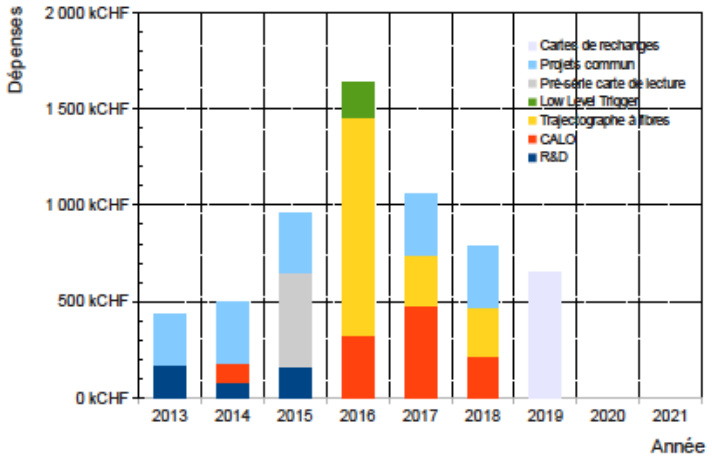


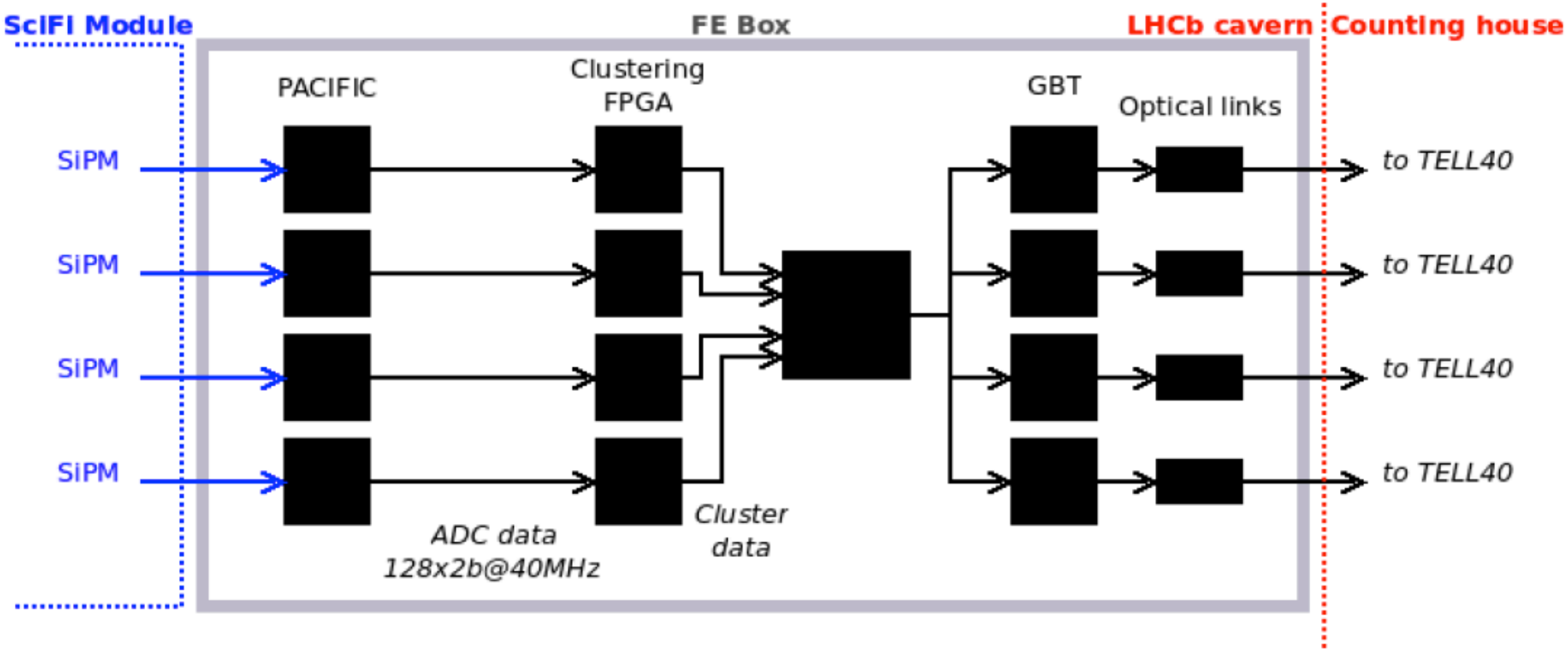
Fig. 5.1: Estimation du profil des dépenses correspondant à la répartition des financements de la Table 6. La production des cartes FEB pour les calorimètres est répartie sur les années 2016 et 2017. Il en va de même pour les cartes front-end du trajectographe mais en 2017 et 2018. Les cartes de lecture pour les calorimètres sont aussi financées en deux fois, 2016 et 2017. La contribution aux projets communs est distribuée uniformément à l'exception de 2016.

