Higgs-10Y

Célébration Orsay-Palaiseau-Saclay

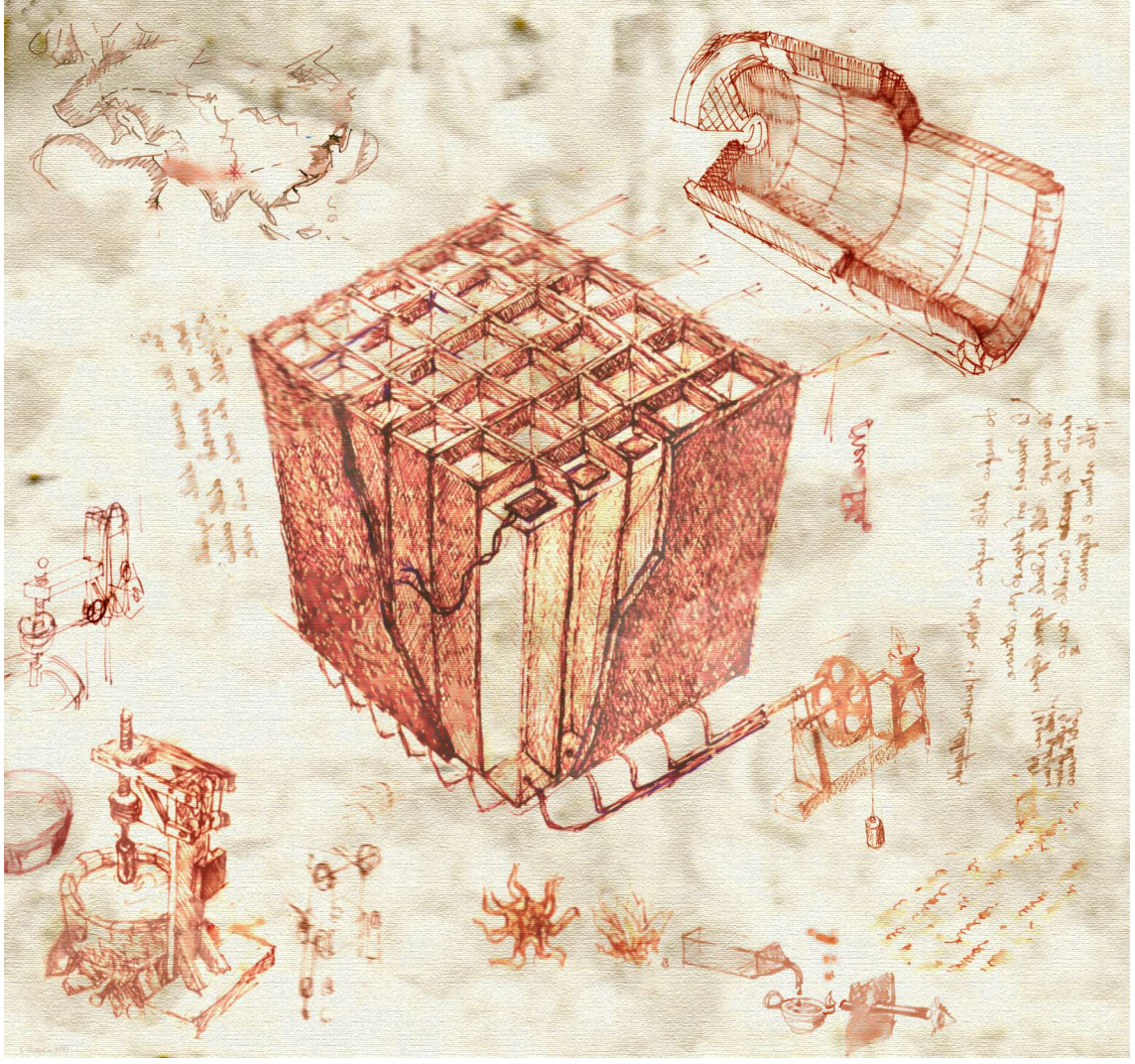
CMS ECAL

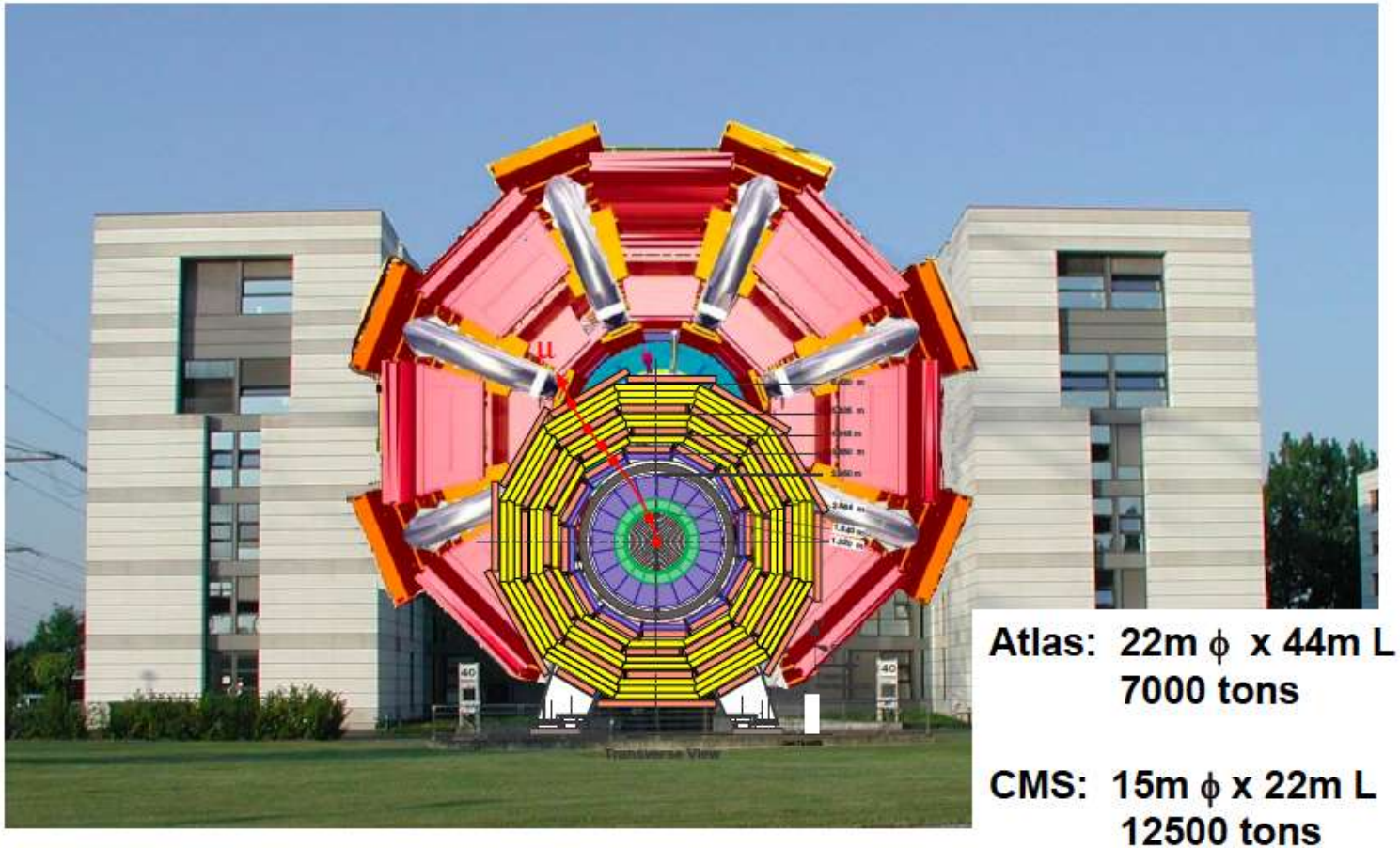
Calorimètre de CMS (Jean-Louis Faure) 13mn

Historique de la conception et raisons de choisir des cristaux.
Défis et difficultés depuis le prototype jusqu'à l'installation et le fonctionnement (marché des cristaux,etc).
Contributions de nos laboratoires (CEA, X), personnels impliqués dans le monde et chez nous.

CEA=Saclay=DAPNIA=IRFU=…

X=Polytechnique=Palaiseau=LLR

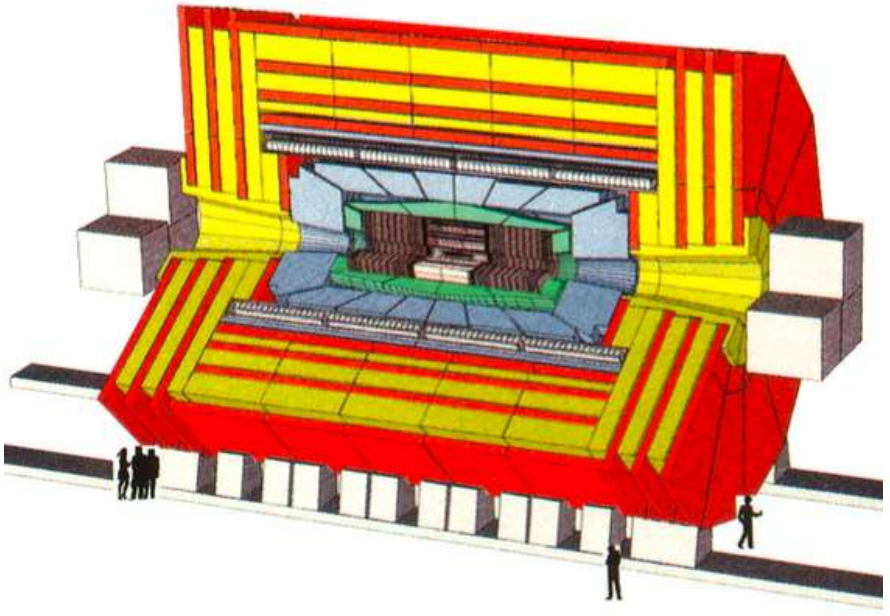




Atlas: 22m ϕ x 44m L
7000 tons

CMS: 15m ϕ x 22m L
12500 tons

Compact **M**uon **S**olenoid



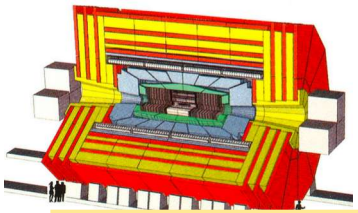
The LHC project (16 TeV pp in LEP tunnel) was really launched in the **Aachen workshop in 1990** (Rubbia, Brianti).

CERN setup the Detector R&D Committee to guide this. Expressions of Interest (EoI) presented in Evian (March 1992) by four proto-collaborations: Ascot, Eagle, CMS, L3P

After Evian three **LoI**s: ATLAS, CMS and L3P were submitted, followed by open presentations in Dec 1992

1993: Approval of ATLAS and CMS

Arrêt du Projet SSC (Octobre 1993)



Phases

1990-1992 Les premières idées

1992-1995 R&D et choix

1995-1999 Etudes détaillées, optimisation , outillages,….
Prototypes, définition outillages

1999-2008 Construction
suivi des productions industrielles Q/C
Fabrication / Assemblage / Installation
2006 Test en surface (cosmique) de CMS quasi-complet

Version LoI 1992

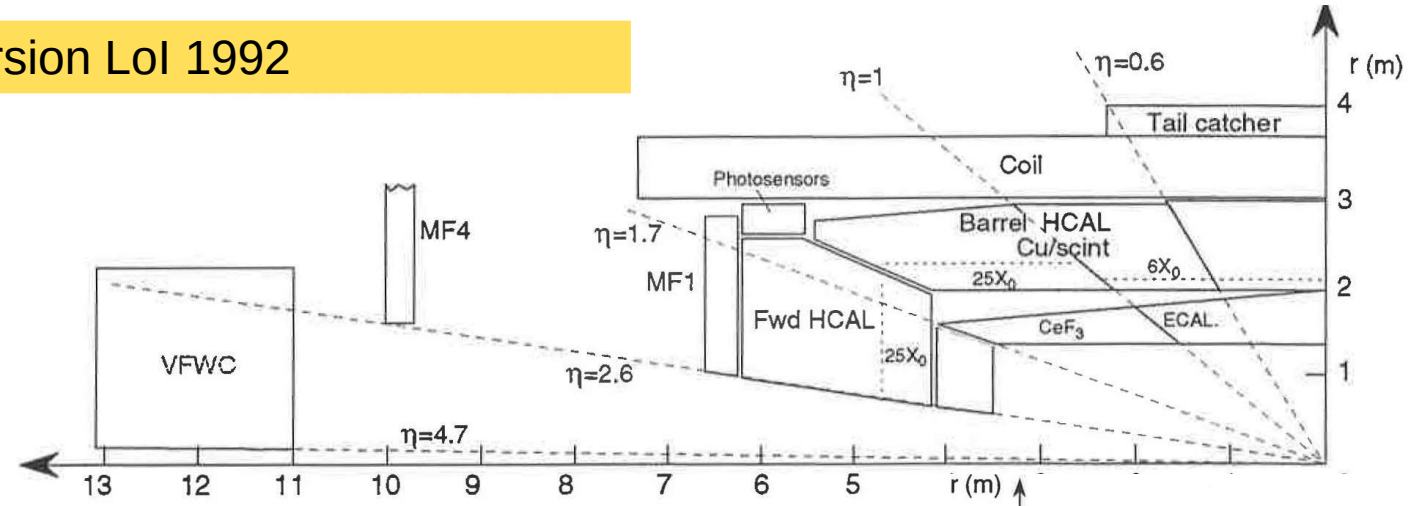


Fig. 4.1: Layout of the calorim

Environnement radiation

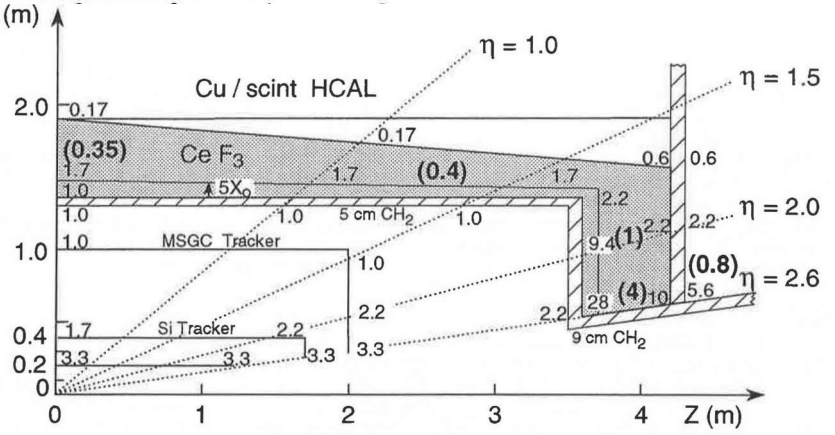


Fig. 1.4 : Neutron fluence and dose in CMS. The numbers in the figure are the fluence in units of 10^{13} n/cm^2. Numbers in bold are the dose in Mrads. These numbers are given for an integrated luminosity of L = 10^{42} cm^{-2}, corresponding to 10 years of running at design luminosity .

