

Soutenance d'habilitation à diriger des recherches

Boson de Higgs

Du simple au double



Jessica Levêque

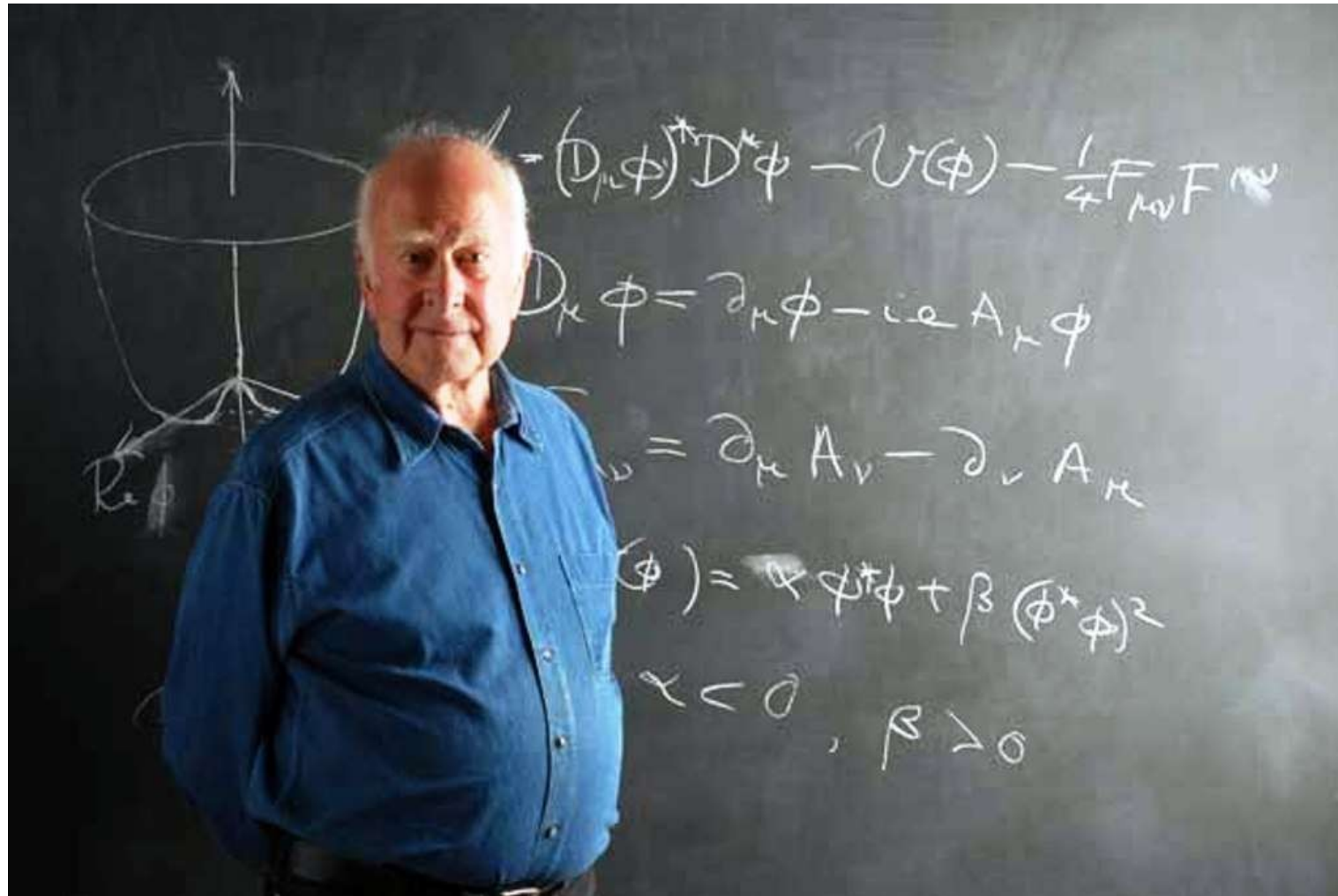
15 octobre
2018



Le Modèle Standard

Quarks	u up	c charm	t top	Force carriers	γ photon
	d down	s strange	b bottom		Z Z boson
					W^+ W ⁺ boson
					W^- W ⁻ boson
					g gluon
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino		
	e electron	μ muon	τ tau		

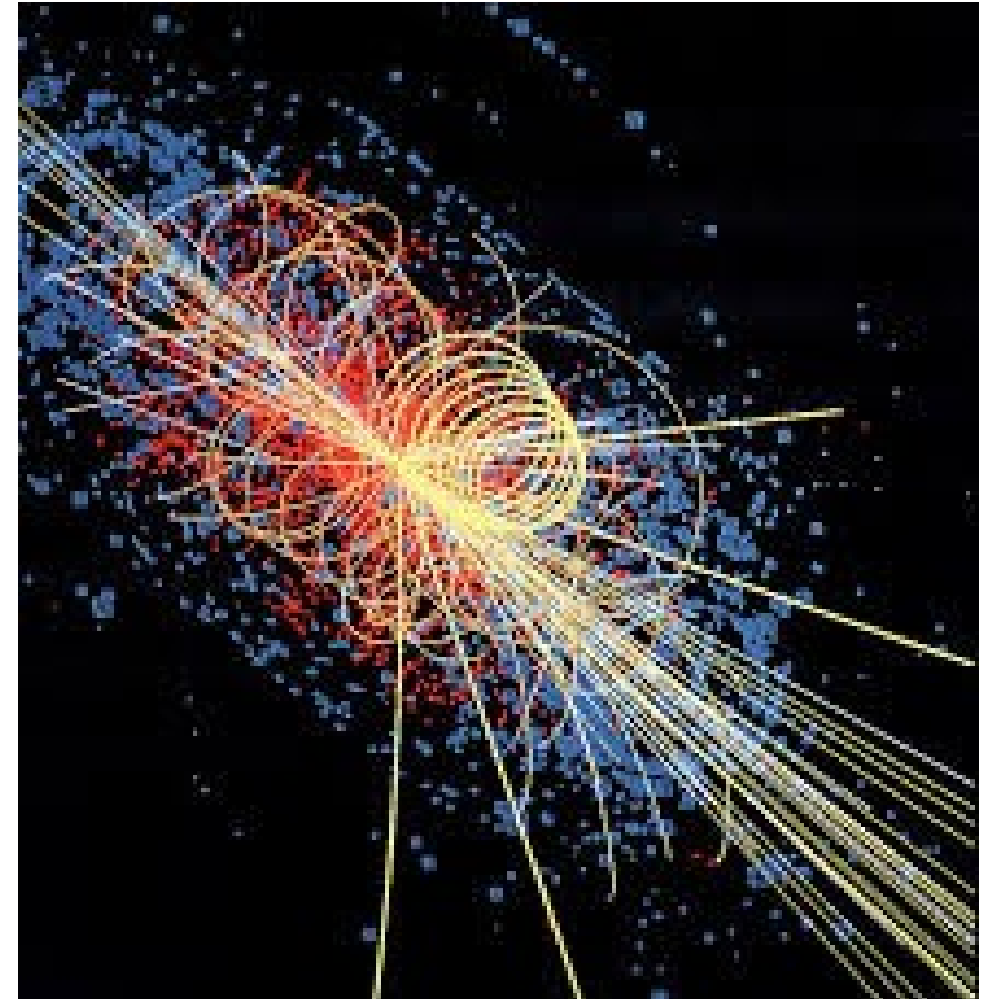
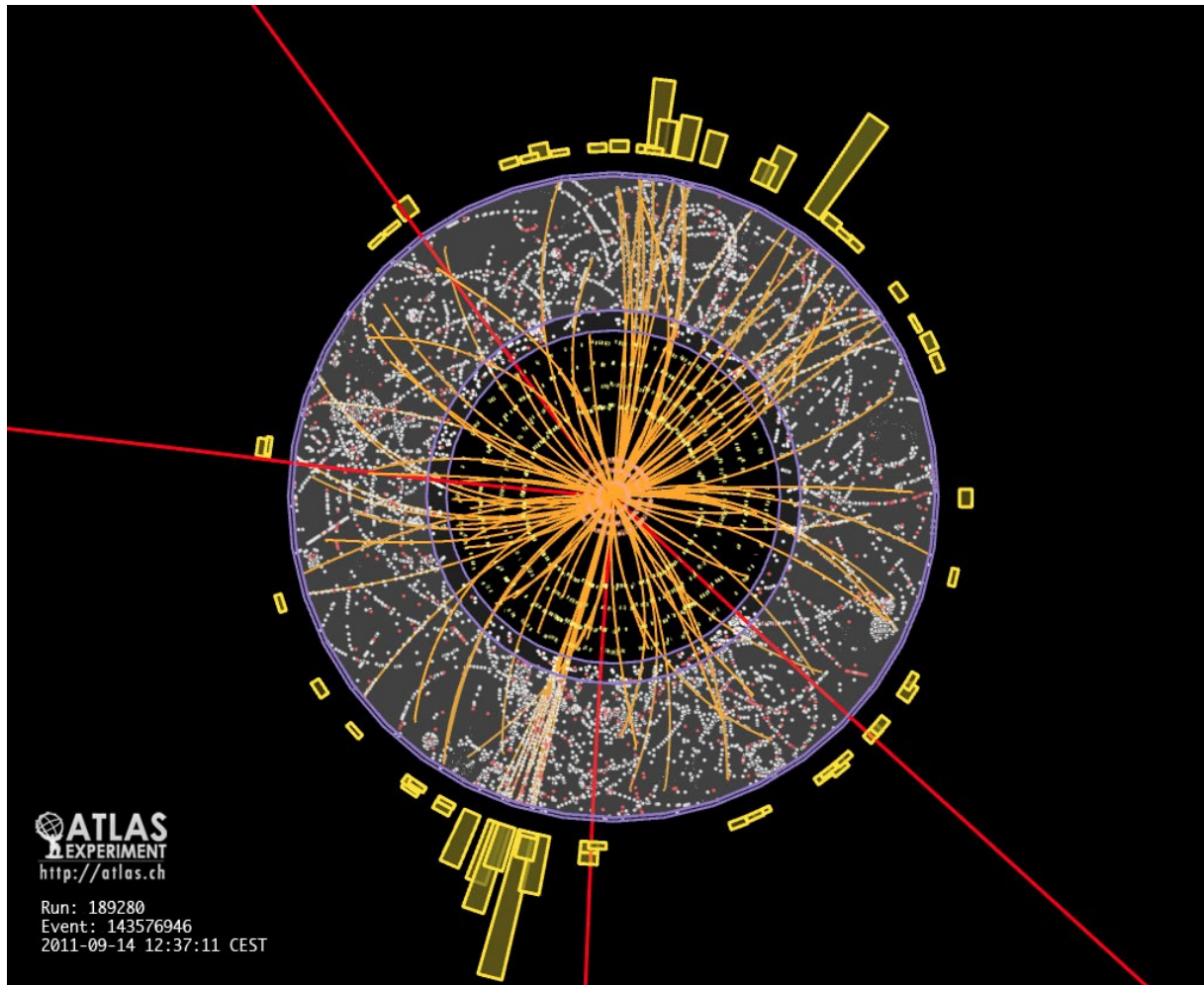
Le Boson de Higgs



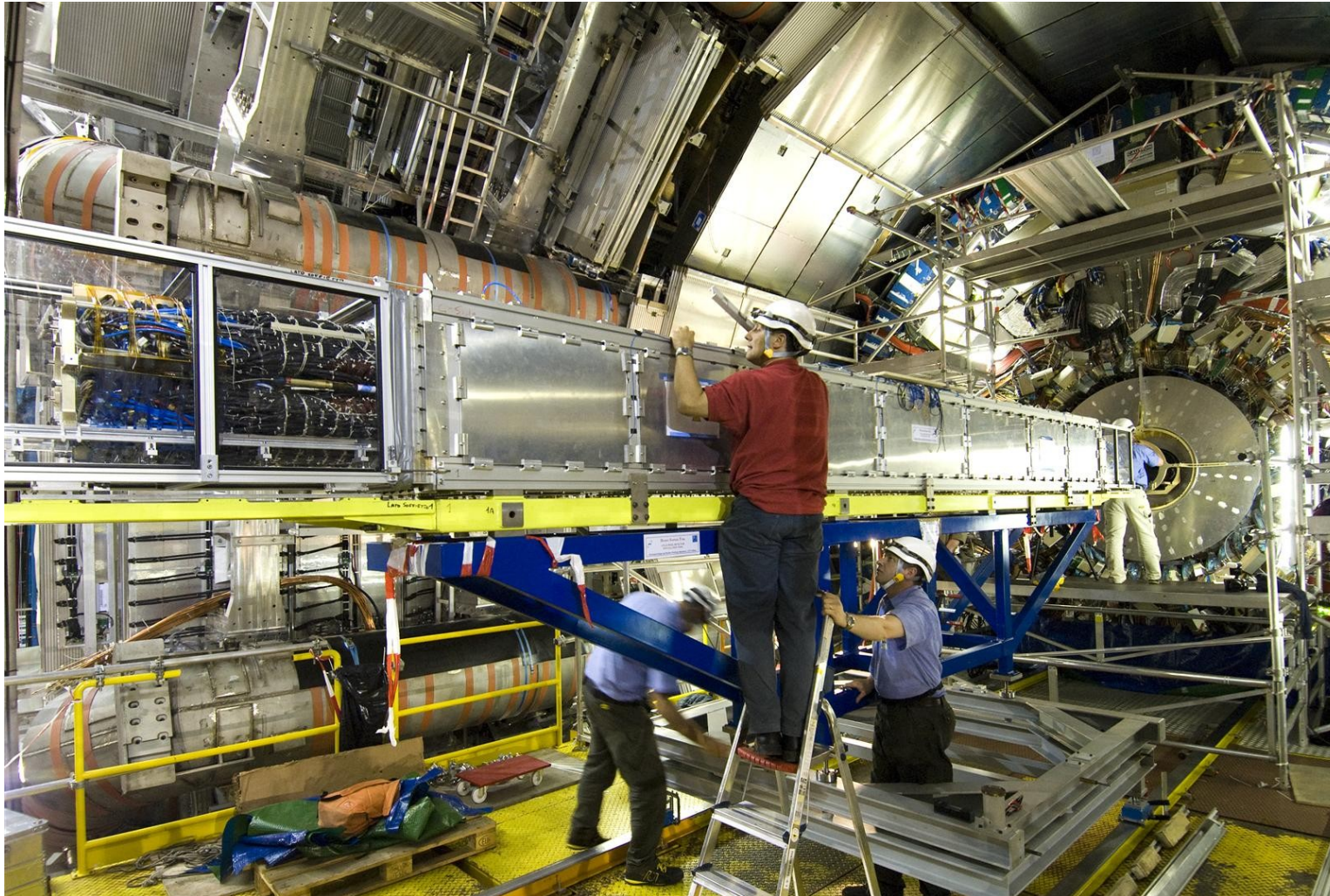
La physique des hautes énergies



Les collisions



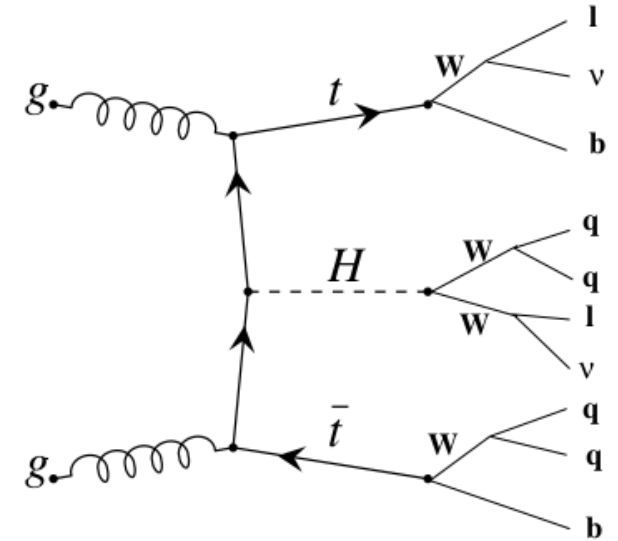
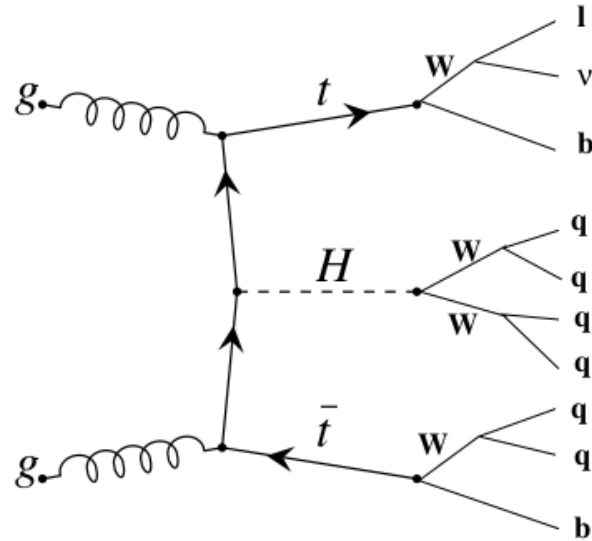
Les gigantesques détecteurs



Thèse [2000-2003]



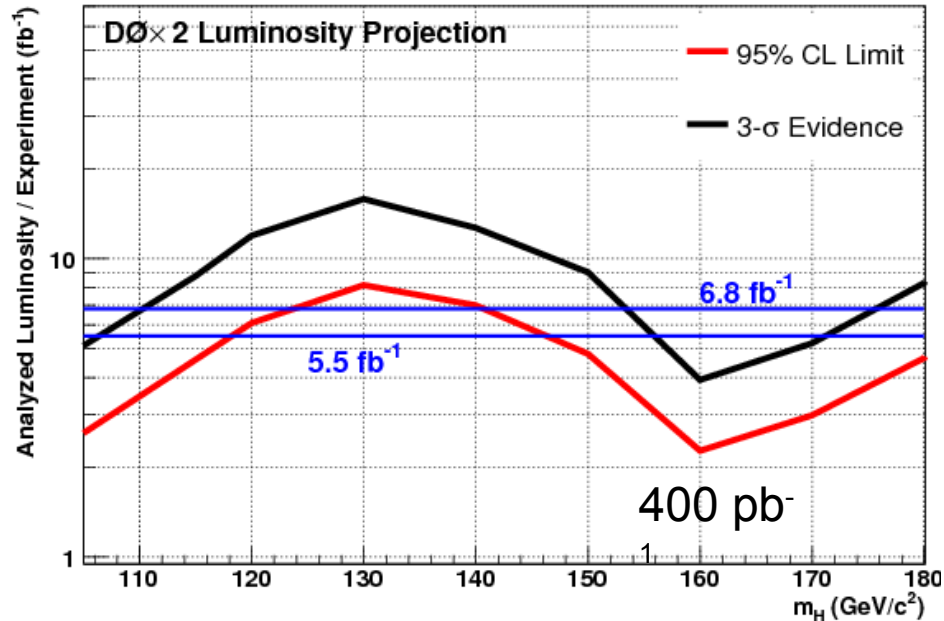
Recherche d'un boson
de Higgs léger produit
en association avec
une paire de quarks
top dans l'expérience
ATLAS.



Théorie

- Modèles
- Générateurs
- Simulations

Post-Doctorat [2003-2006]



Mesure de la section efficace de production des paires de quarks top au Tevatron dans le canal dimuon.

Mesure de l'hélicité du boson W dans la désintégration des paires de quarks tops.

Données

- Acquisition
- Qualification
- Reconstruction

Physique

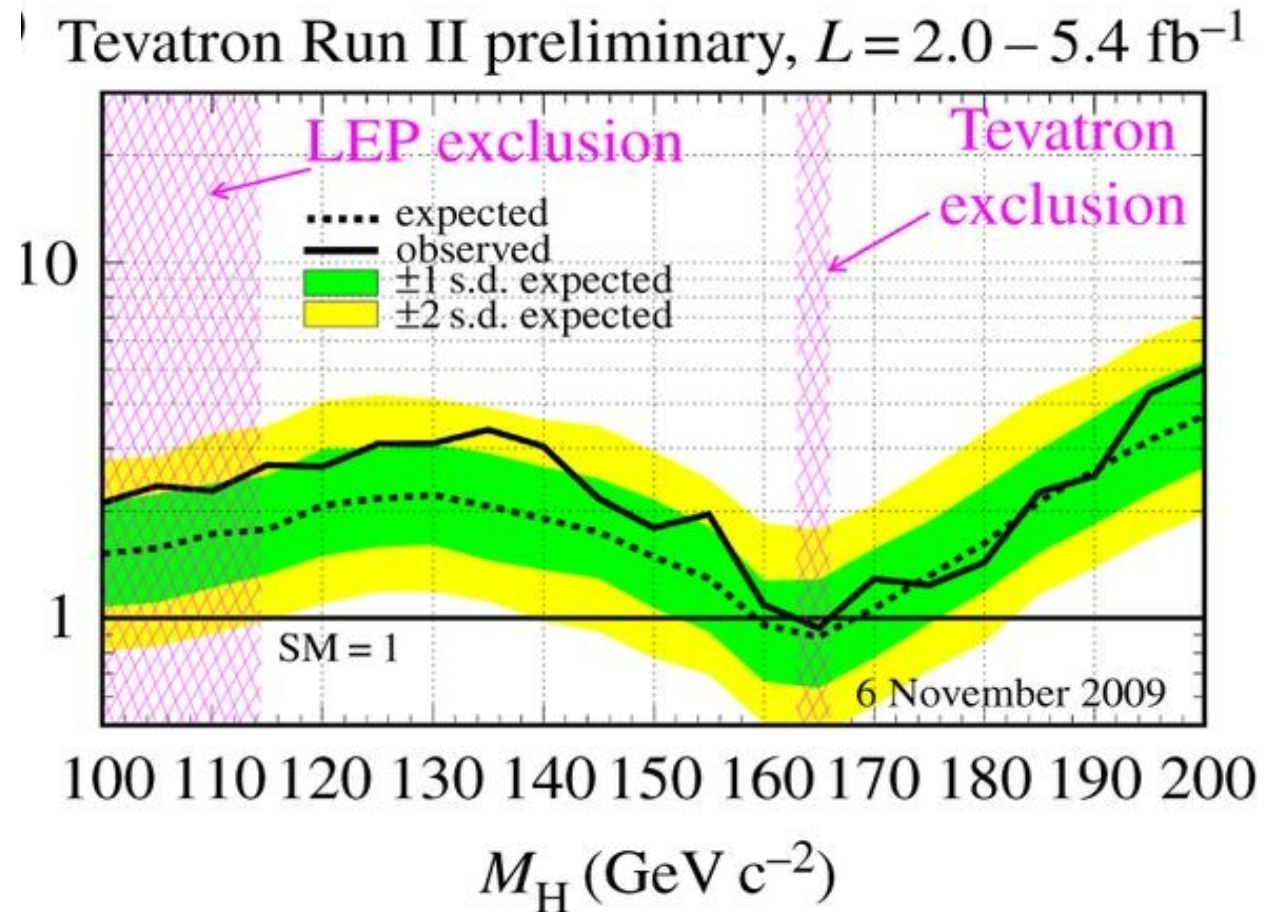
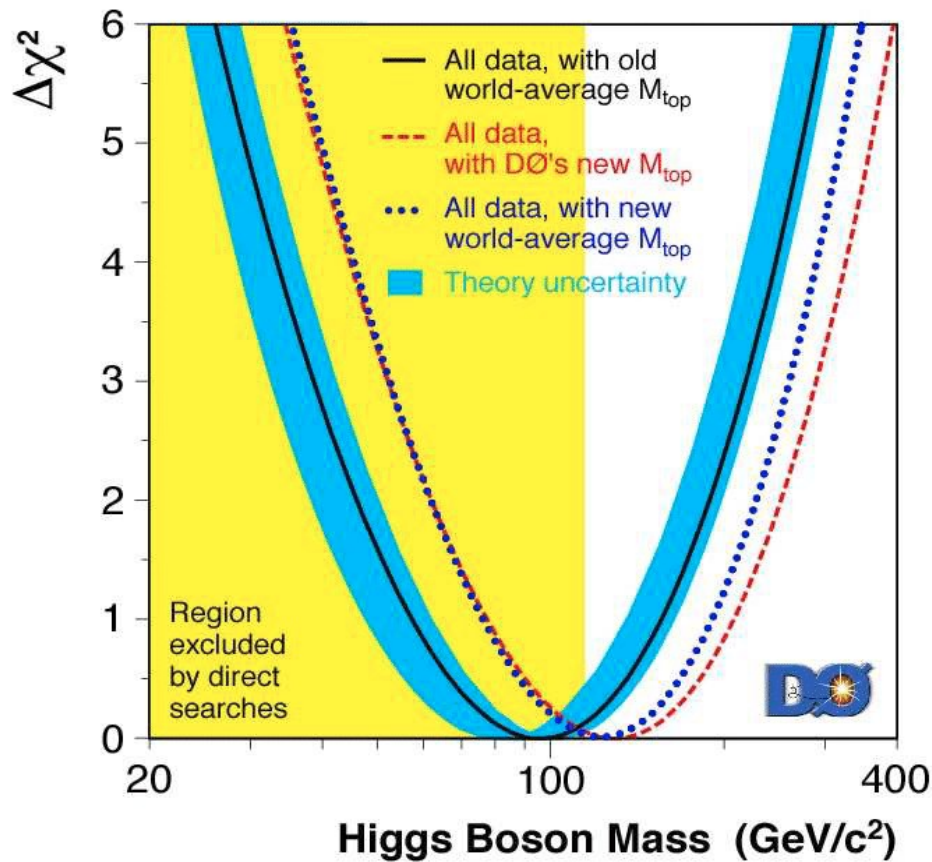
- Performances
- Mesures de précision
- Découvertes

Le casque





ATLAS: Objectif boson de Higgs



Mise en route du détecteur ATLAS [2007-2010]

Détecteur

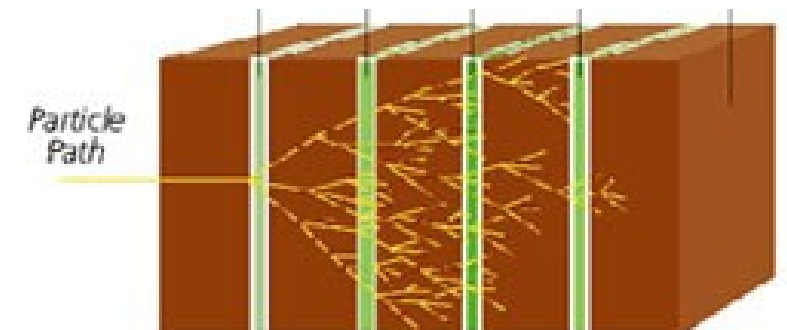
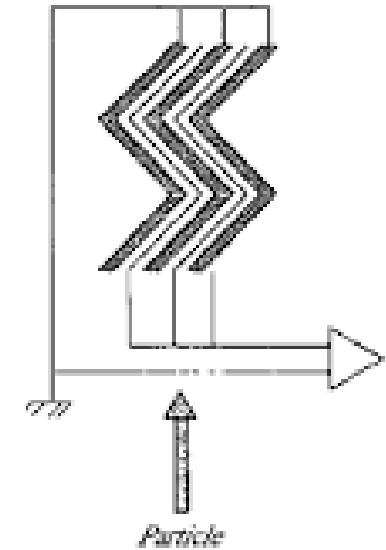
- Conception
- Construction
- Installation
- Opération

Données

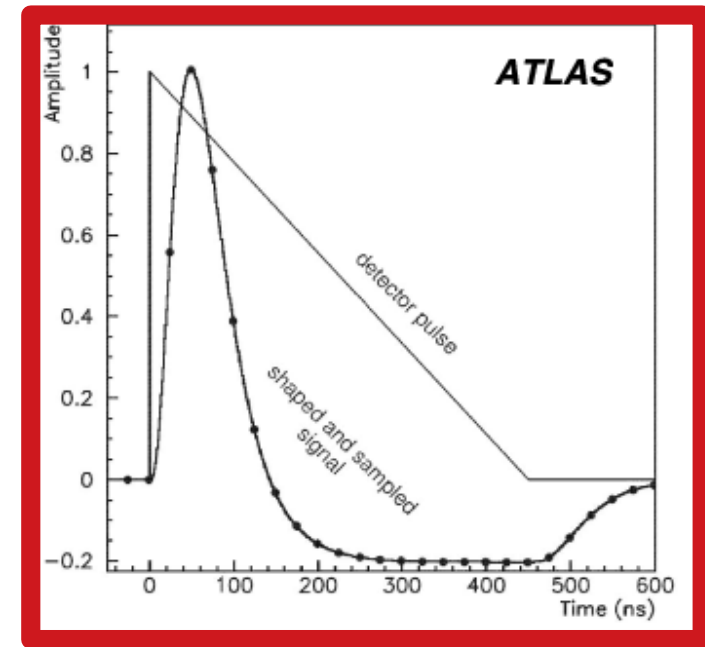
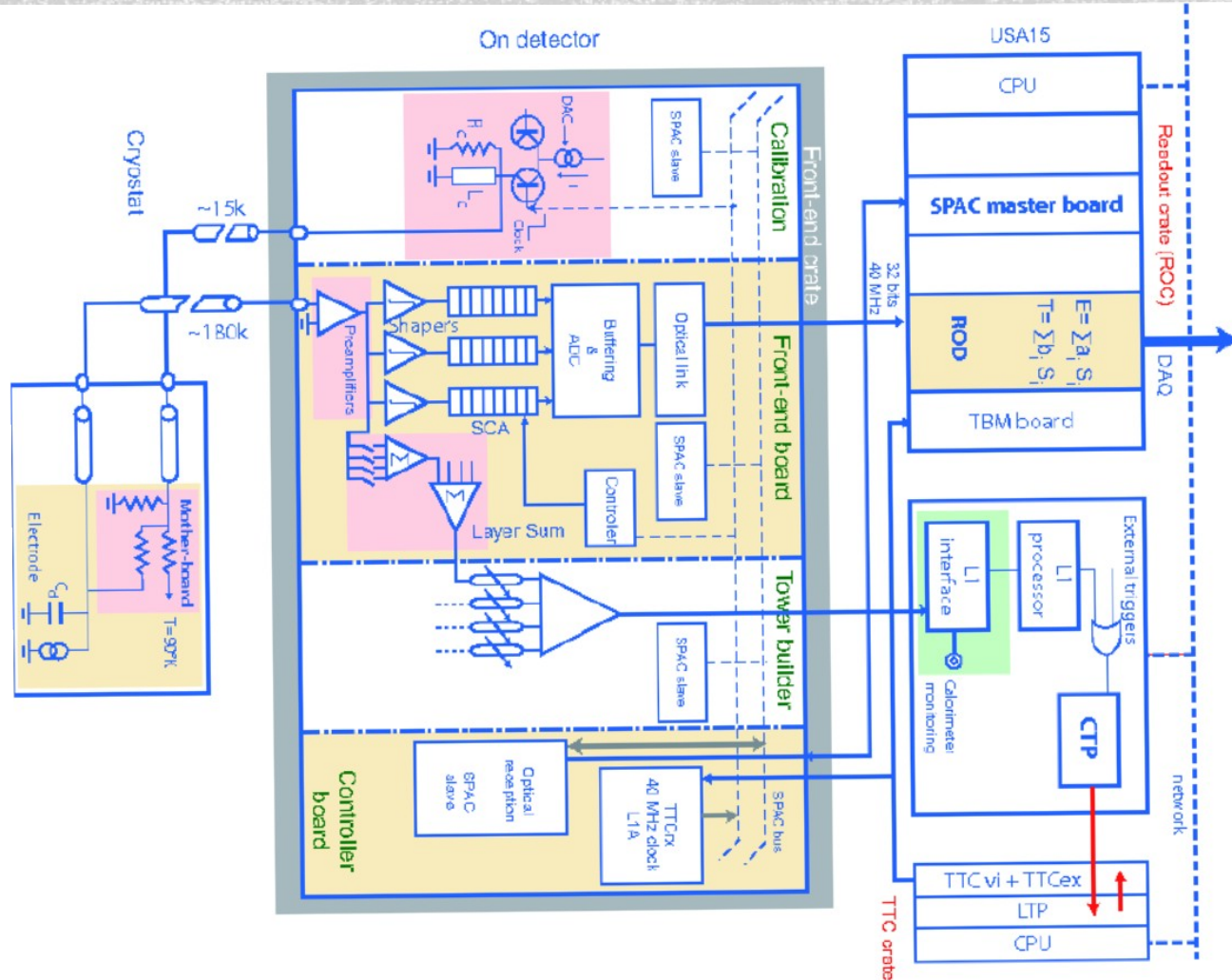
- Acquisition
- Qualification
- Reconstruction