Tab. 6: Répartition des financements sur la période 2014-2018 et au-delà. Les marges pour imprévus ont été réduites à 7% (10% pour l'électronique front-end et 6% pour les cartes de lecture).

Coût [kCHF]	2014-2018	2019 - ...
Calorimètres	1 115	95
Trajectographe à fibres	1 657	425
Low Level Trigger	180	135
Pré-série cartes de lecture	485	
Projets commun	1 514	
Complément R&D	250	
Total	5 200	655

Aujourd'hui 650 kCHF pour la totalité des AMC40 PCI express

Cout total de l'upgrade pour le in2p3: ~5MCHF


SciFI Module
FE Box
LHCb cavern
Counting house
PACIFIC
Clustering FPGA
GBT
Optical links
SiPM
SiPM
SiPM
SiPM
to TELL40
to TELL40
to TELL40
to TELL40
ADC data 128x2b@40MHz
Cluster data

Estimation de l'angle stereo optimal: nu=7.6

Algorithm	Stereo angle	Ghost rate	Track category	Efficiency	Clones
`Forward Tracking`	5°	32.0 %	long	86.4 %	2.9 %
			long + $p > 5$ GeV	93.1 %	1.4 %
	4°	32.1 %	long	86.7 %	3.1 %
			long + $p > 5$ GeV	93.0 %	1.5 %
	3°	33.9 %	long	86.2 %	3.2 %
			long + $p > 5$ GeV	92.7 %	1.6 %
	2°	37.3 %	long	85.8 %	2.3 %
			long + $p > 5$ GeV	91.9 %	1.1 %
`SeedingXLayers`	5°	18.5 %	Strange + T + TT	73.3 %	9.2 %
			Strange + T + TT + $p > 5$ GeV	89.0 %	7.5 %
	4°	14.4 %	Strange + T + TT	74.0 %	10.6 %
			Strange + T + TT + $p > 5$ GeV	89.3 %	8.8 %
	3°	11.4 %	Strange + T + TT	74.5 %	12.6 %
			Strange + T + TT + $p > 5$ GeV	89.4 %	10.8 %
	2°	8.3 %	Strange + T + TT	74.8 %	16.2 %
			Strange + T + TT + $p > 5$ GeV	89.0 %	14.2 %

Table 16: Performances of tracking algorithms for $B_s^0 \to \phi\phi$ events using the new geometry for $\nu = 7.6$ and for various stereo angles.

Le challenge de la vitesse

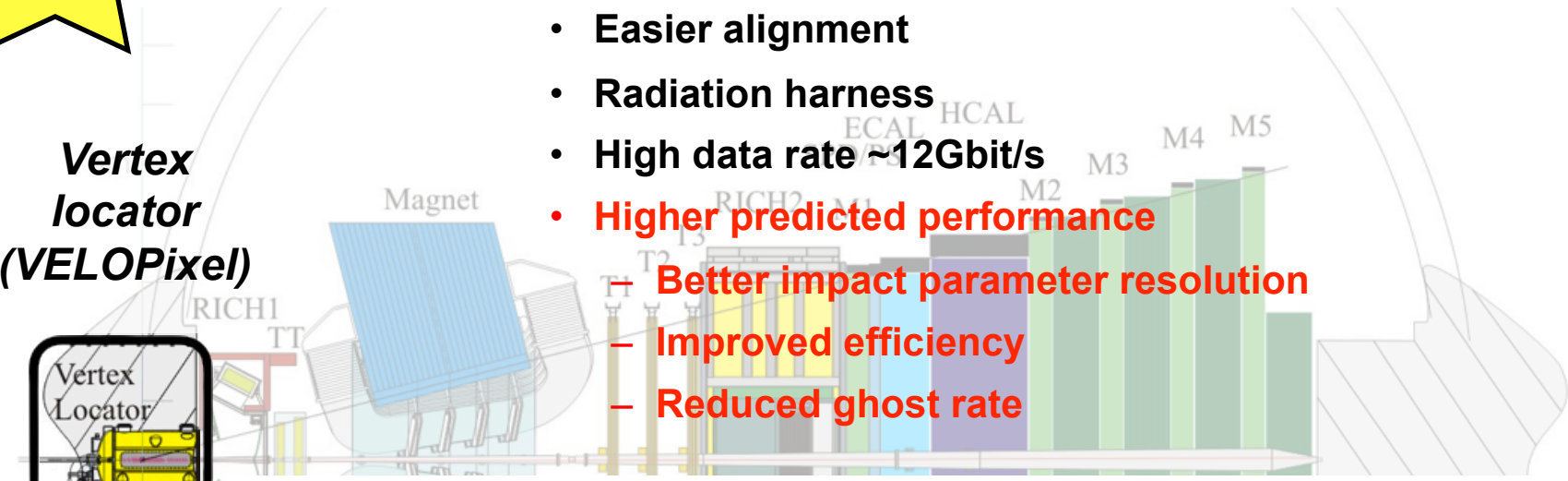
- Nous sommes déjà impliqués sur le software de reconstruction des traces.
- Les algorithmes doivent être très rapides pour reconstruire le traces pour chaque évènement directement au niveau du trigger.
- Une démarche exploratrice des techniques de calcul parallèle, vectorisation, ainsi que utilisation de GPU est en cours.
- Nous y participons, entre autre, en tant que partenaires du ANR LPaSo (LHC Parallel Software), soumis cette année:
  - collaboration entre laboratoires impliqué dans CMS(LLR), ATLAS (LAL, LPC, IRFU/SPP), LHCb (LAL, LPNHE) ainsi que laboratoires d'informatique (LRI, LIMOS) et de physique théorique (LPTHE) .
  - Si succès, un post-doc sera affecté a LHCb, embauché par le LAL mais sensé collaborer avec le LPNHE.
- Il s'agit d'une activité et une collaboration que l'on souhaite poursuivre indépendamment de l'approbation de l'ANR.