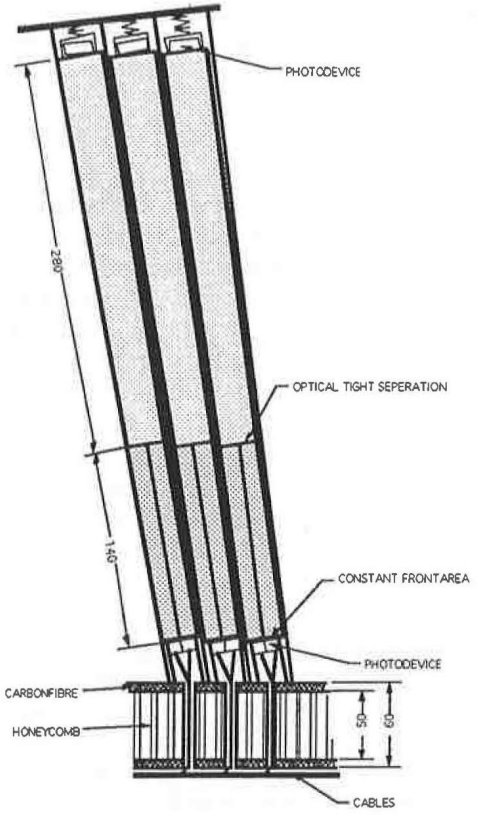


Fig. 4.3: Structure of single towers

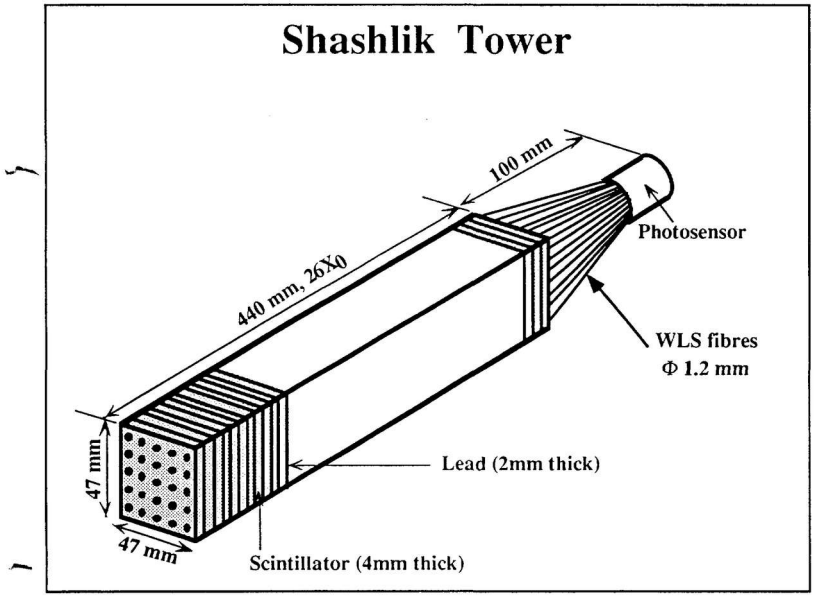
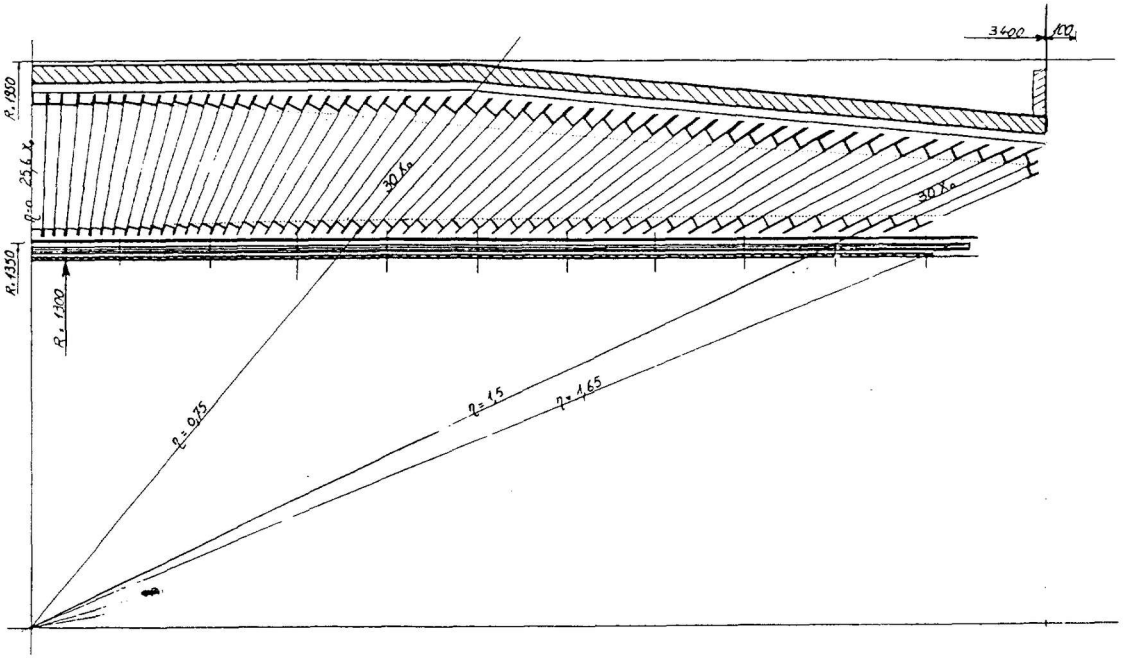


Figure 1. Mechanical design of a CMS Shashlik calorimeter prototype tower equipped with 25 aluminized WLS fibres.

Deux options de design DRDC

Shashlik (RD 36)
Cristal (RD18 *Crystal Clear*) (CeF3, …..)



RD36 DRDC 1993

LLR CERN LAPP

JNR ITEP IHEP INR

LIP

IC RAL BRUNEL

—
SPLIT
BOMBAY

Shashlik (440+100 mm) + Preshower

A lot of simulations
Idea of mechanical design
Prototypes
Preshower Si+Pb

Table 1.1: Comparison of properties of various crystals

	NaI(Tl)	BGO	CSI	BaF_2	CeF_3	$PbWO_4$
Density [g/cm^3]	3.67	7.13	4.51	4.88	6.16	8.28
Radiation length [cm]	2.59	1.12	1.85	2.06	1.68	0.89
Interaction length [cm]	41.4	21.8	37.0	29.9	26.2	22.4
Molière radius [cm]	4.80	2.33	3.50	3.39	2.63	2.19
Light decay time [ns]	230	60 300	16	0.9 630	8 25	5 (39%) 15 (60%) 100 (1%)
Refractive index	1.85	2.15	1.80	1.49	1.62	2.30
Maximum of emission [nm]	410	480	315	210 310	300 340	440
Temperature coefficient [%/°C]	–0	–1.6	–0.6	–2/0	0.14	–2
Relative light output	100	18	20	20/4	8	1.3

Après Evian (1992)
Des groupes L3 rejoignent CMS

Groupe L3 Cern
LAPP, IPNLyon
INFN (Rome, Turin)
ENEA
Caltech
Princeton

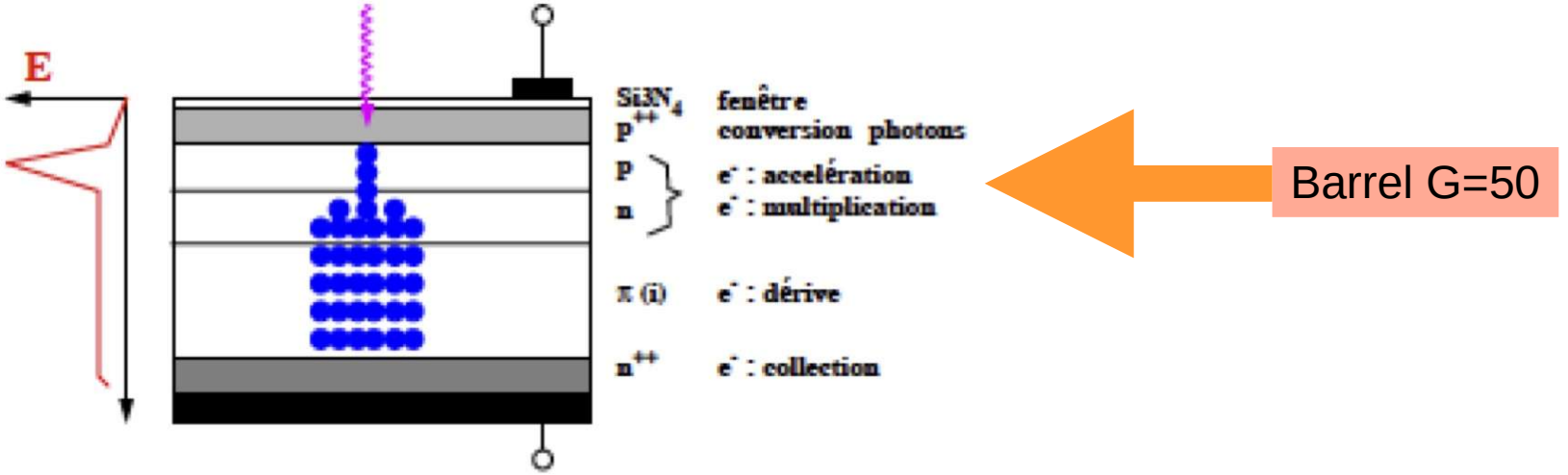
ETHZ
……

RD18 (**Saclay, LLR**, INPL,INFN, CERN,….) + Physiciens du solide(Minsk, Lyon,ENEA)

CeF3
PbWO4

Septembre 1995	Heure des choix
Shashlik	Sampling Calorimètre
CeF3	Small radiation length implique un tell catcher
PbWO4	Small (very small) light yeild

Le 22 Septembre 1995	Heure des choix (**1**)
~~Shashlik~~	~~Sampling Calorimètre~~
CeF3	The radiation length implique un tell catcher Cristal très long (2 parties,(long 280 + 140 mm) , lecture compliquée)
PbWO4	Small (very small) light yeild Nécessite un amplificateur de lumière Fonctionnant à 4 tesla UTILISATION de APD (Avalanche PhotoDiode) VPT dans le Endcap



Barrel G=50

EndCap G=10

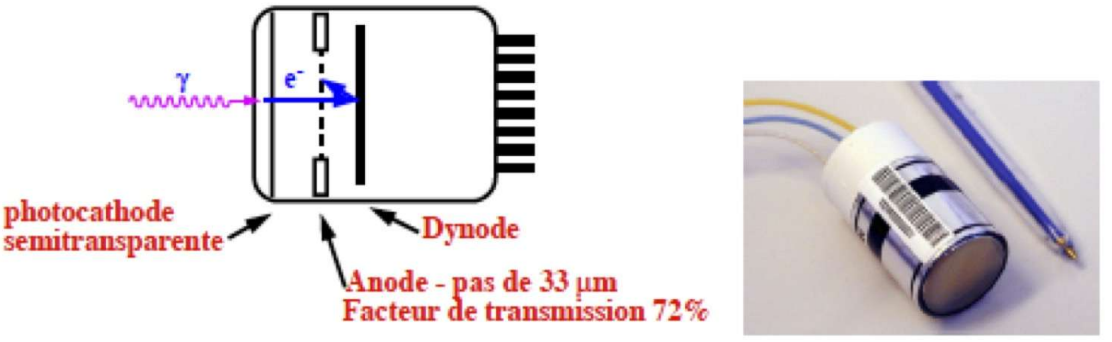


FIG. 5.28: Diagramme schématique d'une VPT et photographie d'une VPT.

Le 23 Septembre 1995 Heure du choix (**2**)

PbWO4 Producteurs
Bogorodisk Chemical Technical Plant (BCTP Russia)
Shanghai Ceramic Institute (SCI China) (producteur BGO de L3)

APD Producteurs EG&G et Hamamastu

1995-1999 Optimisation des choix

Optimisation Doping etc

Tenue aux radiations Irradiateurs Gamma
Neutron Reacteurs Ulysse (Saclay), Tapiro (ENEA Casaccia It),
Faisceau PSI (p, ..)

Organisation des suivis de productions
Cristal Regional Renter (Cern, Rome (INFN)
APD Caracterisations (PSI,Minnesota at Cern)

Choix Mécanique / Electronique / Calibration

1997 TDR (Technical Design Report)

PbWO4 Producteur
Bogorodisk Chemical Technical Plant (BCTP Russia)

Audit sur la capacité de production

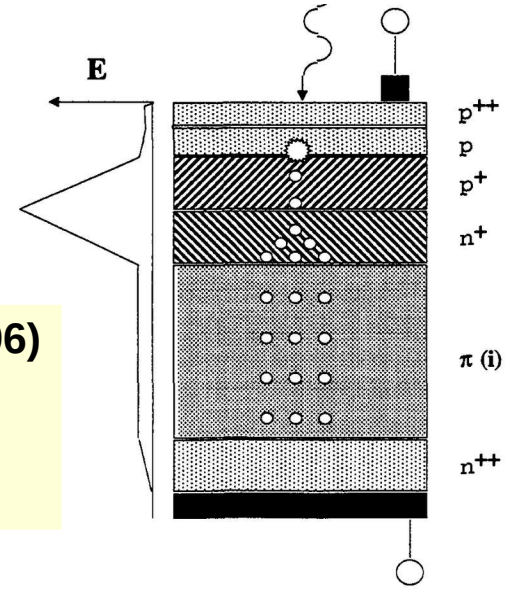
Mais rôle important de l'ISTC (International Science and Technology Center (ISTC) in Moscow
Crée en 1992 (US , EU, Japan,…..)
Pour financer la conversion dans des activités civiles l'industrie militaire de l'ex-URSS
Accord avec le Cern soutien à plusieurs projets dans ATLAS via des laboratoires de l'ex-URSS

Le Directeur exécutif (EU représentant) Alain Gérard était un copain et ancien du CEA (DPhN)
- Financement de la préproduction 6000 cristaux
- Mise au norme des lignes de production (> 105 fours)
- Gestion des procédures de douane
- Payement direct des salaires en Russie

	EG&G	HAMAMATSU
Id moyen après 3 10^{13} n/cm²	7 µA	3.5 µA
Bruit électronique moyen après 3 10^{13} n/cm²	35000 e-	27000 e-
Modification de ε_Q après irradiation ?	non	non
Modification de M après irradiation ?	non	non
Taux de survie après irradiation	93 %	100 %
Taux de survie après 2 mois de manipulation	77 %	100 %

APD

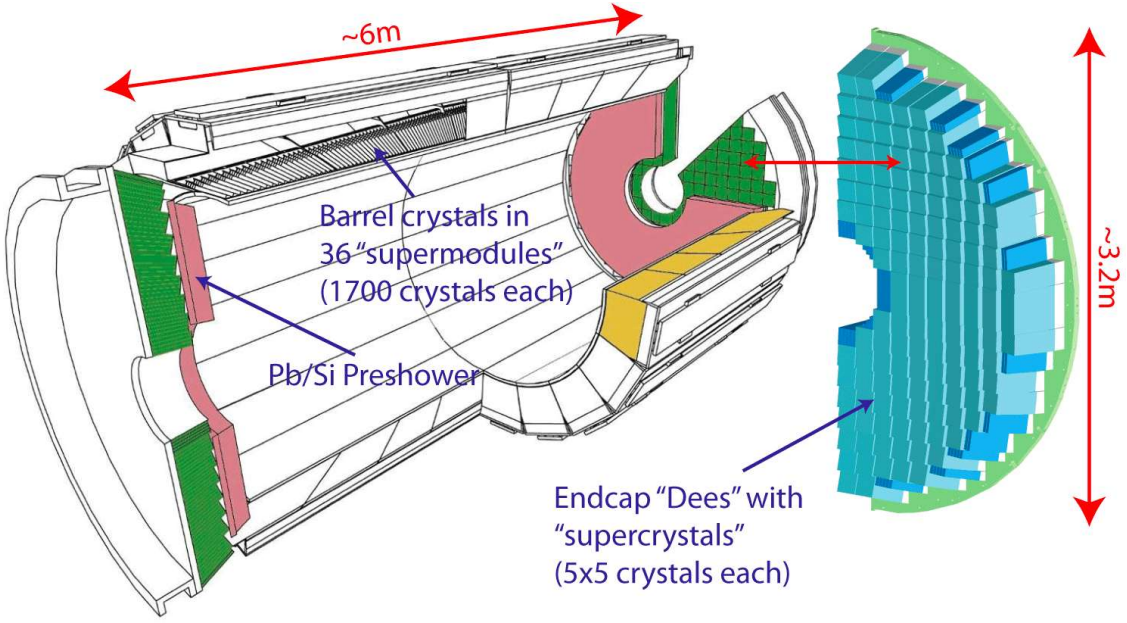
Technique non utilisée car ‘classifiée’
Même cas
Optimisation pour nos utilisations
PSI, **Saclay**, Minnesota, IPNL