Le calorimètre à argon liquide

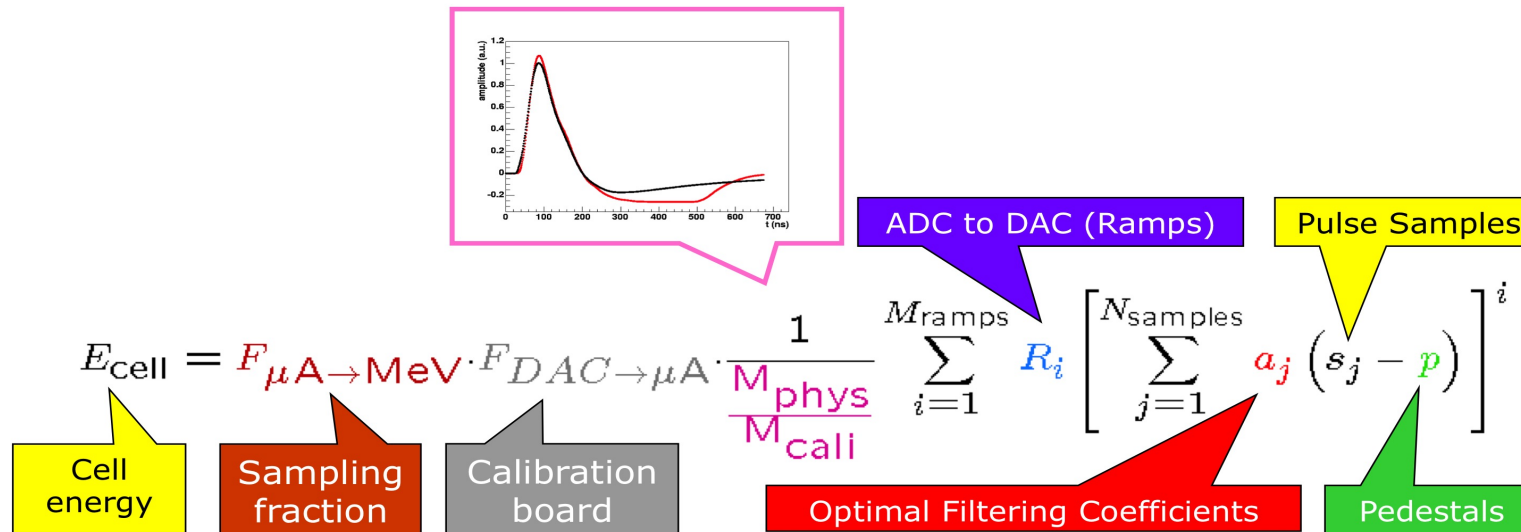


Le “pulse” de l’argon liquide



**FEB
ROD
DSP...**

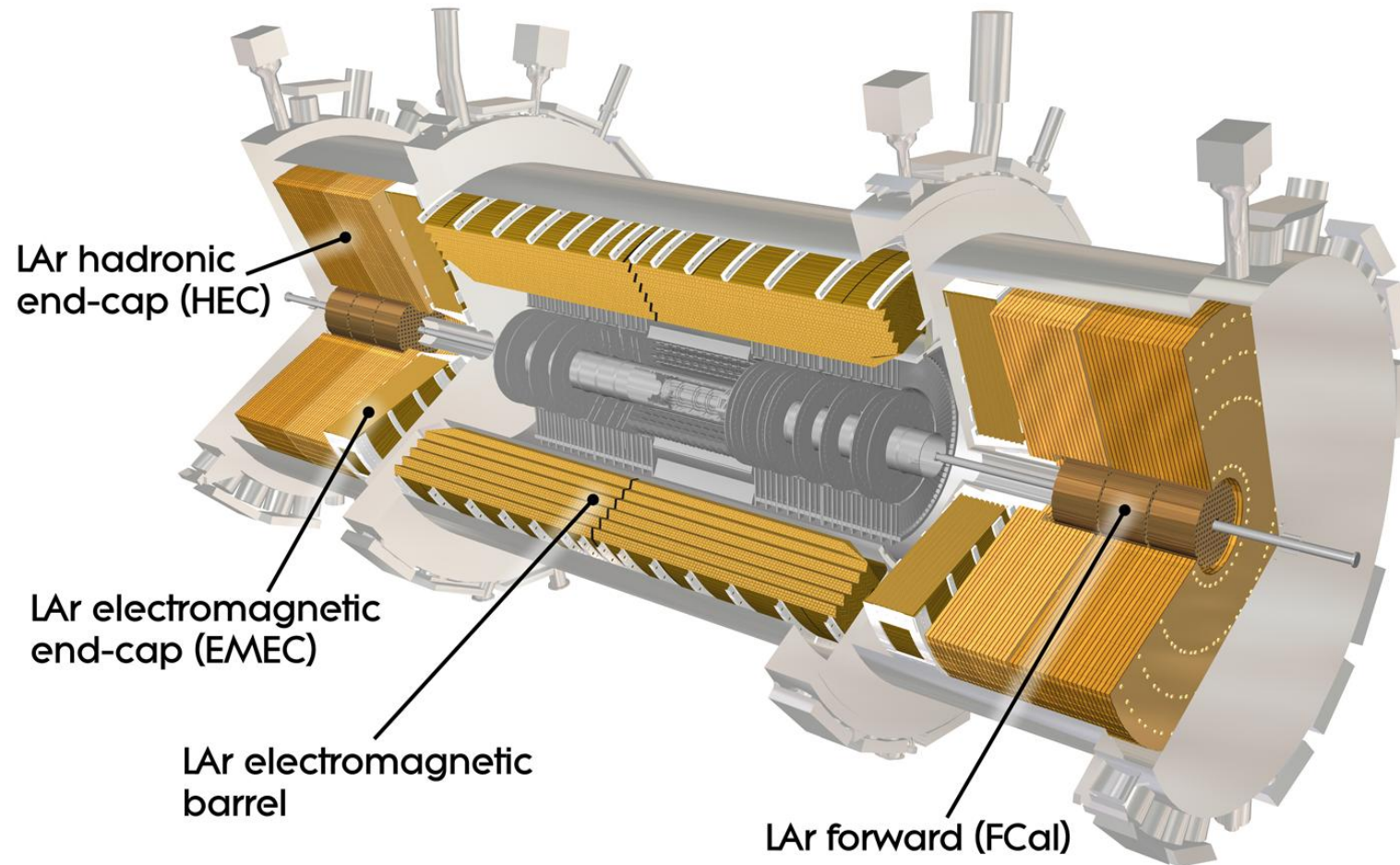
La reconstruction de l'énergie



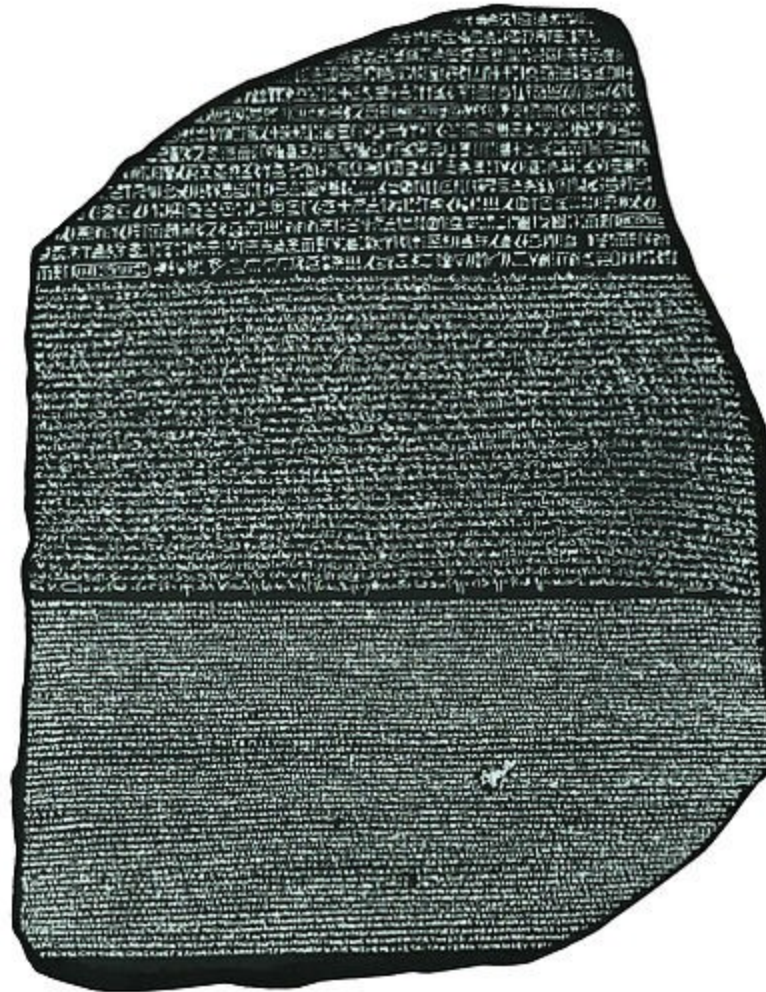
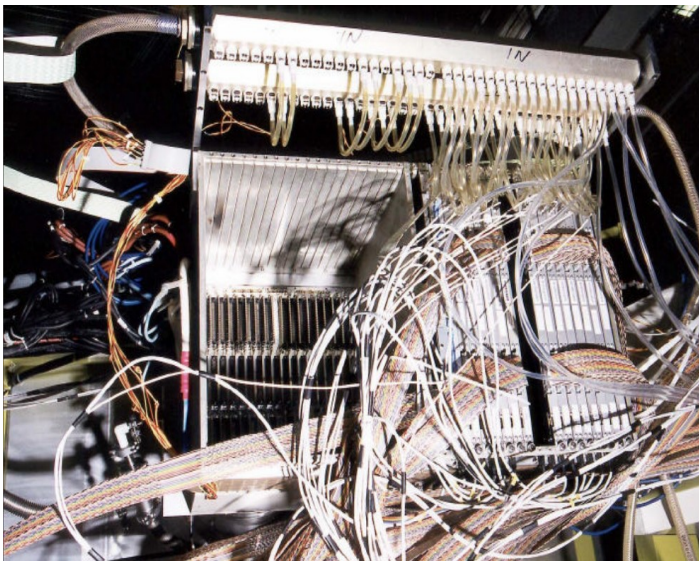
The above formula describes the LAr electronic calibration chain (from the signal ADC samples to the raw energy in the cell). Note that this version of the formula uses the general M_{ramps} -order polynomial fit of the ramps. We use a linear fit as the electronics are very linear, and we only want to apply a linear gain in the DSP in order to be able to undo it offline, and apply a more refined calibration. In this case, the formula is simply:

- Détecteur physique: DCS
 - → Haute-tension
 - → LVPS
 - → température
- FEB/ROD/DSP:
 - → Intégrité du signal
 - → pédestaux
 - → OFC
 - → bruit
- Monitoring des runs de calibration

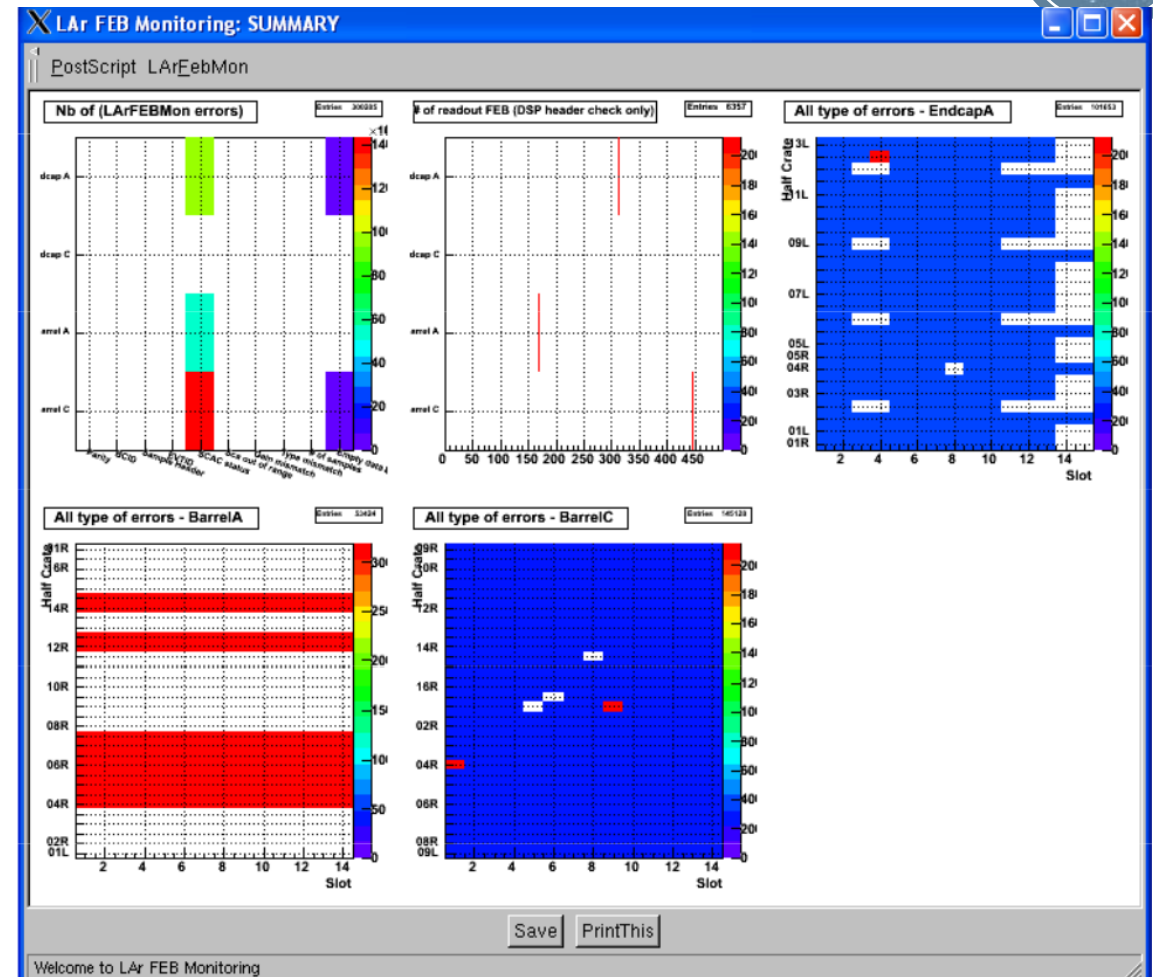
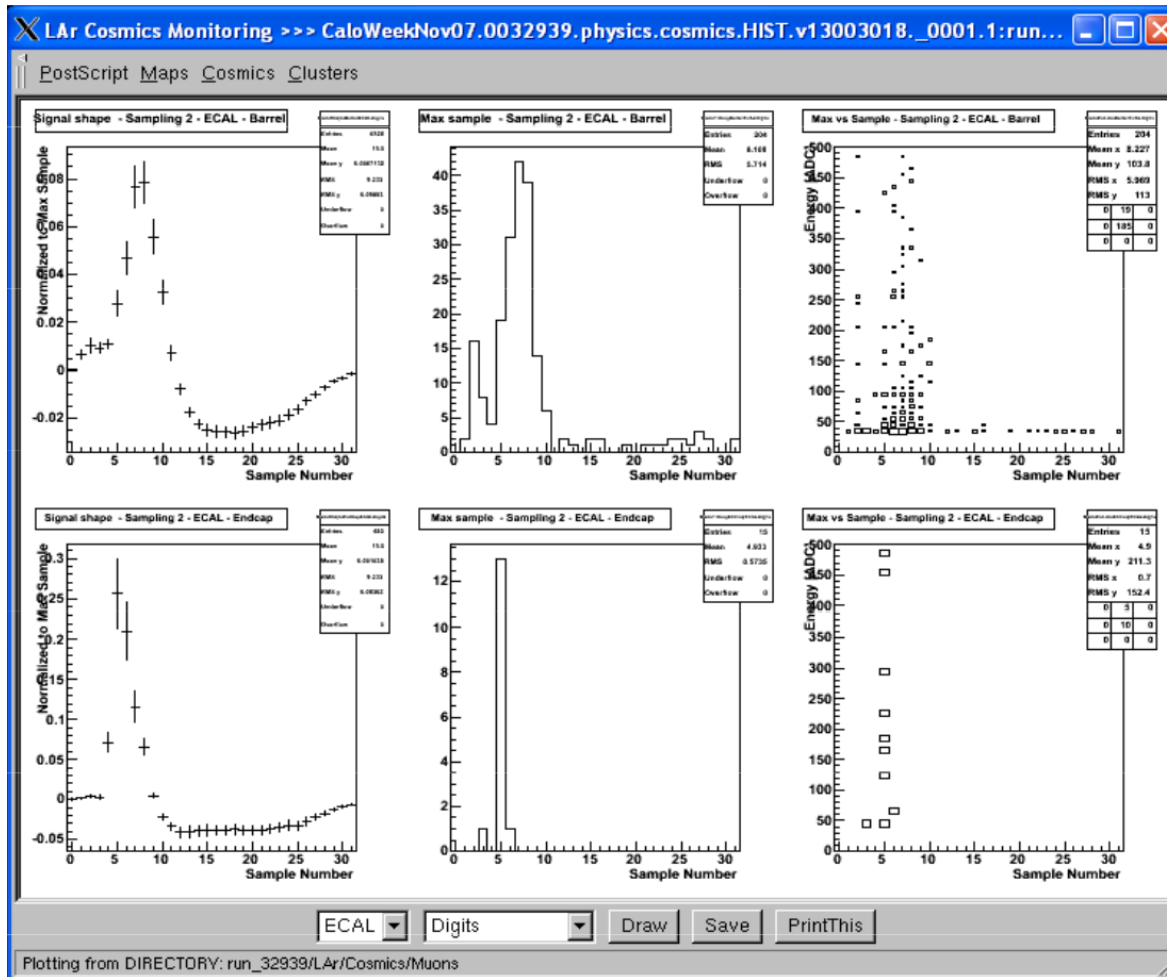
1524 FEBs / 182 468 cellules



Des Experts aux Shifters

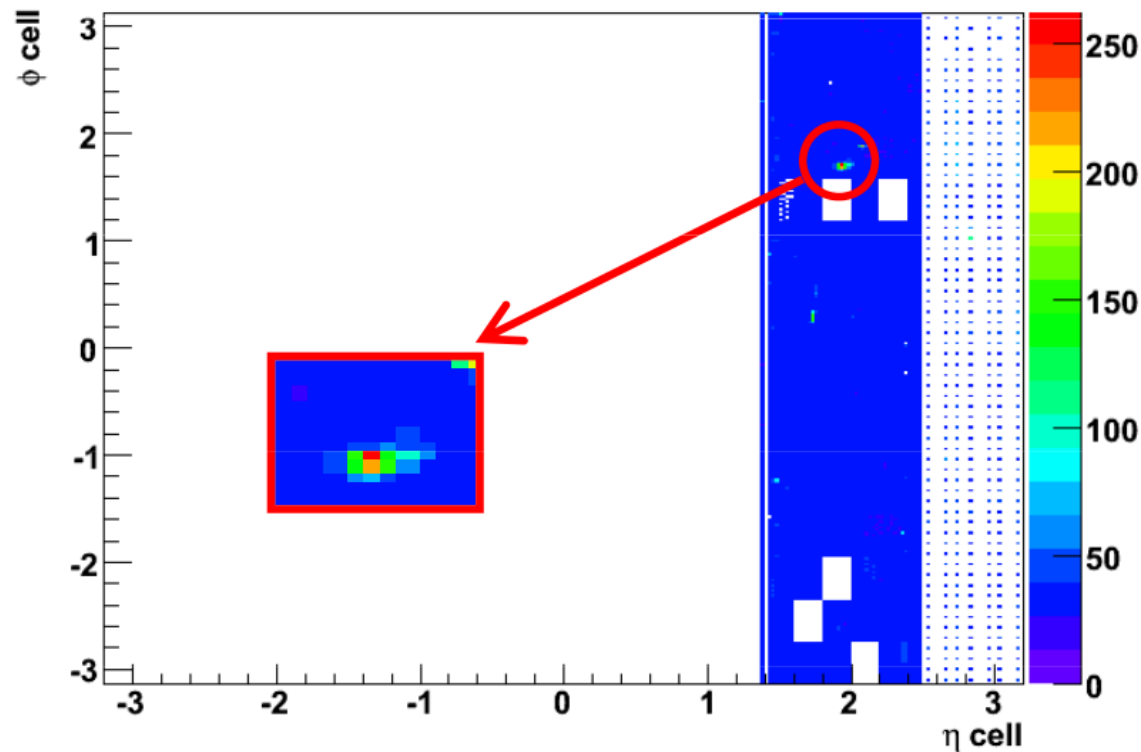


Le premier “vrai” pulse online (muon cosmique)



Monitoring des cellules bruyantes

Noise [MeV] - Sampling 2 - ECAL

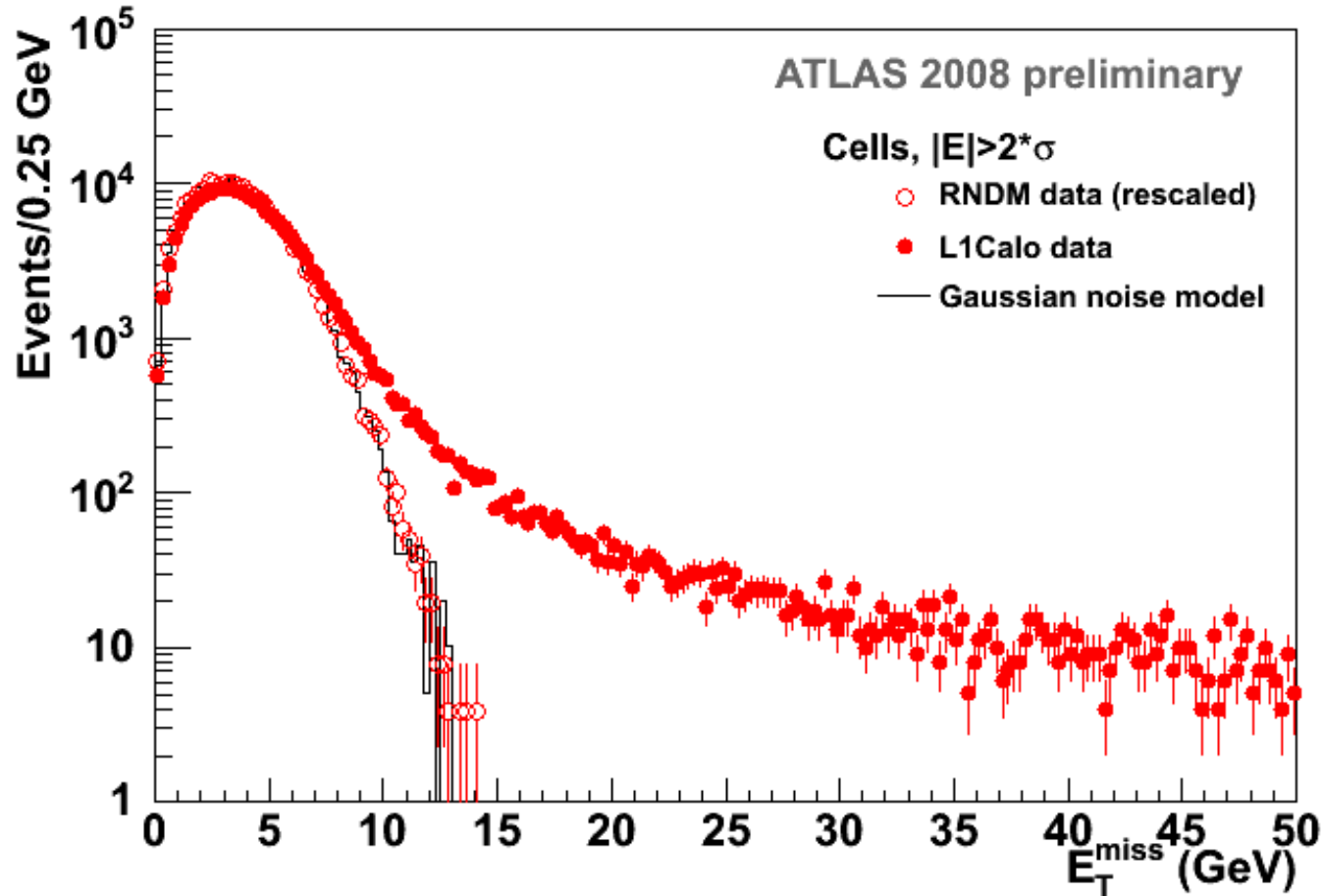


Average Noise : 31.614 MeV

NBins above 5 sigmas : 15

NoiseSampling2ECALRawChannels(1.487500;-1.239457)
NoiseSampling2ECALRawChannels(1.737500;0.257709)
NoiseSampling2ECALRawChannels(1.737500;0.282252)
NoiseSampling2ECALRawChannels(1.737500;0.306796)
NoiseSampling2ECALRawChannels(1.737500;0.331340)
NoiseSampling2ECALRawChannels(1.912500;1.681243)
NoiseSampling2ECALRawChannels(1.912500;1.705787)
NoiseSampling2ECALRawChannels(1.937500;1.681243)
NoiseSampling2ECALRawChannels(1.937500;1.705787)
NoiseSampling2ECALRawChannels(1.962500;1.681243)
NoiseSampling2ECALRawChannels(1.962500;1.705787)
NoiseSampling2ECALRawChannels(1.987500;1.705787)
NoiseSampling2ECALRawChannels(2.062500;1.877593)
NoiseSampling2ECALRawChannels(2.087500;1.877593)
NoiseSampling2ECALRawChannels(2.837500;1.018563)

Energie transverse manquante



Etudiante de Master: Elisabeth Petit

Nettoyage “à la main”
→ automatisation

- liste de cellules par run/LB
- base de données
- masquage automatisé pendant la reconstruction

LArWeb Extractor

(le monitoring presque sans shifter)

LAr WebDisplay Extractor - Prod Version 05-02-04

Run Number: 350361 Report Type: LADeS-express Run Report Submit Use atlasdqm-dev.cern.ch ☐

Expert options: Data stream: express Source: tier0 Processing version: 1

Advanced options (do not touch unless you know what you do!)

Noisy cell tables: Standard (both) Cluster plot thresholds (EM / Calo): Et > 4/10GeV Min. number of clusters: Default (lumi. dependent) 150 sporadicBurstNoise thresholds(events): NClusters / NClusters (PS)

MNB treatment: Default MNB suspicious FEBs: Custom list EMBC_27_7 EMBC_27_5 EMBC_27_14 EMBA_9_2 EMBA_10_10

Unmatched cells: No flag proposal in Inner wheel/FCal Consider LCE input for HEC cells ☐ Consider Eth plots in inner wheel front ☐ Exclude LBs in sporadic column: Do not extract noisy cells ☐ Include ATLAS not ready LBs ☐ Old CaloMonitoring (before 21.0.68) ☐

[Show trigger prescales in LArNoiseBurst stream](#)

Run Info	LAr Global	CP Global	Partition	Data Integrity	Non-nominal HV	NullDigit/Saturation	Noise Bursts (LArNoisyRO)	DSP energy computation	Mean timing
Stream	LB: %events (number)			FEBs with >1% of errors	HV correction	FT,SL,CH,%ev,error	LB: %events (number)		(ns)
express	express	express		express	express	express	express	express	express
Run 350361 Wed 16 May 02:48->12:47 ATLAS ready: 76-678 198 pb-1 554980 events Run characteristics ATLAS operation logbook	Detector status DCS Errors None HV Trips Database no trip found EventInfo::LArError 0.025% of data Overall Data Rejection - 0.025%	2-8TeV jet occupancy 1 jets at maximum	EMBA	No PU trigger errors			Noise burst Mini noise bursts	Less than 1 errors per FEB/LB No LB with > 5 errors	Within 0.69 ns
Tier0 processing x562_h299 21.0.70-tier0 End of Calib. Loop Fri 18 May - 12:52 Useful DQ links Tier0 Webdisplay DQ logbook (read-only archive) DQ logbook (writable version)	Corrupted: 0.000% Corrupted(Veto): 0.000% Noise Burst(Veto): 0.025% Data Corruption >=1 FEB: 0.000% - 1 LBs: show all >=4 FEB: 0.000% Corrupted: 0.000%		EMBC	No PU trigger errors			Noise burst Mini noise bursts After veto - Clean Before veto - 1 LBs: show all	No LB with > 5 errors	Within 0.65 ns
			EMECA	No PU trigger errors			Noise burst After veto - Clean Before veto - 13 LBs: show all Mini noise bursts	Less than 1 errors per FEB/LB No LB with > 10 errors	Within 1.46 ns
			EMECC	Nb of errors Checksum:1 1 FEBs with < 0.000180% show No PU trigger errors			Noise burst After veto - Clean Before veto - 12 LBs: show all Mini noise bursts	Less than 1 errors per FEB/LB No LB with > 10 errors	Within 1.56 ns

- Liste des “Defects” par run
- → “Defect database”
- → “Good Run List”
- Liste des canaux avec haute tension non-nominale
- → Base de donnée
- → Correction automatisée pendant la reconstruction
- Liste des cellules bruyantes
- → base de donnée dédiée
- → correction/masquage automatique lors de la reconstruction

Transférer l'information de la salle de contrôle aux analyses

- **Classification des “défauts” observés dans les données**
 - Données corrigeables / non-corrigeables
 - Action immédiates dans la salle de contrôle
 - Monitoring de la fraction de données impactée et des temps morts induits
 - Modification des procédures d'opération en concertation avec les experts LAr
- **Phénomènes récurrents, rares ou sporadiques ?**
 - Rejet des données par événement, par LB (1 minute), par fenêtre “veto”
 - Masquage et corrections par événement, par LB
 - Monitoring des problèmes rares → quel impact sur le long terme ?
 - Transfert des corrections à appliquer lors de la reconstruction des données (base de données)
 - Archivage de l'information sur la qualité des données pour les défauts minimes
- **Formation des shifters / Documentation**
 - Pérennisation des outils sur le long terme
 - Automatisation/simplification progressive pour éviter les erreurs humaines, et la supervision continue
- **Cohérence des procédures et critères DQ entre sous-systèmes ?**

JINST 9 (2014) P07024

[Show Runs](#)

Data Quality Summary

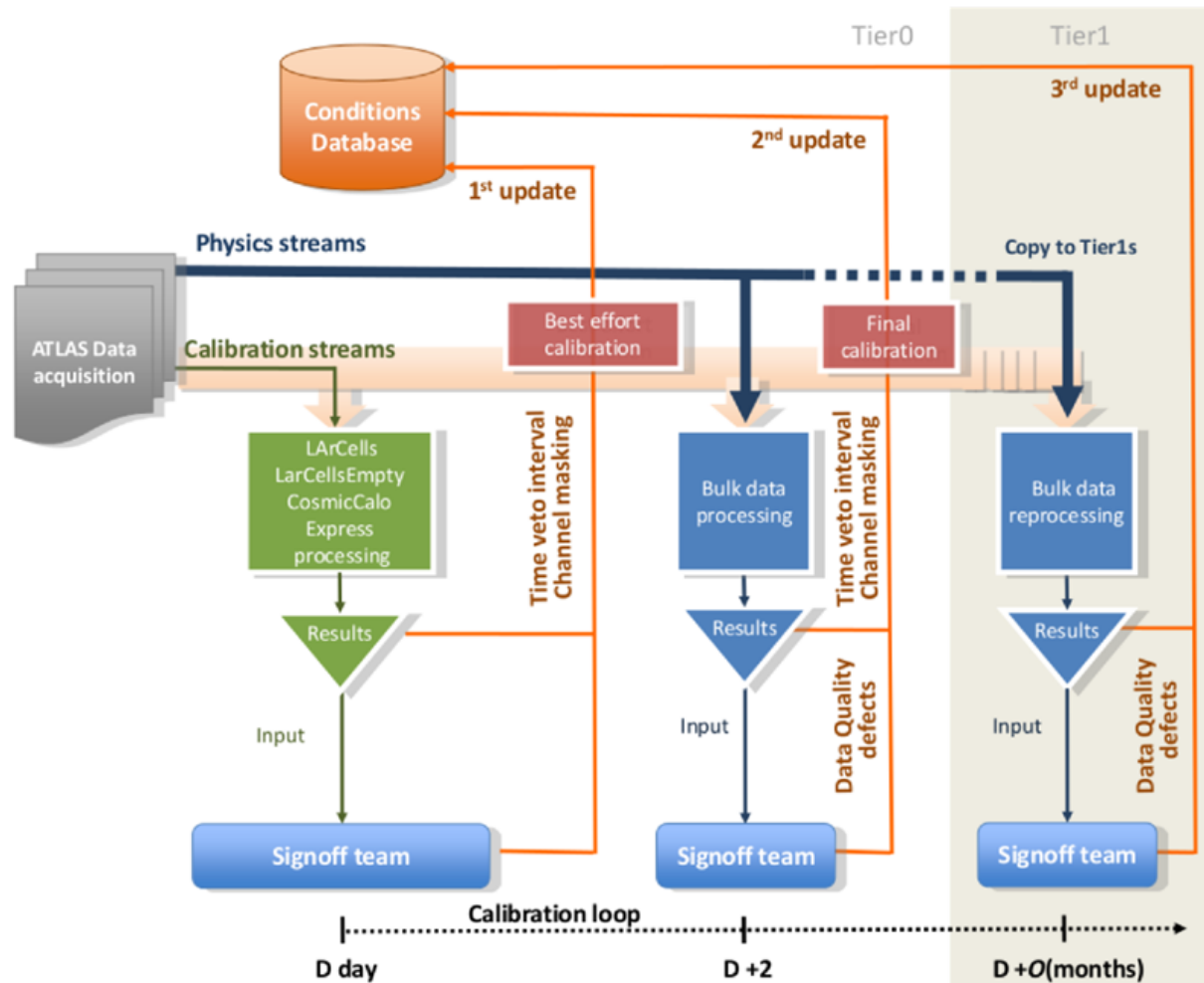


Missing Sign-Off			Defects in ATLAS Ready (show tolerable)			
Run Info	ES1	BLK	Calo	Tracking	Muon	Trigger & Lumi
350361 data period D1 COMA, DCS, DS, defects DQlogbook, DQWebDisplay Start: Wed, 16 May 2018 02:49:20 End: Wed, 16 May 2018 12:47:46 Stable Beam ATLAS Ready 1-71: FALSE 1-76: 0 71-680: TRUE 76-679: 1 680-683: FALSE 679-683: 0 Ready Recorded: 197.40 pb ⁻¹ (-1) Global Not Ready: 0.00 pb ⁻¹ (-1) Global Busy: 2.49 pb ⁻¹ (-1) DQ Lumi Loss: 3.50 pb ⁻¹ (-1)	CALO EGAMMA ID JET LAR LCD LUMI METS MCP MET MS PIXEL SCT TAU TILE TRIG_HLT_BJT TRIG_HLT_ELE TRIG_HLT_GAM TRIG_HLT_IDT TRIG_HLT_TAU TRIG_L1_CIP TRIG_L1_ZDC TDT	BTAG_BULK CALO_BULK EGAMMA_BULK ID_BULK JET_BULK LAR_BULK MCP_BULK MET_BULK MS_BULK PIXEL_BULK SCT_BULK TAU_BULK TRIG_HLT_MUO_BULK TRY_BULK		ID_BS_RUN/AVERAGE 629-666 	MS_TGC_EC_STANDBY_HV 289,572-573 	LUMI_EMITTANCSCAN 88-124, 628-665
350310 data period D1 COMA, DCS, DS, defects DQlogbook, DQWebDisplay Start: Tue, 15 May 2018 17:59:54 End: Wed, 16 May 2018 00:05:38 Stable Beam ATLAS Ready 1-87: FALSE 1-92: 0 87-447: TRUE 92-446: 1 447-460: FALSE 446-460: 0 Ready Recorded: 90.37 pb ⁻¹ (-1) Global Not Ready: 0.00 pb ⁻¹ (-1) Global Busy: 1.96 pb ⁻¹ (-1) DQ Lumi Loss: 2.07 pb ⁻¹ (-1)	ID METS TILE TRIG_HLT_ELE TRIG_HLT_GAM TRIG_HLT_TAU TRIG_L1_ZDC	BTAG_BULK CALO_BULK EGAMMA_BULK ID_BULK JET_BULK LAR_BULK MCP_BULK NET_BULK MS_BULK PIXEL_BULK SCT_BULK TAU_BULK TRIG_HLT_MUO_BULK TRY_BULK		ID_BS_RUN/AVERAGE 110-148, 397-433 	ALFA_DISABLED ZDC_DISABLED	LUMI_EMITTANCSCAN 108-149, 396-434 92-440 92-445