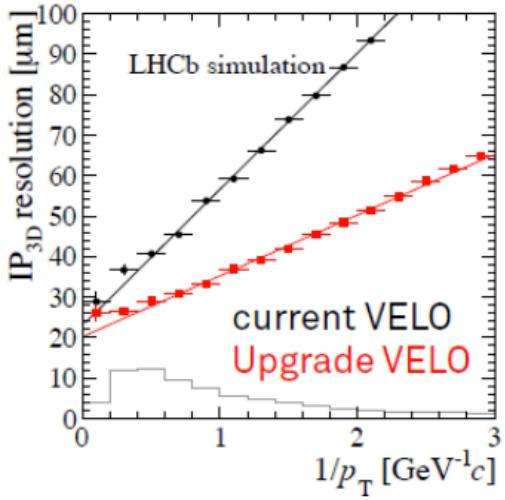
The new VErtex Locator: VELOPixel

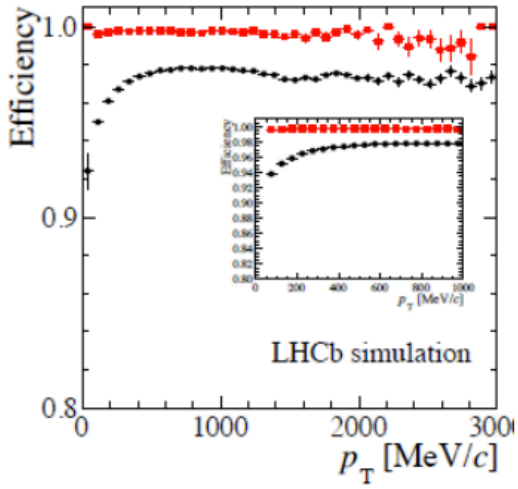
NEW

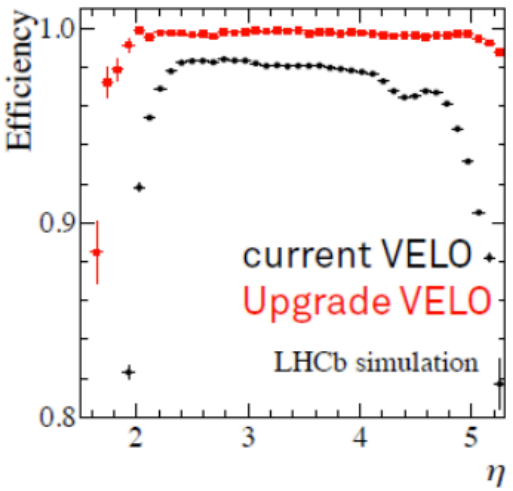
Vertex locator (VELOPixel)

- Change from silicon micro-strip to pixel detector
  - Reduce material budget
  - Easier pattern recognition
  - Easier alignment
  - Radiation harness
  - High data rate ~12Gbit/s
  - Higher predicted performance
    - Better impact parameter resolution
    - Improved efficiency
    - Reduced ghost rate