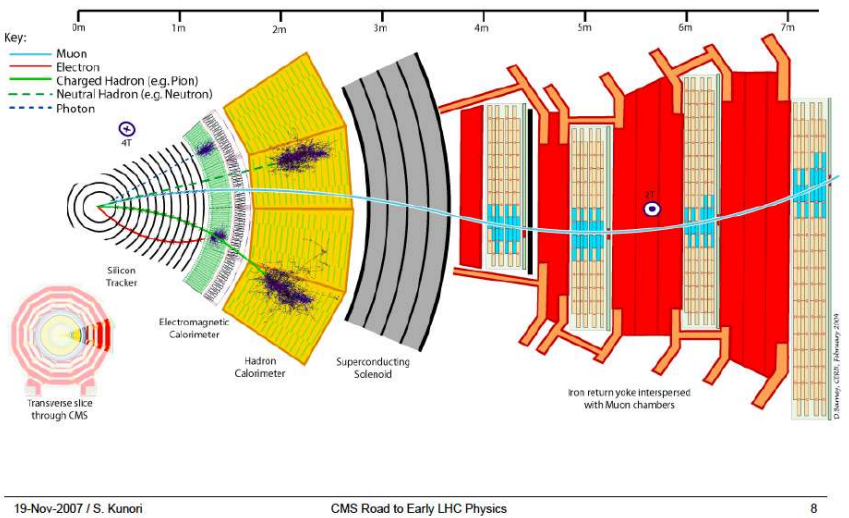
Conference on New Developments in Photodetection (NDIP96)

Beaune

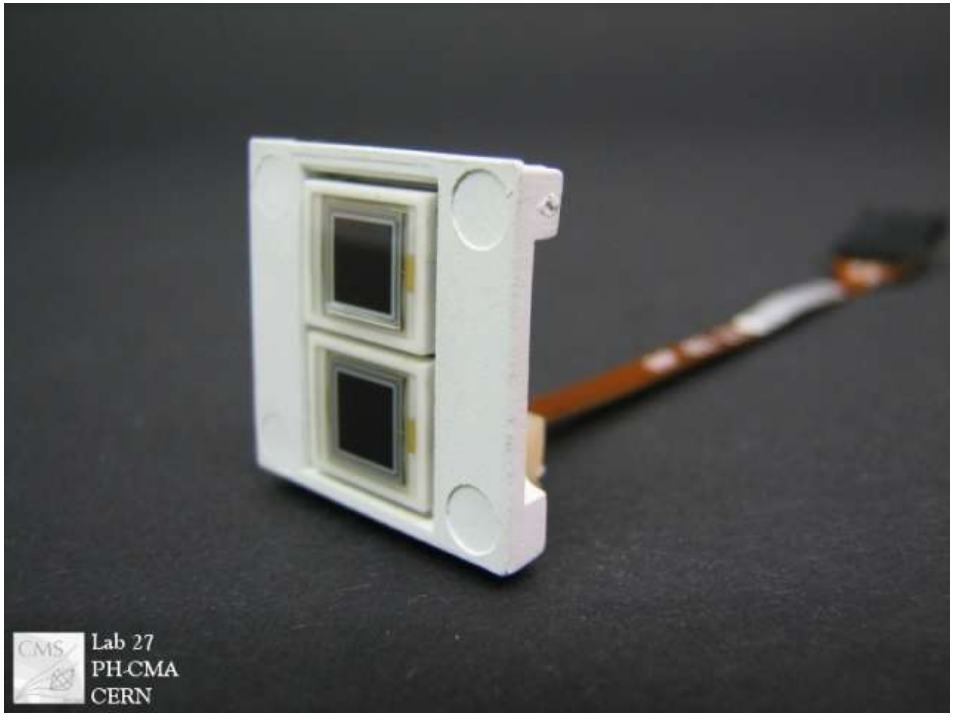
(Saclay,LAPP) 1996



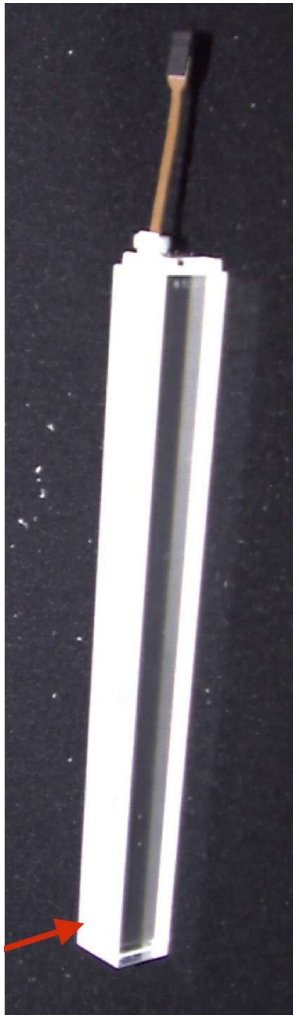
The CMS detector



19-Nov-2007 / S. Kunori CMS Road to Early LHC Physics 8

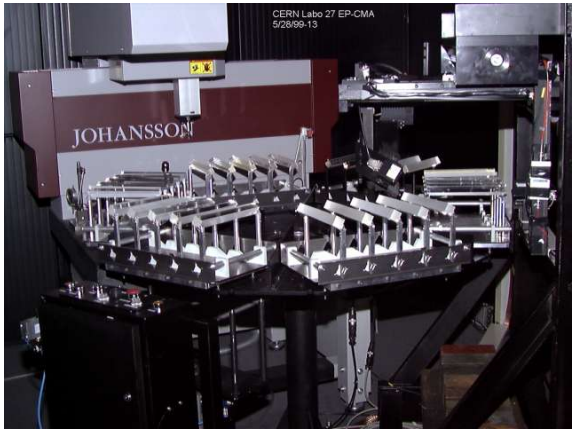


IPNL, CERN



230 mm

25.8 X_0



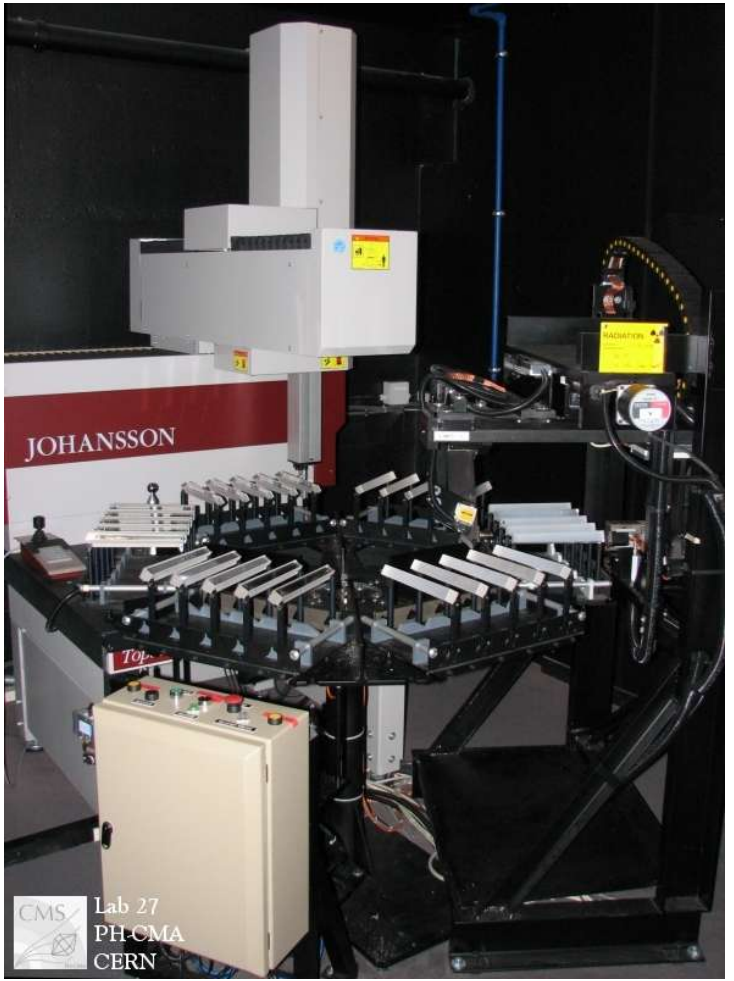
PRODUCTION

ACCOS machines

Machine prototype LAPP (suite expérience avec L3)

Deux ‘regional center’ Cern et Rome, lien avec la DB de production

Fournitures de machines ACCOS aux producteurs pour minimiser les rejets
Fournitures machines de coupe et de polissage



BCTP (Russie)

PRODUCTION

Pulling speed	5 mm/h
Rotation speed	10 min^{-1}
Temperature	1060 °C
Diameter of crystal	33 mm
Length of crystal	250 mm
Weight of crystal	2.5 kg
Duration of process	90 h

Pre-Production

PRODUCTION

Production

BCTP (Russia)

EB	62235
EE	12635

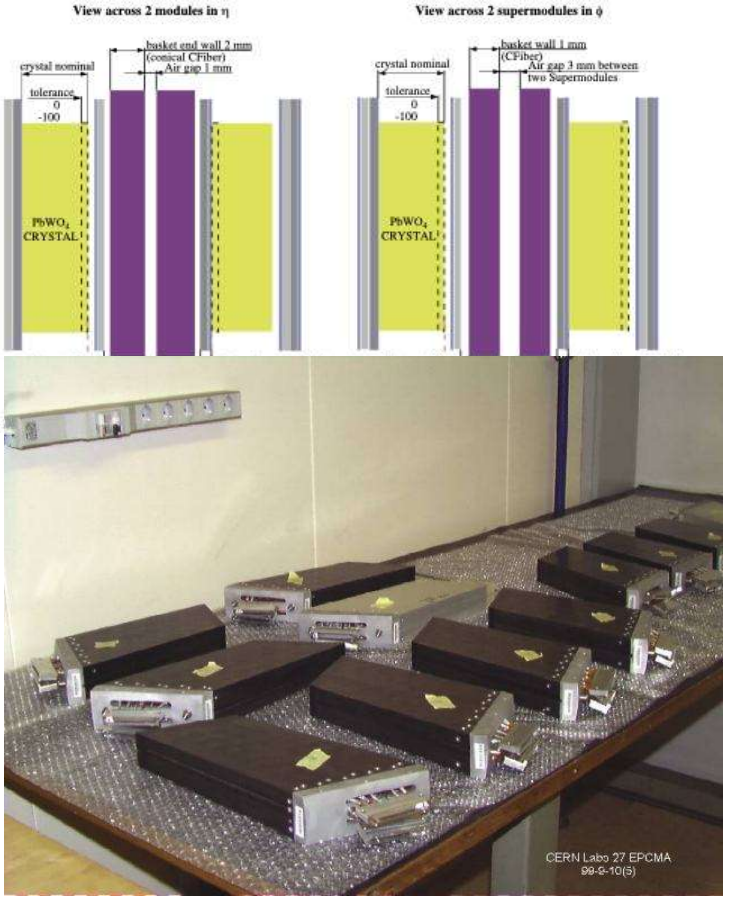
SIC (China)

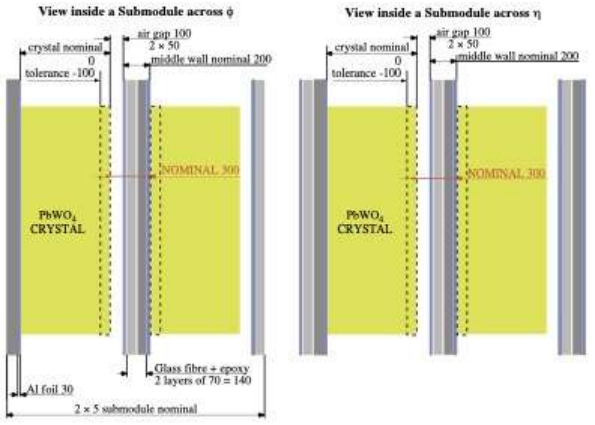
EB	1815
EE	2668

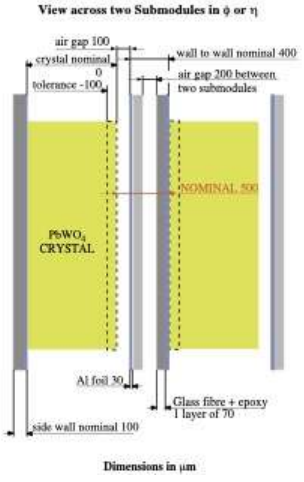
Minsk, Bogorodysk (BCTP), Protvino

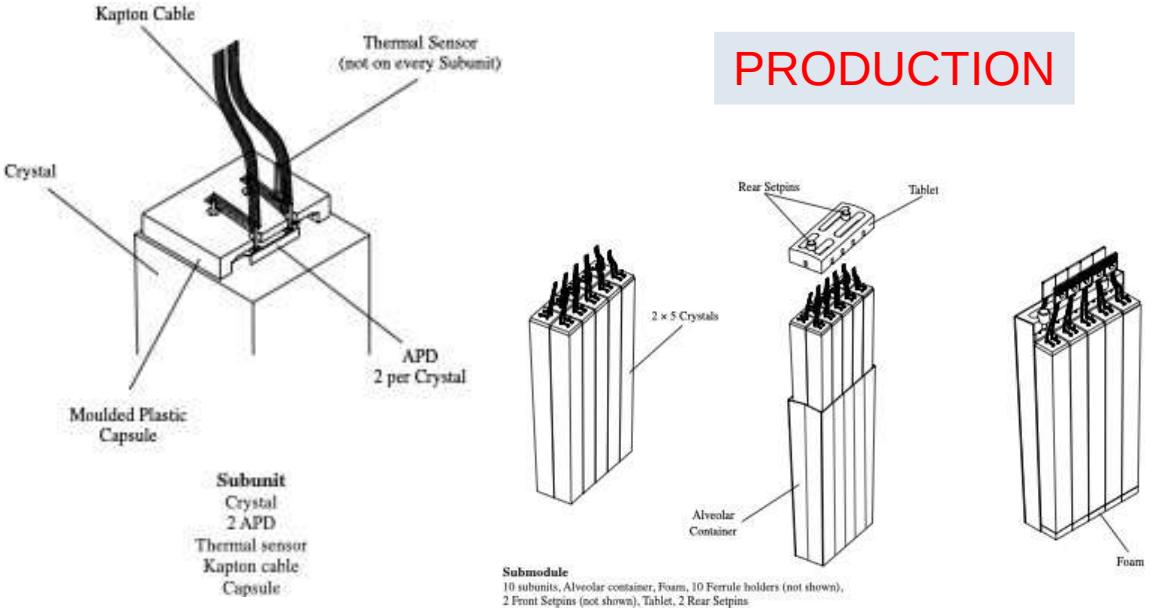
1995-1999	Optimisation des choix
Choix	Mécanique (simulations) Stabilisations temperatures (2 %/degré) Outillages

LLR
IPNL
INFN
ETHZ
CERN

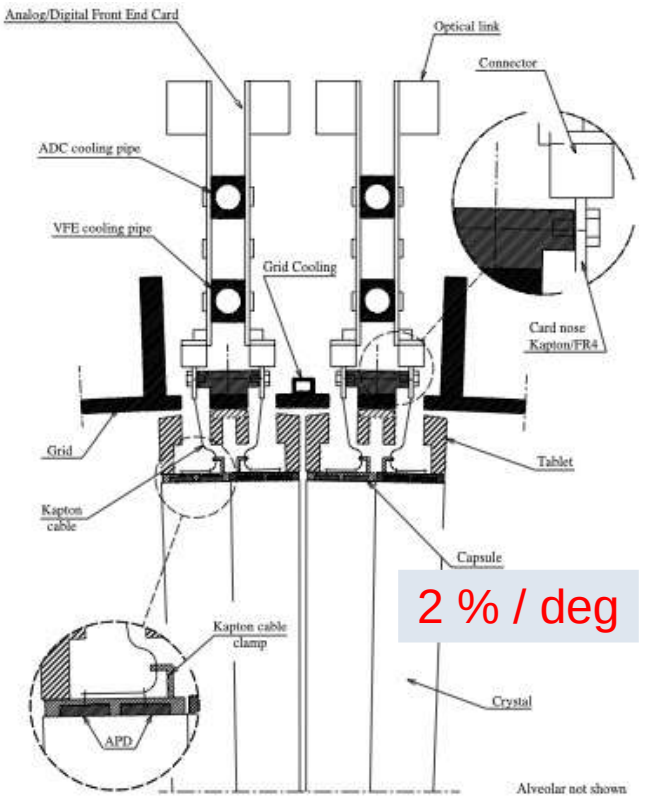

View across 2 modules in η
crystal nominal
basket end wall 2 mm (conical CFiber)
Air gap 1 mm
tolerance 0 -100
PbWO4 CRYSTAL
View across 2 supermodules in ϕ
crystal nominal
basket wall 1 mm (CFiber)
Air gap 3 mm between two Supermodules
tolerance 0 -100
PbWO4 CRYSTAL
CERN Labo 27 EPCMA 99-9-10(5)