- 1) Responsable d'opérations pour le calorimètre à argon liquide (2009-2010)
 - Online Monitoring Expert on-call
 - Formation des shifters
- 2) Coordinatrice de la qualité des données LAr (2011)
- 3) Coordinatrice de la qualité des données pour ATLAS (2012)



Du détecteur à l'analyse : 1 semaine



2018 13TeV proton-proton

Dataset B-D,E,I,K-M2 [v102-pro22-03]

B, C, D, F, I, K, L, M	348885 - 360402	Peak Lumi	2.09x10 ³⁴ cm ⁻² s ⁻¹
		Peak Events/BX	63.04
		Delivered Ready (pb ⁻¹)	50905.1
		Recorded Ready (pb ⁻¹)	48835.3
		All Good (pb ⁻¹)	47830.3
		LAr Ready (pb ⁻¹)	47824.5

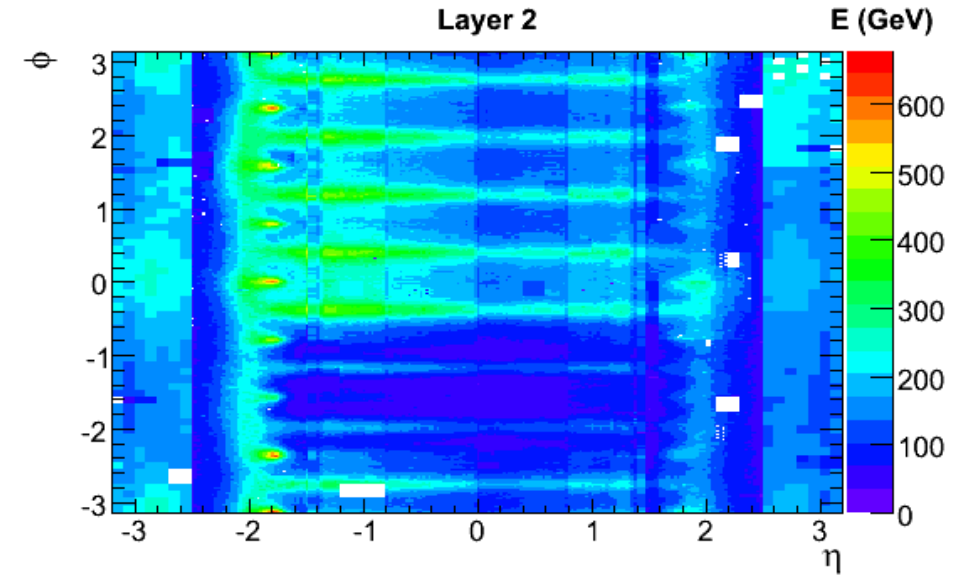
Global Status		CP and Physics				Inner Detector		Calorimeters		Muon Detectors		Trigger & Magnets	
All	97.9	Tracking	99.3	Jet	99.6	All	99.5	All	99.6	All	99.4	Trigger	99.2
25 ns	97.9	MCP	98.7	MET	99.0	IBL	100.0	LAr EM	99.6	MDT	99.8	L1	100.0
Global	100.0	EGamma	98.9	Tau	98.9	Pixel	99.7	Tile	100.0	RPC	99.7	HLT	99.2
Ready	99.7	Lumi	99.7	Btag	98.9	SCT	99.7	LAr HEC	99.7	CSC	100.0	Sol.	100.0
ReadyOnly	100.0			Magnet	100.0	TRT	100.0	LAr FCAL	99.7	TGC	100.0	Tor	100.0

Premiers faisceaux

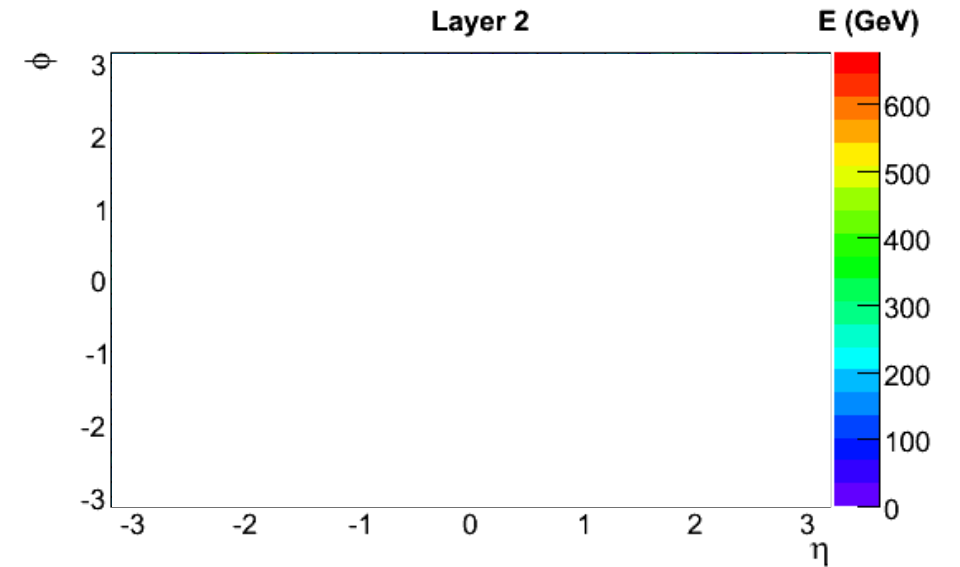
[2009-2010]



Septembre 2009



Septembre 2009

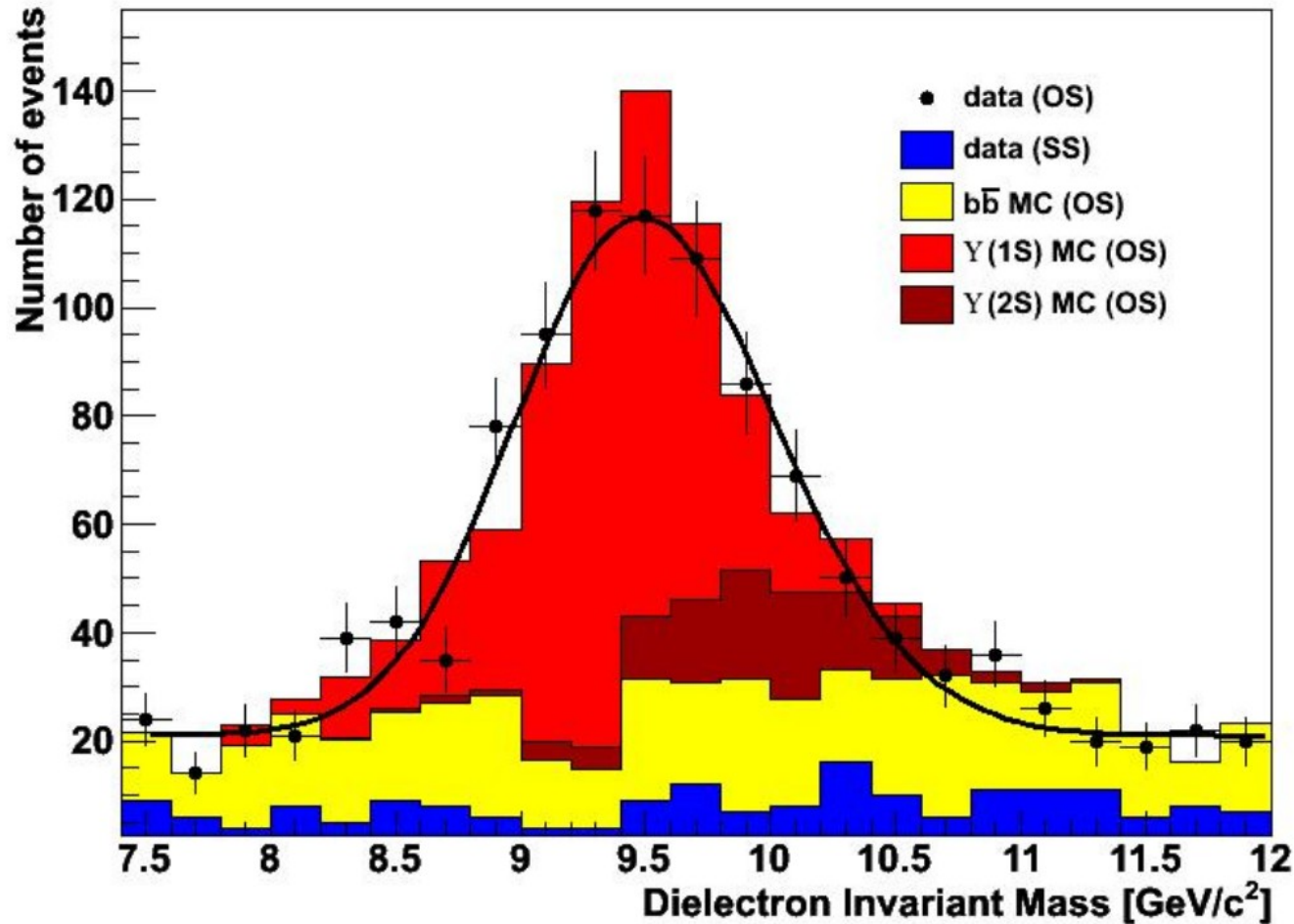


Premières collisions: Upsilon et diphoton

Physique

- Performances
- Mesures de précision
- Découvertes !

(Re) Découverte du Upsilon



CERN Summer Student: Maud Schwoerer

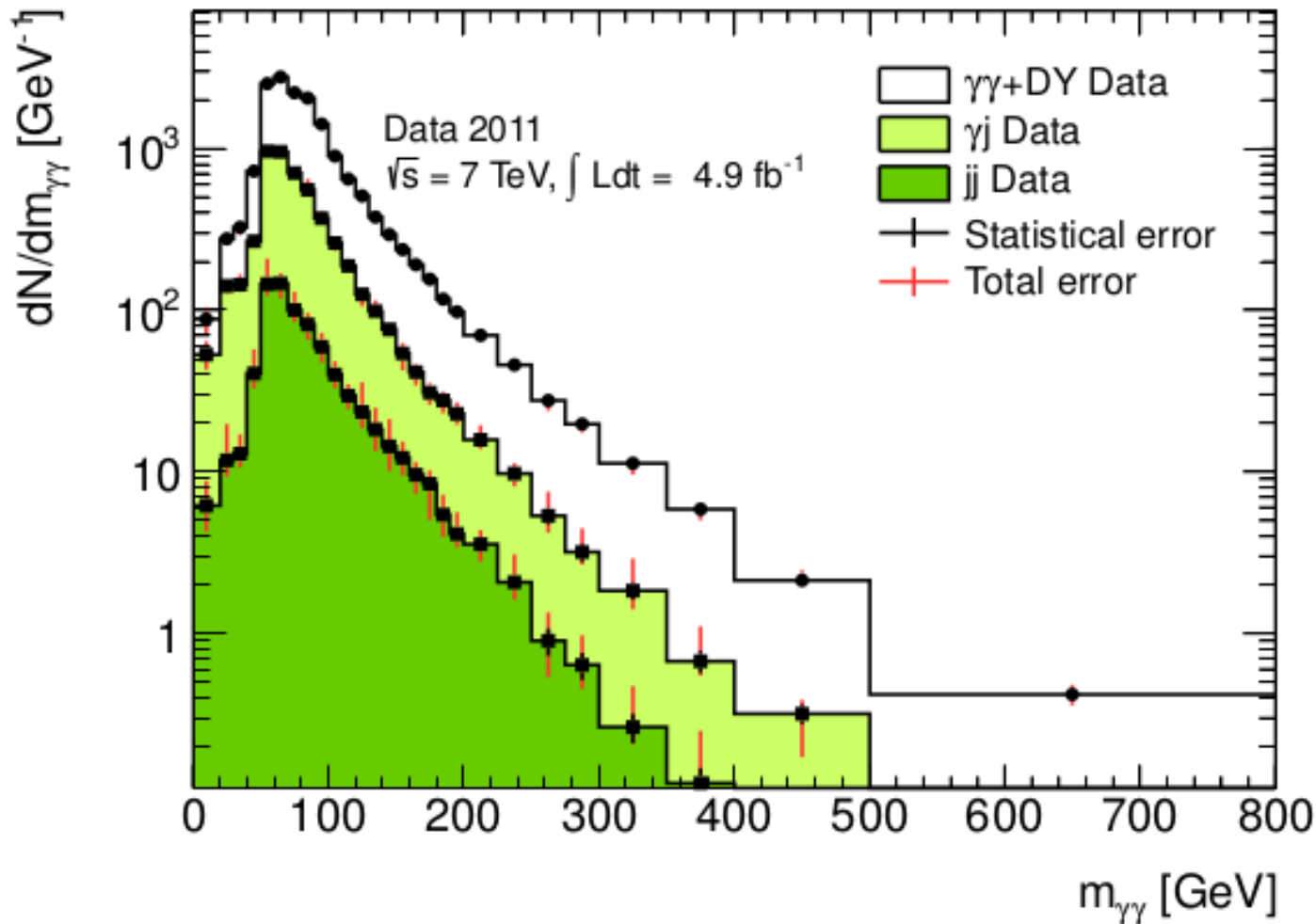
Thèse au LAPP (2010-2013)

Co-direction : Marco Delmastro

Direction : Isabelle Wingerter

Processus Diphoton

Phys.Lett. B716 (2012) 1–29



Thèse: Maud Schwoerer

- Etude approfondie de la reconstruction des photons : efficacité d'identification, isolation
- Décomposition du spectre diphoton en bruit de fond réductible/irréductible
- Mesure des sections efficaces différentielles
 - Test QCD perturbative et des générateurs MC

“Guillet Shoulder”

Journal of High Energy Physics 2013 no. 1, (2013) 86

Thèse: Maud Schwoerer (2010-2013)

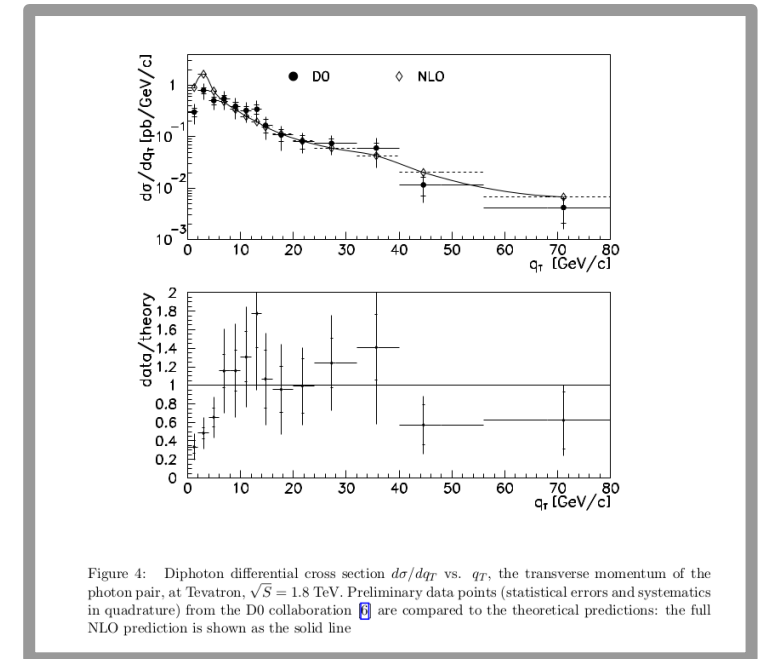
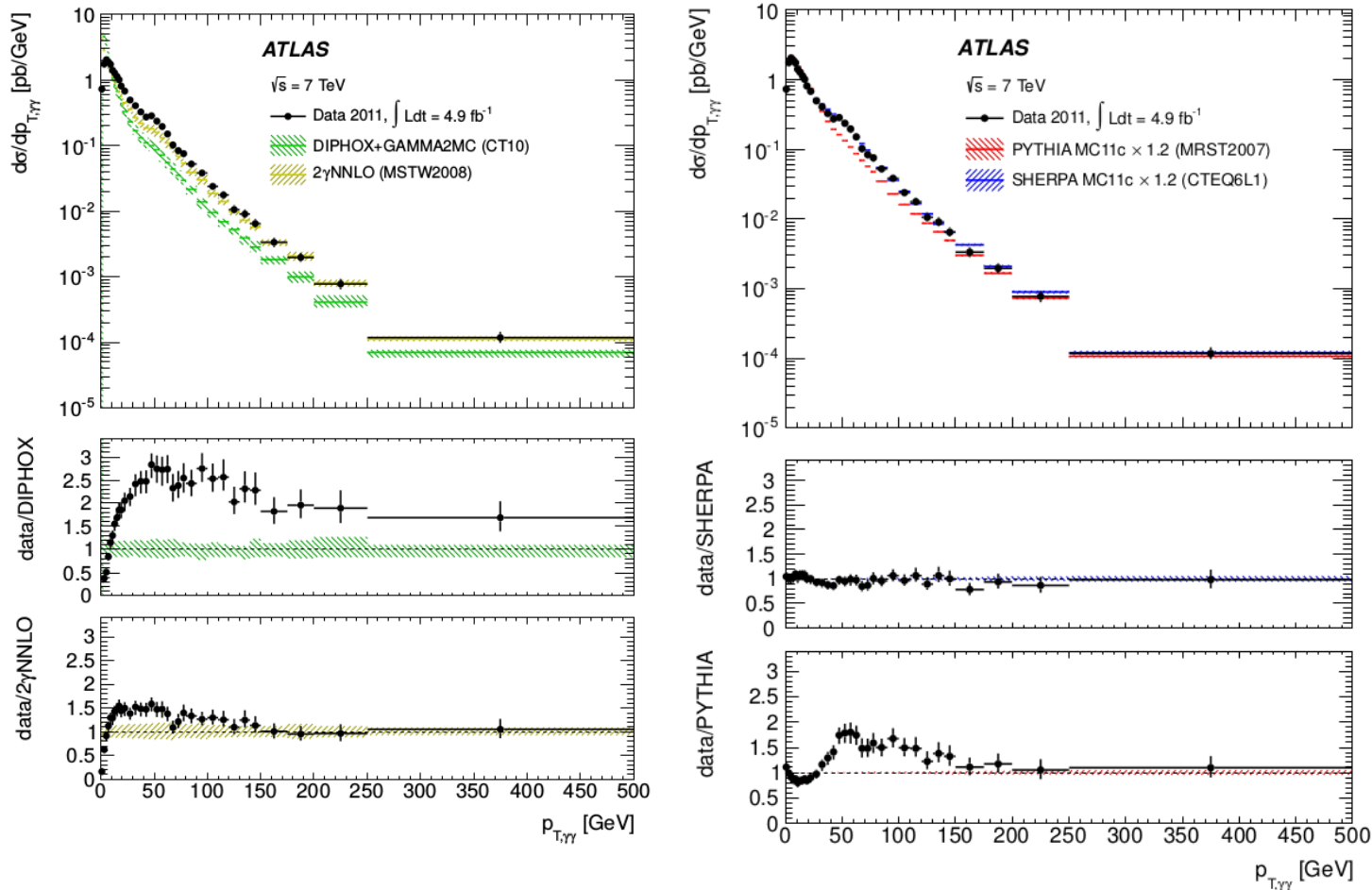


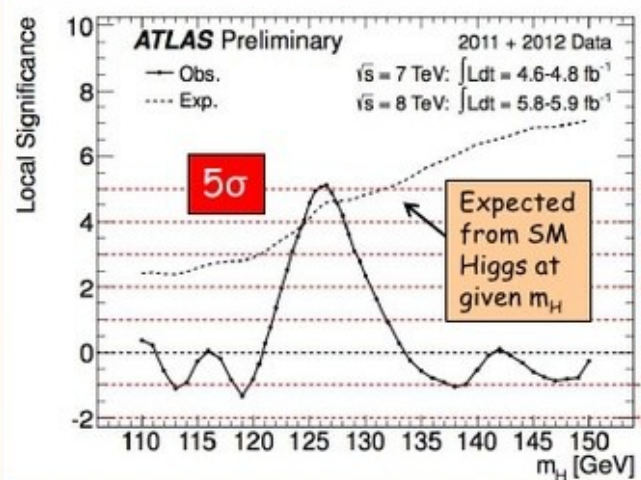
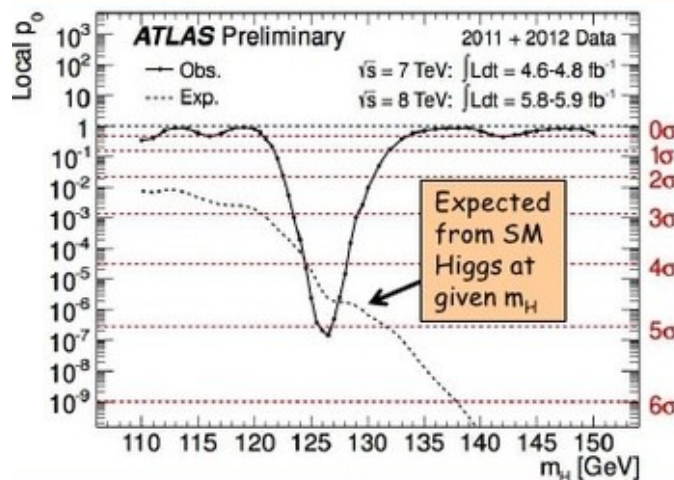
Figure 4: Diphoton differential cross section $d\sigma/dq_T$ vs. q_T , the transverse momentum of the photon pair, at Tevatron, $\sqrt{S} = 1.8$ TeV. Preliminary data points (statistical errors and systematics in quadrature) from the D0 collaboration [8] are compared to the theoretical predictions: the full NLO prediction is shown as the solid line

4 juillet 2012



Le boson de Higgs (en Comic Sans)

Combined results: the excess



Maximum excess observed at

$m_H = 126.5 \text{ GeV}$

Local significance (including energy-scale systematics)

5.0σ

Probability of background up-fluctuation

3×10^{-7}

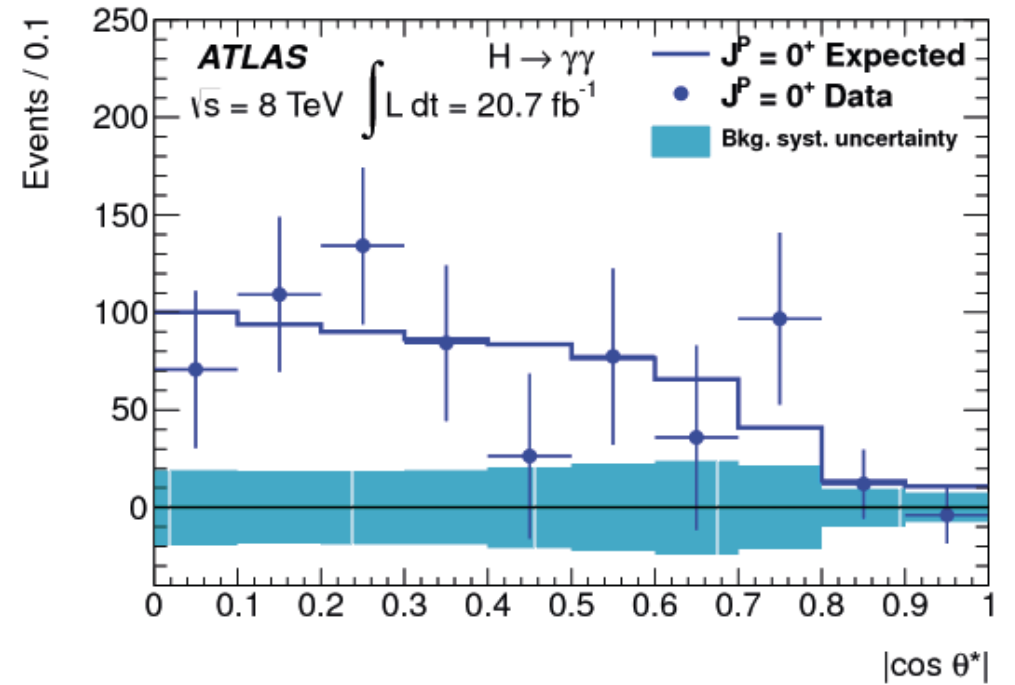
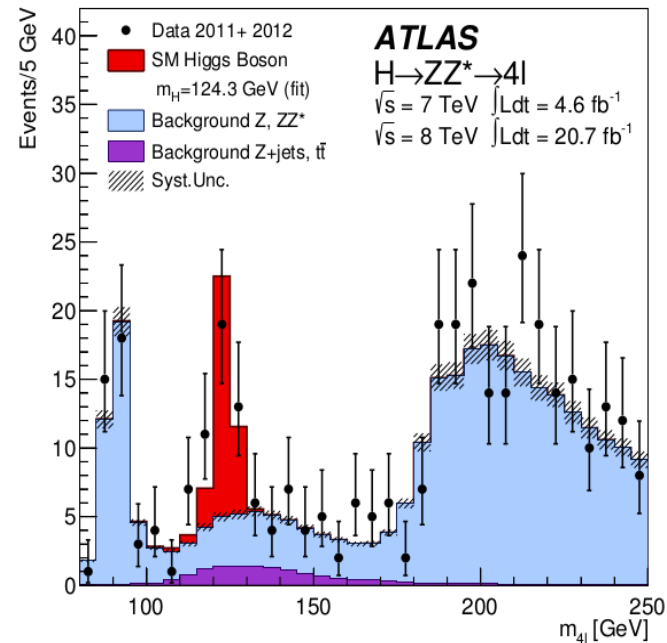
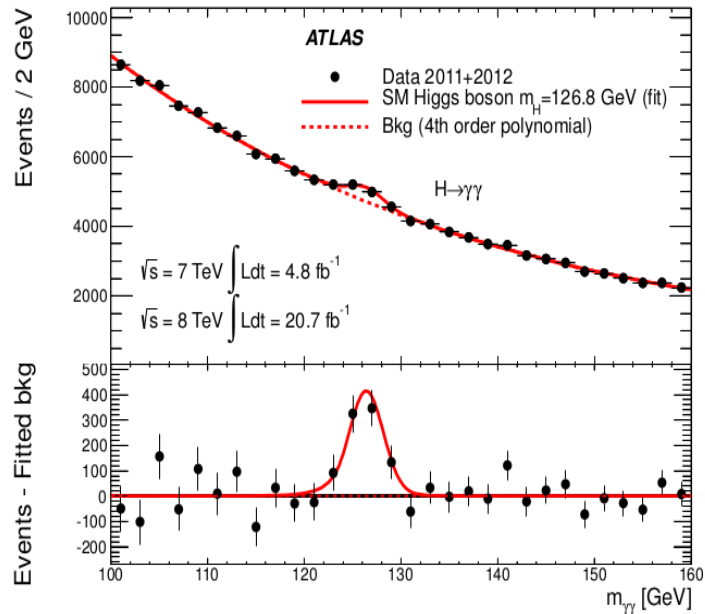
Expected from SM Higgs $m_H=126.5$

4.6σ

Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)

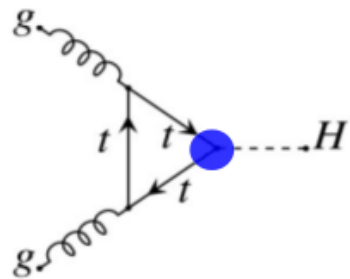


“Higgs-like Particle”

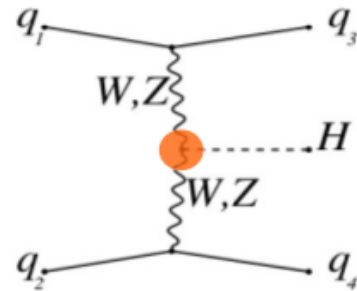


Modes de Production

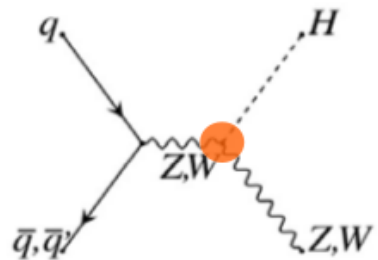
Thèse: Maud Schwoerer (2010-2013)