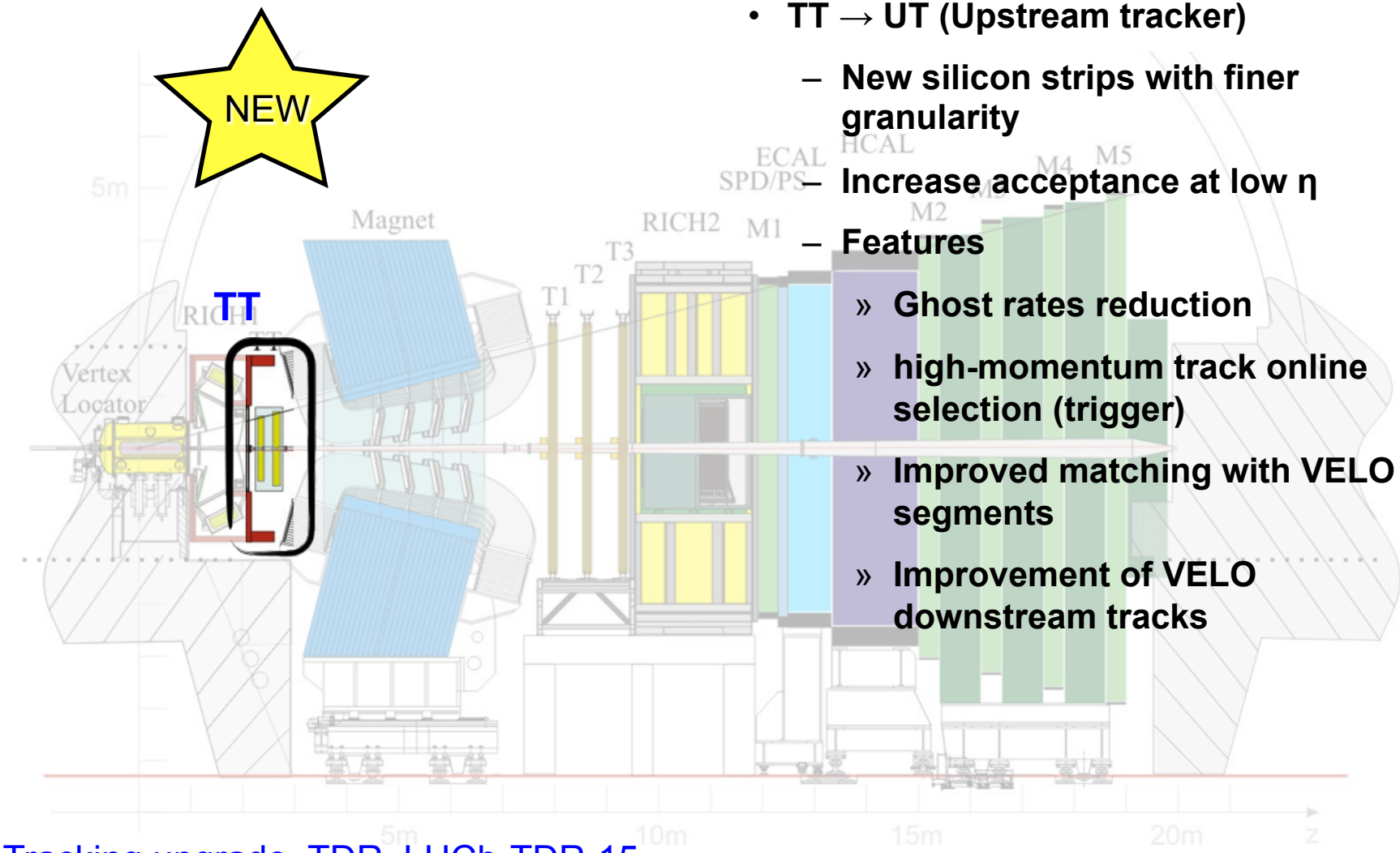






[VELO upgrade, TDR, LHCb-TDR-13]