View inside a Submodule across ϕ
crystal nominal
air gap 100
2 × 50
middle wall nominal 200
tolerance 0 -100
NOMINAL 300
PbWO4 CRYSTAL
Glass fibre + epoxy 2 layers of 70 = 140
Al foil 30
2 × 5 submodule nominal
View inside a Submodule across η
crystal nominal
air gap 100
2 × 50
middle wall nominal 200
tolerance 0 -100
NOMINAL 300
PbWO4 CRYSTAL


View across two Submodules in ϕ or η
air gap 100
crystal nominal
wall to wall nominal 400
air gap 200 between two submodules
tolerance 0 -100
NOMINAL 500
PbWO4 CRYSTAL
Al foil 30
Glass fibre + epoxy 1 layer of 70
side wall nominal 100
Dimensions in μm



PRODUCTION

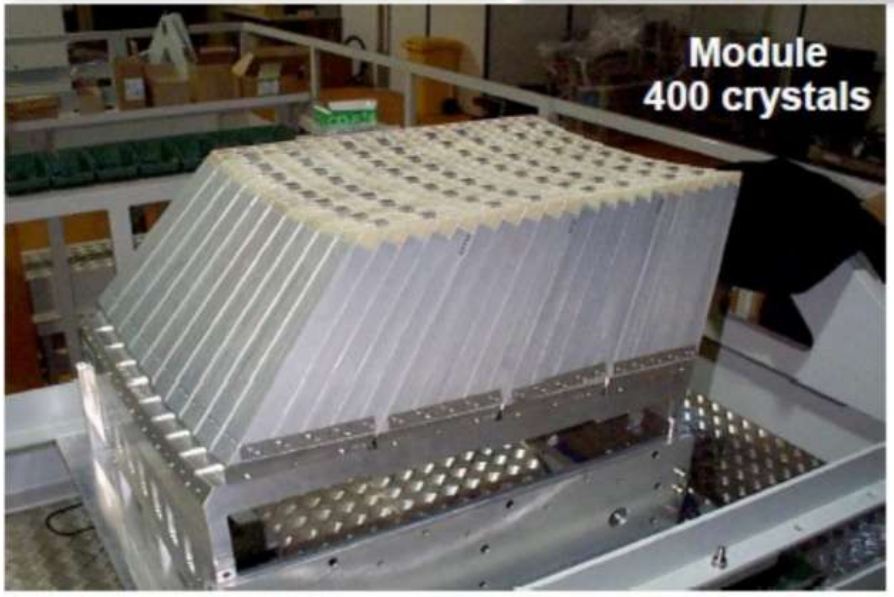


2 % / deg

LLR
IPNL
INFN Roma
ETHZ
CERN

0.05 deg

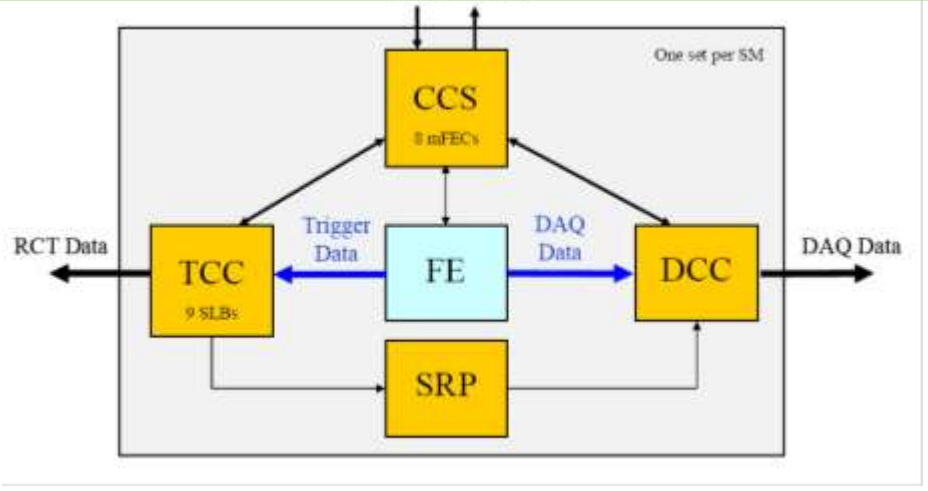
PRODUCTION



Total 36 Supermodules

Electronique

CERN, RAL, IC
cmos 250 nm développement avec le Tracker
Carte ETHZ , **Saclay** , Turin, IPNL