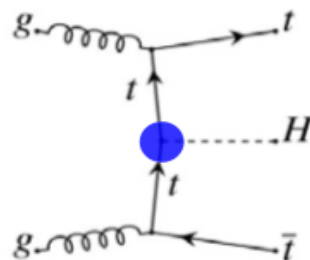
(a) : ggF



(b) : VBF



(c) : ZH, WH

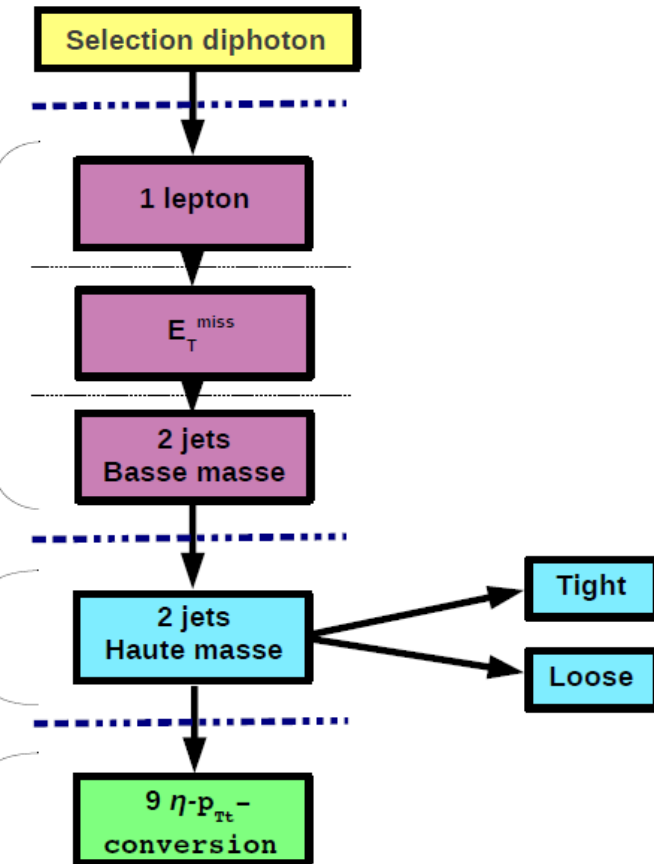


(d) : $t\bar{t}H$

Catégories
enrichies en
événements VH

Catégories
enrichies en
événements VBF

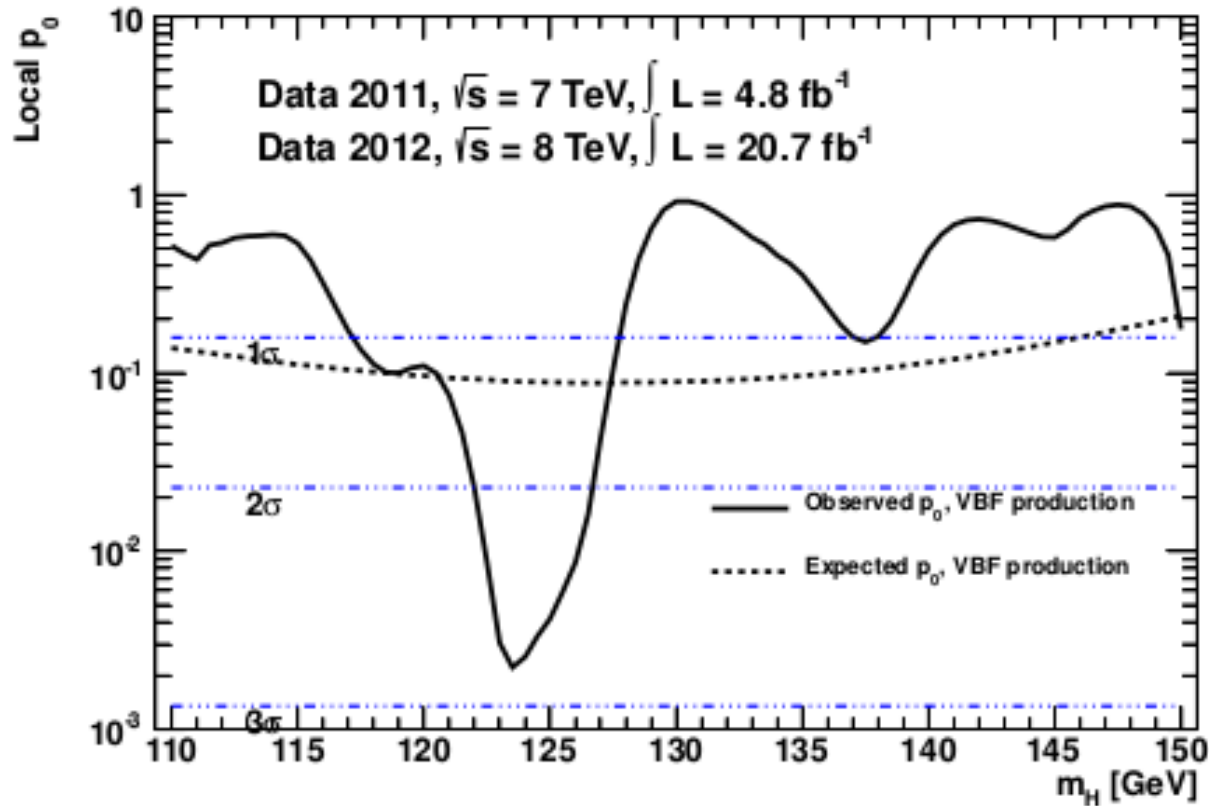
Catégories
enrichies en
événements ggF



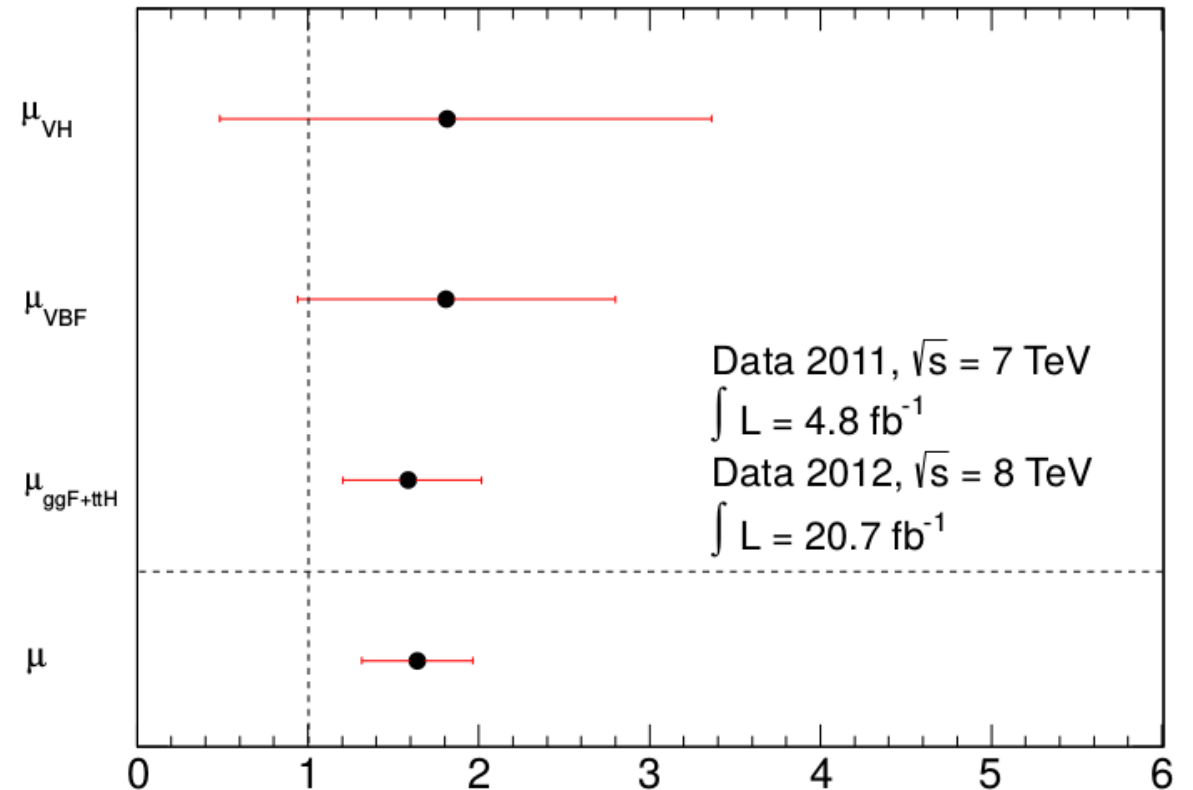
Canal VBF & couplages

Phys.Lett. B726 (2013) 88–119

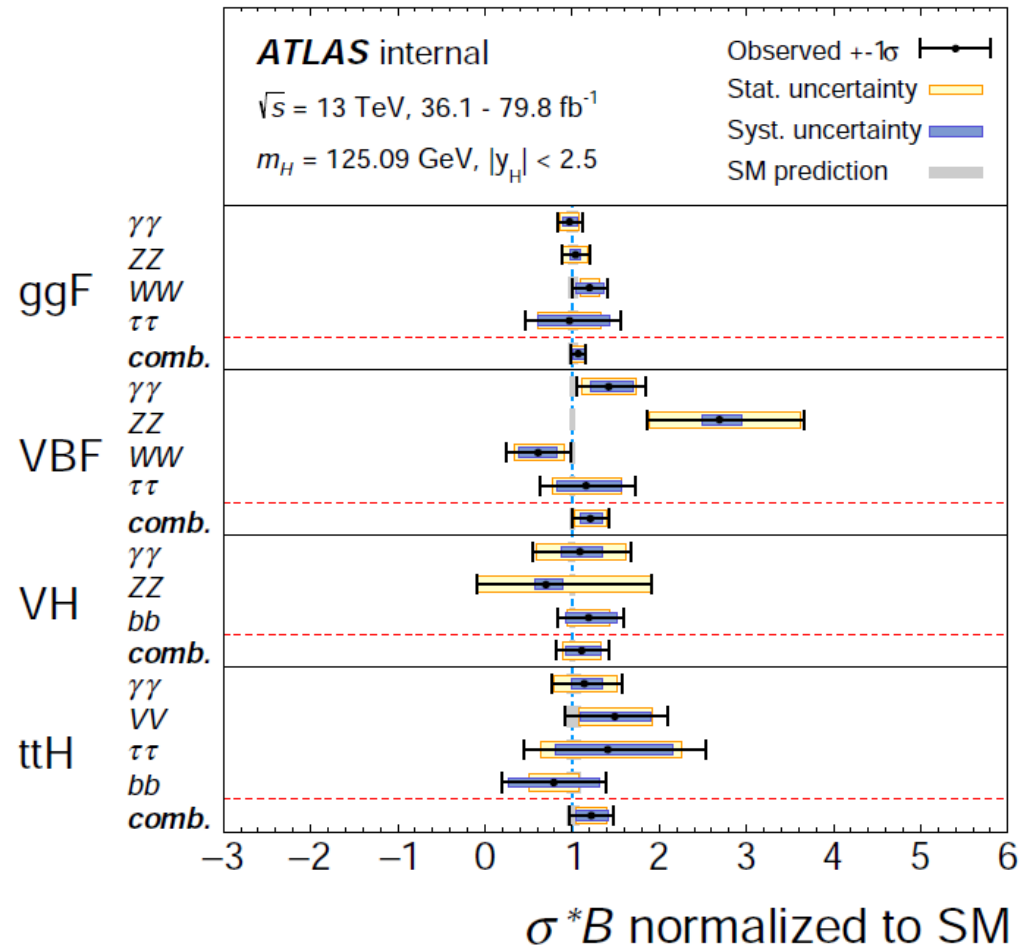
Thèse: Maud Schwoerer (2010-2013)



2.9 sigmas



ICHEP 2018

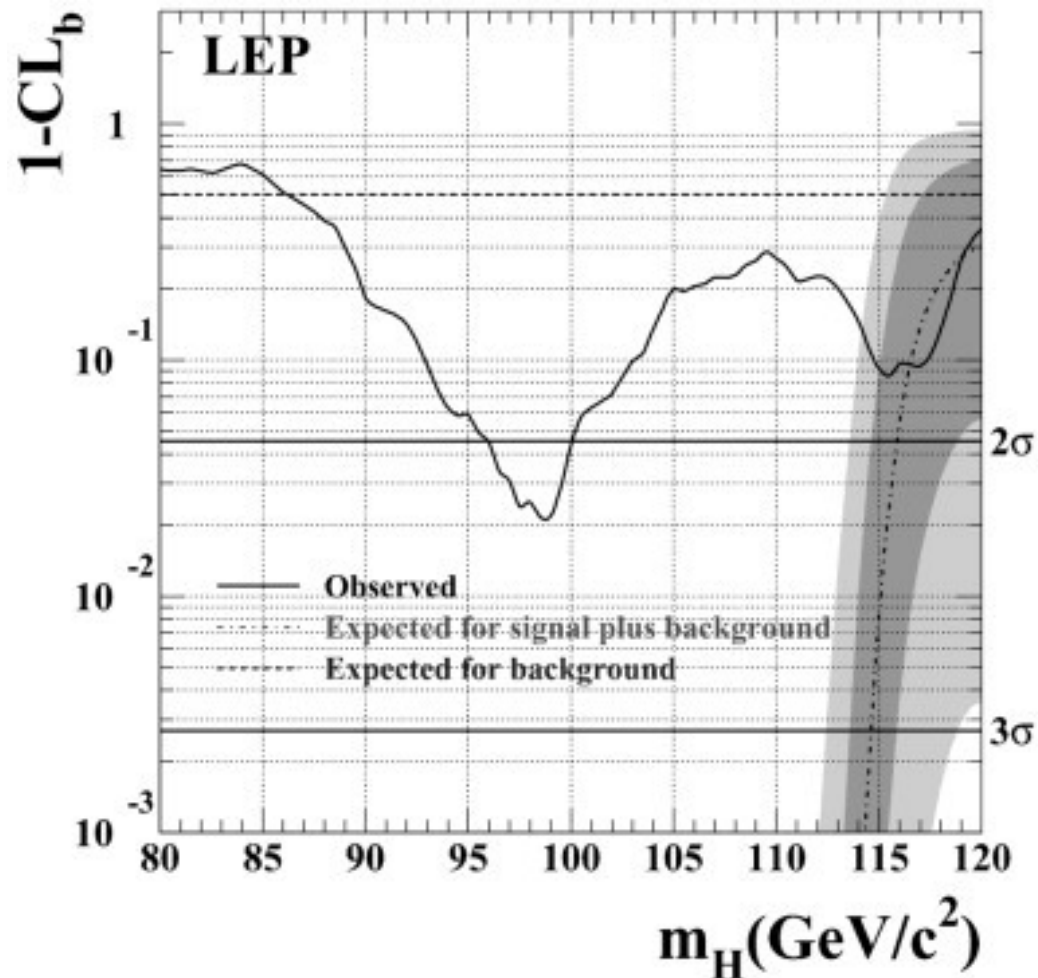


Un deuxième boson ?

[60 – 600] GeV

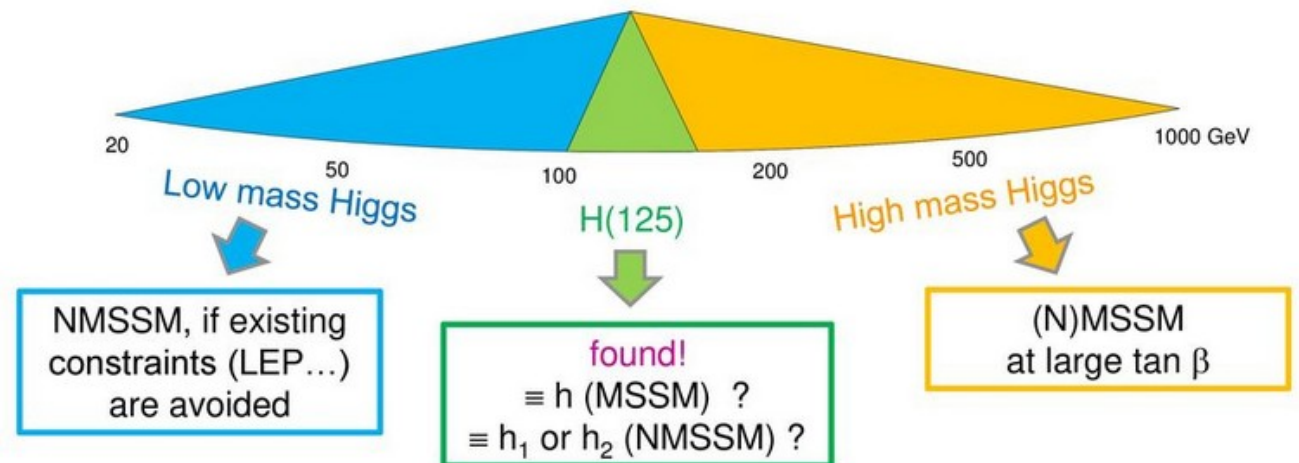


LEP & SUSY

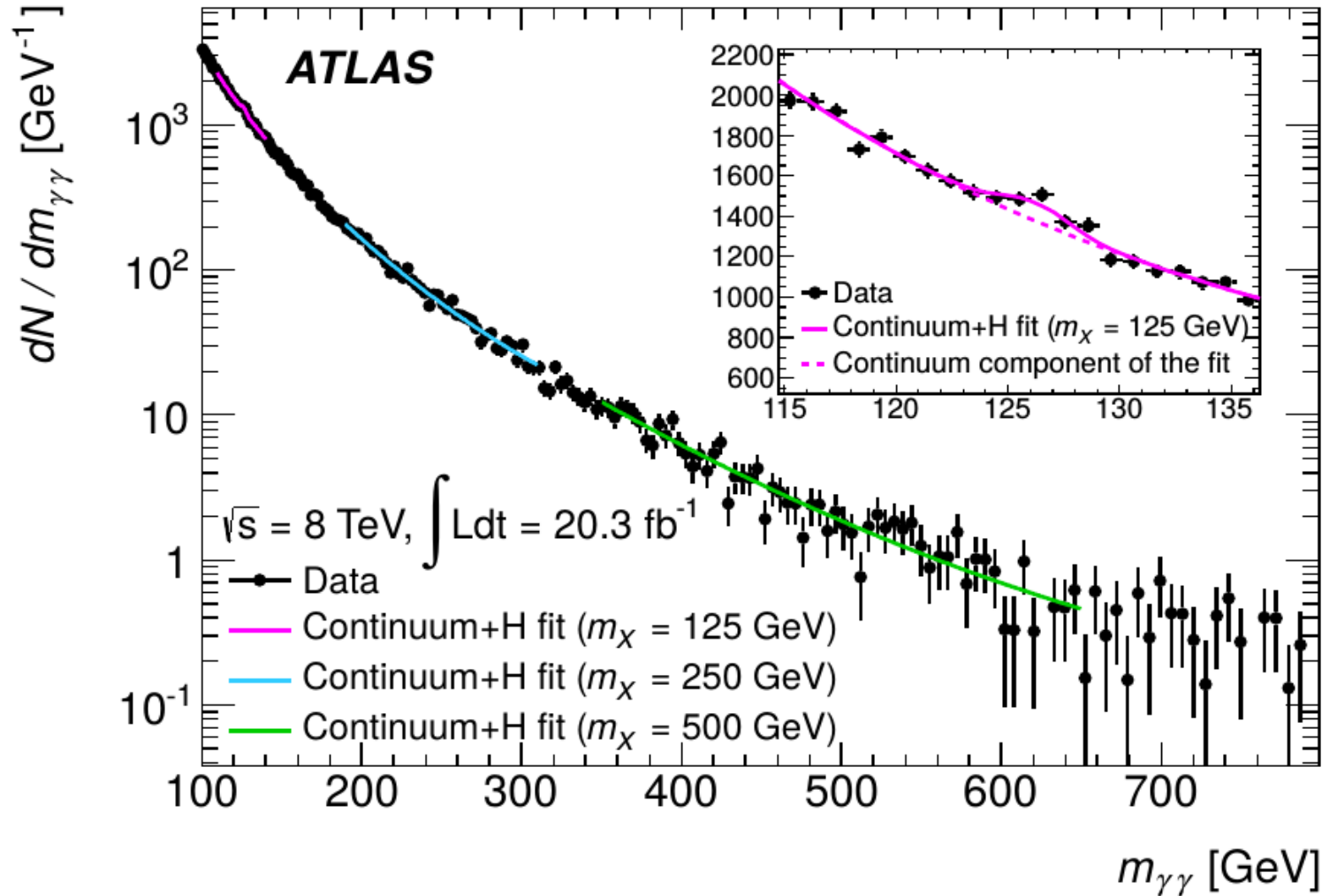


Model	Structure	CP-even	CP-odd	Charged
MSSM	2 doublets	h, H	A	$H^\pm$
NMSSM	2 doublets+1 singlet	h_1, h_2, h_3	a_1, a_2	$h^\pm$

$(h, H, A) = \phi$



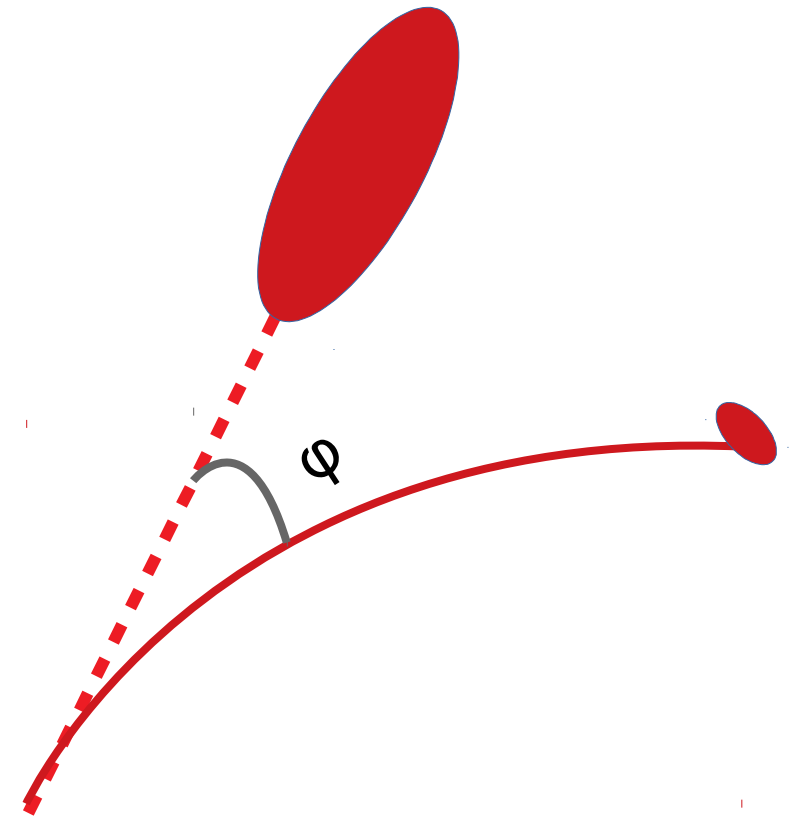
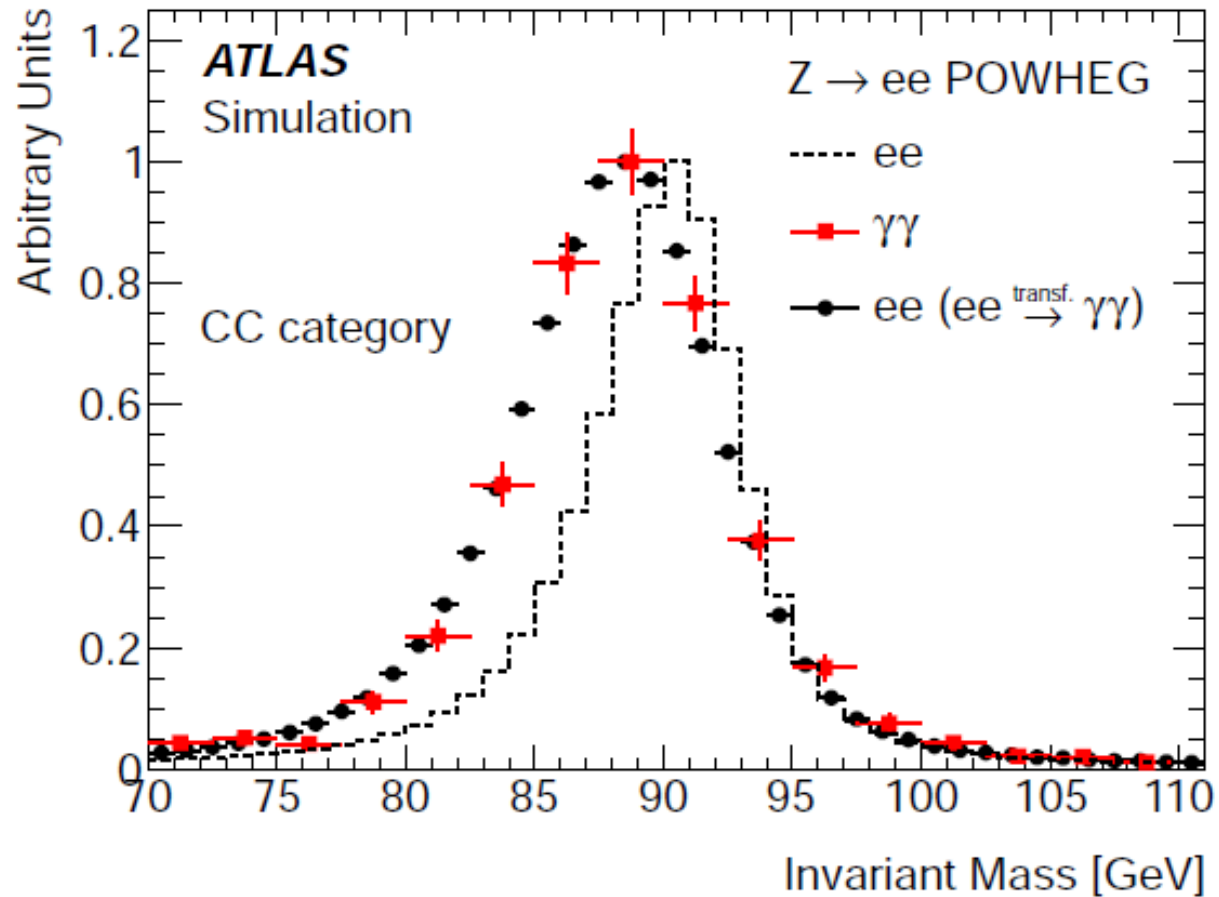
2013: le boson de Higgs est un bruit de fond



Analyse
100% LAPP

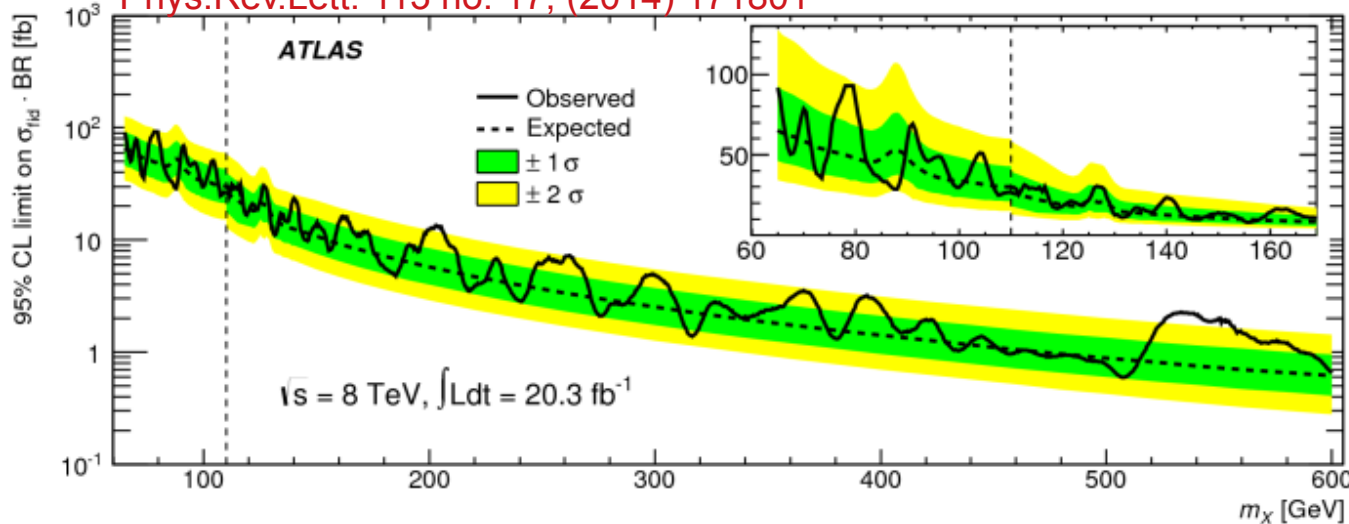
N. Berger
Z. Barnovska
M. Delmastro
R. Lafaye
E. Petit
J. Levêque

Basse masse : $Z \rightarrow \gamma\gamma$



Pas de scalaire supplémentaire...

Phys.Rev.Lett. 113 no. 17, (2014) 171801



☒ Physics [archive:] ☐ Quantitative Biology ☐ Quantitative Finance ☐ Statistics

Select years to search (default is to search all years)

☐ Past year or the year or the years from to

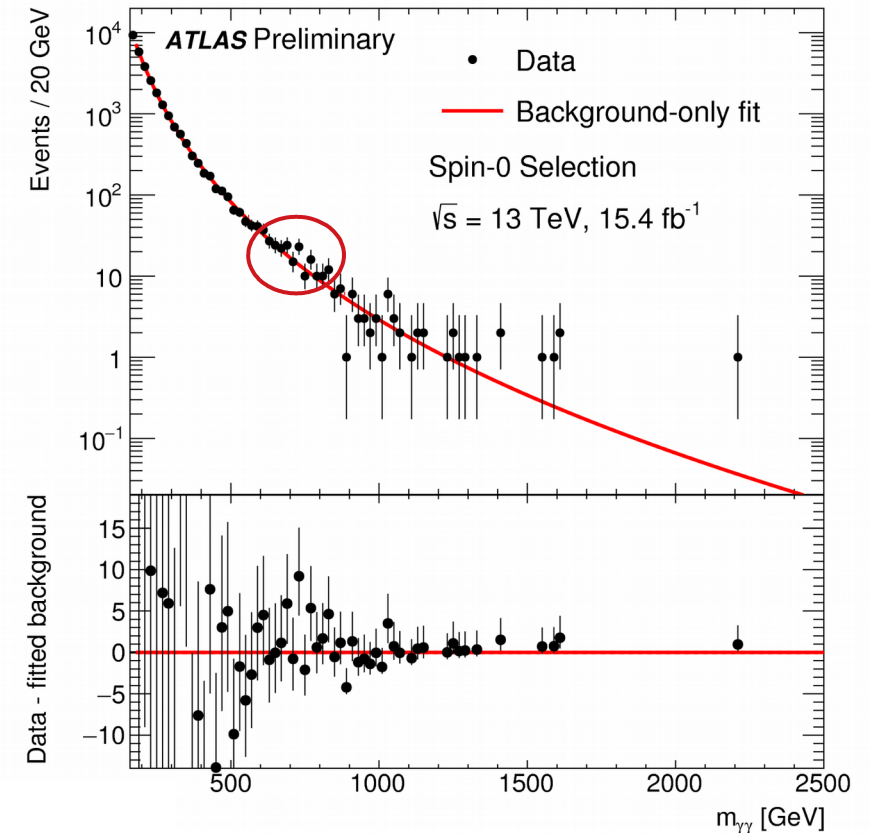
Title: AND

Abstract: AND

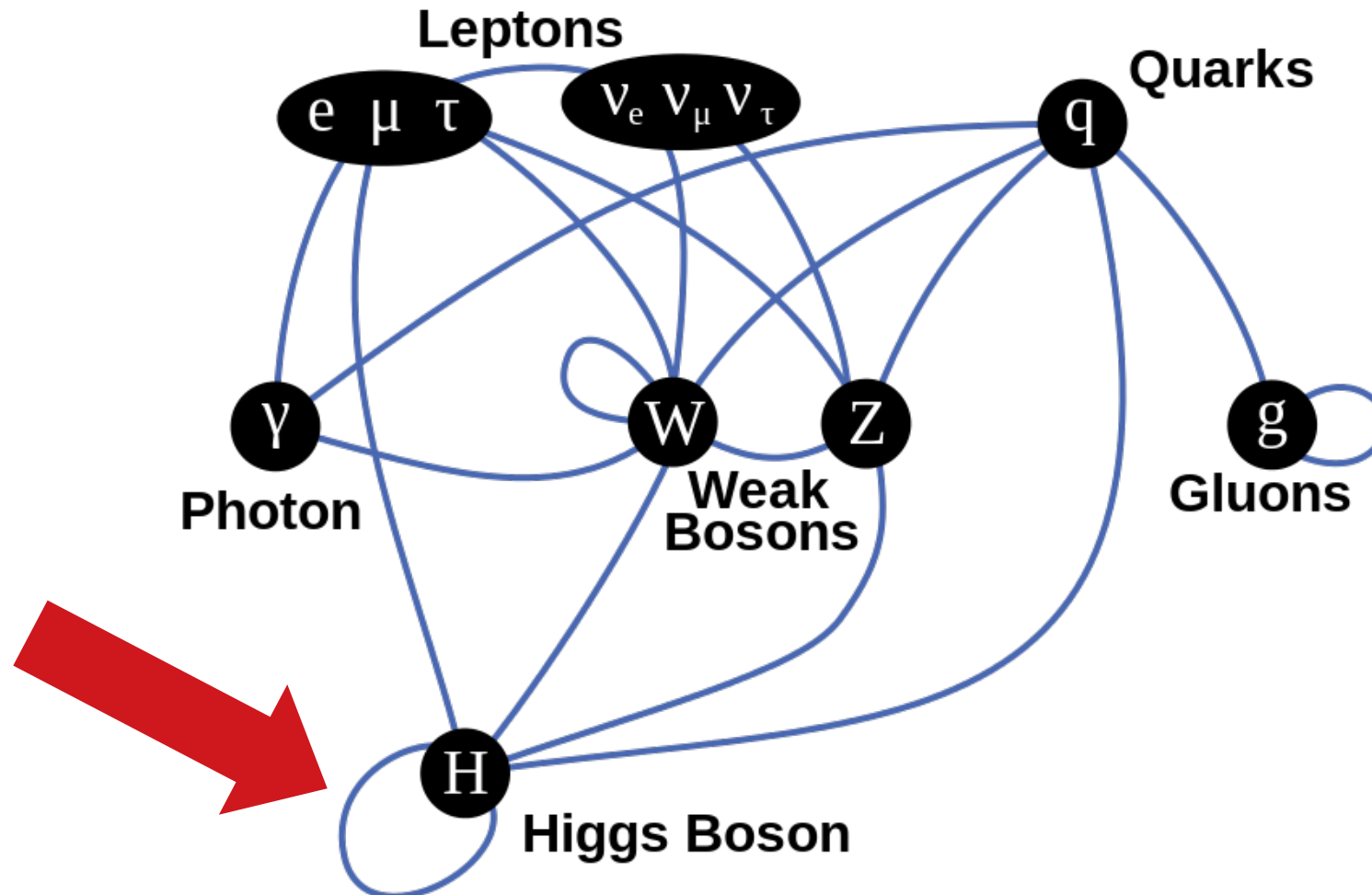
Author(s):

Showing results 1 through 100 (of 175 total) for (ti:(750 AND gev) AND abs:(750 AND gev))