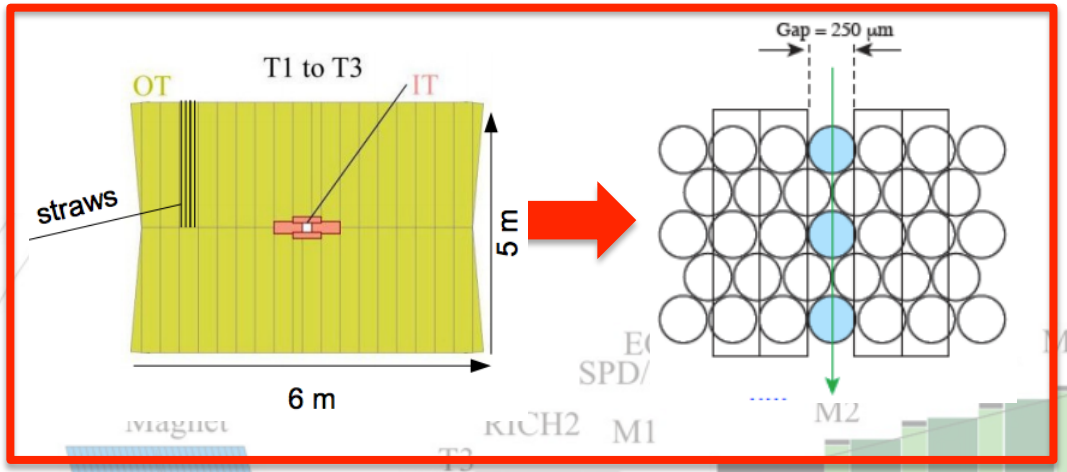
The new tracking system:TT

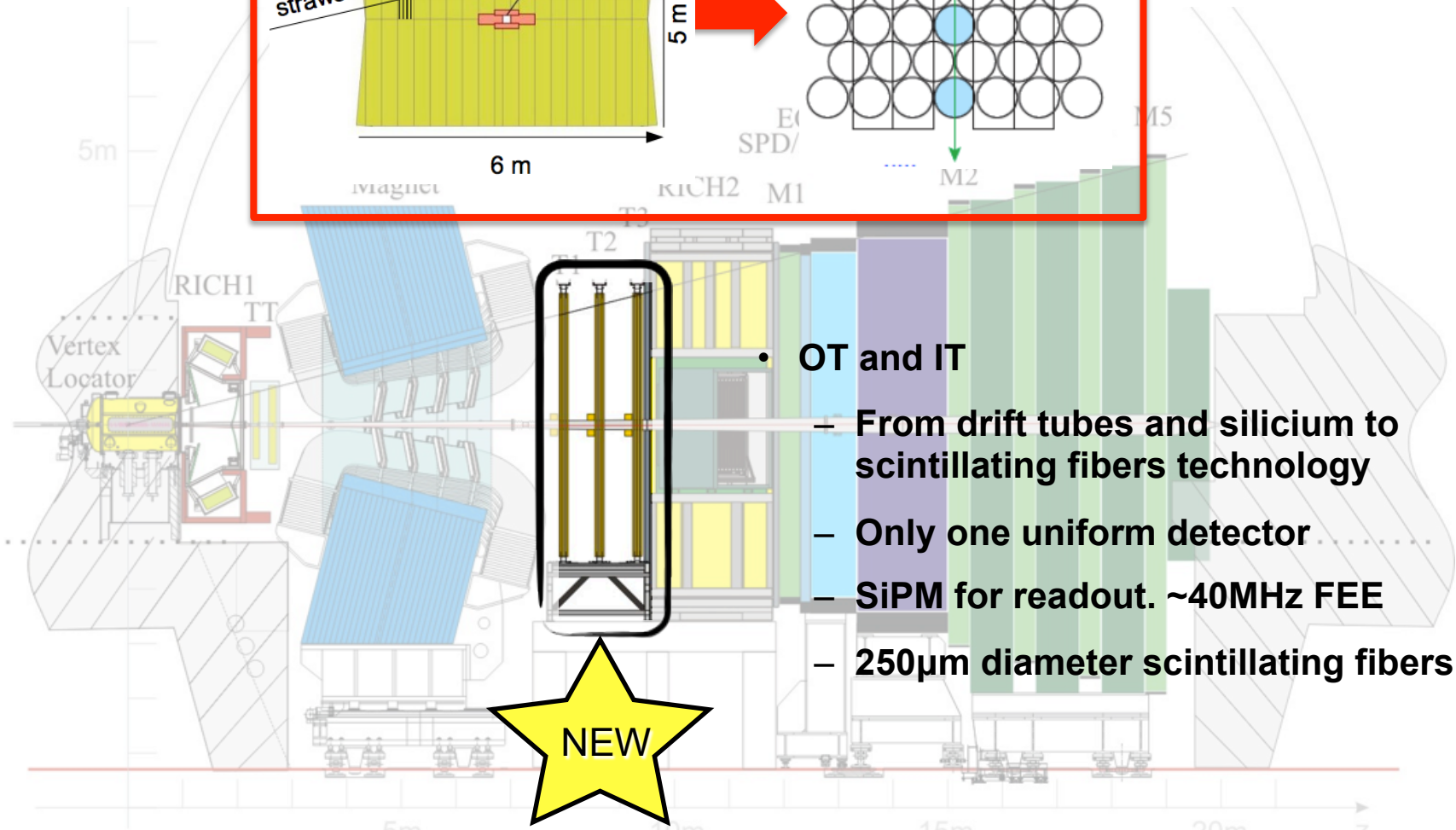


- TT → UT (Upstream tracker)
  - New silicon strips with finer granularity
  - Increase acceptance at low η
  - Features
    - » Ghost rates reduction
    - » high-momentum track online selection (trigger)
    - » Improved matching with VELO segments
    - » Improvement of VELO downstream tracks

Tracking upgrade, TDR, LHCb-TDR-15

The new tracking system: SciFi





- **OT and IT**
  - **From drift tubes and silicium to scintillating fibers technology**
  - **Only one uniform detector**
  - **SiPM for readout. ~40MHz FEE**
  - **250μm diameter scintillating fibers**

[Tracking upgrade, TDR, LHCb-TDR-15]