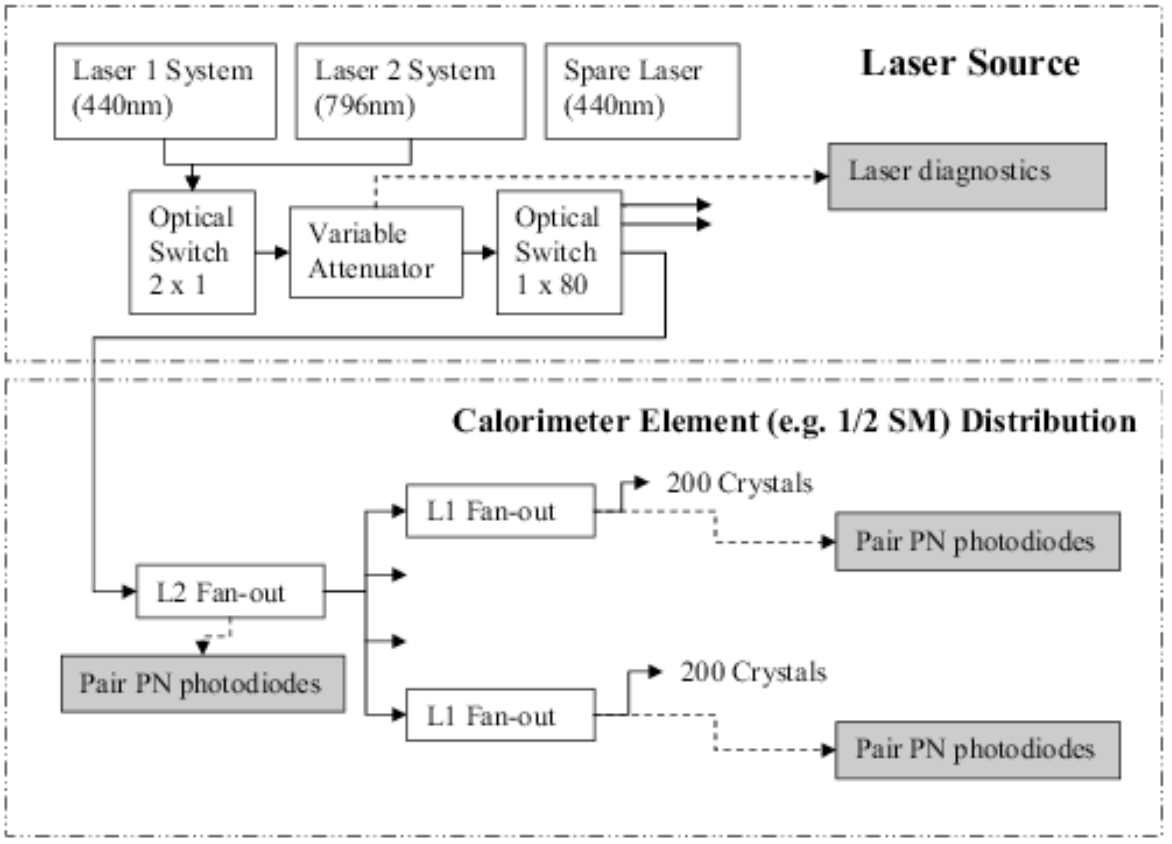


LLR
Voir A.Zabi

LIP

Saclay

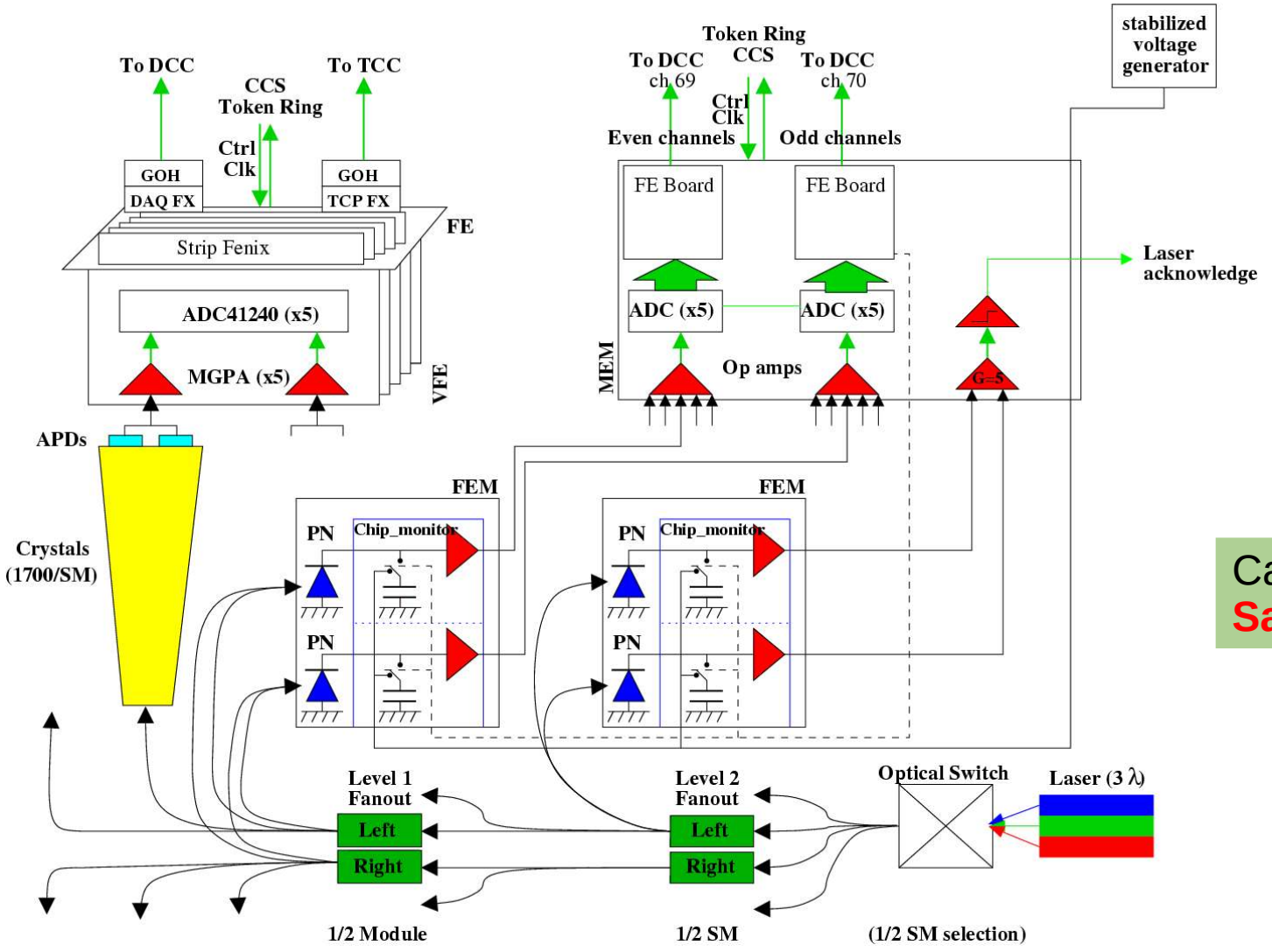
Monitoring



CALTECH

SACLAY

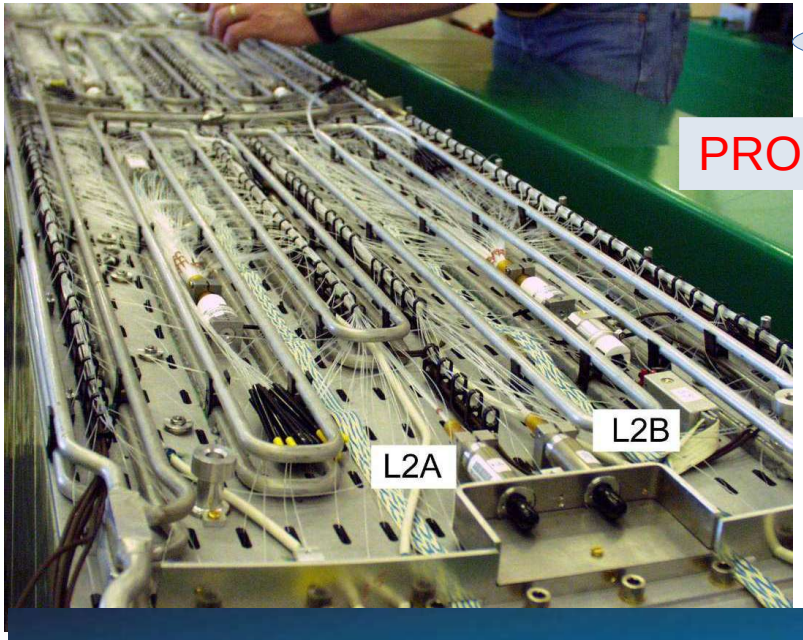
Monitoring



Caltech (laser)
Saclay

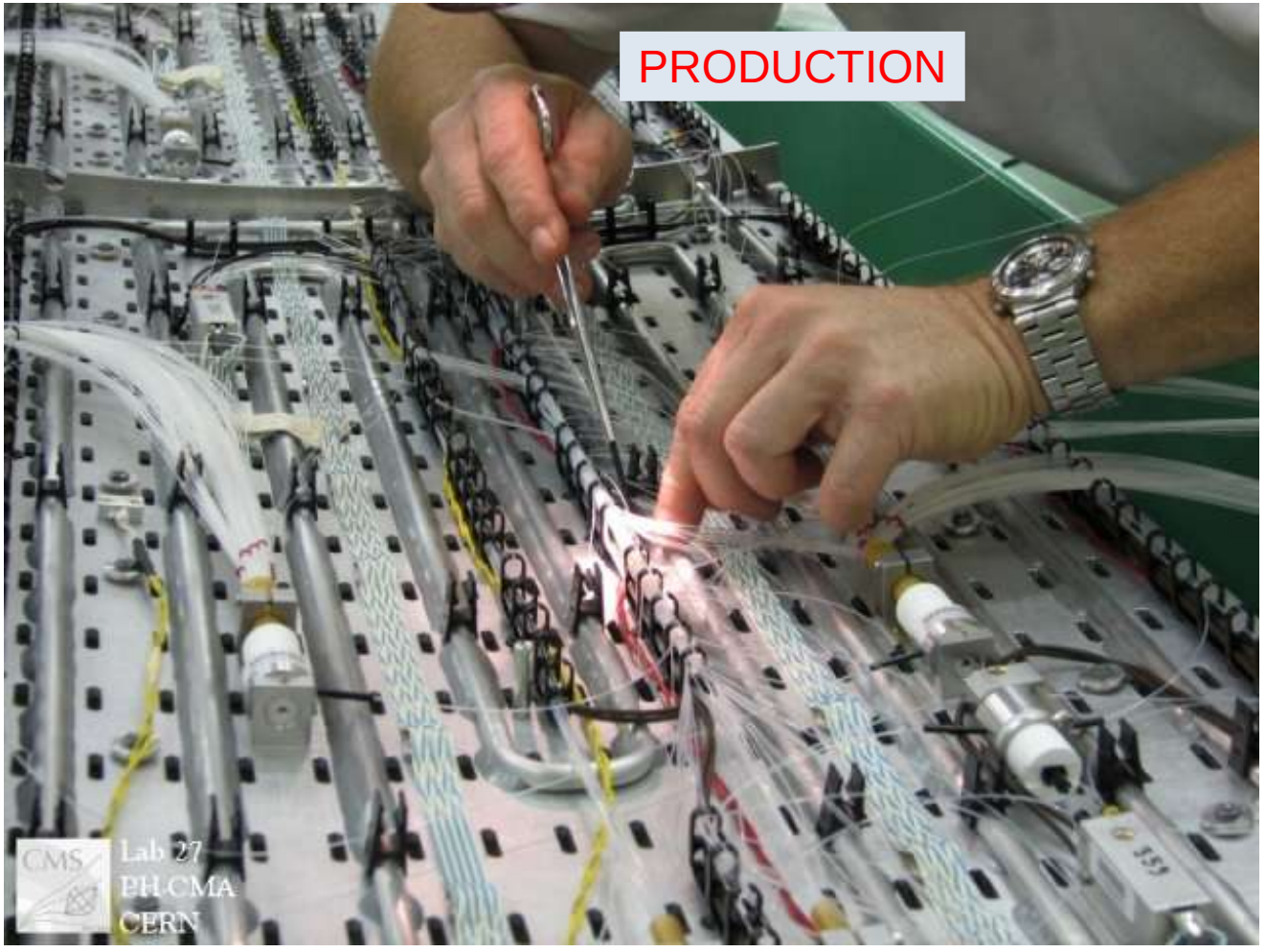
Tenue aux rayonnements

PRODUCTION



Monitoring

Saclay



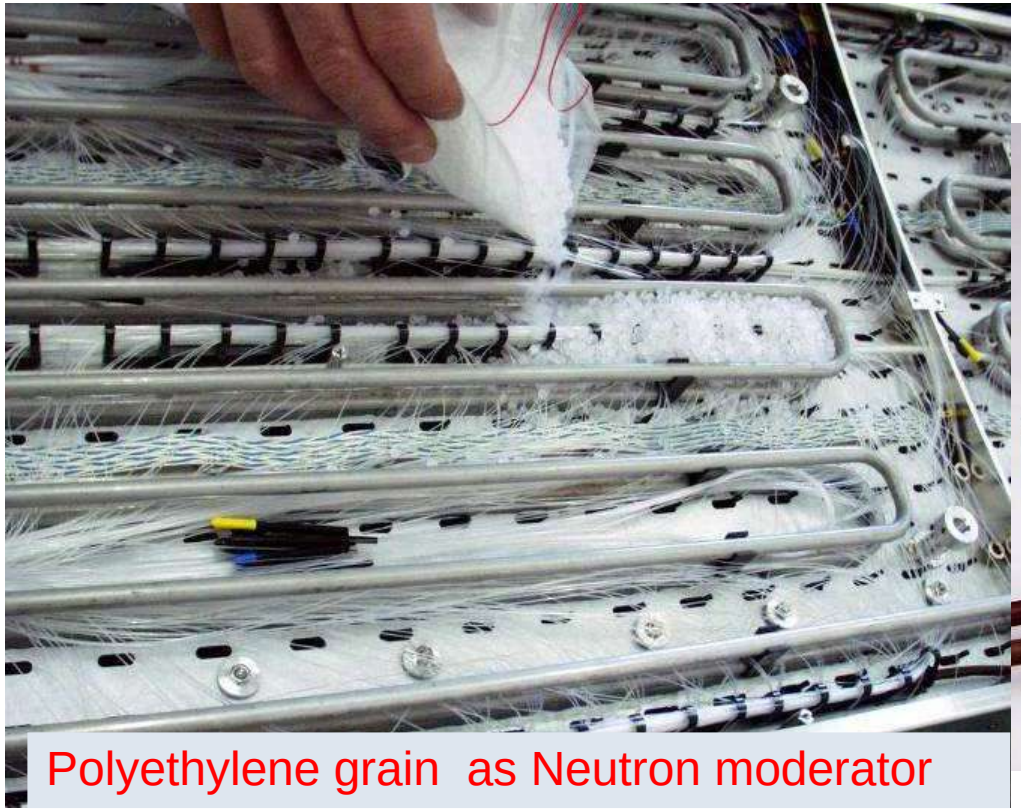
Monitoring

Saclay

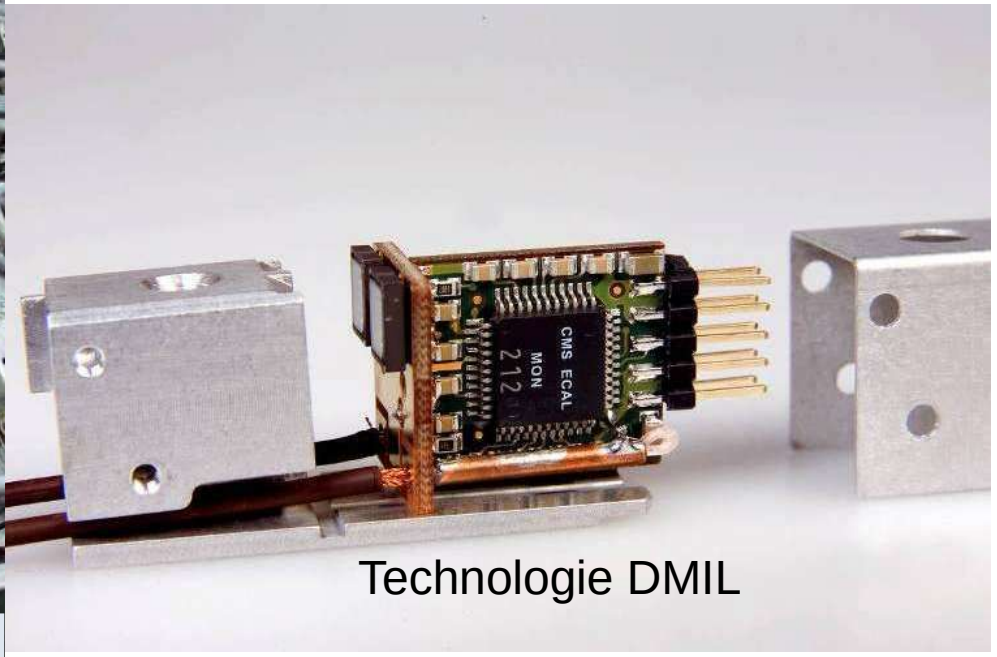
PRODUCTION

Monitoring

Saclay



Polyethylene grain as Neutron moderator



Technologie DMIL

Monitoring

Saclay

PRODUCTION

Electronique
Installation

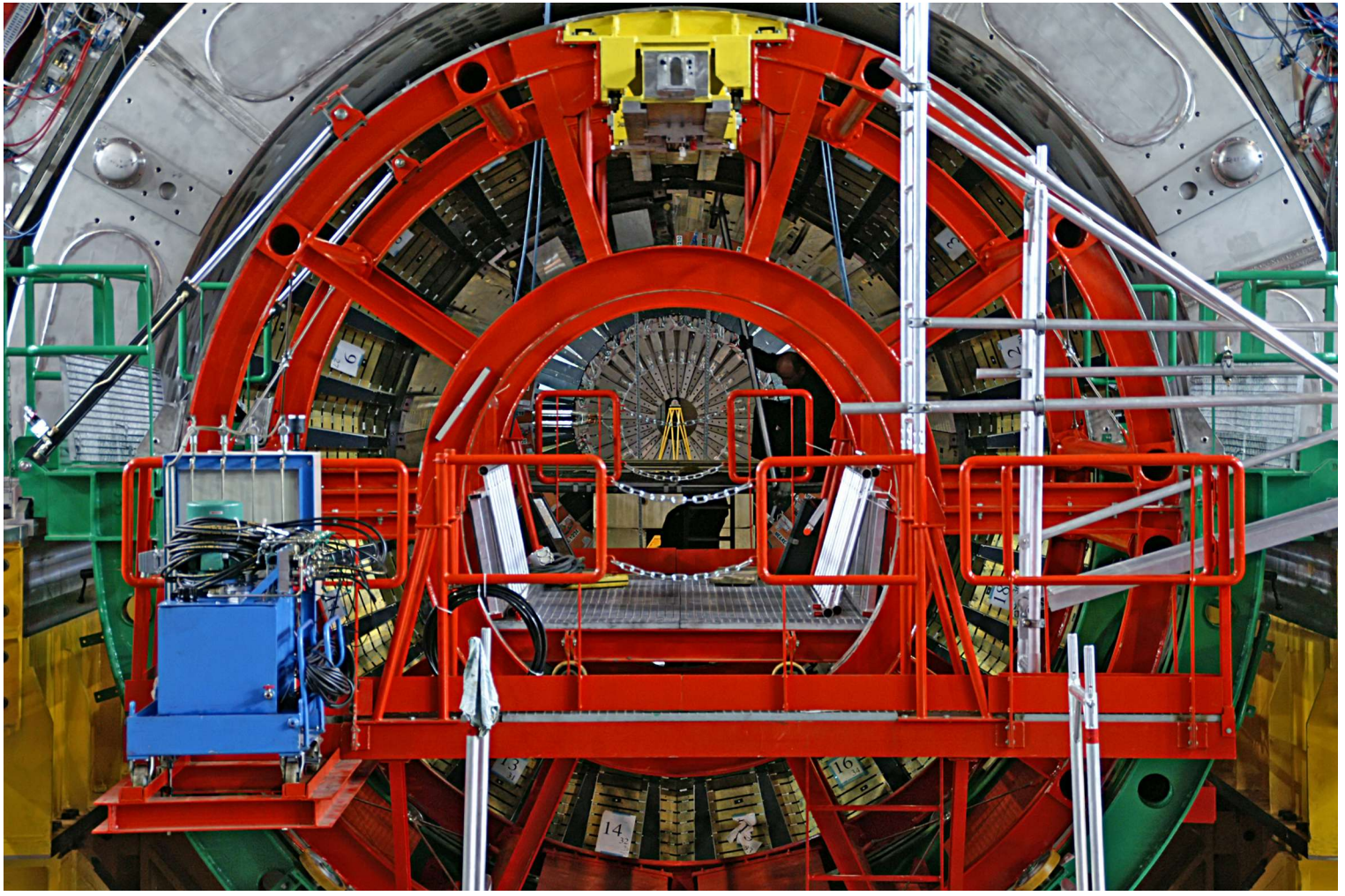
Organisation ETHZ
Tout les groupes ECAL-CMS

PRODUCTION

Test
et
Pré-calibration

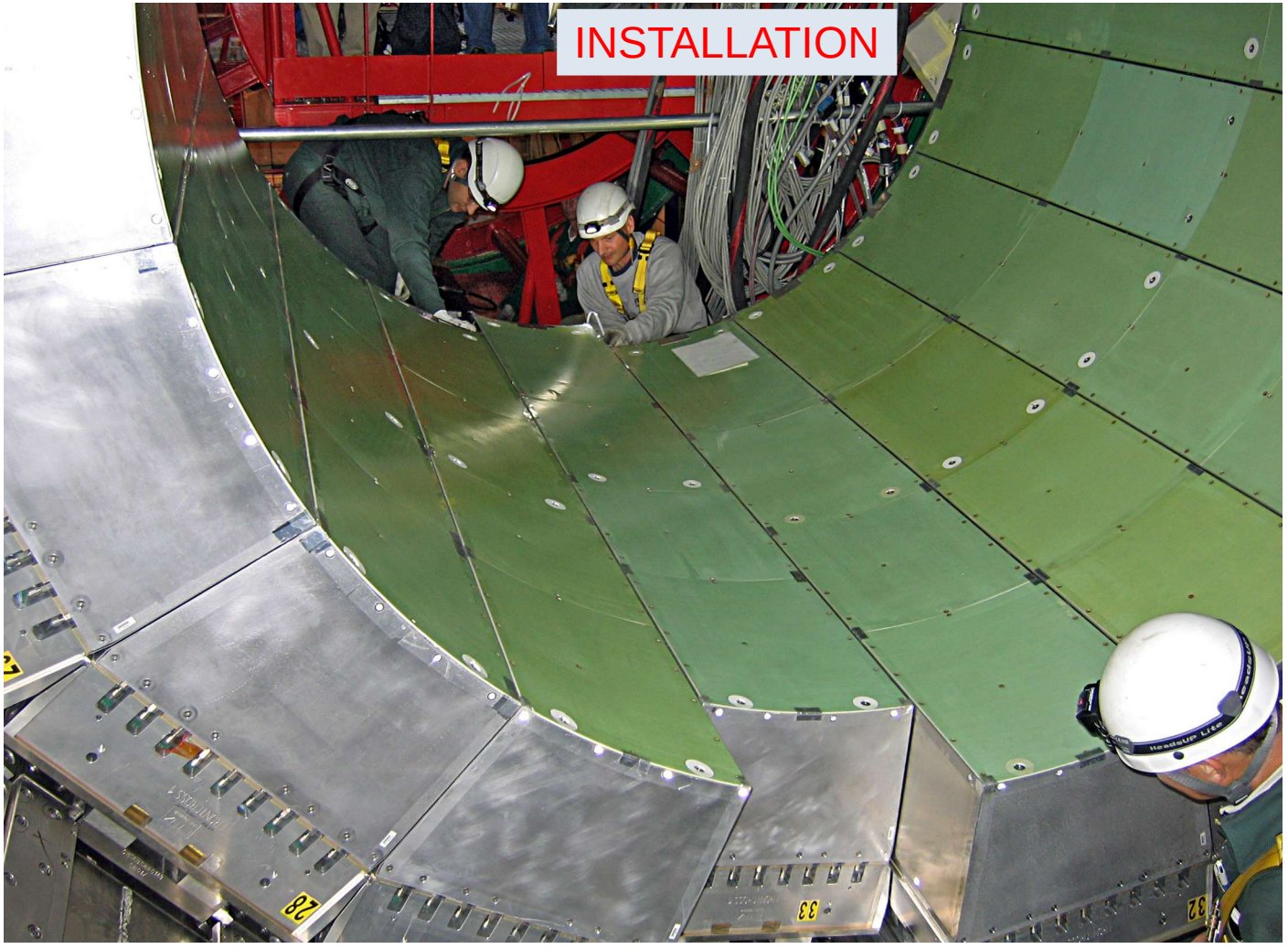
Test beam H4

Saclay / LLR
IPNL

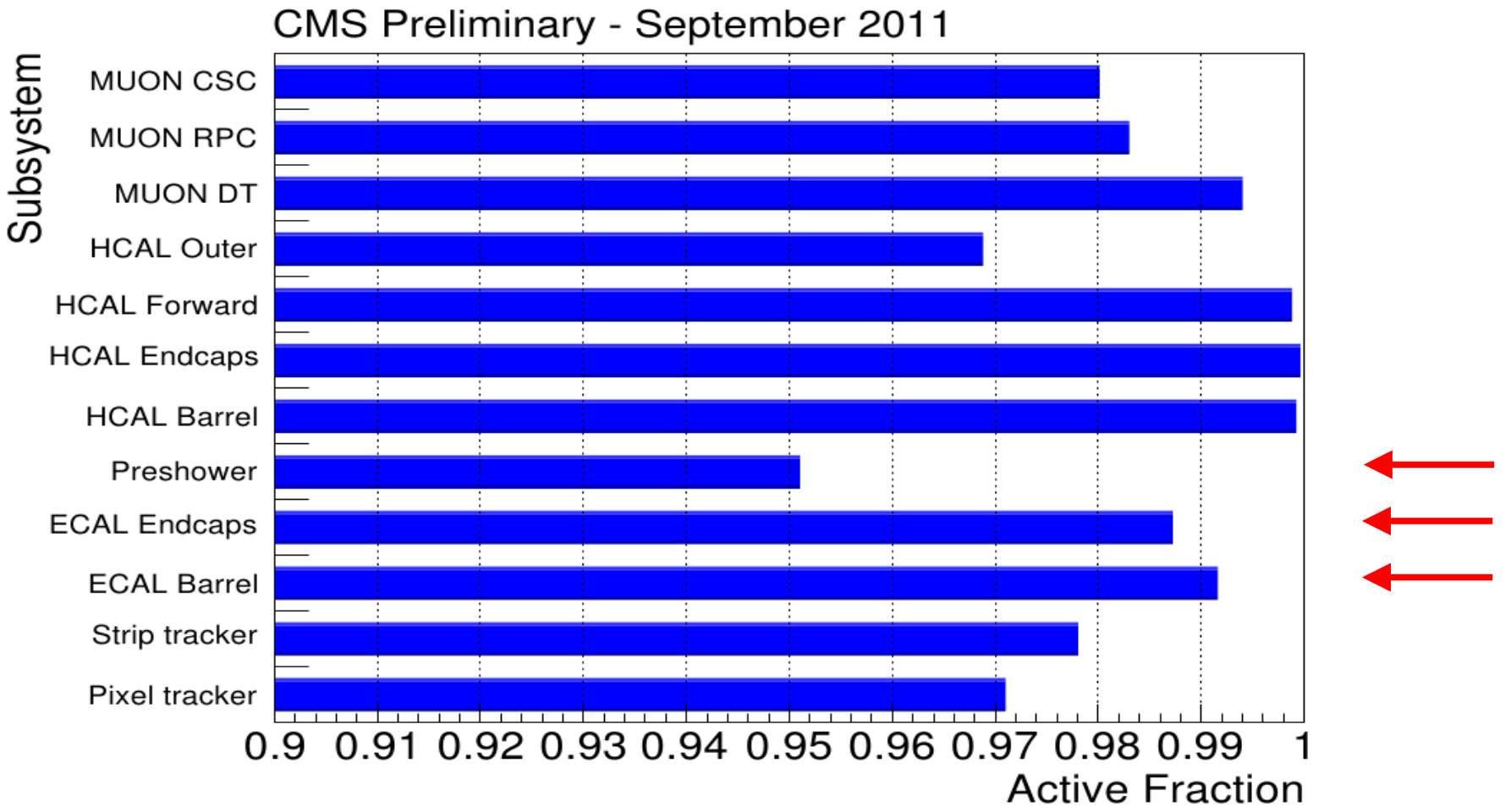


Enfourneur

Saclay
et
Cern



Cern


CMS Preliminary - September 2011
Subsystem
MUON CSC
MUON RPC
MUON DT
HCAL Outer
HCAL Forward
HCAL Endcaps
HCAL Barrel
Preshower
ECAL Endcaps
ECAL Barrel
Strip tracker
Pixel tracker
0.9
0.91
0.92
0.93
0.94
0.95
0.96
0.97
0.98
0.99
1
Active Fraction