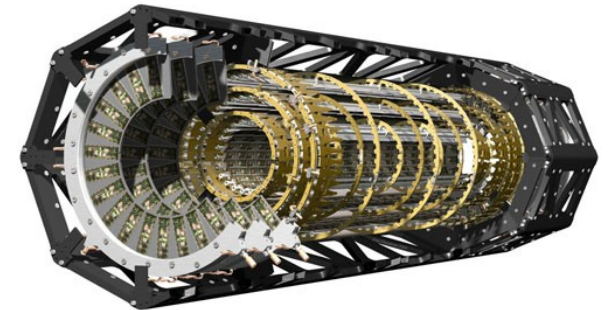
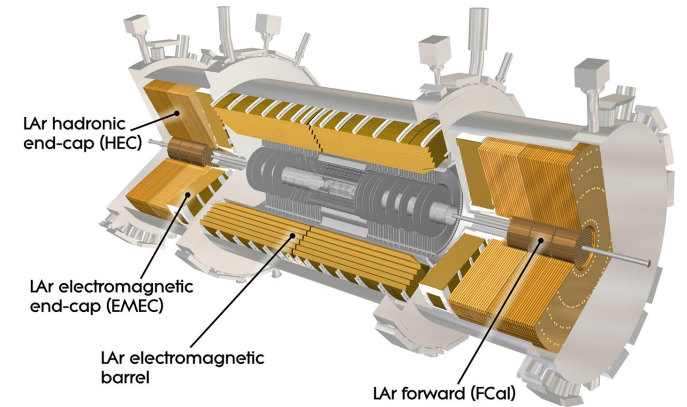
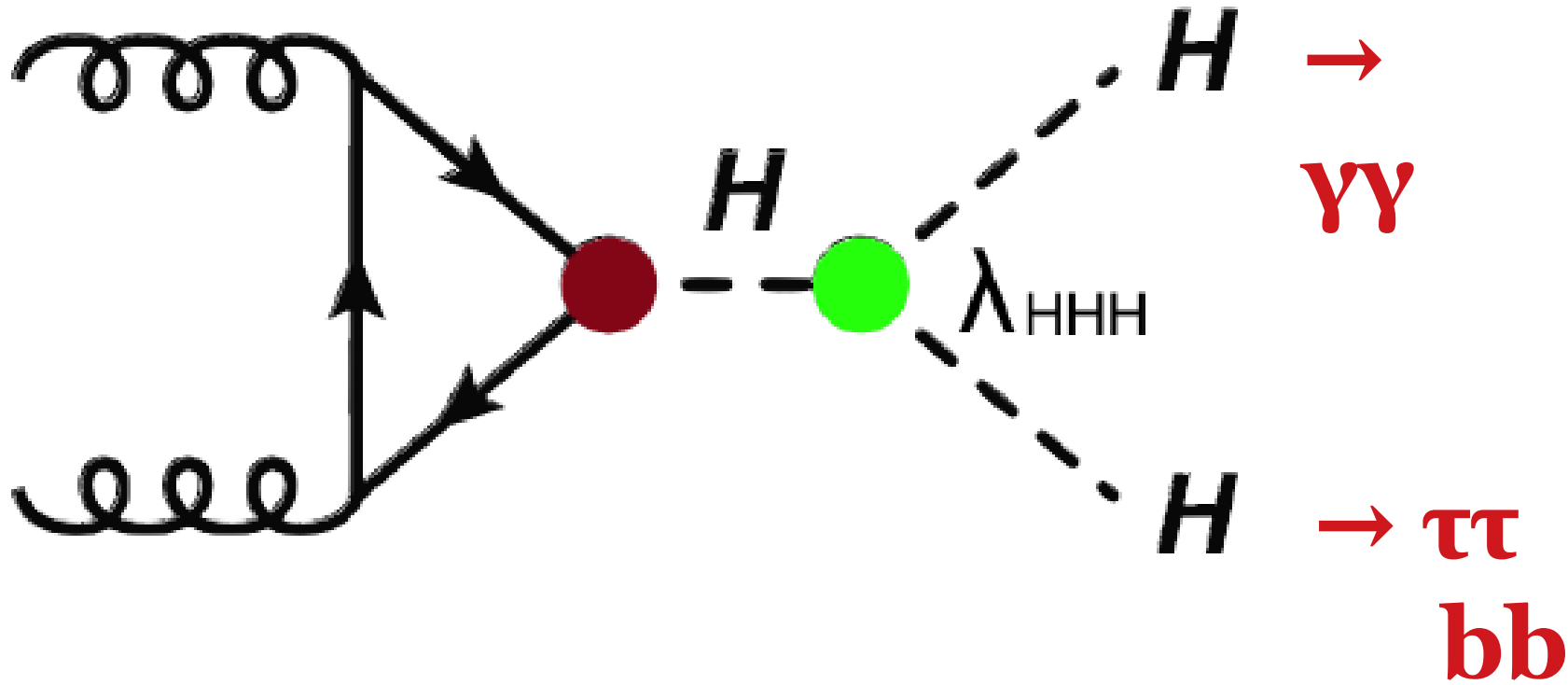
Fausse alerte en
2015



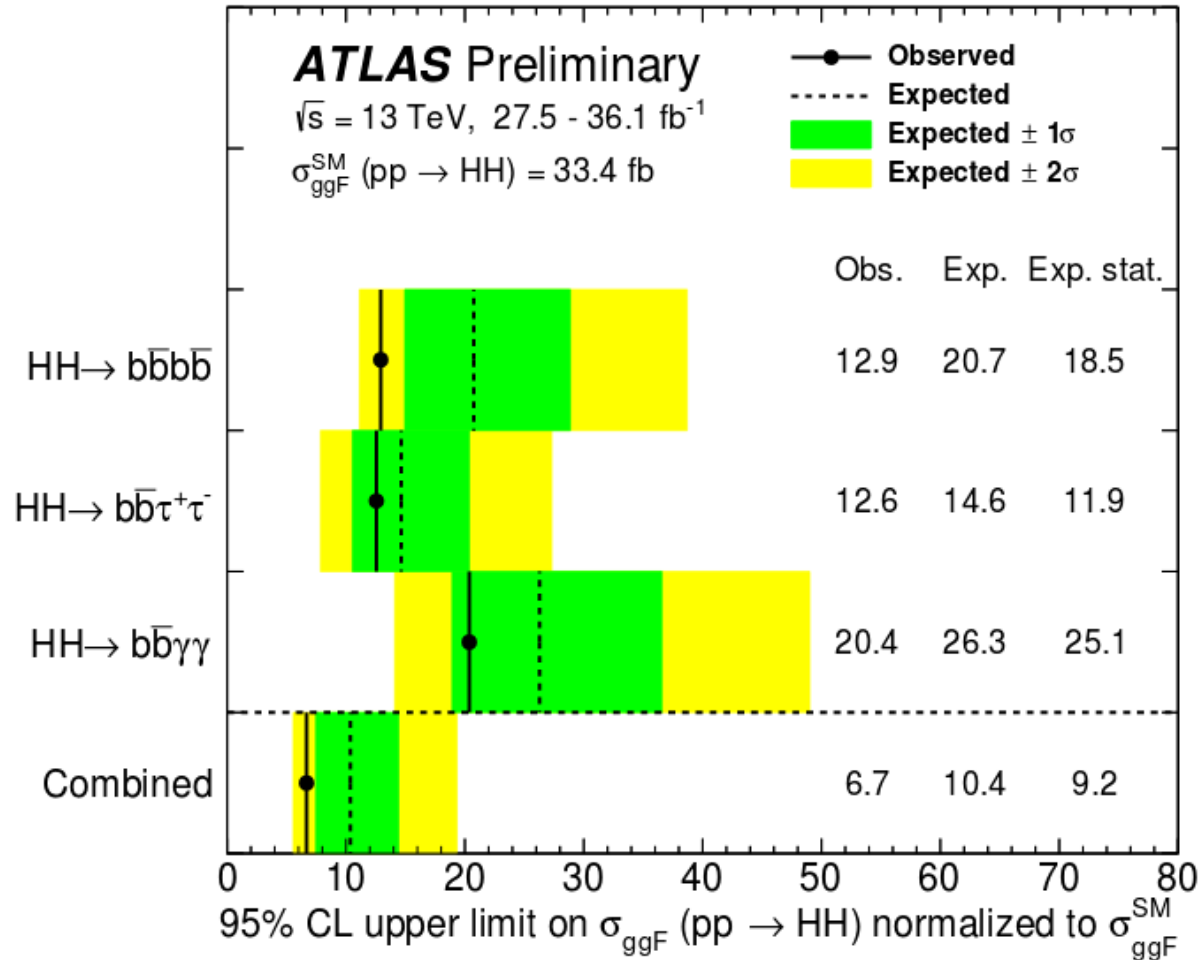
L'auto-couplage du boson de Higgs



Auto-couplage du Higgs

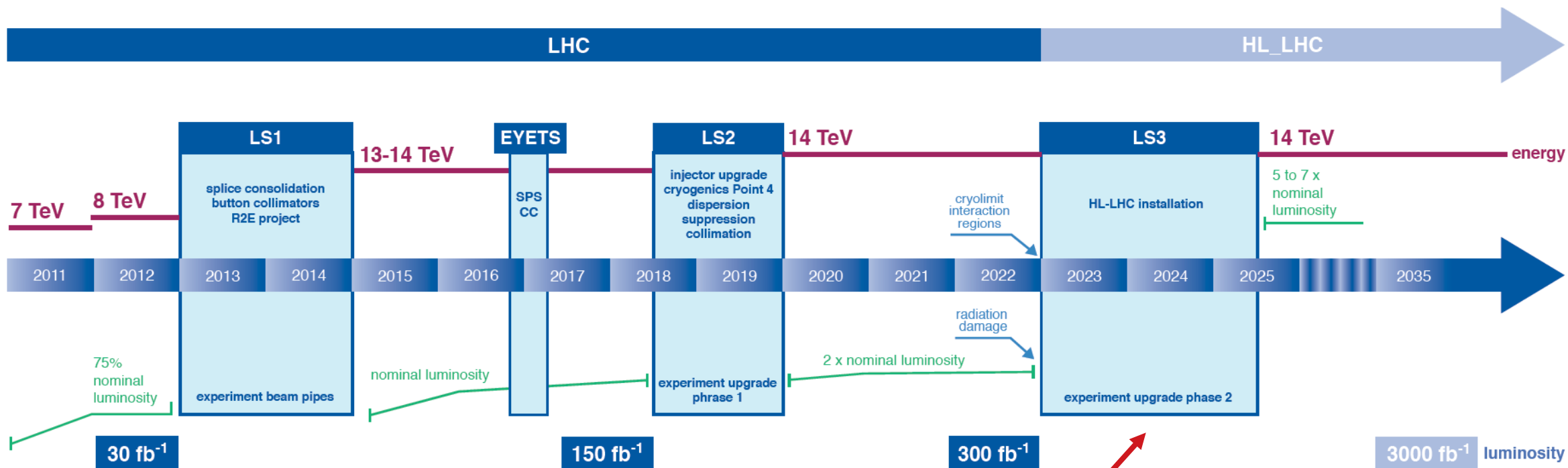


Paires de Higgs au LHC



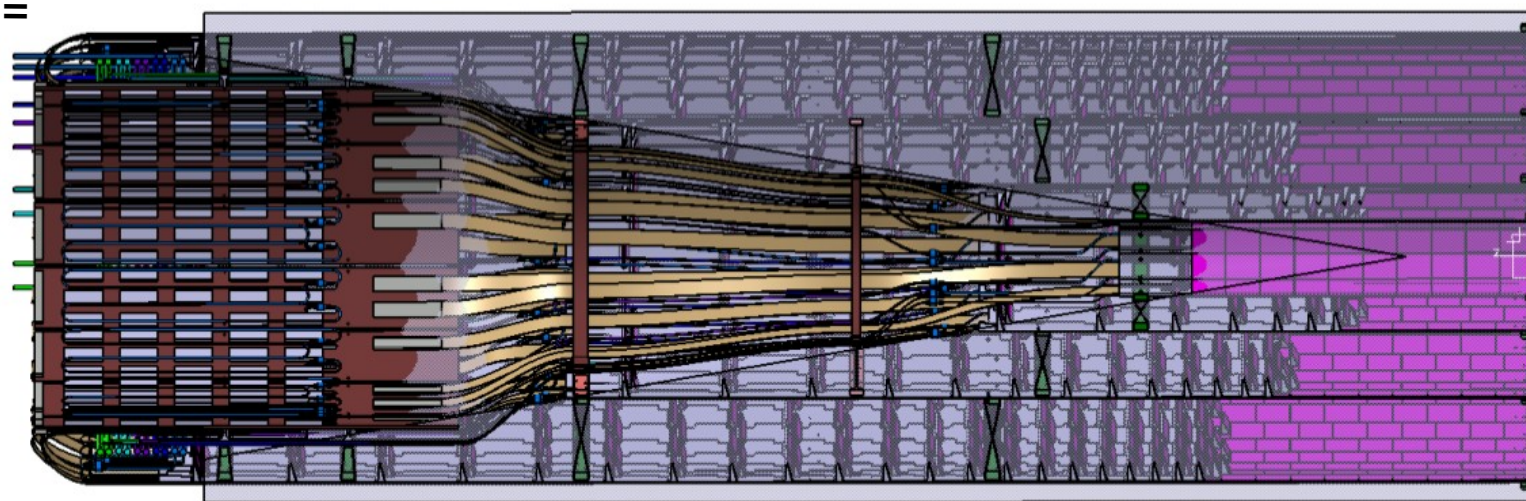


Upgrade pour le HL-LHC



Remplacement du trajectographe d'ATLAS

Upgrade du Tracker au LAPP

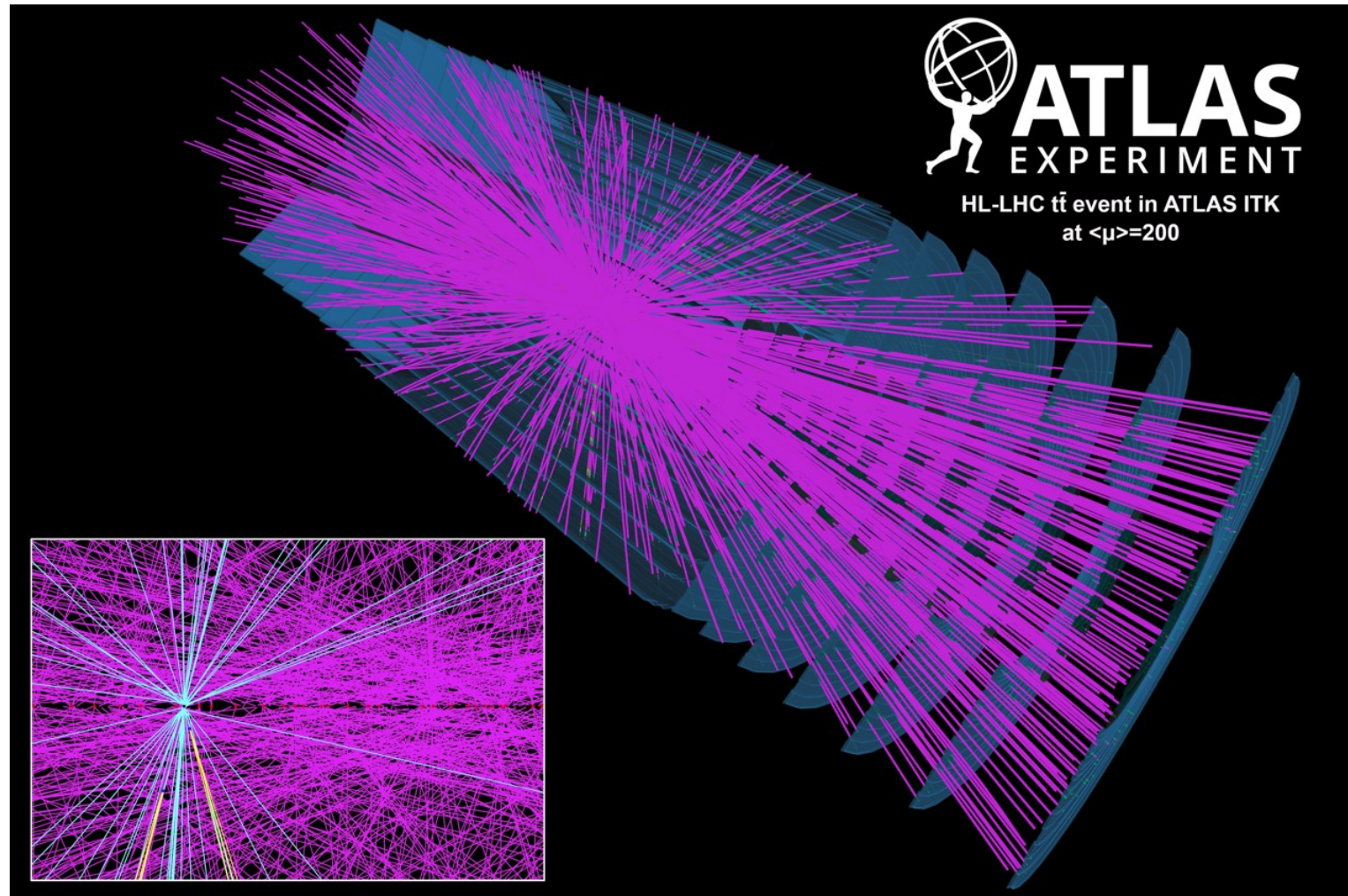


Détecteur

- Conception
- Construction
- Installation



200 collisions par Croisement de faisceau



Pile-up = low PT

Performances = low Xo

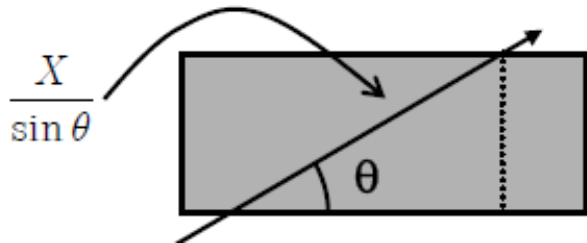
the momentum resolution tend to

$$\frac{\delta p}{p^2} \rightarrow \frac{k_p}{p} \sqrt{\frac{X}{X_o}} \quad \frac{\delta p}{p^2} \rightarrow \frac{K_p}{p\sqrt{\sin \theta}}$$

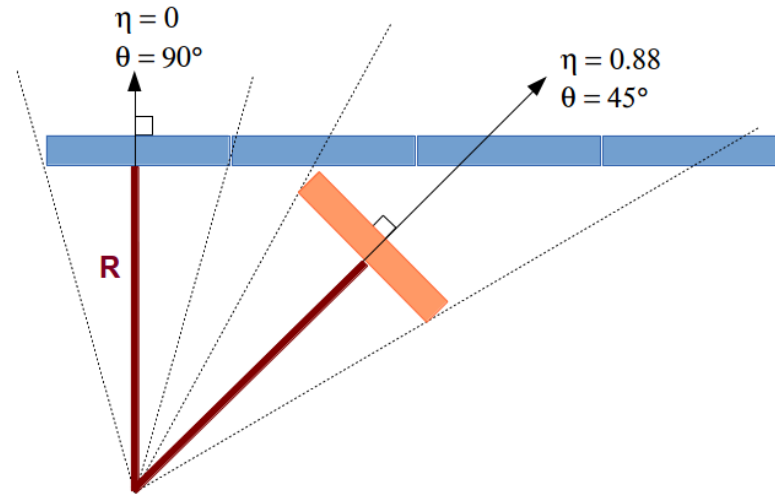
the impact parameter resolution tend to

$$\sigma_{ip} \rightarrow \frac{k_{ip}}{p} \sqrt{\frac{X}{X_o}} \quad \sigma_{ip} \rightarrow \frac{K_{ip}}{p\sqrt{\sin \theta}}$$

The amount of material actually traversed by the particles depend on the polar angle

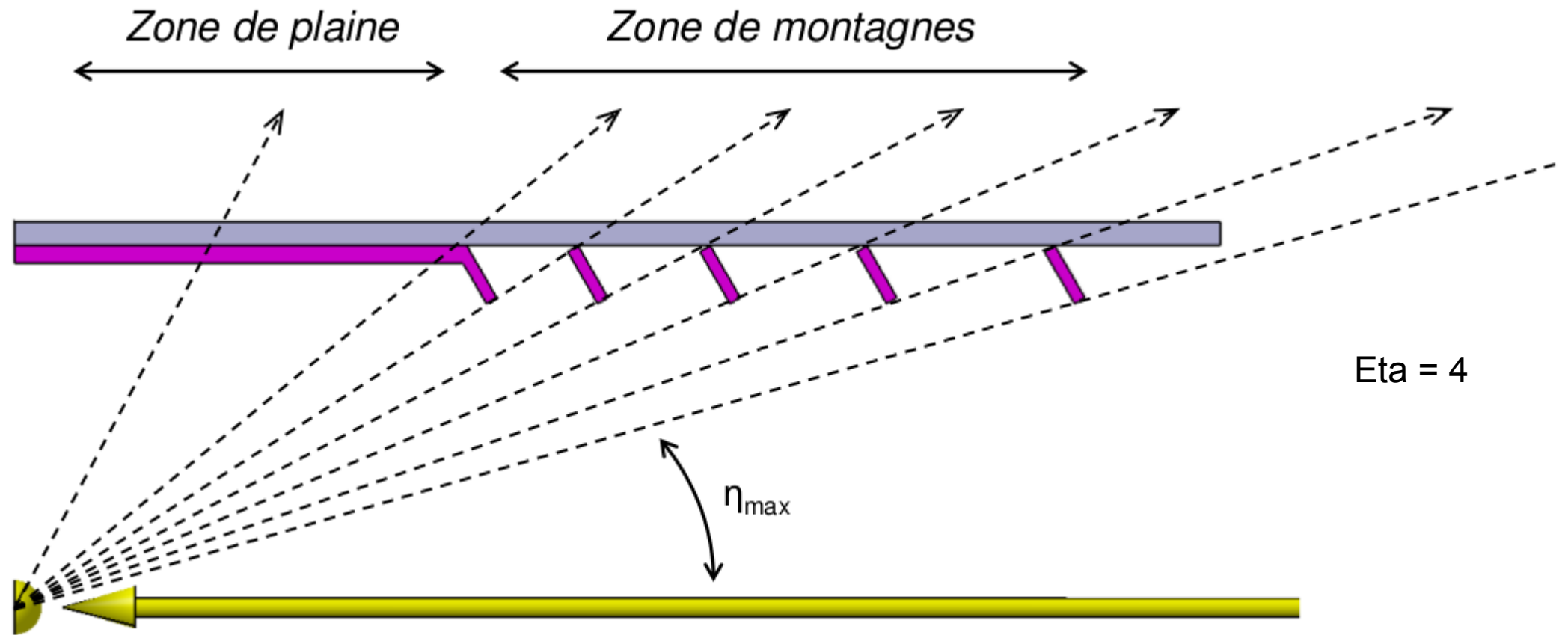


Modules inclinés

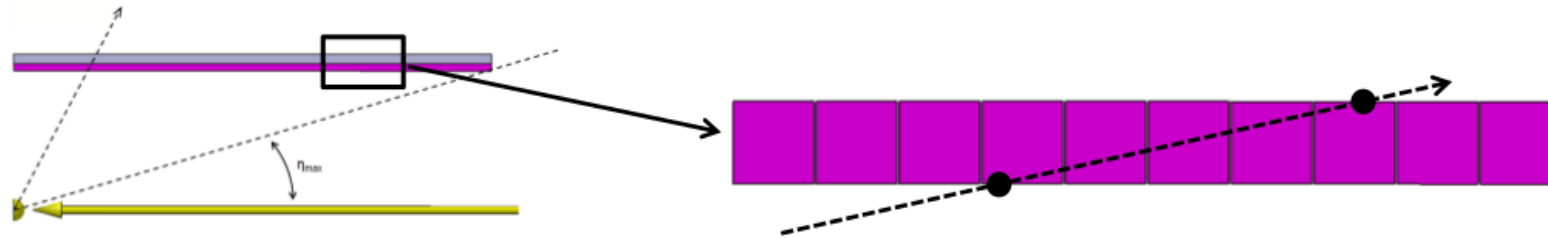


1. Minimise la quantité de silicium traversée
2. Réduction du nombre de modules
3. Réduction des services électriques
4. R&D: Co2 diphasique, structure carbone et circuits flexes

Le détecteur Alpin



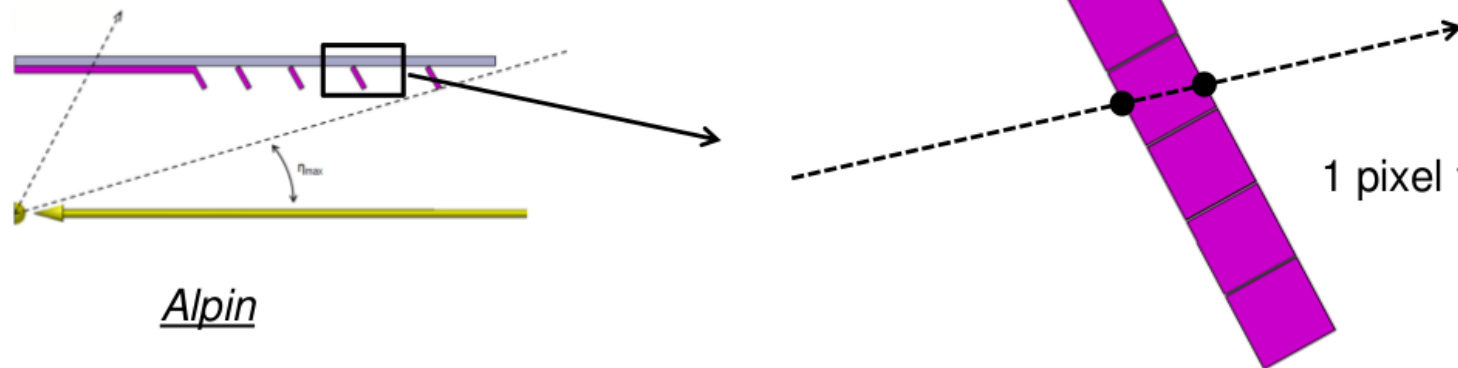
Géométrie classique / inclinée



Classique

5 pixels touchés

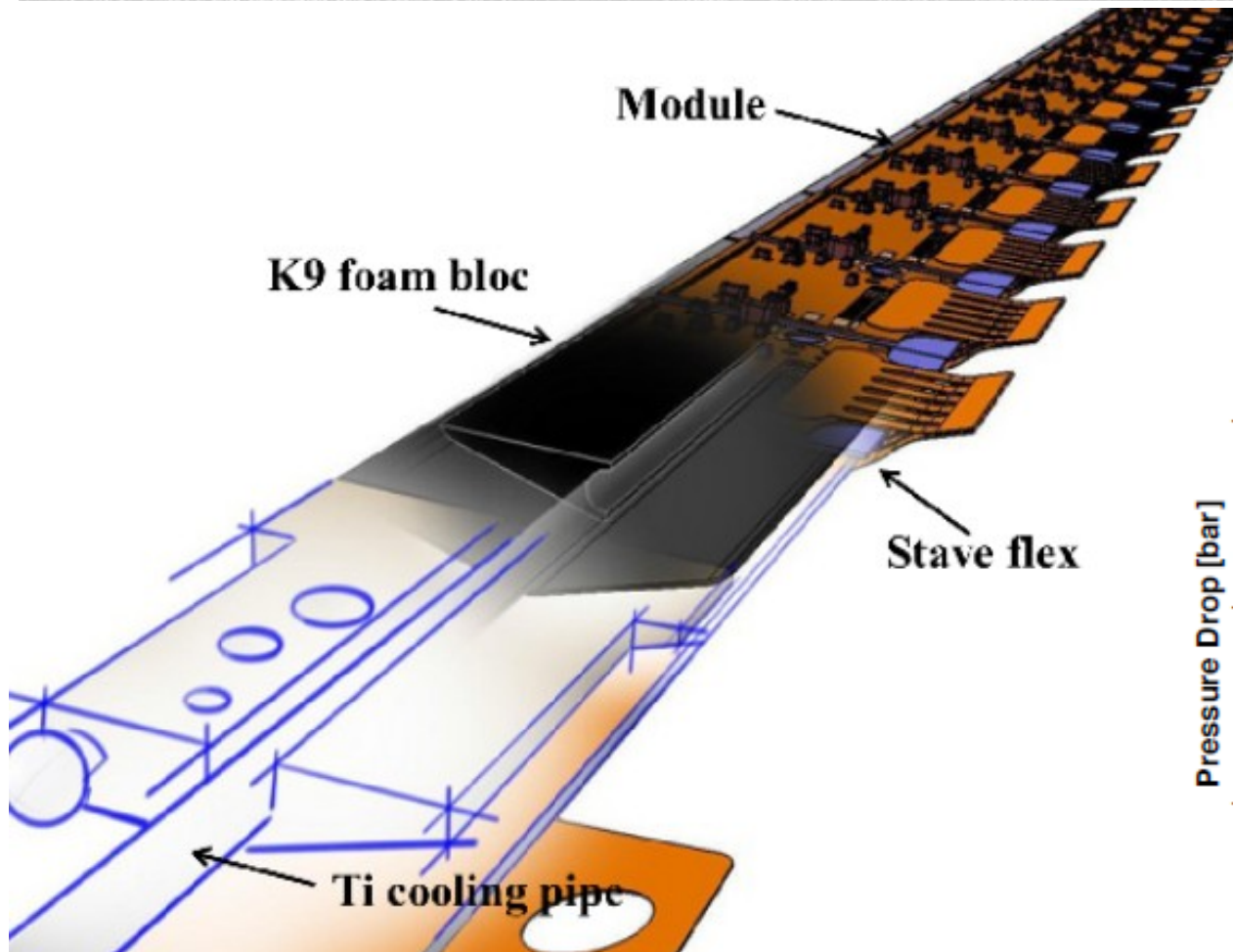
- Meilleure précision sur la position des hits
- Moins de matière traversée
- 40% de modules en moins
- → Réduction des services électriques