Carte de front-end

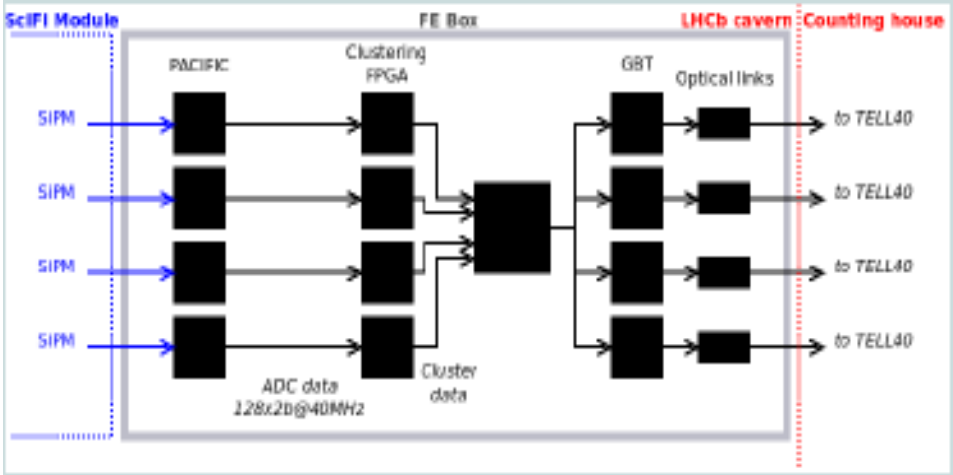


Figure : Synoptic of the FE board

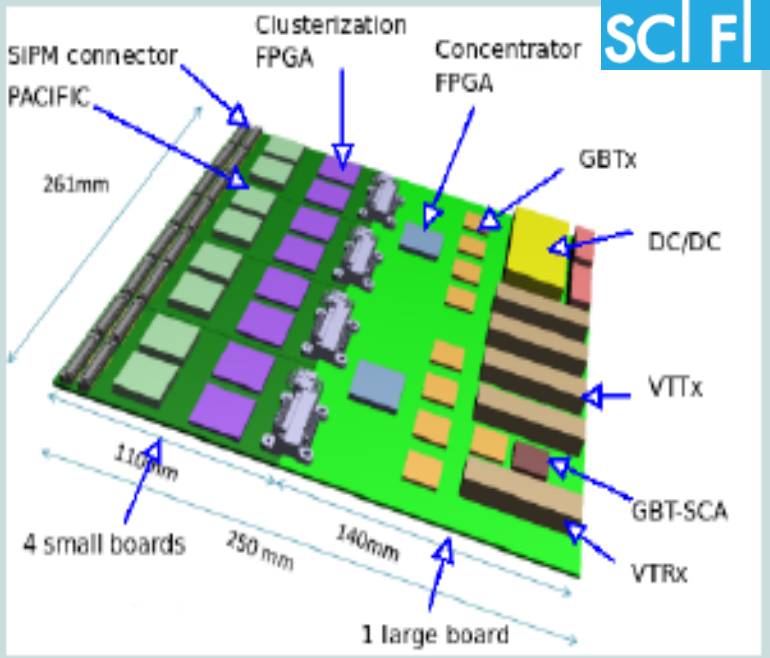
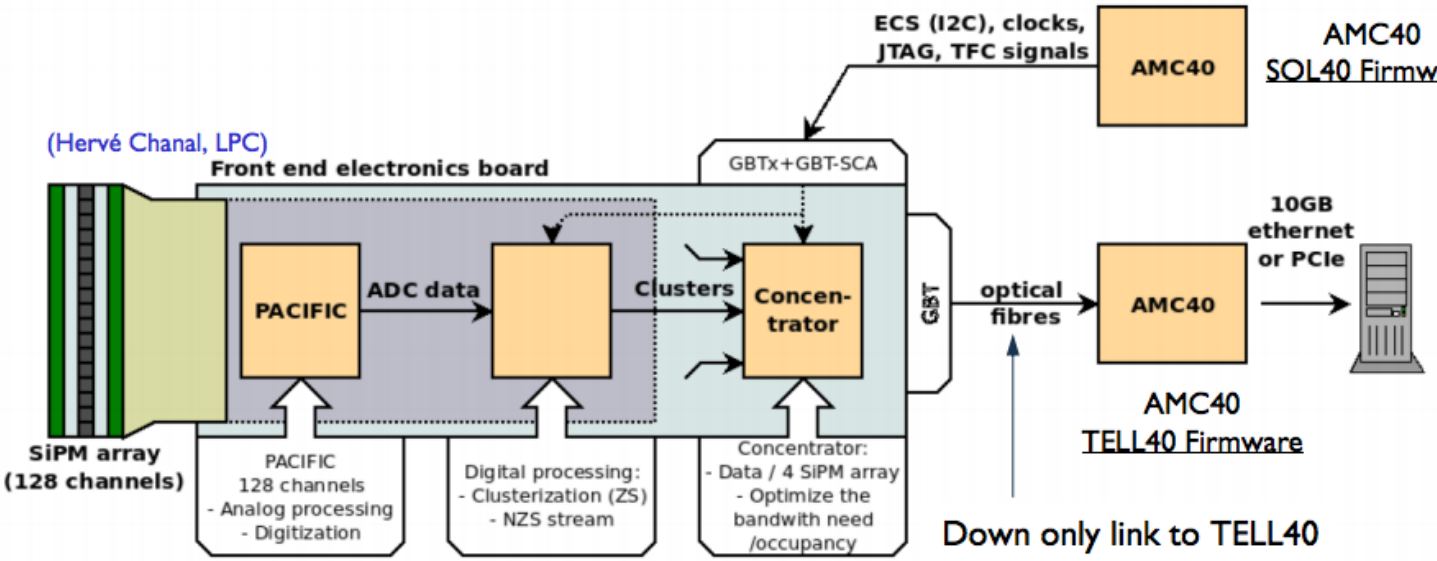