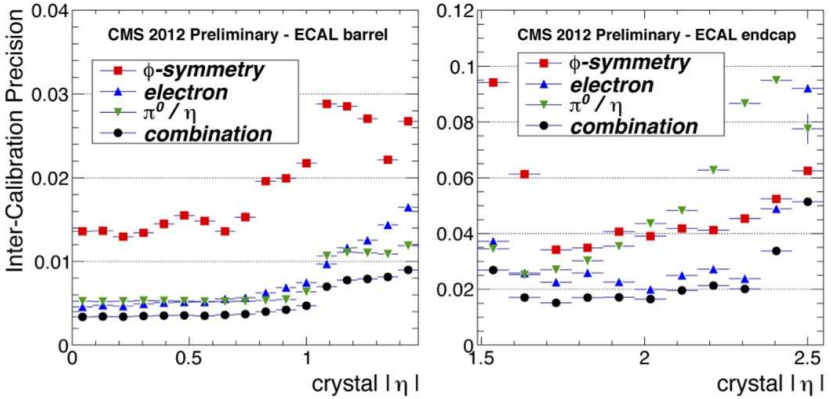


Fig. 5. Precision of single channel inter-calibration, using energy deposits, as functions of pseudorapidity for the CMS ECAL barrel (left) and endcaps (right) in 2012

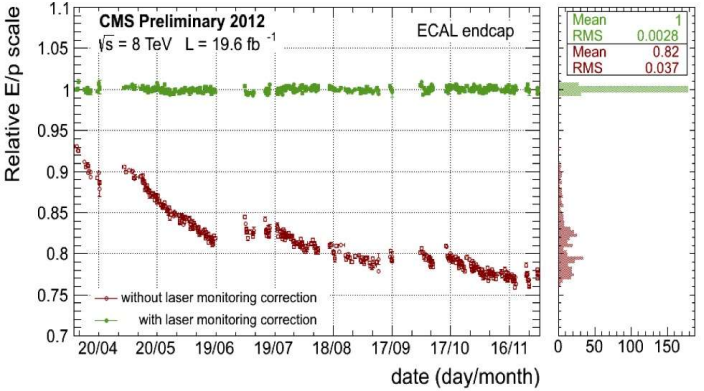
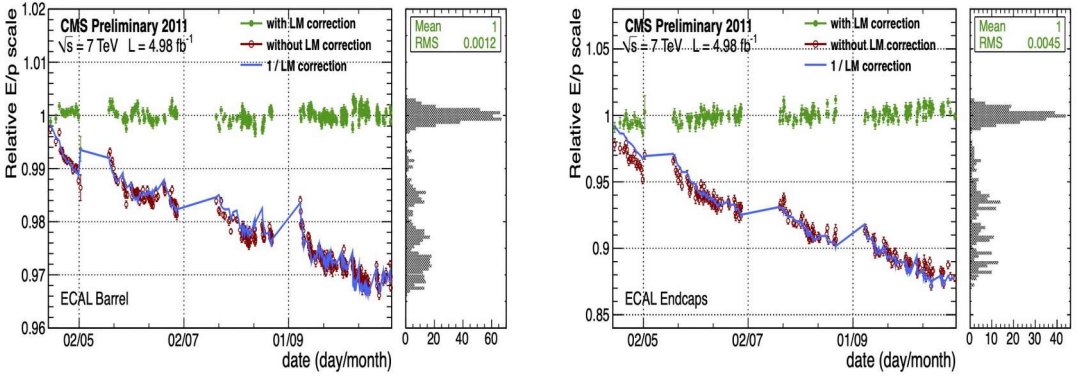


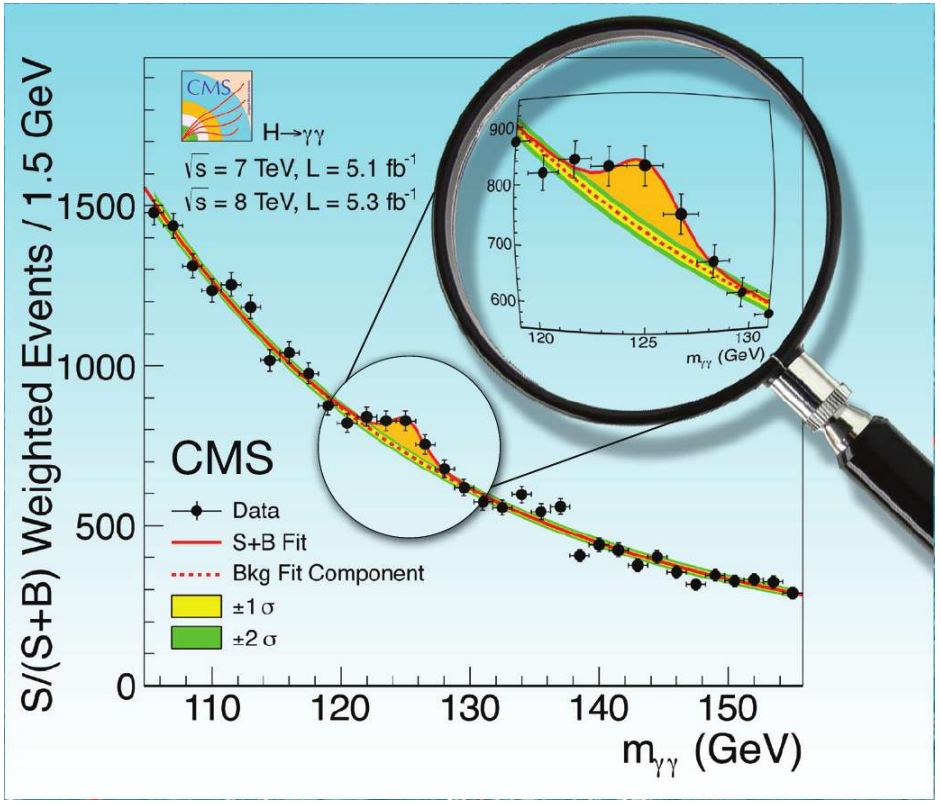
Fig. 7. History plots for 2012 data of the ratio of electron energy E, measured in the ECAL endcaps, to the electron momentum p, measured in the tracker, before and after correcting for response losses using the laser monitoring system

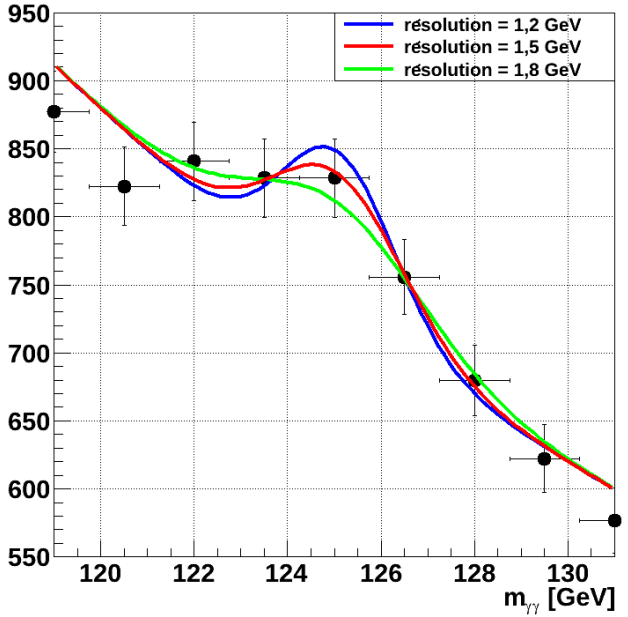


Détails dans la présentation de Fabrice Couderc

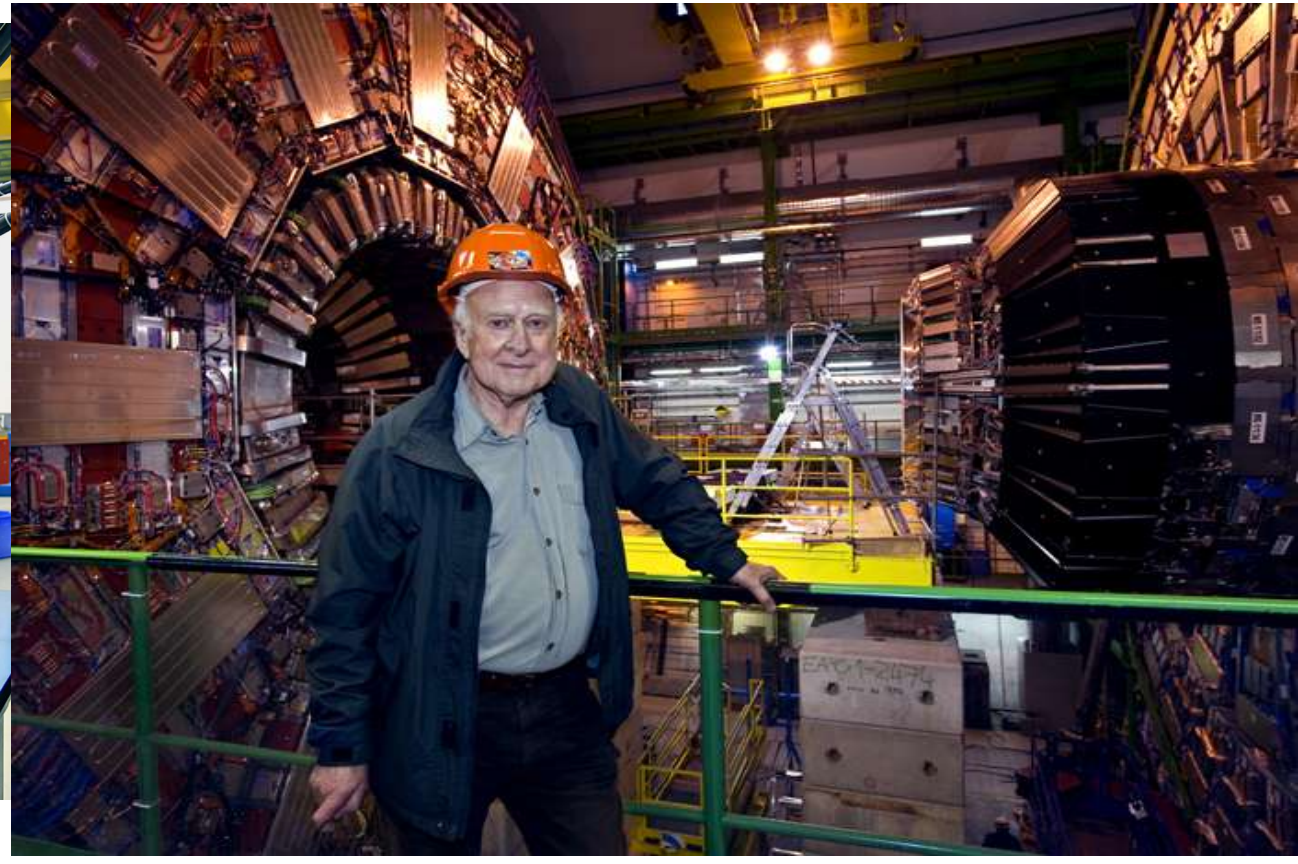
$$\frac{\sigma}{E} = \frac{3\,\%}{\sqrt{(E)}} \oplus 0.39\% \oplus \frac{129MeV}{E}$$

Figure 6. Stability of the energy response of the barrel (left) and endcap (right) from the ratio of electron energy E, measured in the ECAL to the electron momentum p measured in the tracker, before (red points) and after (green points) response corrections are applied.





$$\frac{\sigma_m}{m} = \frac{1}{2}\left(\frac{\sigma_{E_1}}{E_1} \oplus \frac{\sigma_{E_2}}{E_2} \oplus \frac{\sigma_\vartheta}{\tan\vartheta/_2}\right)$$