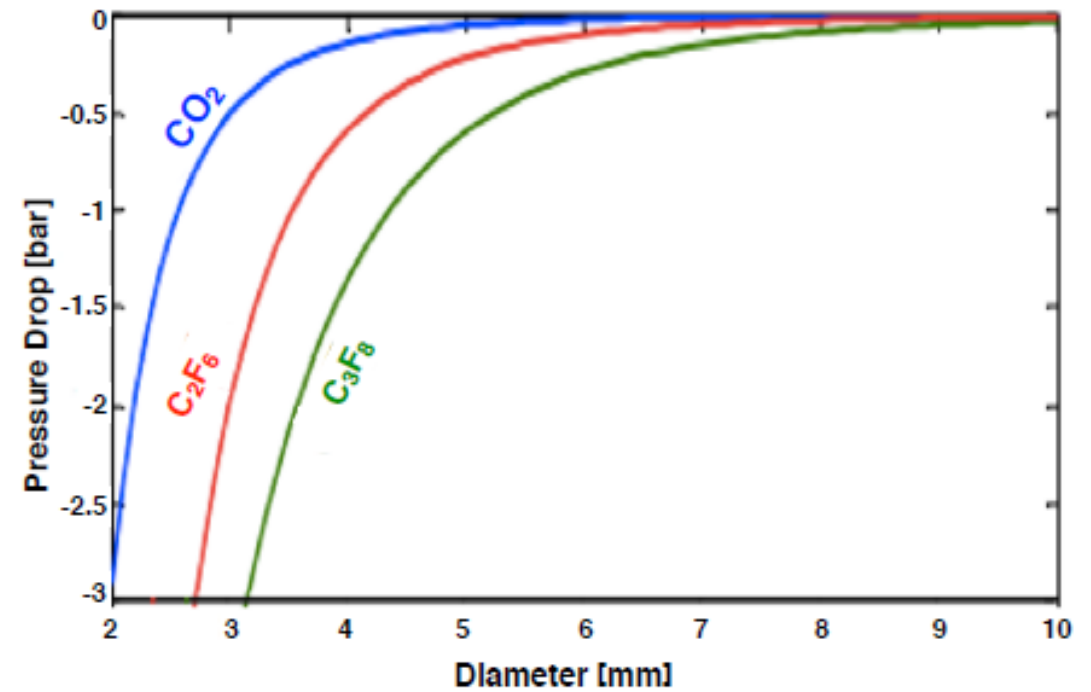
Alpin

1 pixel touché

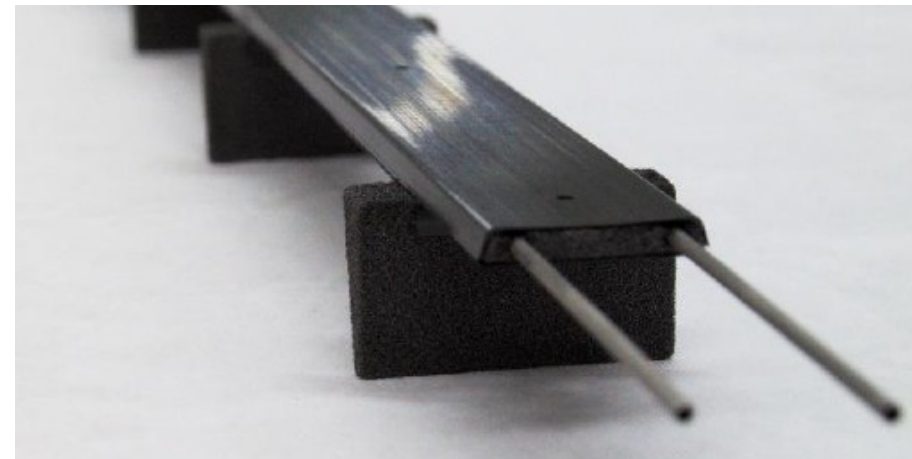
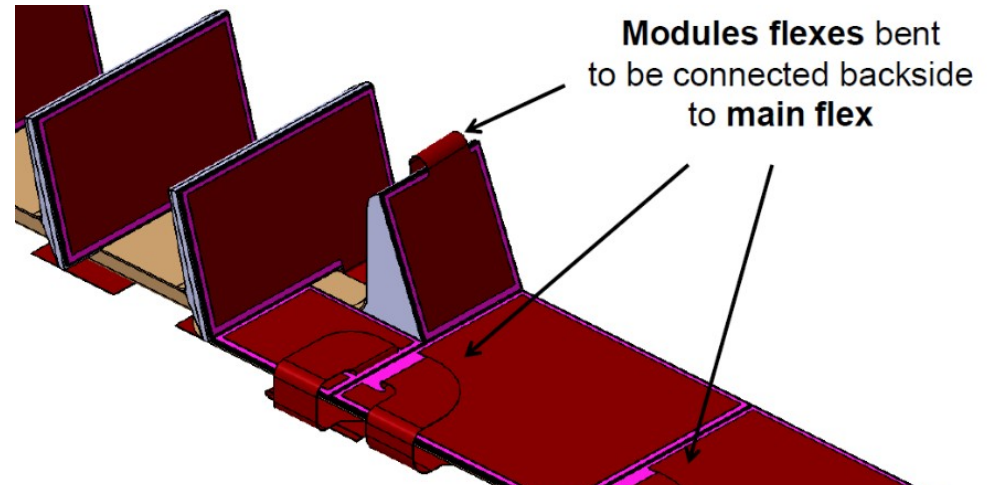
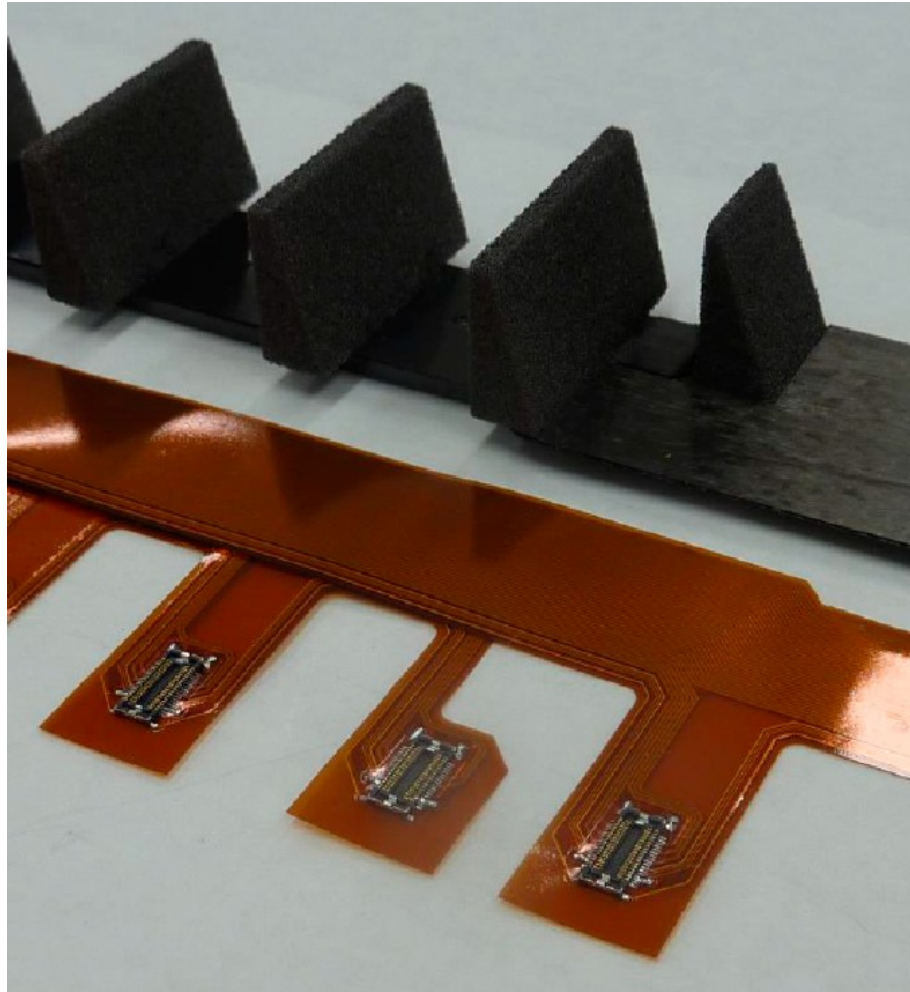
Les échelles IBL



Refroidissement CO_2 diphasique

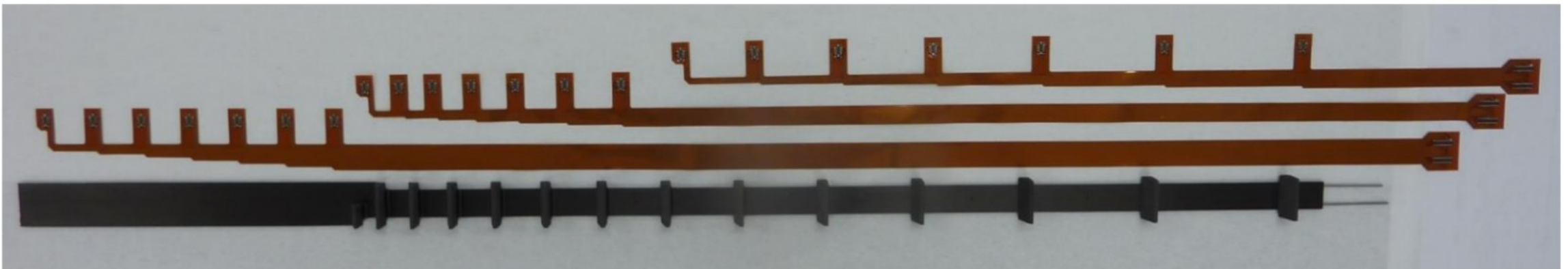
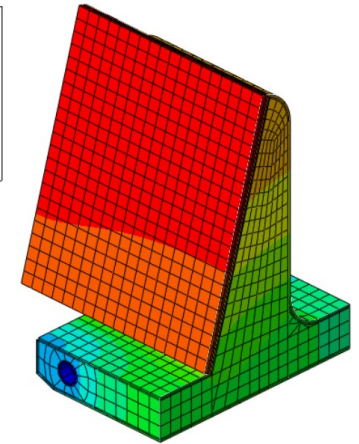
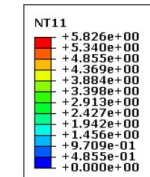


L'échelle Alpine (100% LAPP)

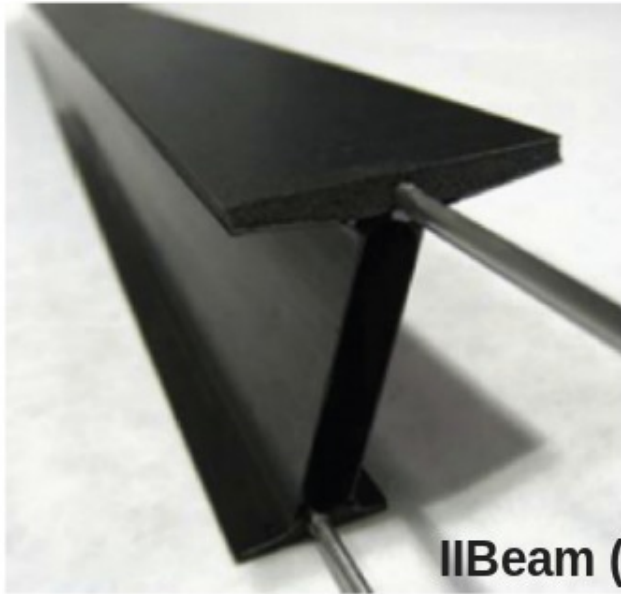


Faire ses preuves...

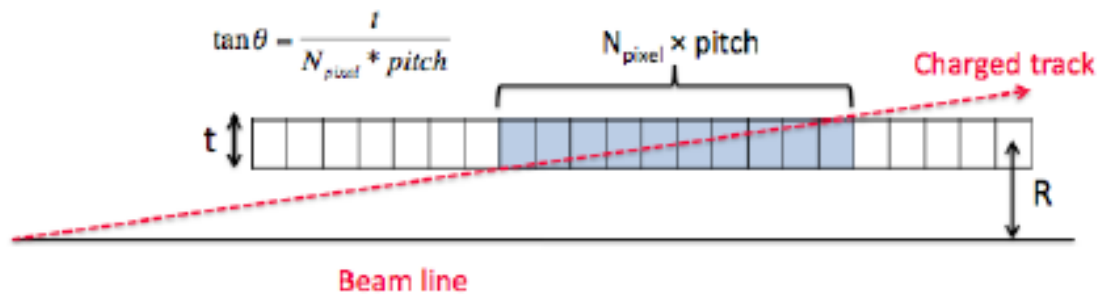
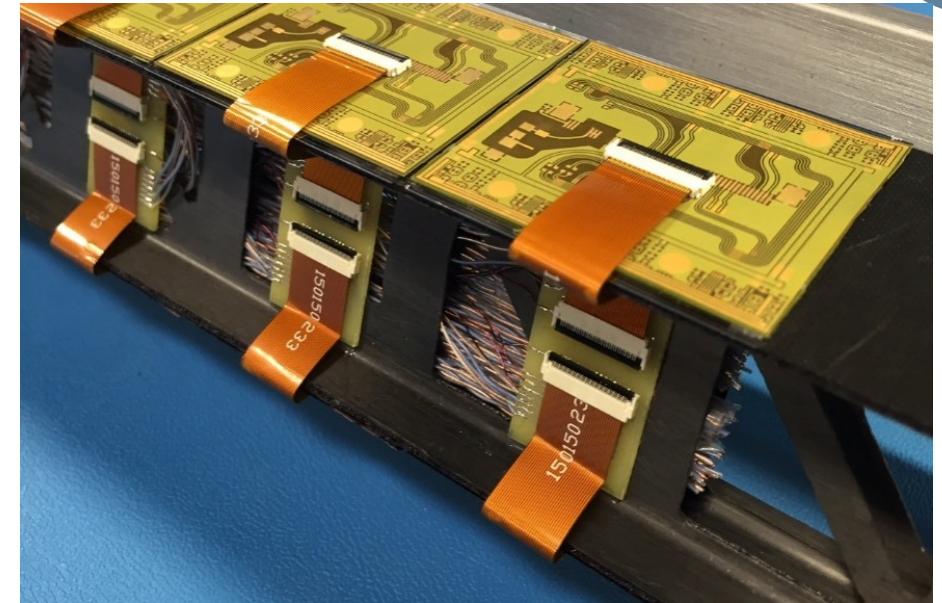
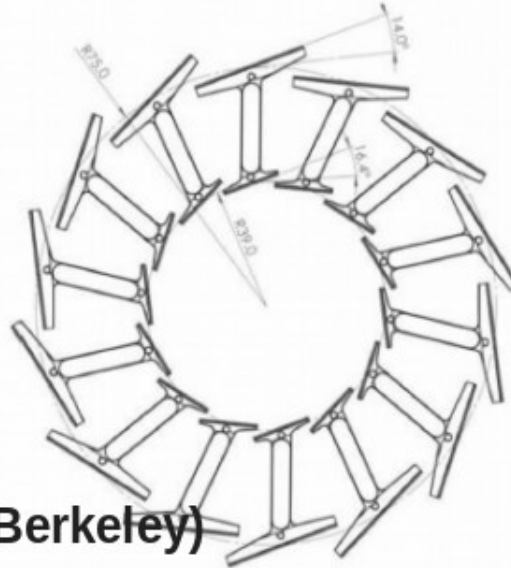
1. Refroidissement de l'électronique (6W/module)
2. Transmission des données à 5 Gb/s avec XO minimal
3. Rigidité des structure mécaniques (1.60 m)
4. Tracking: herméticité et performances des modules inclinés



Extended IBeam



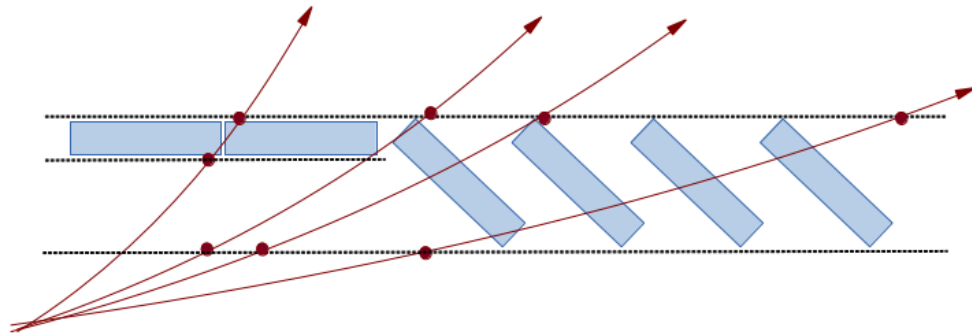
IIBeam (Berkeley)



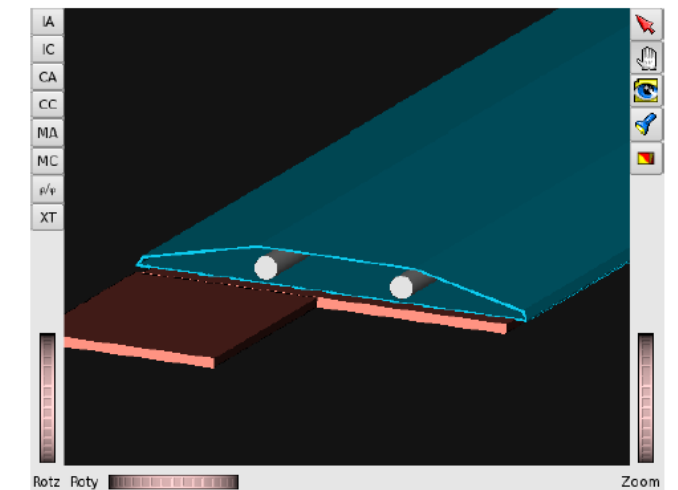
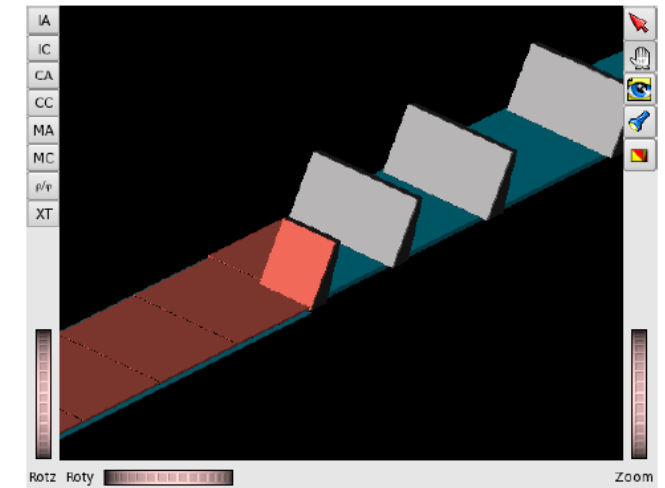
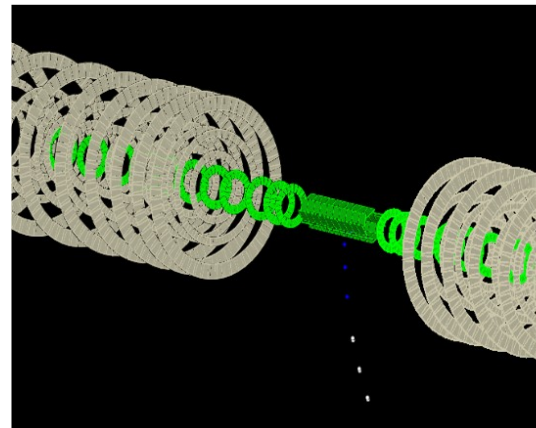
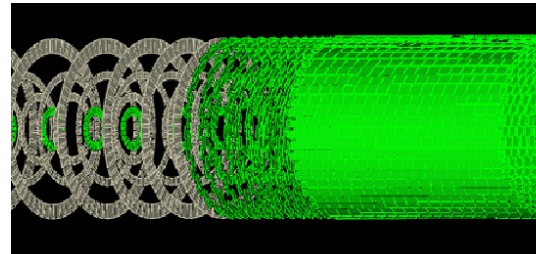
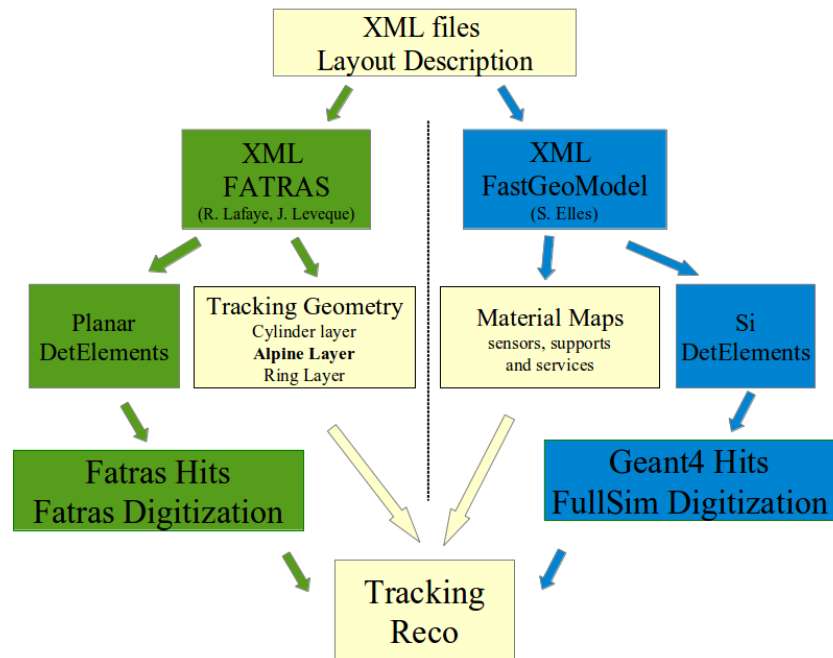
- Couches de pixels couplées → rayons non-optimaux
- Très grande quantité de matière liée aux services
- Pic de matière complètement asymétriques en ϕ
- Beaucoup trop de matière traversée à l'avant

US → couches internes
Europe/Japon → couches externes

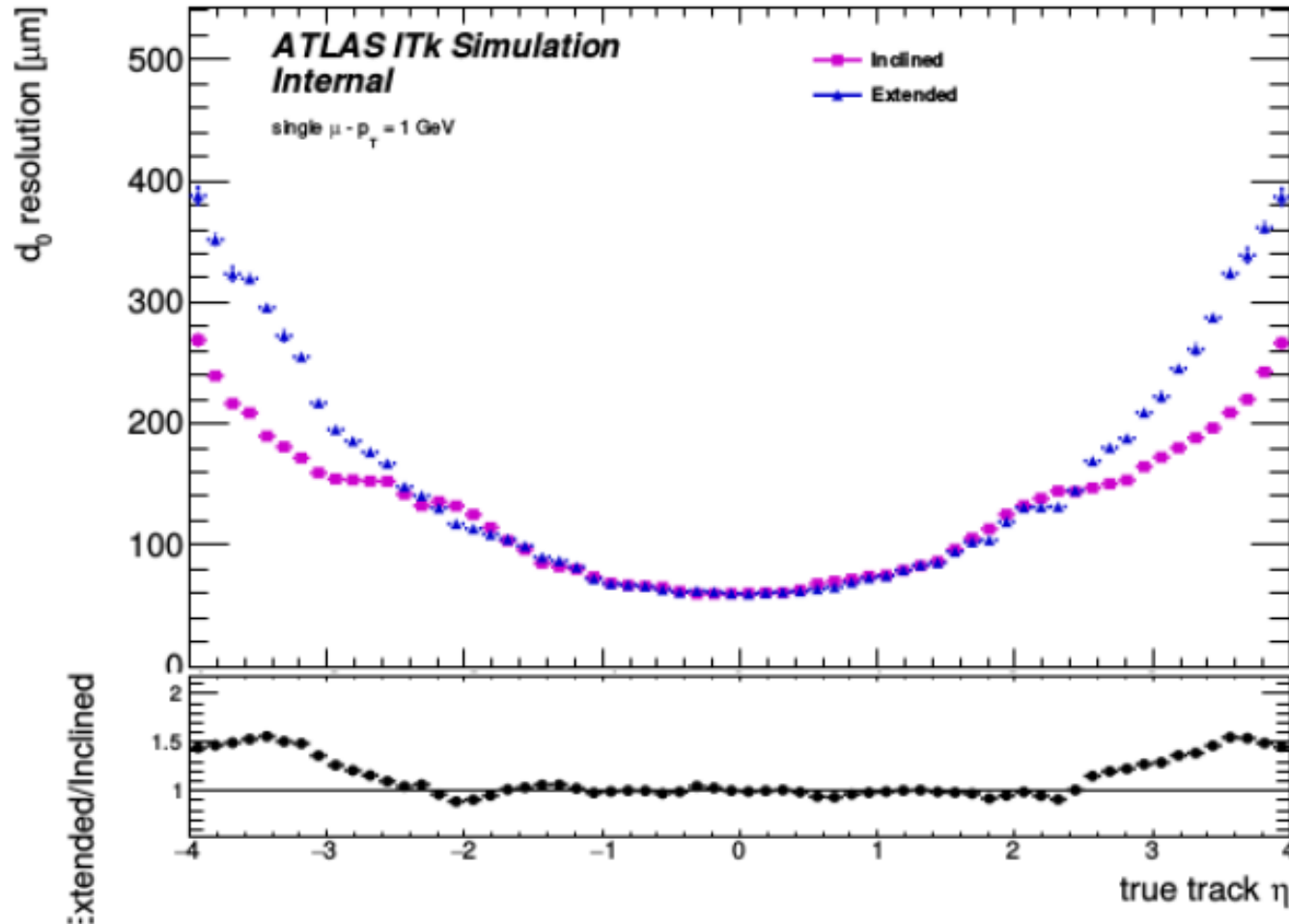
Tracking & Geant 4



Sabine Elles
Rémi Lafaye



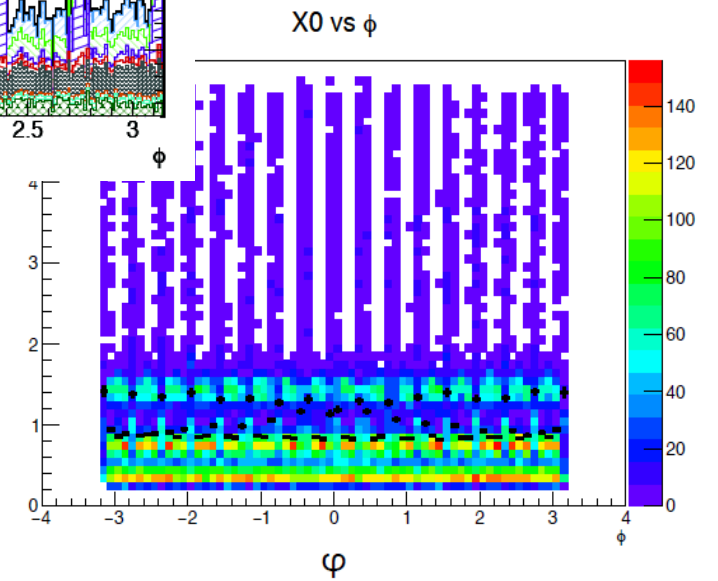
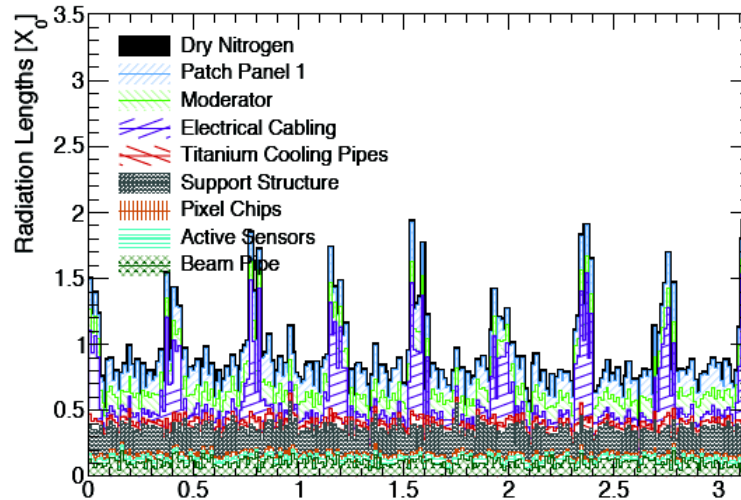
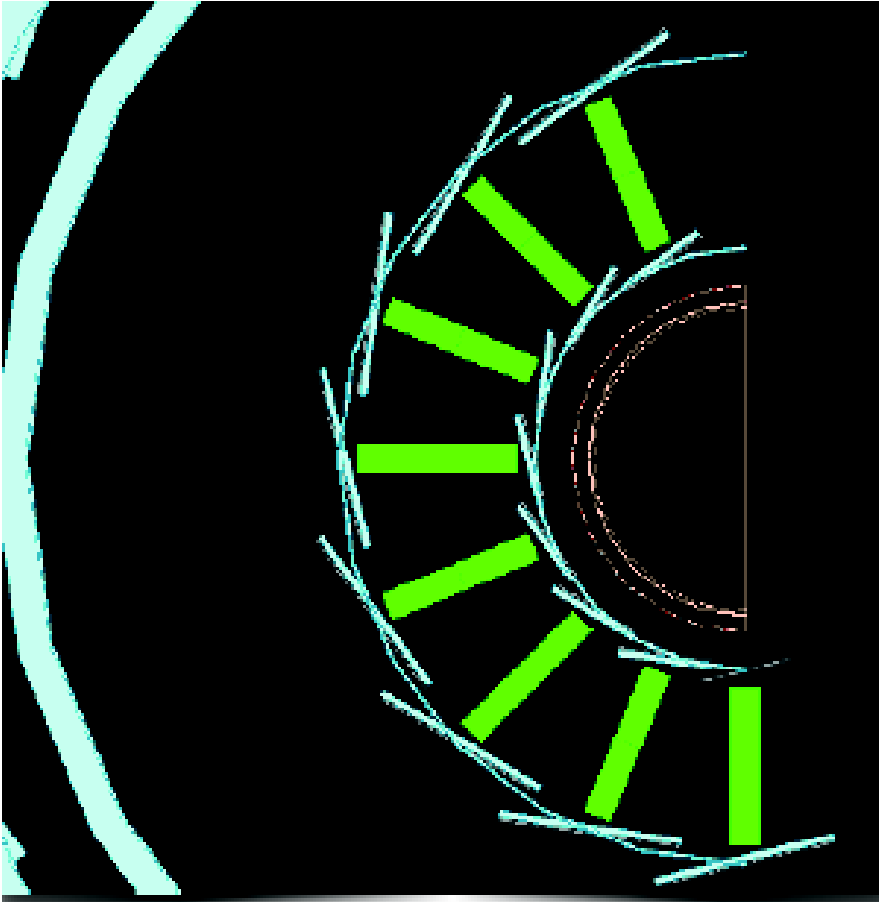
Janvier 2017: LTF conclusions



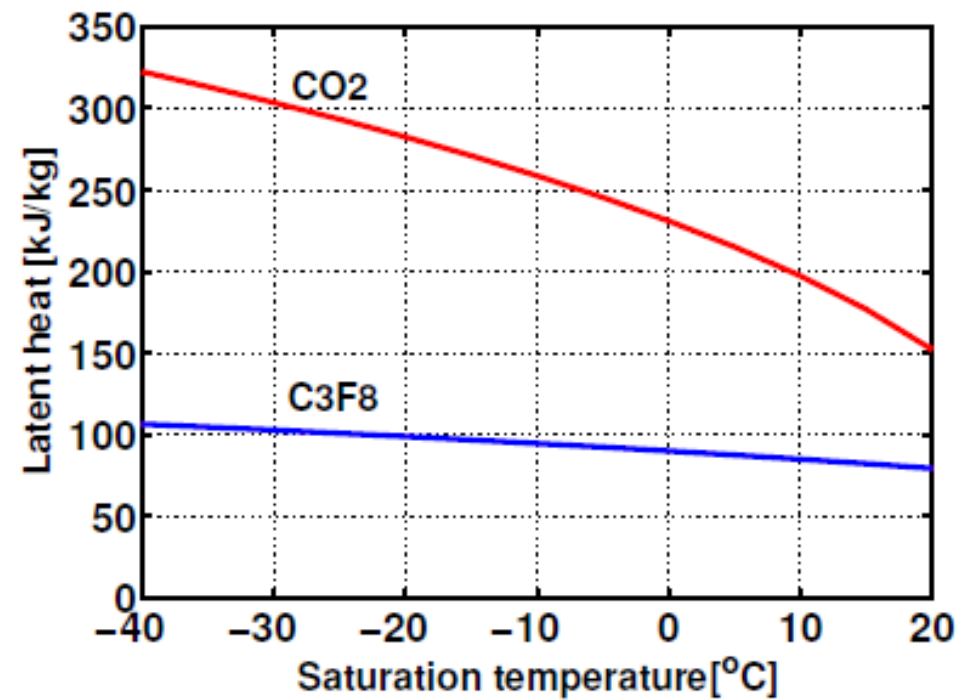
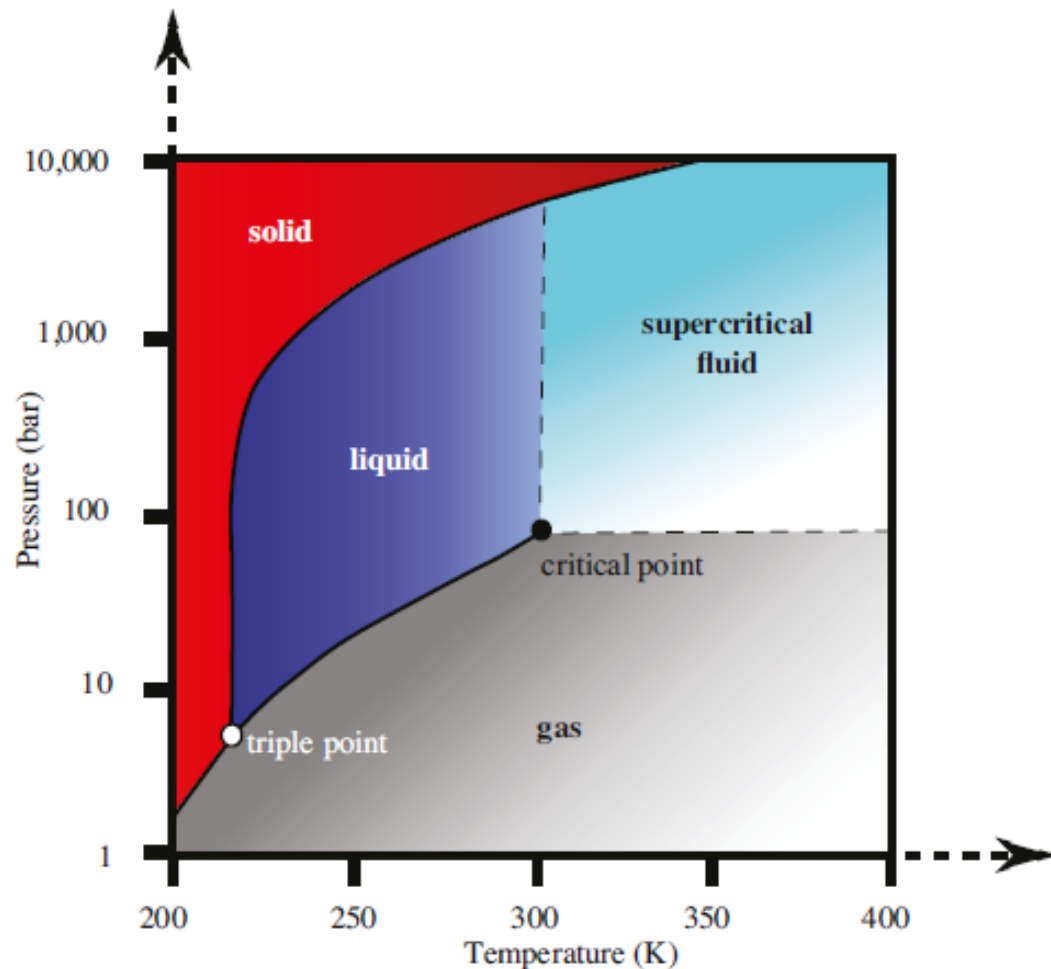
We recommend the ITk community build the **Pixel system that embraces the features that have driven the design of the Inclined layout.**

Particular care and effort should be taken to minimize the amount of material before the first two (innermost) measurements to guarantee the optimal impact parameter resolution over the entire range of pseudorapidity.