Figure : Possible FE board

- PACIFIC: 128 channel ASIC with analog processing and digitization
- Clusterization FPGA to handle the digital processing (zero-suppression)
- Concentrator FPGA to optimize the bandwidth (1 for 4 SiPM)
- Modular design (maintenance and test)
- Power, control and clock distribution under heavy study

SciFi Electronics Front-end and Back-end

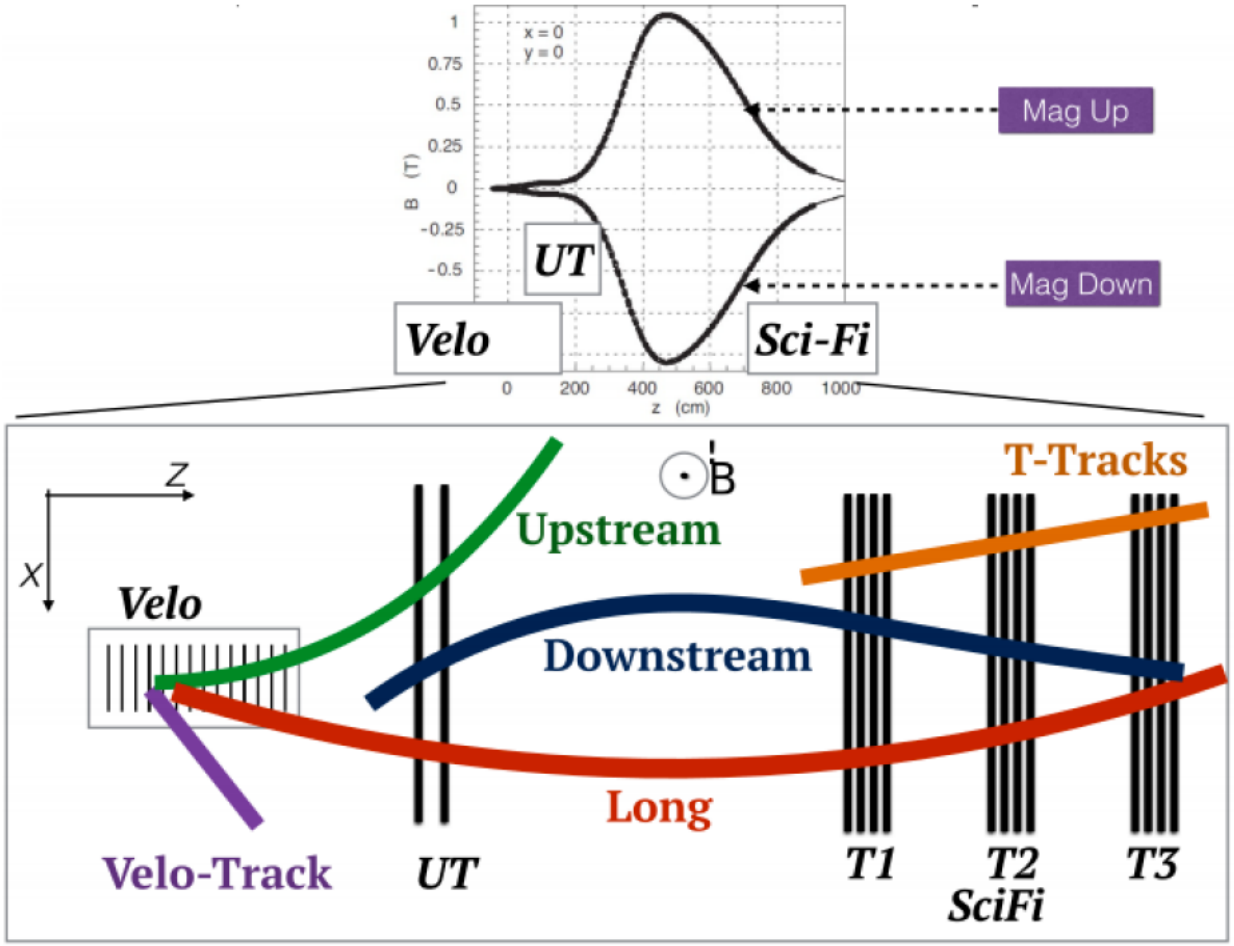


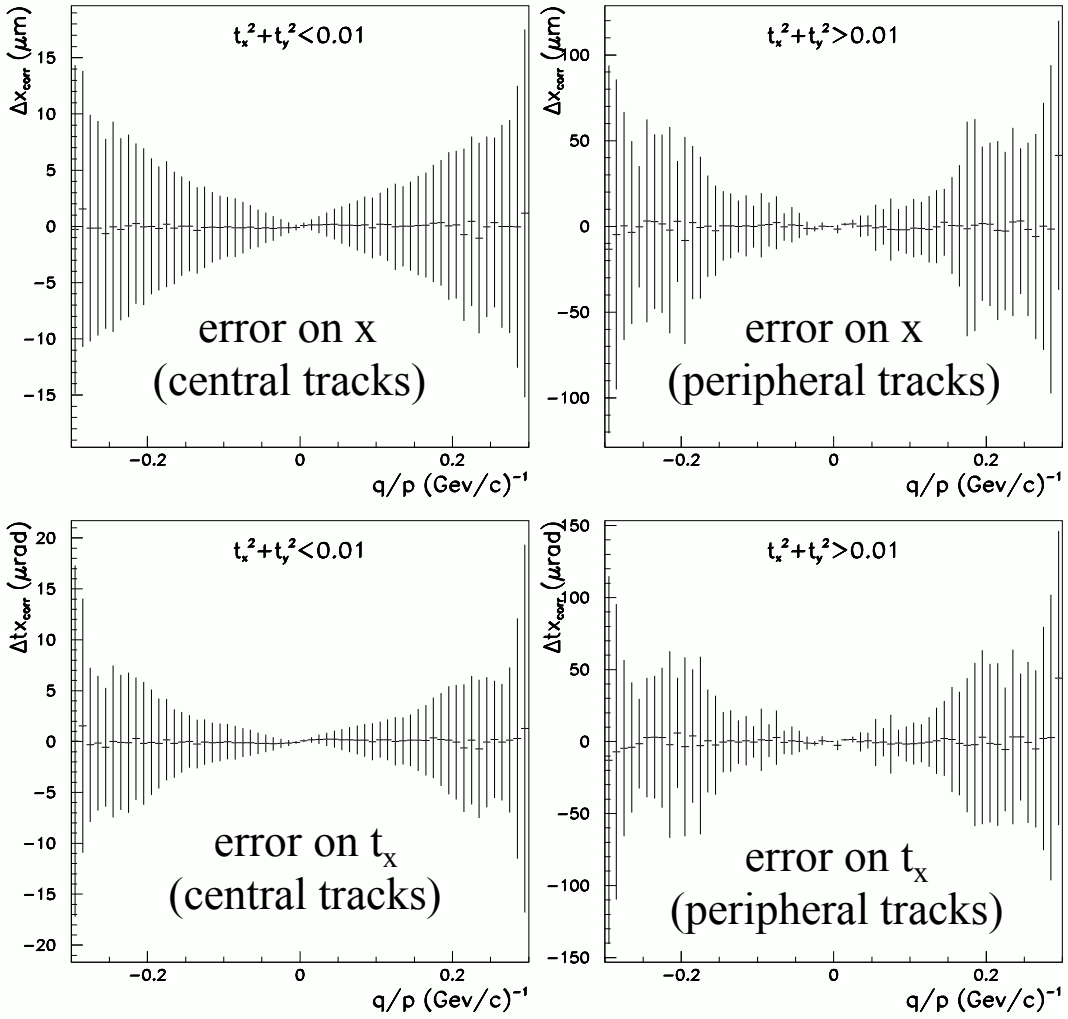
- AMC40 TELL40 configuration:
  - 24 (4x6) GBT Input links @ 4.8 Gbits/s
  - 8/12 Output links to DAQ (10 GBE or other)
- 1 GBT : data from 1, 2 or 4 SiPM depending on the FE board configuration

La collaboration a finalement decidé d'utiliser les AMC40 sur des cartes en format PCIexpress (PCIe40) au lieu du format ATCA (TELL40) .

Il y aura en total 112 cartes PCIe40.

Publication: TDR + 2 notes publiques





quite acceptable
in the zx plane
after global correction
of degree 7 in q/p