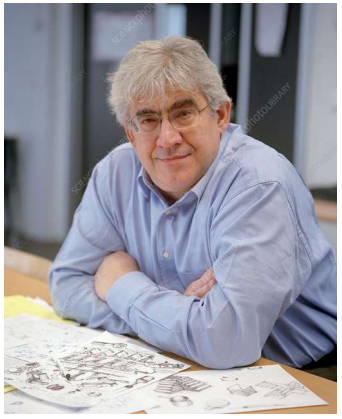


Visites de personnalités pendant la construction

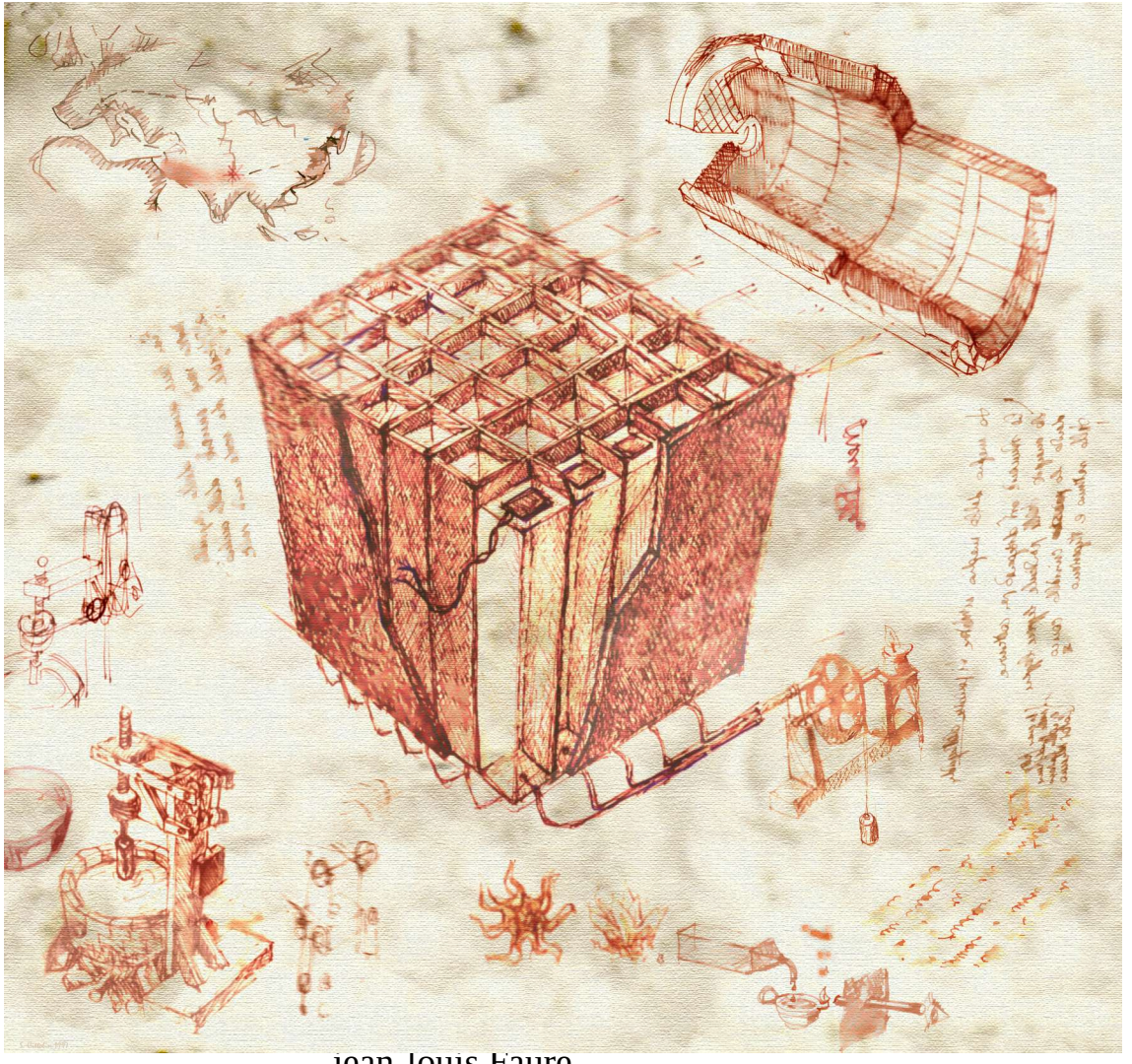
Merci

Visa-Russie-jlf-1994

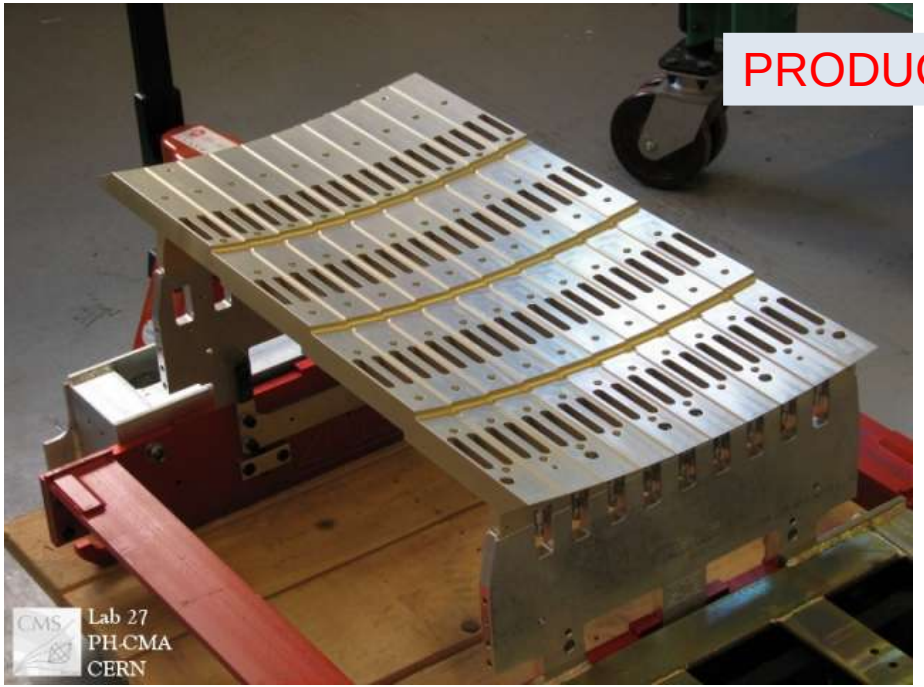
Annexes-Compléments

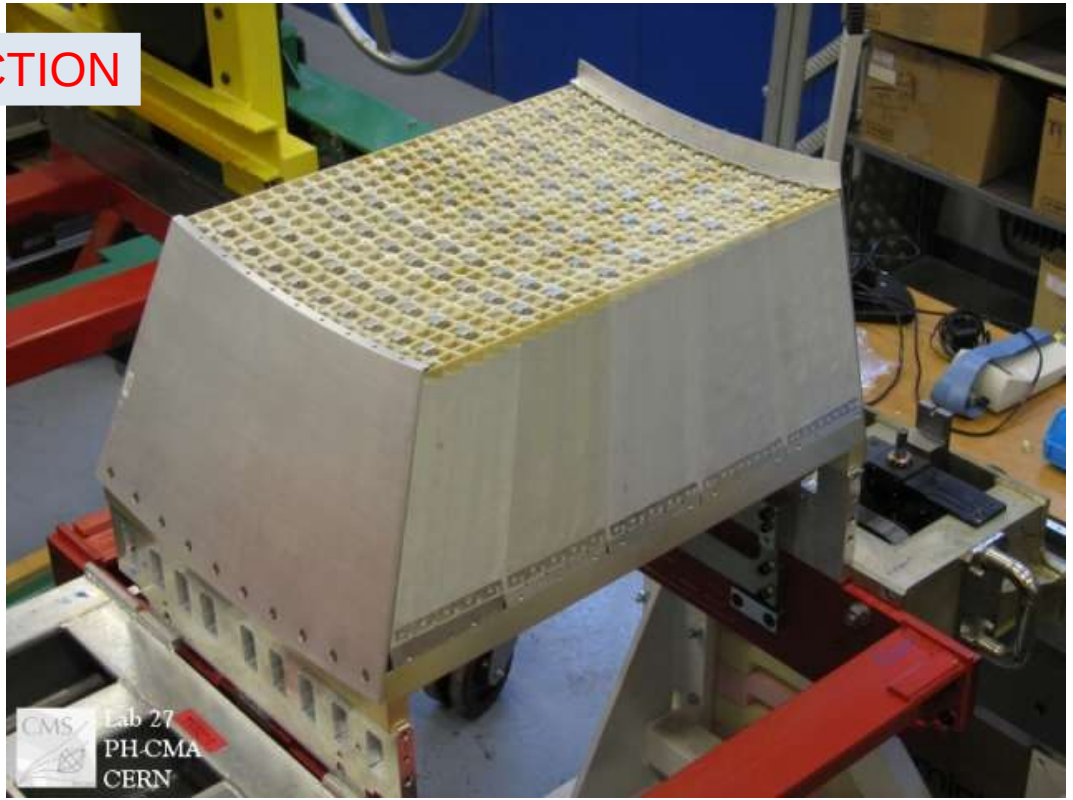


Sergio Cittolin



PRODUCTION

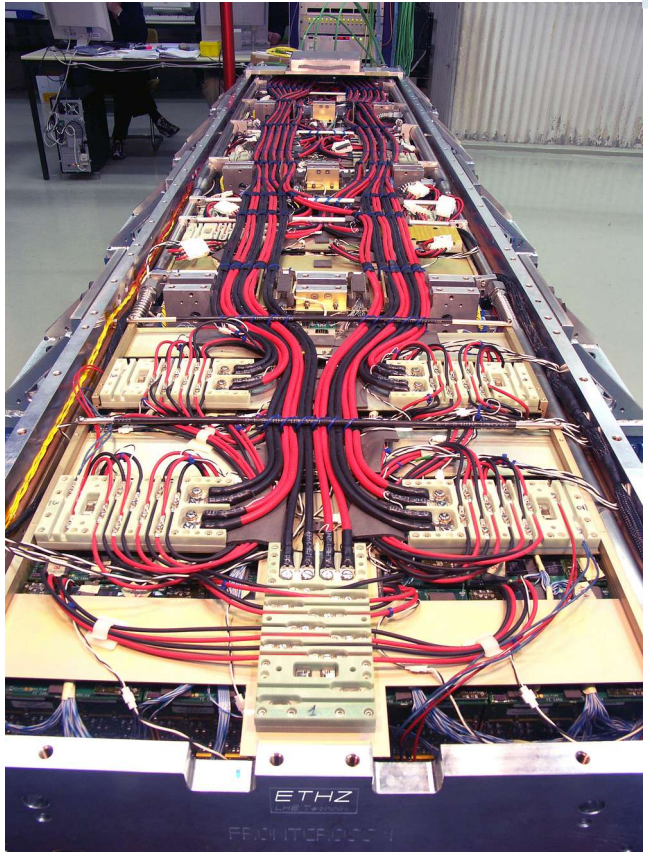


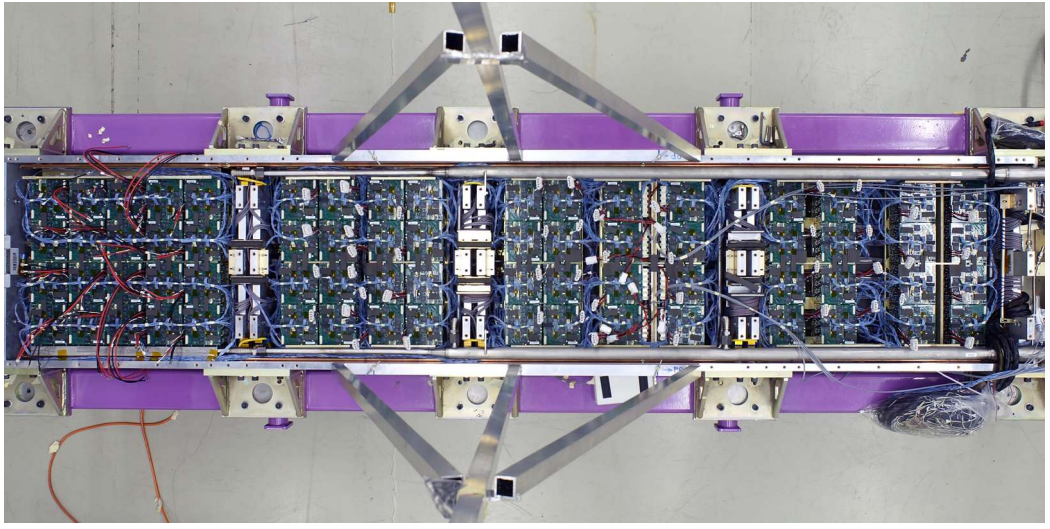


PRODUCTION

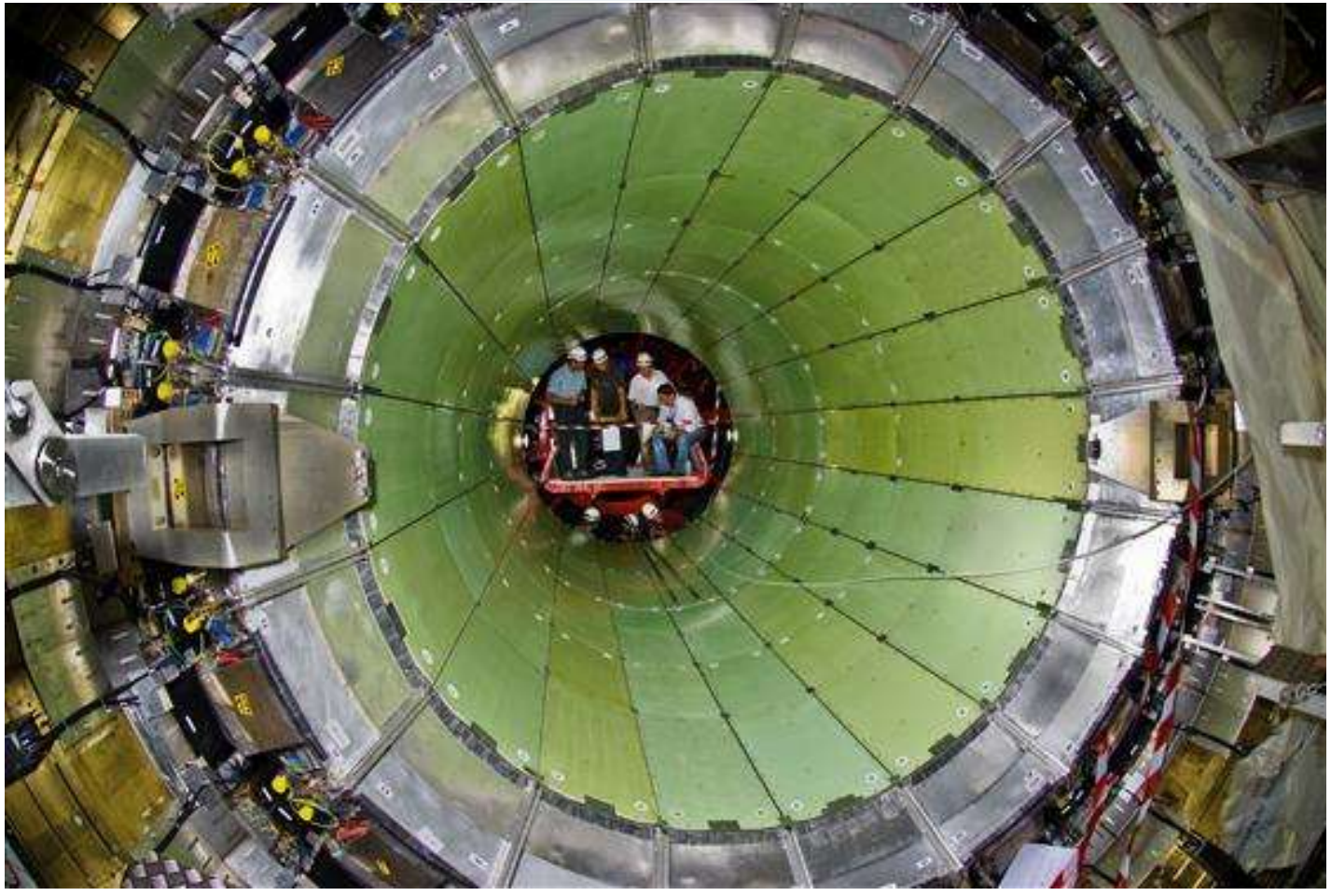
Electronique
Installation

Organisation ETHZ
Tout les groupes ECAL-CMS





INSTALLATION



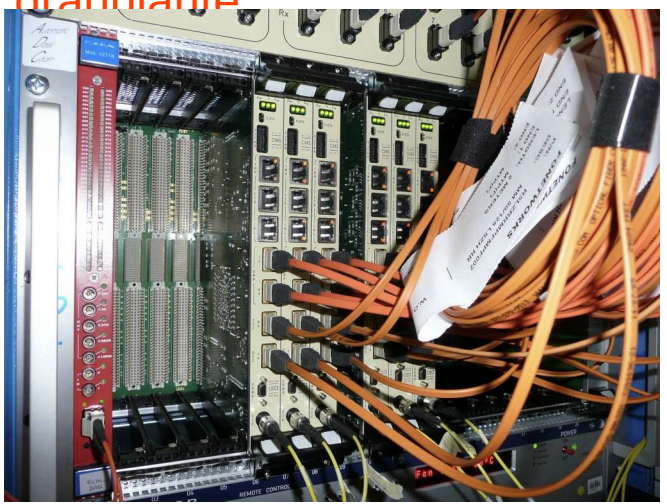
Cern

ECAL: 75848 cristaux – canaux de lecture
4032 unités de déclenchement (lecture synchrone 40 MHz)
3072 unités de lecture (lecture asynchrone)

Lecture totale ECAL(1,5 Mo) > Taille événement CMS (1 Mo): Impossible!
SRP: Réduction intelligente /20 (sans perdre d'information pour la physique)
Pas de suppression de zéros massive
Lecture de zones d'intérêt hiérarchisées
Lecture de tous les dépôts d'énergie avec une grosse granularité

Cartes de SRP faites à Saclay et opérationnelles depuis le début de la prise de données

Saclay



Center Highlights in 1999

CERN - ISTC: Partnership in Progress

In 1999, the European Center for Nuclear Research (CERN) continued its active support, participation,
and funding for ISTC projects in high energy physics. CERN is now Partner or Collaborating organization on
more than 20 continuing or planned ISTC projects.