Ibeam & Twinaxes

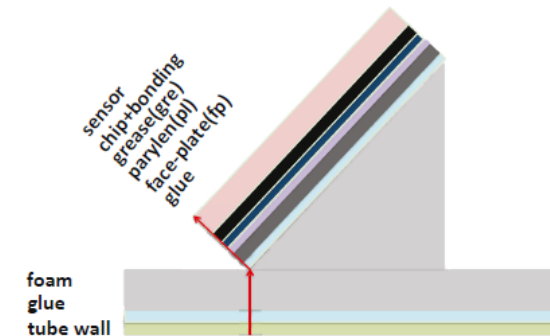
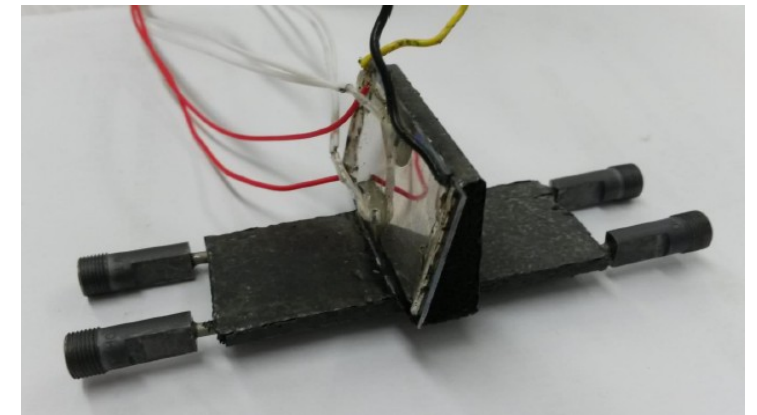
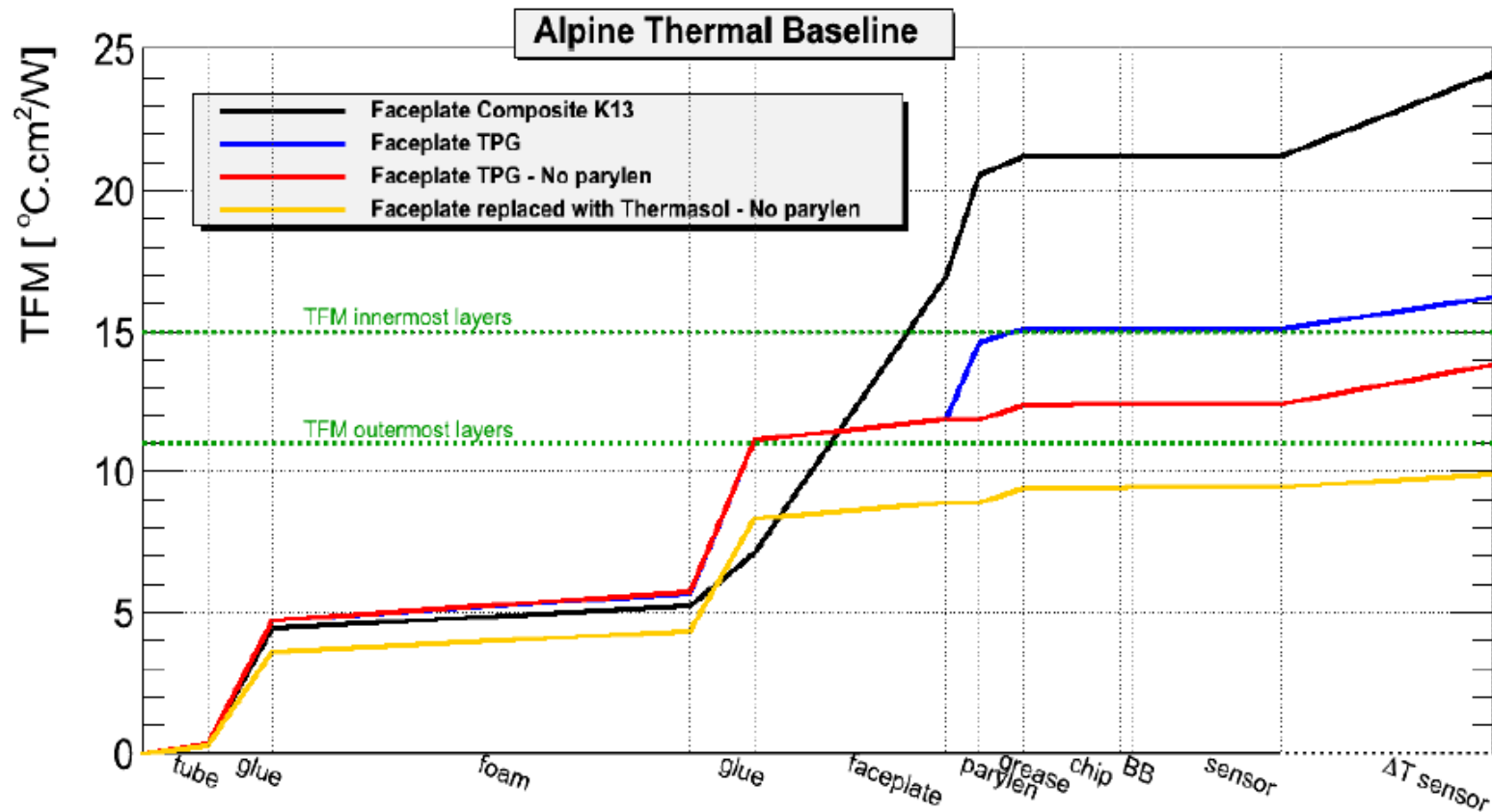


Refroidissement CO₂ diphasique

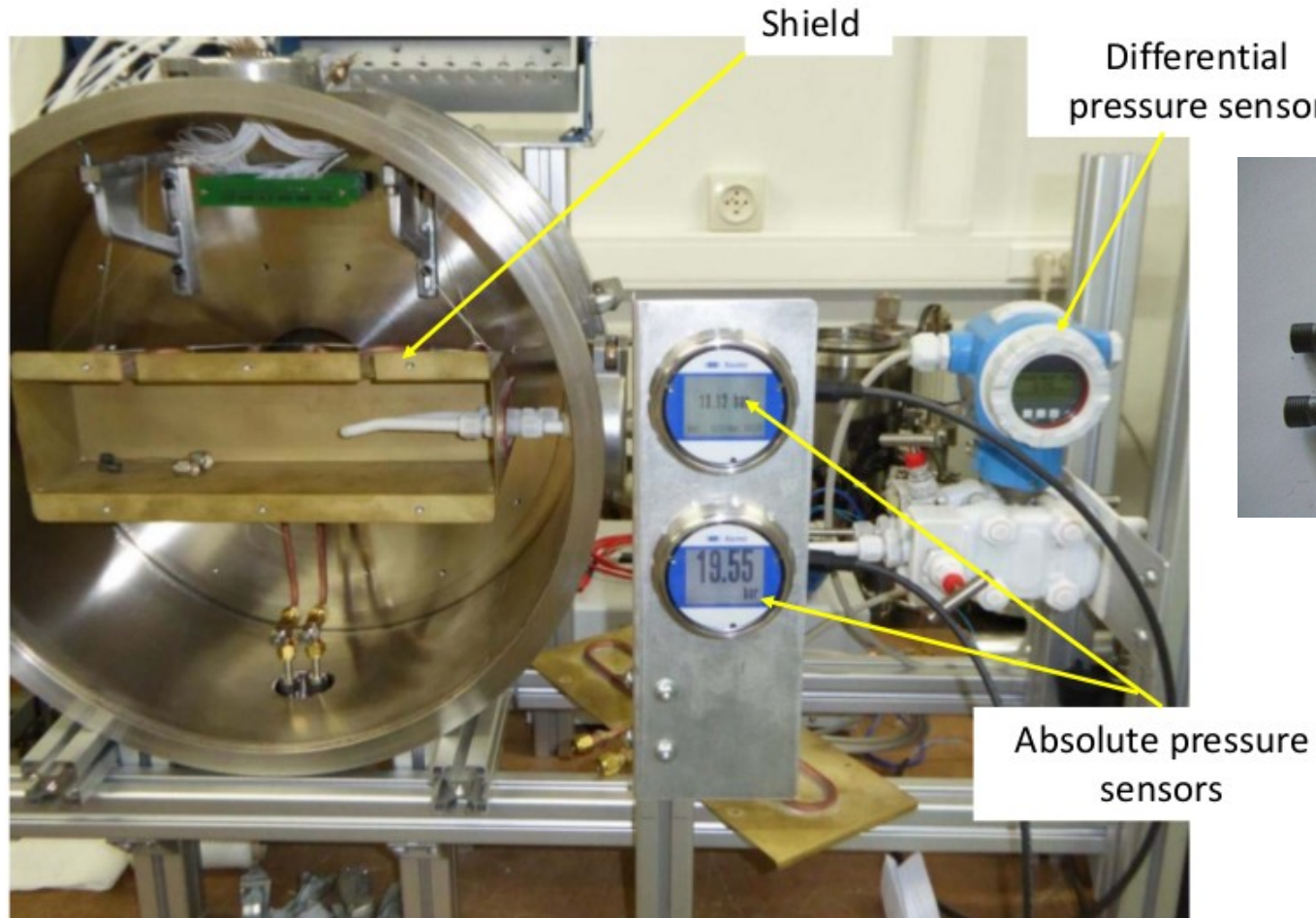


Mesures thermiques (1)

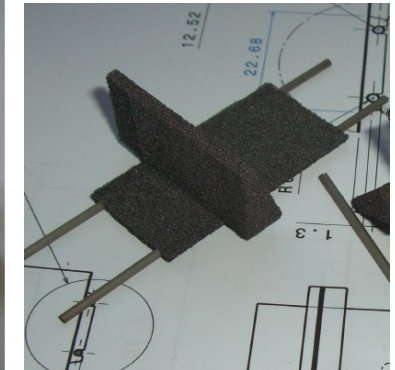
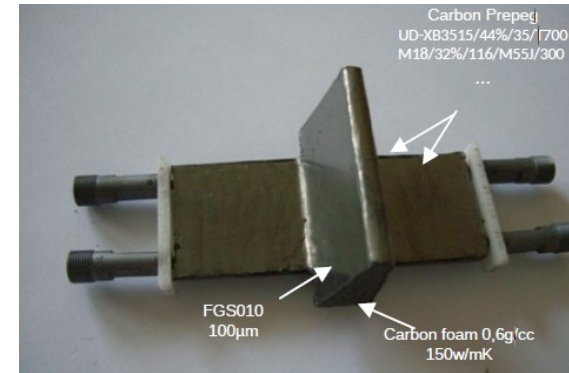
Thèse de Zhan Zhang (2012 -2015)



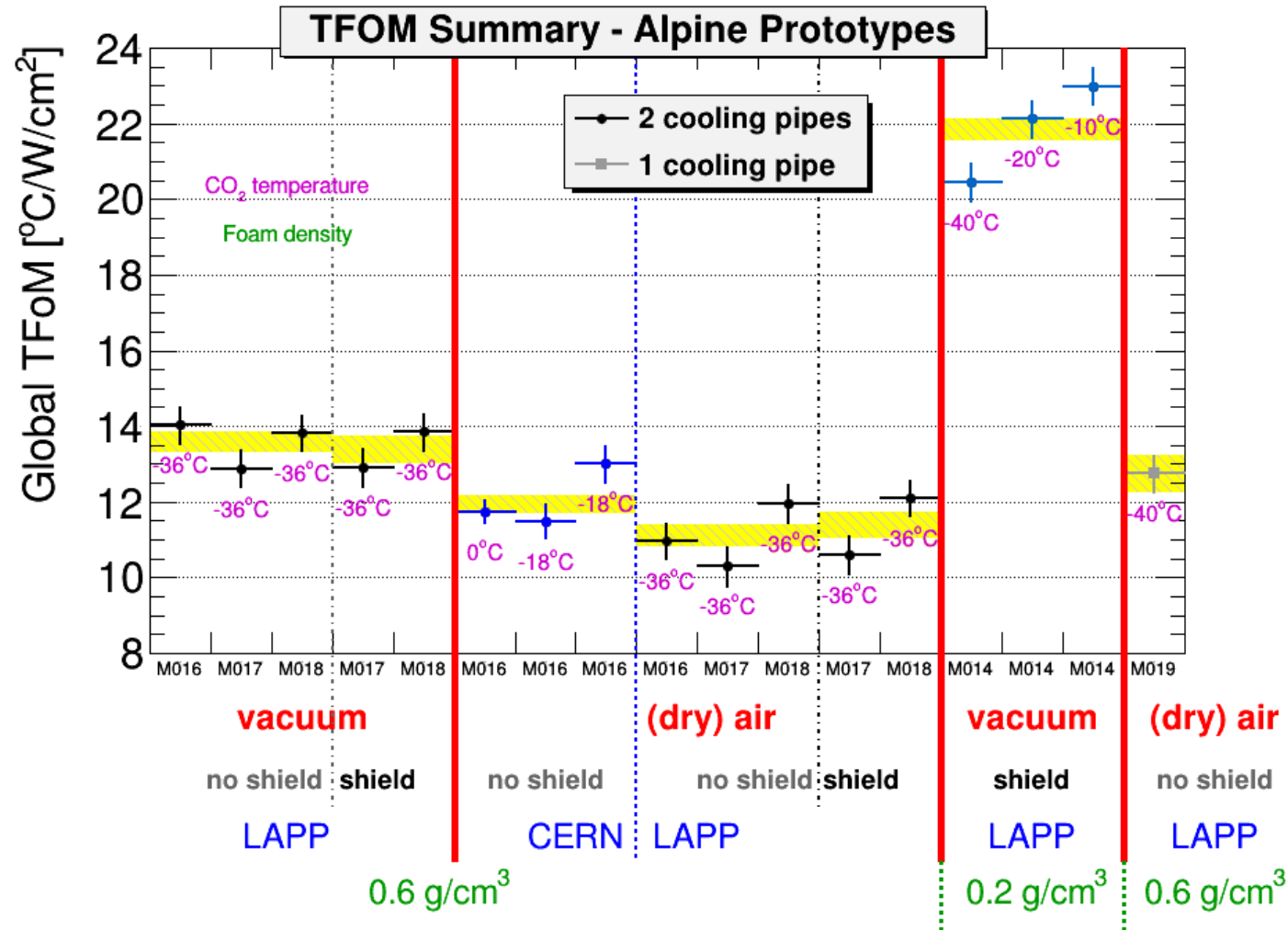
Mesures Thermiques (2)



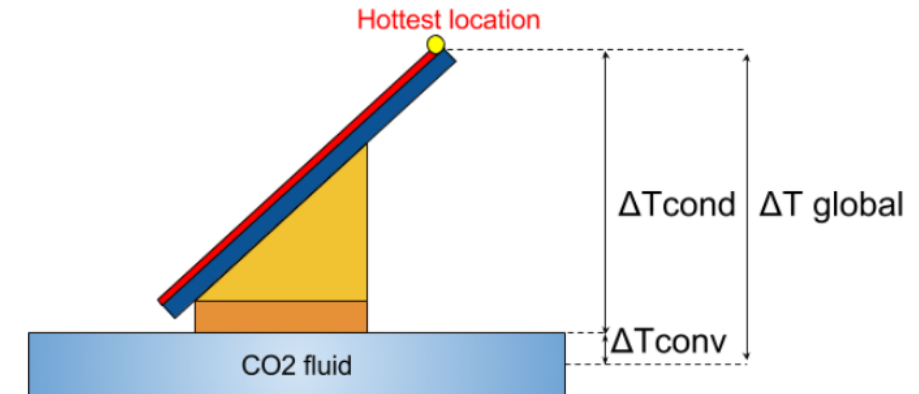
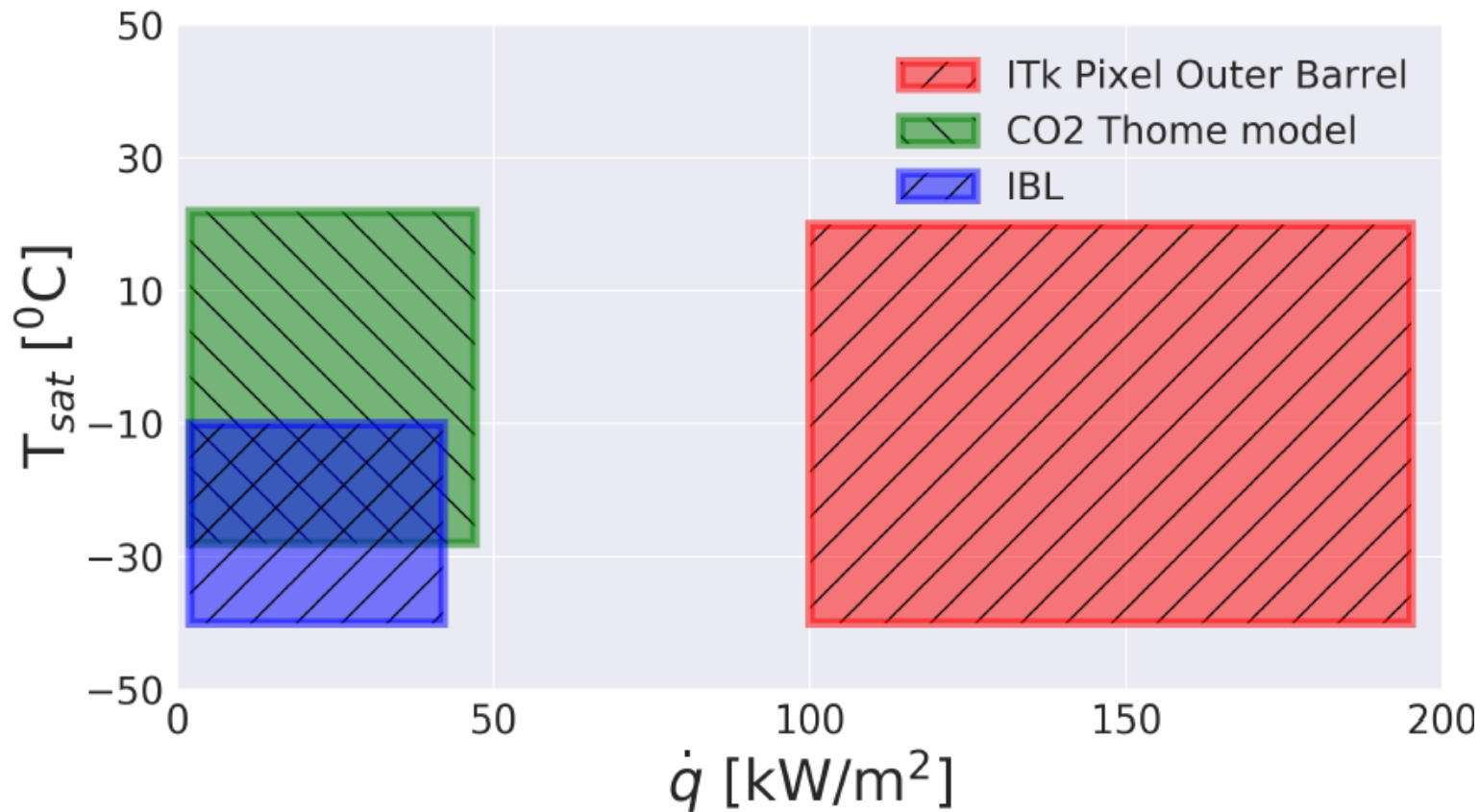
Thèse de Pierre Barroca (2016 -2019)
Co Direction J. Levêque / S. Jézéquel



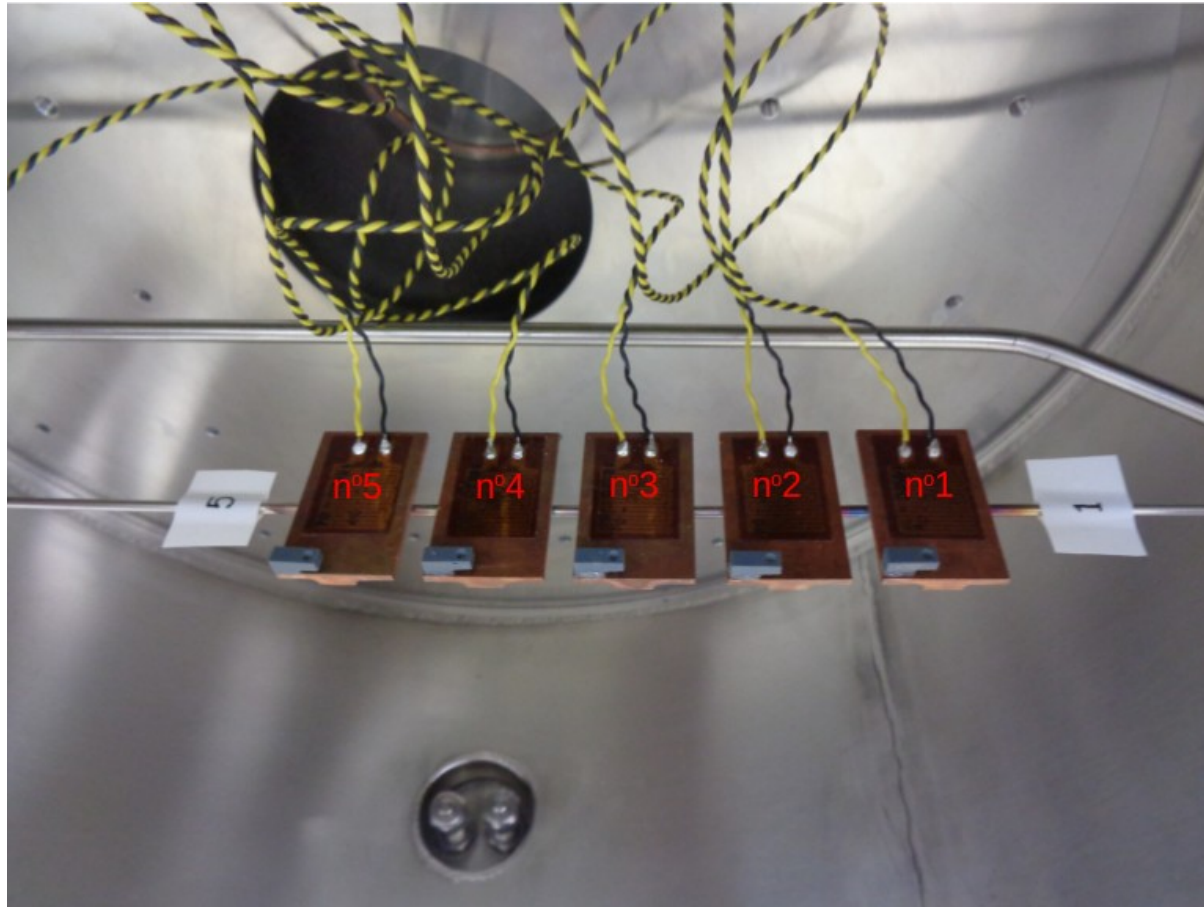
Performances Alpines



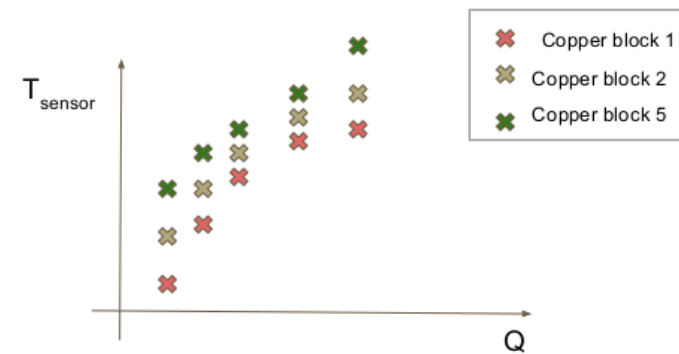
Test du modèle CO₂ diphasique



Test du modèle CO2 diphasique



Thèse Pierre Barroca (2016 -2019)



$$T_{\text{sensor}}(Q) = T_{\text{CO2}} + T_{\text{conv}}(Q) + T_{\text{cond}}(Q)$$

$$T_{\text{conv}} = \text{func}(\text{Vapor Quality}, Q, \mathbf{A})$$

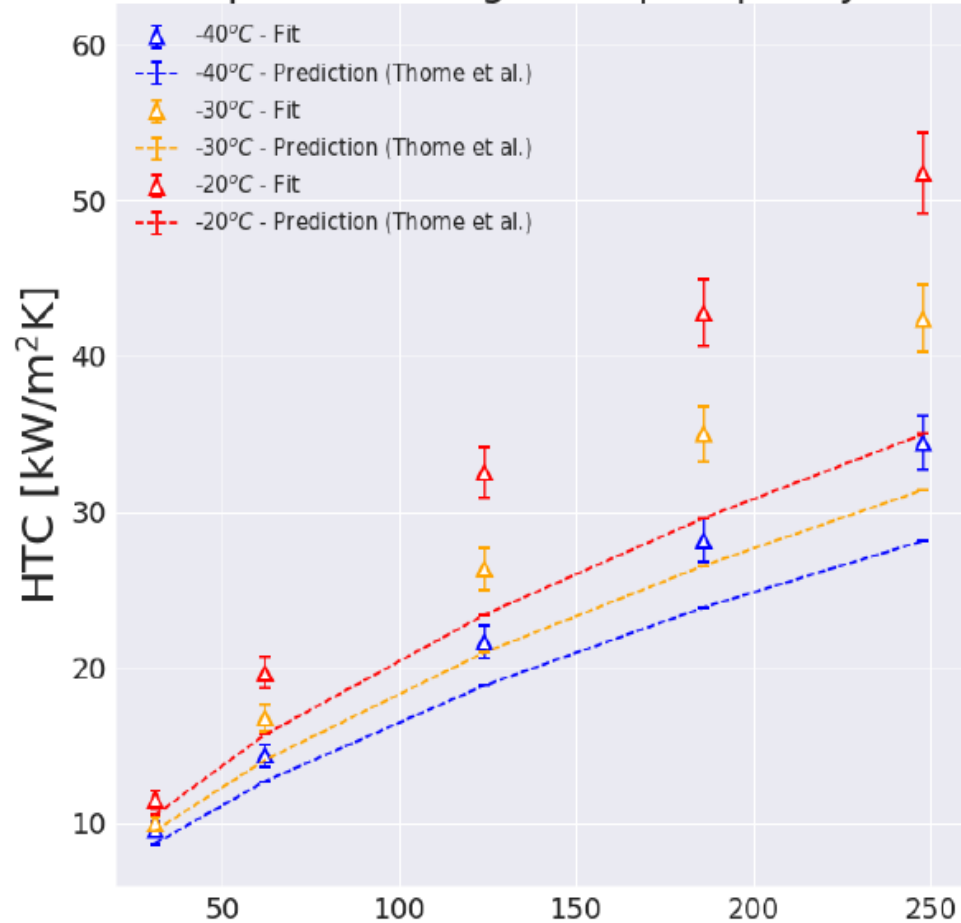
$$T_{\text{cond}} = Q/k_i(T) \text{ with } k_i(T) = \alpha_i(\beta \cdot T + k_0) \text{ [one set per copper block]}$$

Nicolas Berger

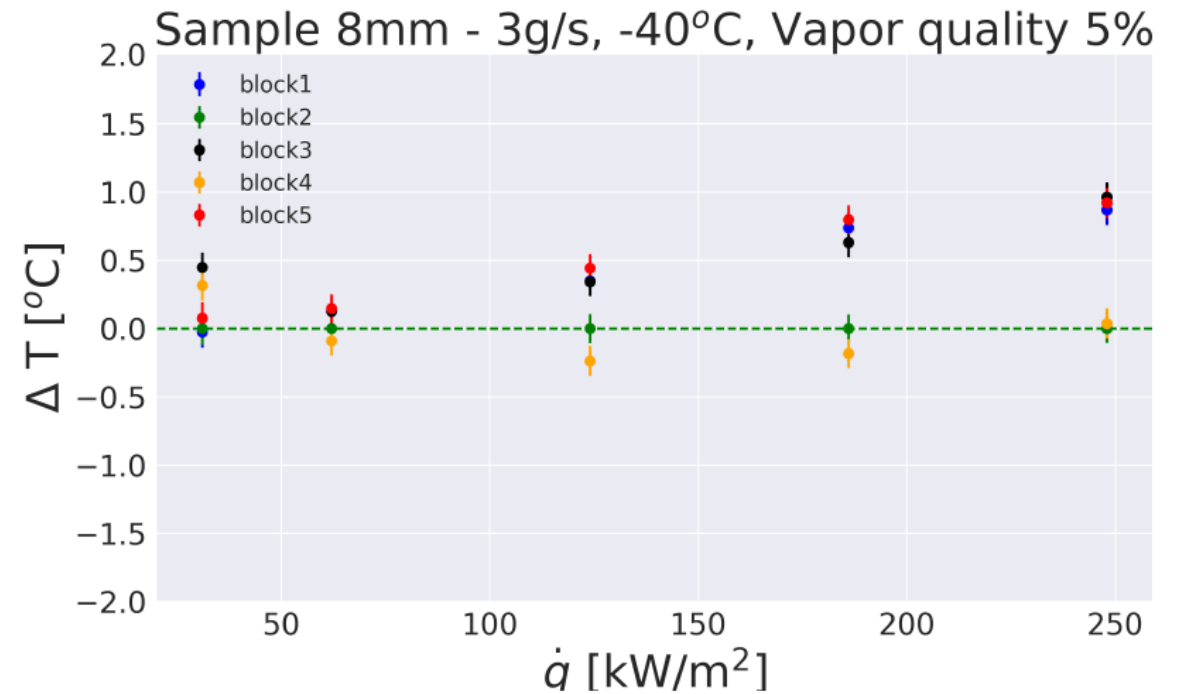
Test du modèle CO₂ diphasique



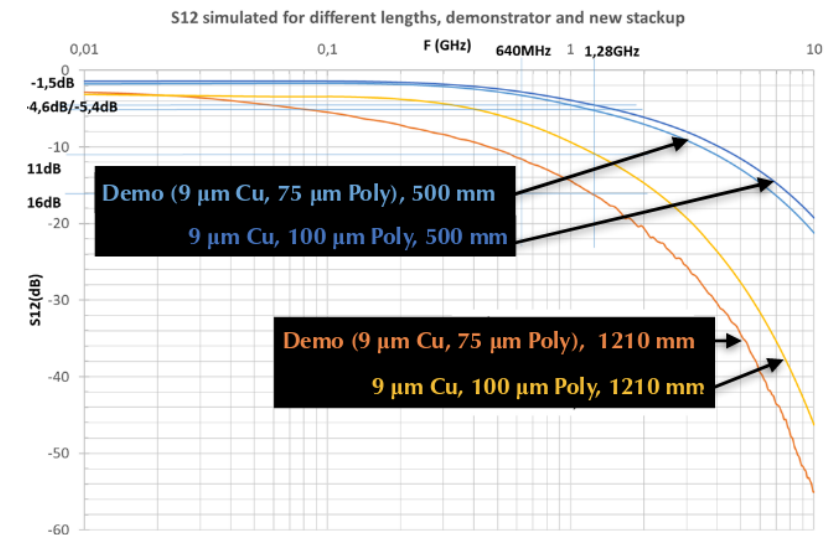
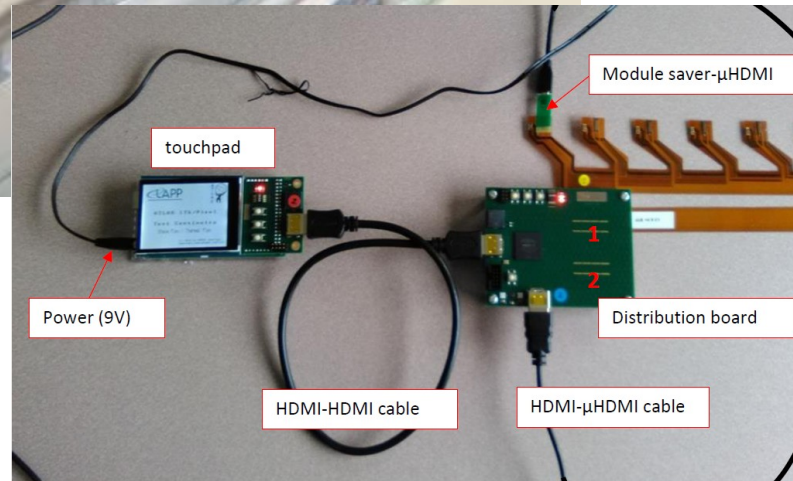
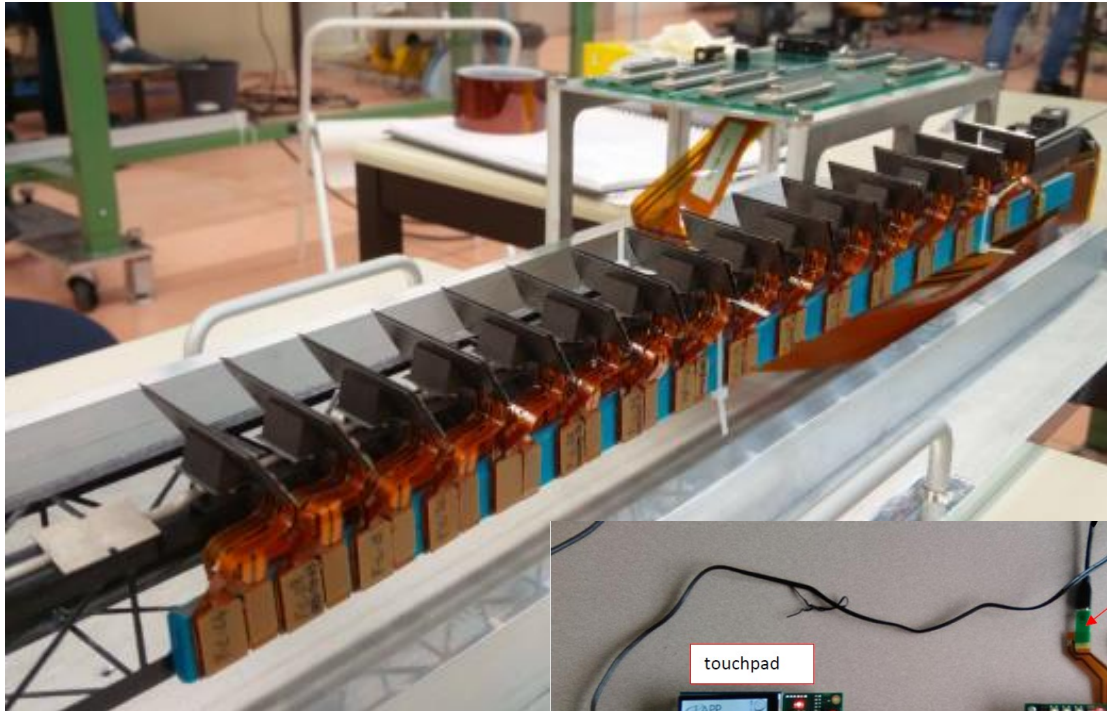
Sample 8mm - 2g/s - Vapor quality 5%



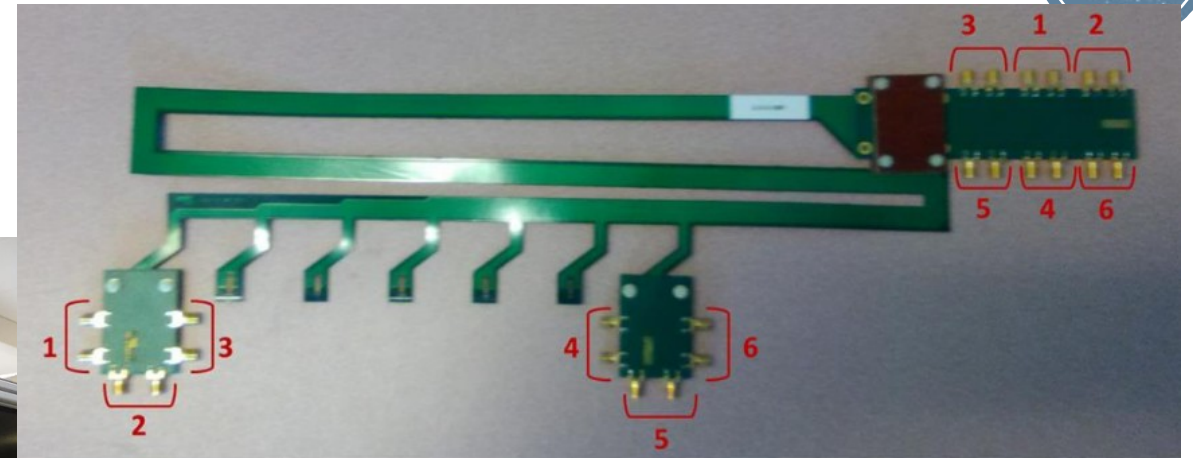
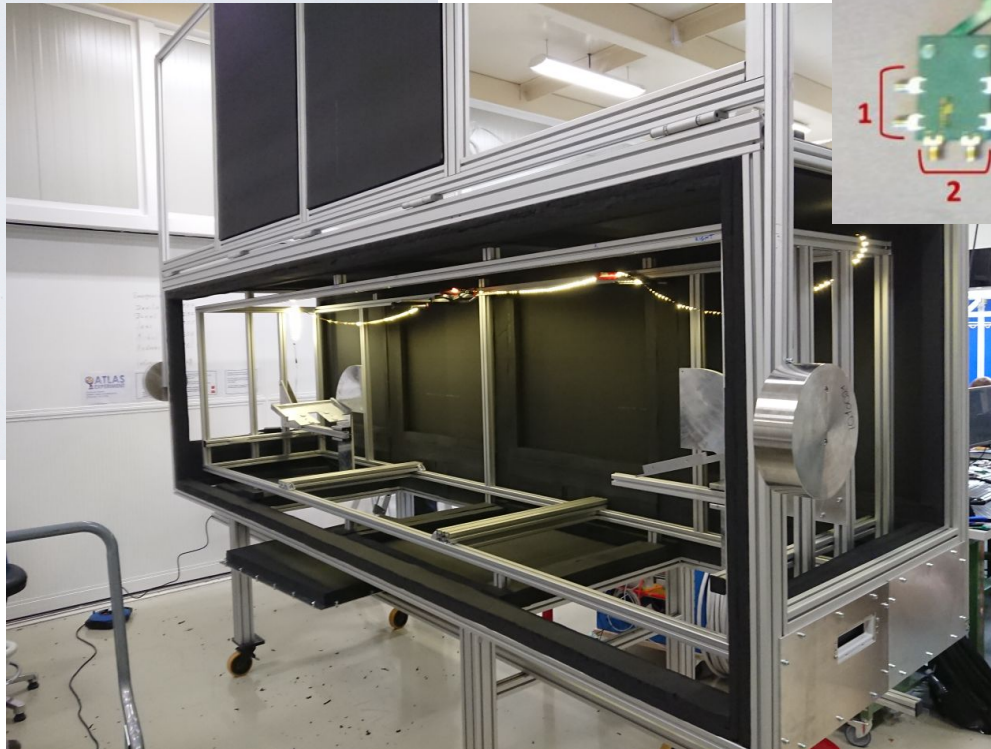
Thèse de Pierre Barroca (2016 -2019)



Progamme démonstrateur Outer Barrel [2017- 2018]



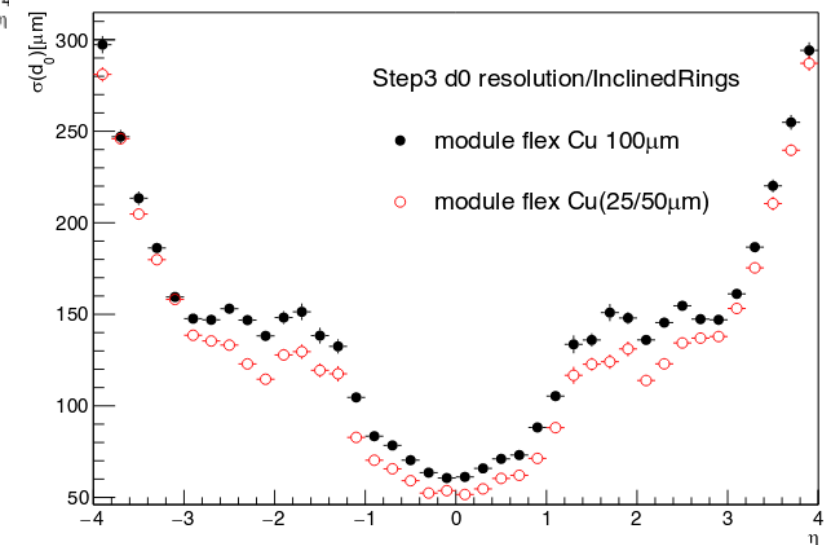
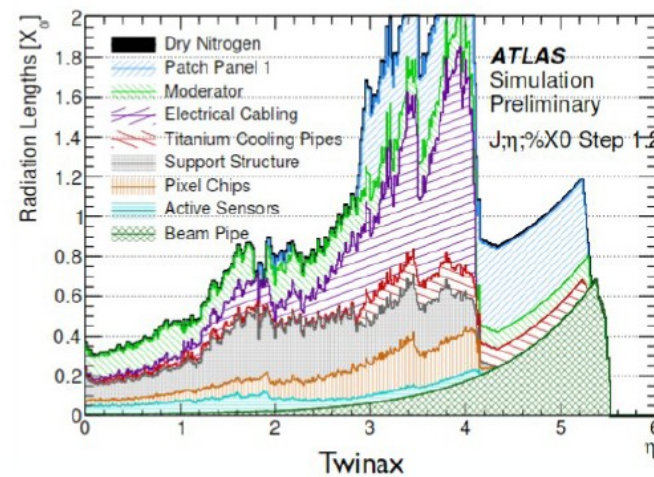
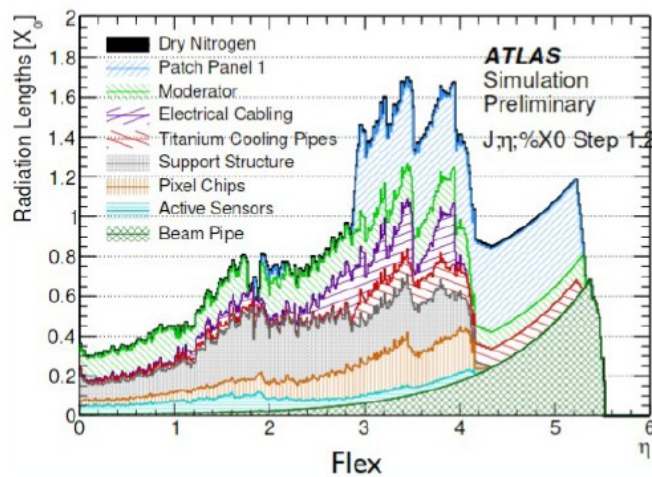
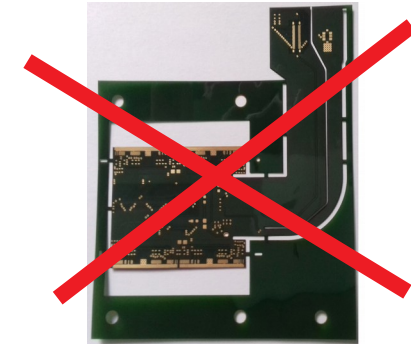
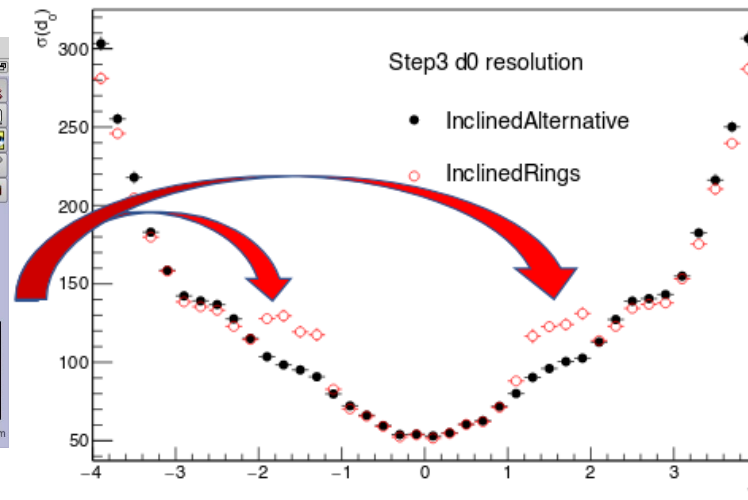
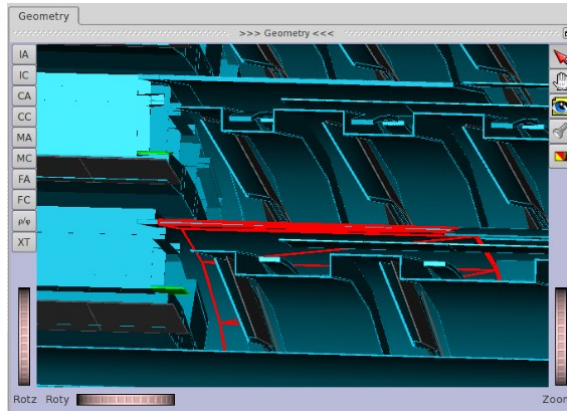
TDR Pixel 2018 & Engagements du LAPP



- Production de 100% des services de type 0 pour le Outer Barrel
- Production et test de 20% des supports équipés de module (Cluster ALPACA)



Police du X_0



Résumé & Perspectives



Physique Expérimentale des Hautes Energies

Théorie

- Modèles
- Générateurs
- Simulations

Détecteur

- Conception
- Construction
- Installation
- Opération

Physique

- Performances
- Mesures de précision
- Découverte ?

Données

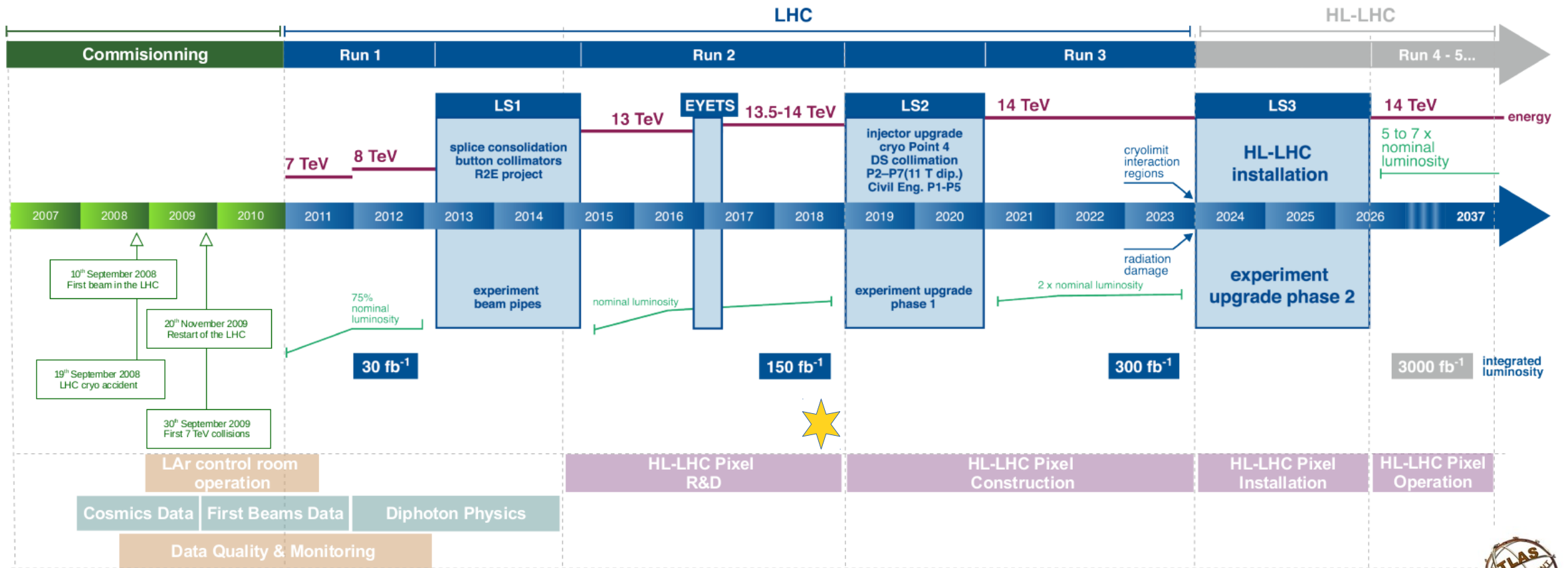
- Acquisition
- Qualification
- Reconstruction

Humain

- Collaboration
- Etudiants
- Grand Public

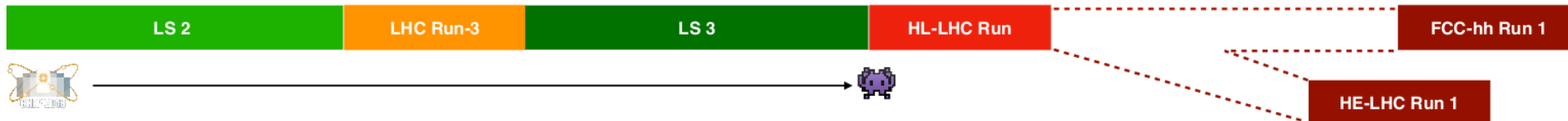
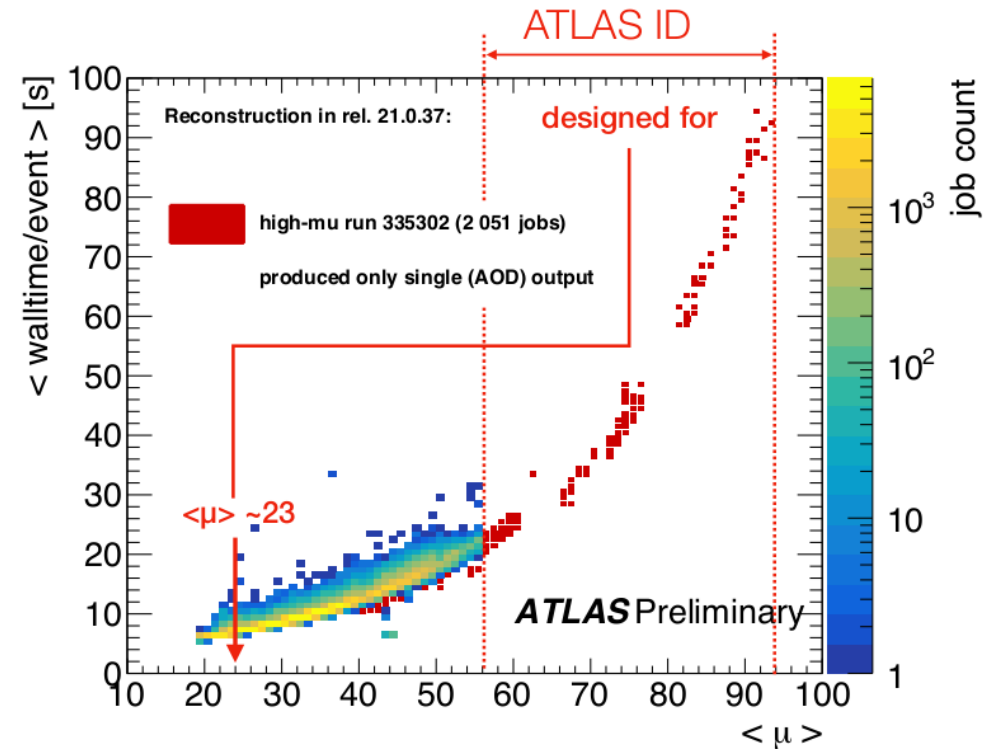
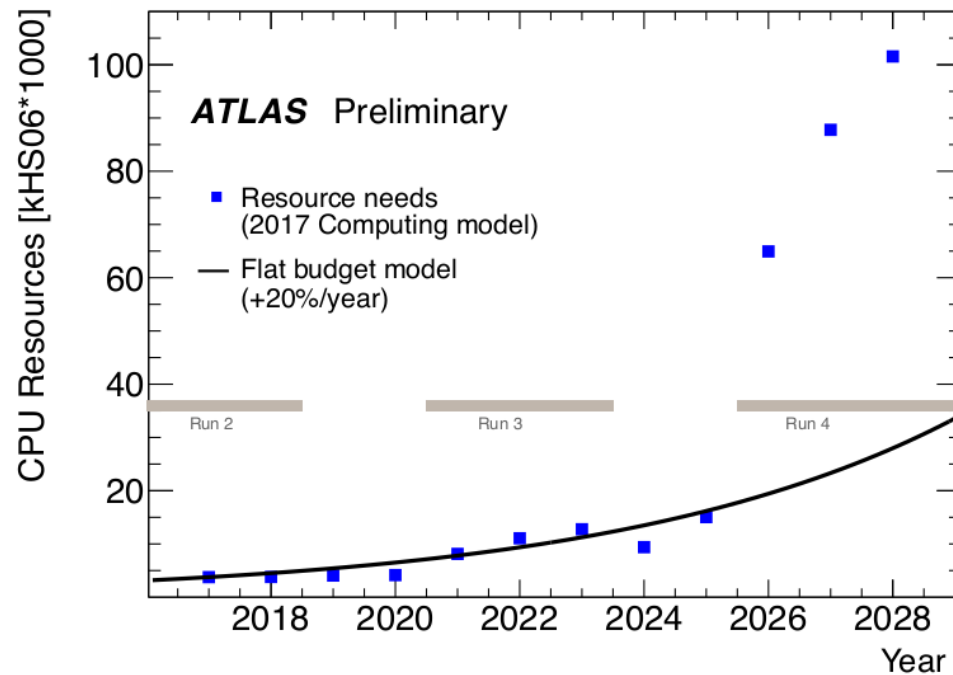


20 ans d'ATLAS

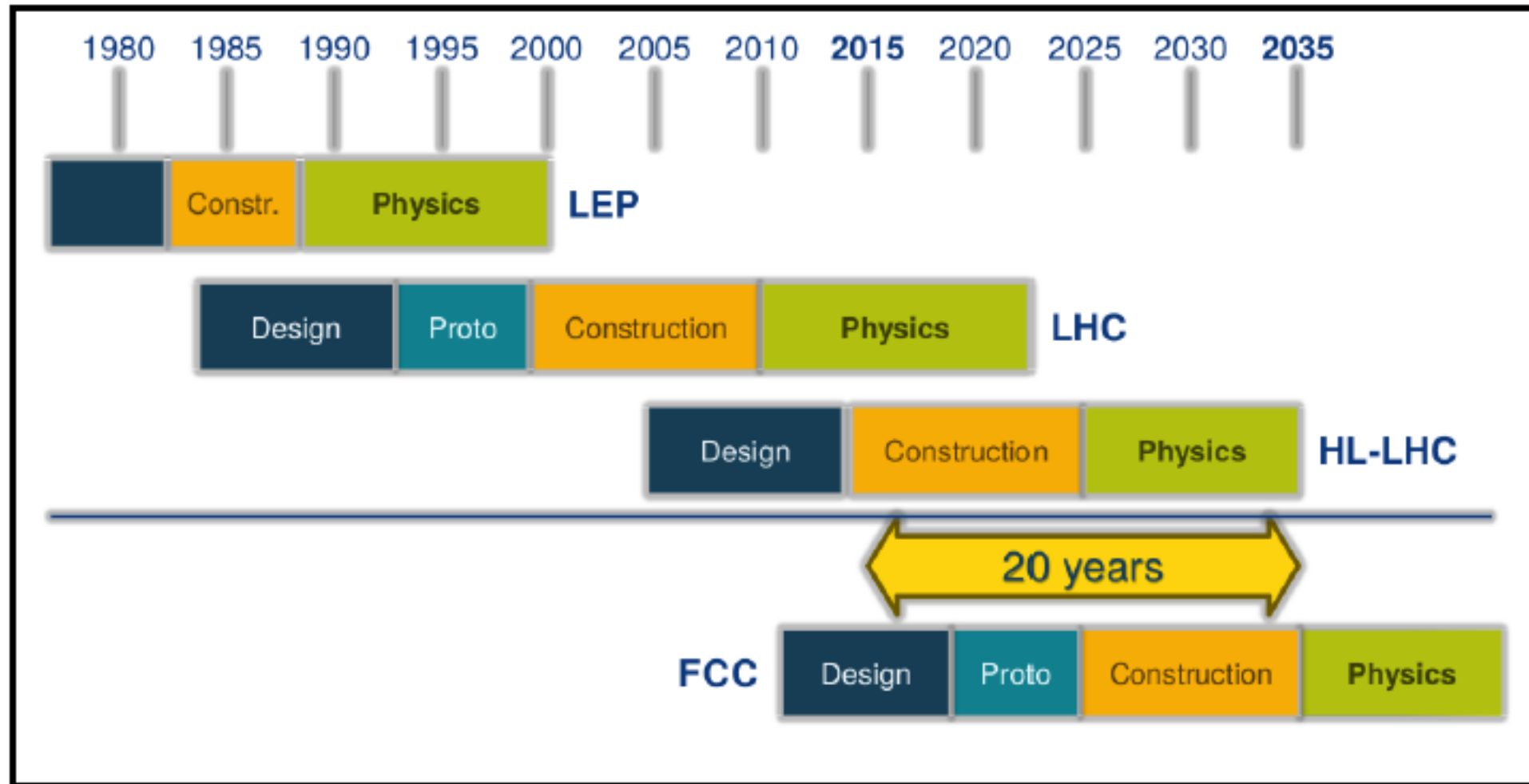


Community Driven Tracking Software

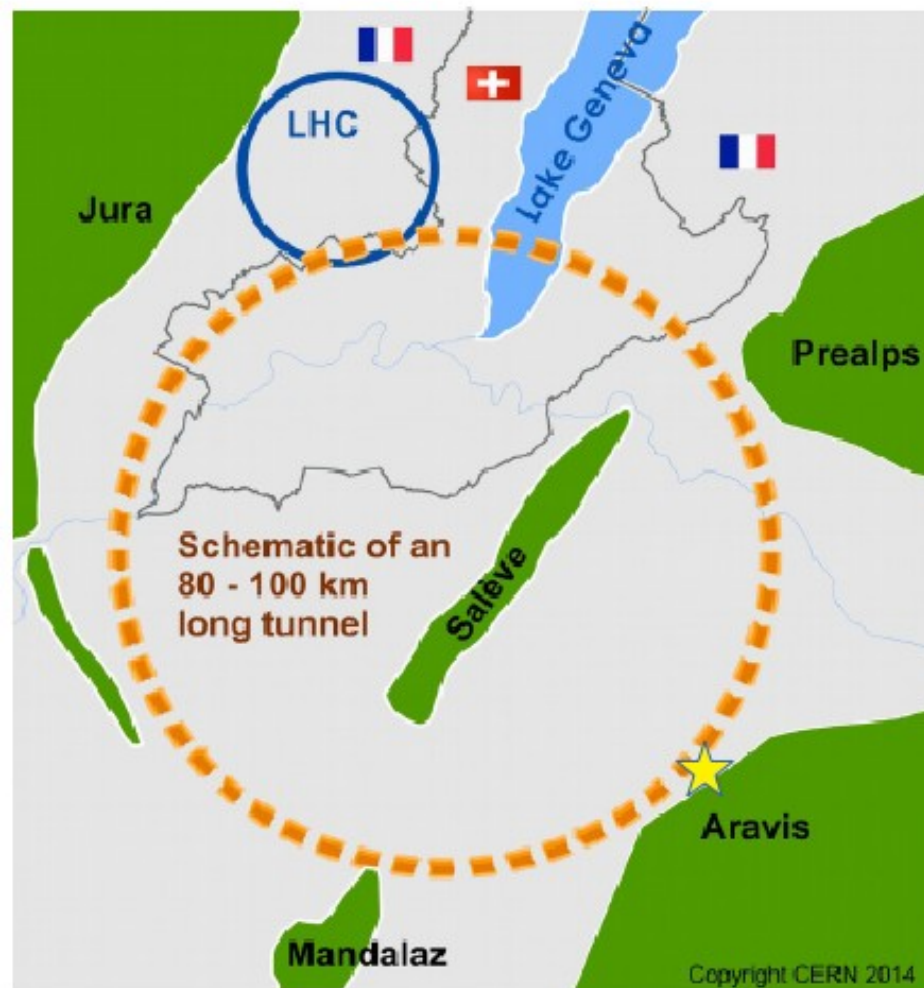
From CHEP2018 to CHEP2026



FCC (2035 ?)



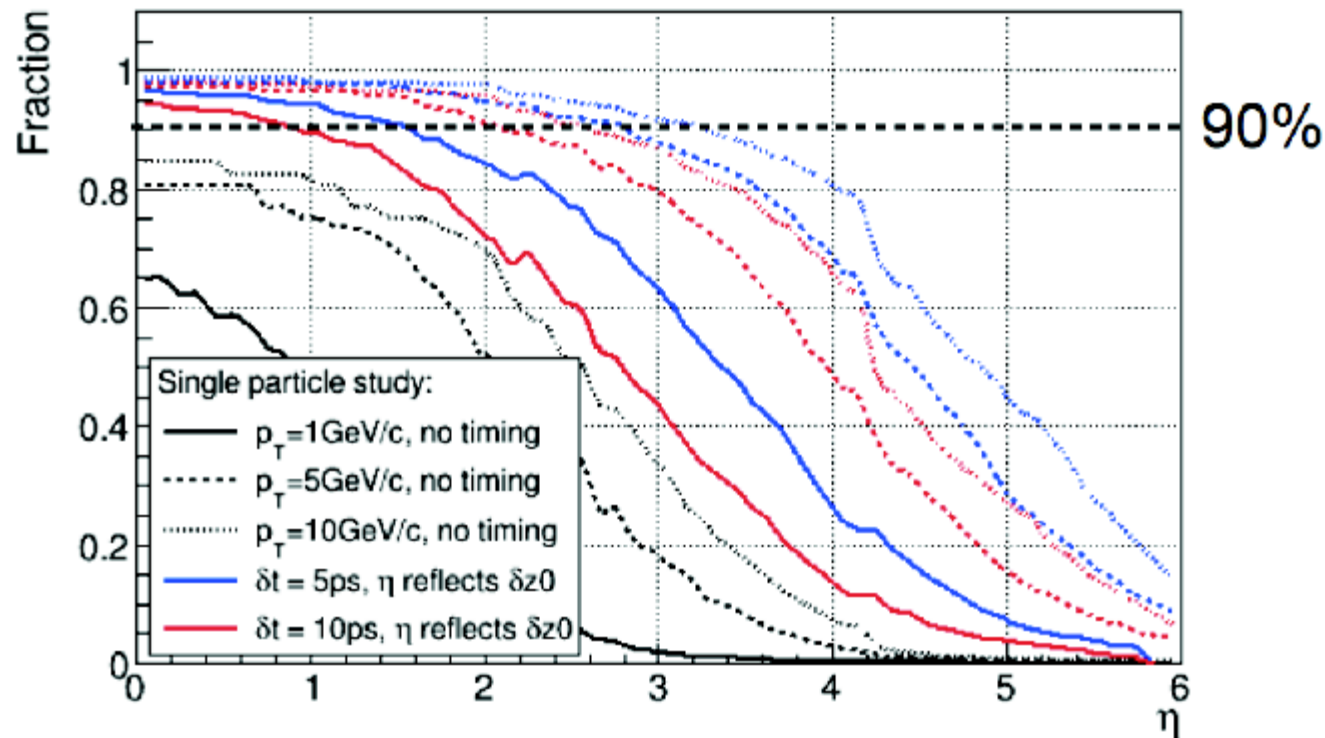
FCC (2035 ?)



Pile-up 1000 (FCC-hh)

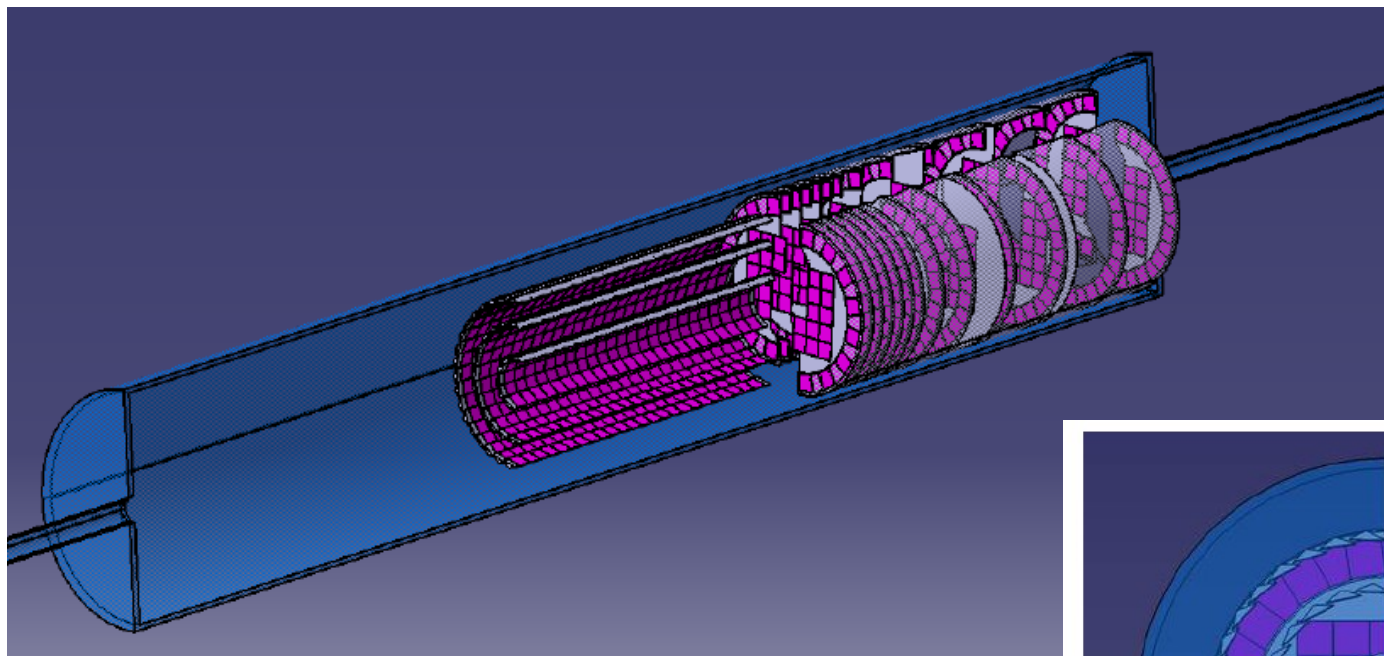
FCC-hh scenario @ PU=1000
Tilted layout

Fraction of tracks being unambiguously assigned to PV @95% CL: $\langle \mu_{\text{tot}} \rangle = 1000$



Facteurs limitants $\eta > 3$:
Matière du tube à vide
Bras de levier

EVEReST (FCC - hh)



Extended
Vacuum Embedded
Retractable
Silicon
Tracker