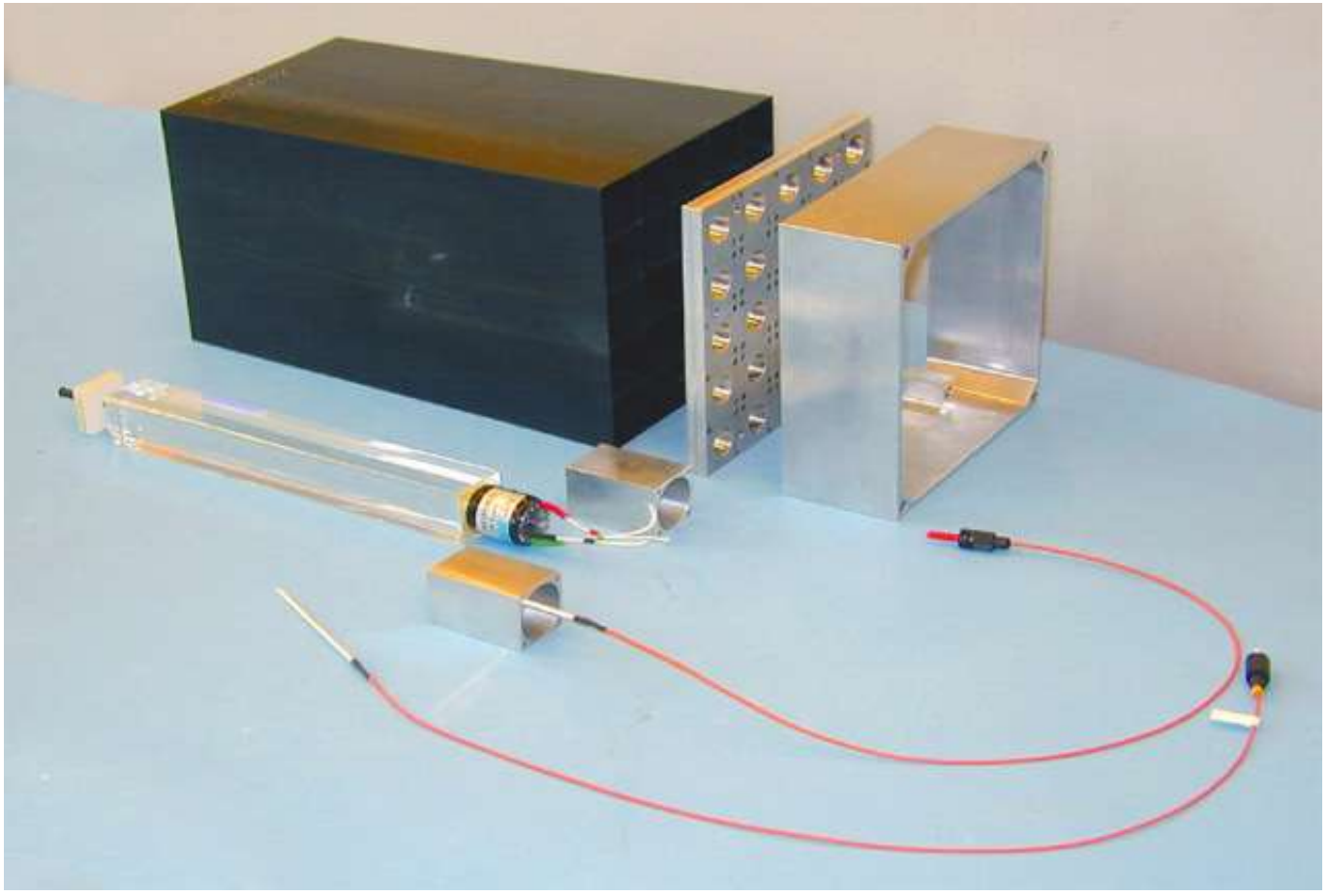
On Monday, 22 November, major collaboration contracts were finalized between CERN and
the ISTC. These contracts, worth more than 12 million Swiss Francs, are a large step forward
in the cooperation between these two institutions. The agreement, which almost doubles the
financial support for the ISTC Partner Program, will result in new technical equipment for
CERN's latest project, the Large Hadron Collider (LHC). The two organizations finalized the
contracts within the framework of the ISTC Partner Program which was developed in 1997.
There are almost 60 Partners, e.g. electrical, biomedical or chemical industries or research
centers such as CERN. The contribution of the contracts with these Partners amounts to
about 14 million US Dollars. With the contracts finalized, almost 13 million Swiss Francs will
be added to this sum.

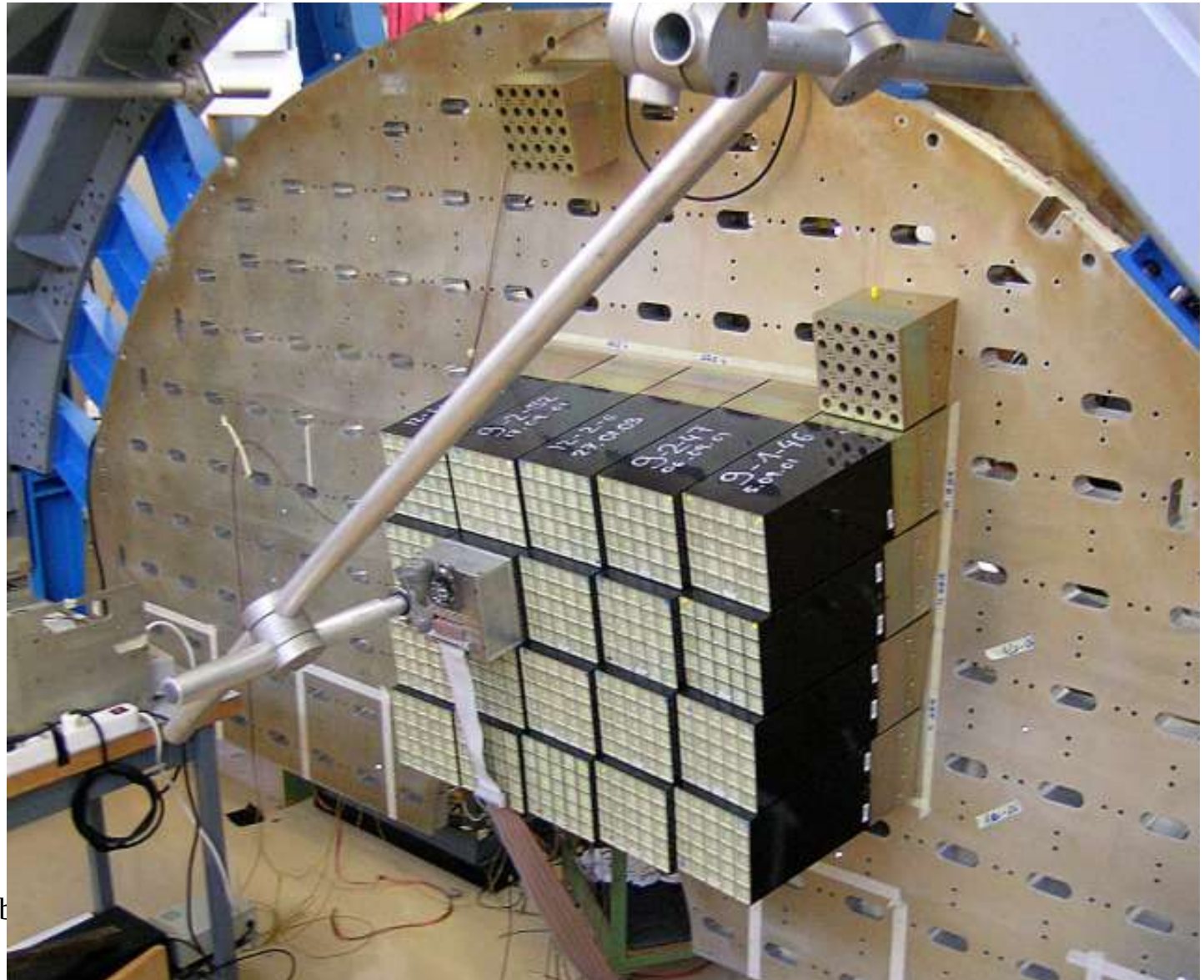
"Clearly the ISTC has come of age. The confidence of governments, the analysis of experts and the reviews of independent professionals have documented the effective operation
of the Center. That is why the High Energy Physics Community
at CERN has chosen to entrust to
the Center major research and development projects of critical importance to the timely construction of the LHC detectors.
We are looking forward to state of the art contributions from our Russian and other NIS colleagues
in the years to come with the effective mediation and support of
ISTC."
Roger Cashmore -
Research Director, CERN

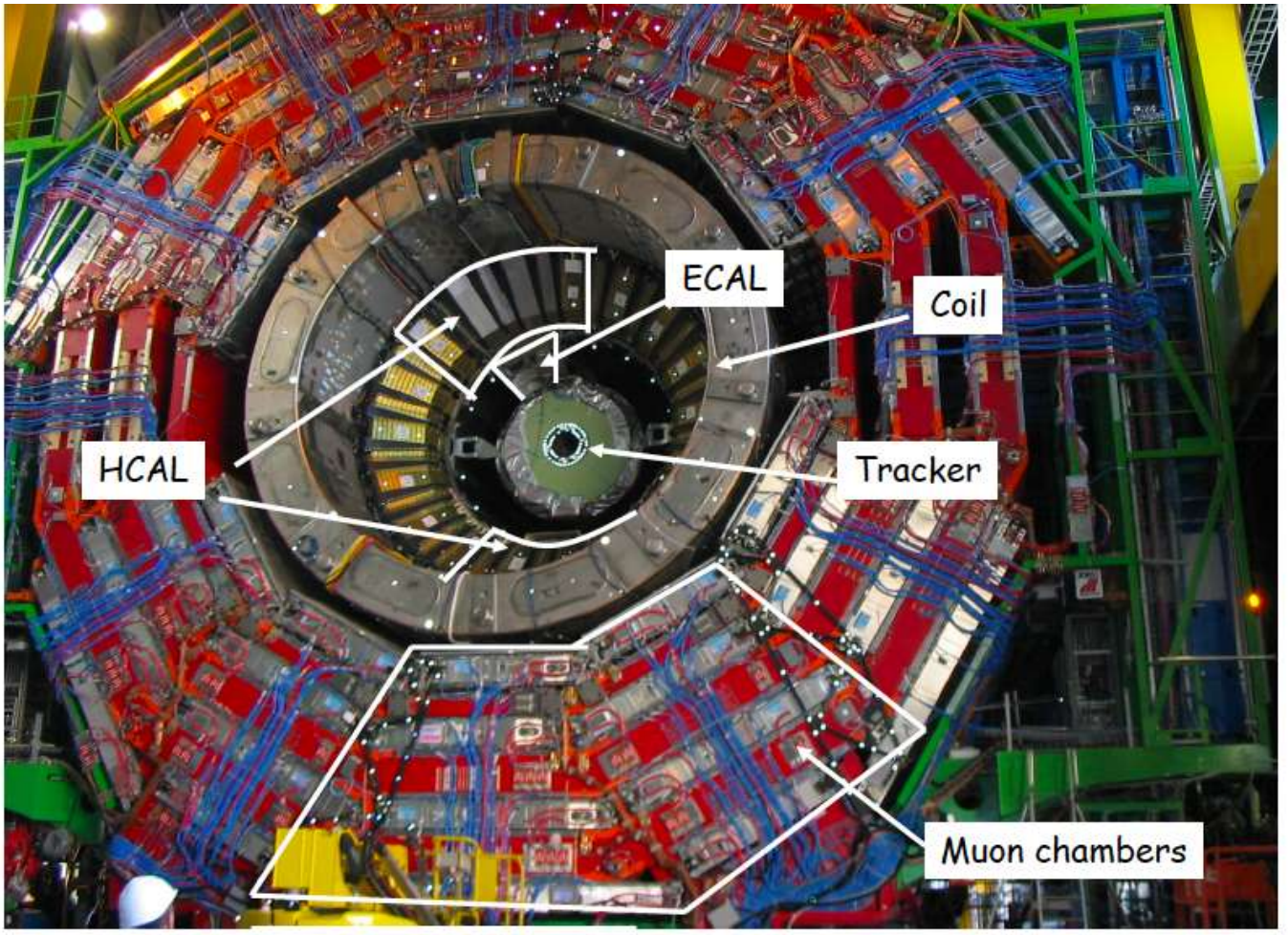
The activities of the present R&D are the common responsibility of all institutions each of them taking part of the whole work which is shared as given in the table 10.

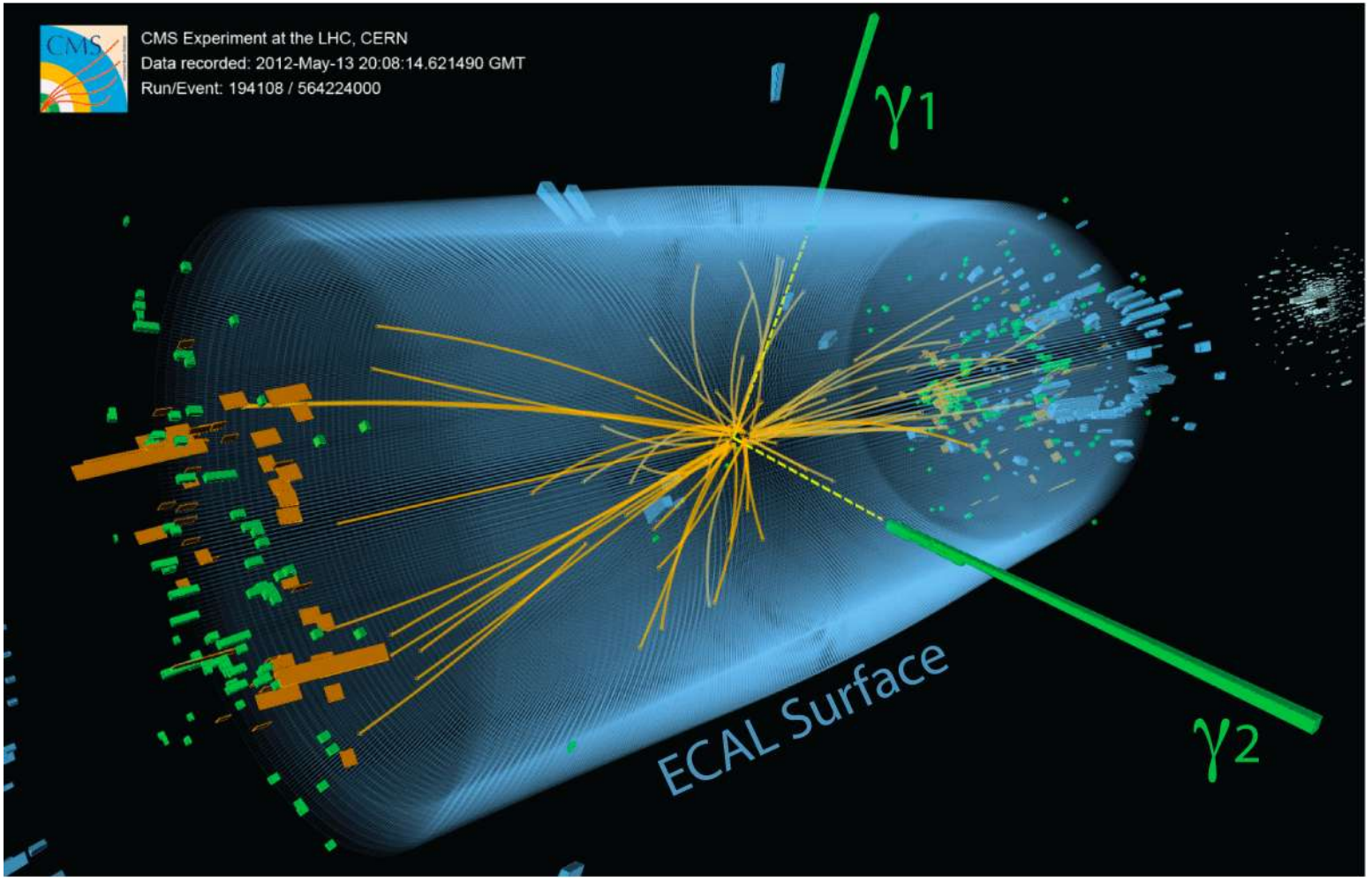
Institution	Shashlik Calorimeter	Preshower	Radiation	Simulation
Brunel			• Irradiation • radiation tests	
DUBNA		• Si det. production • Mec. for prototypes • Test beam DAQ	• n irradiation • radiation tests	• Simulation: - Shashlik - Preshower
CERN	• Finite element • Test beam DAQ • Readout	• Structure design • Mec. for prototypes • Readout electronic	• Irradiation at LiL	
Ecole Poly-technique	• Calo. design • prototypes • Readout	• Test beam DAQ	• Irradiation. • Data analysis	• Fast algorithms
IHEP (Protvino)	• Production of: - scintillator - WLS fibres • construction: - scint. mold – towers • Readout: - new detectors - low noise amplifiers		• Irradiation • Analysis of data	• light collection optimization
INR (Moscow)	• Production of: - scintillator - WLS fibres • construction: - scint. mold – towers • Readout: - new detectors - low noise amplifier • Monitoring	• Monte Carlo	• Irradiation • Analysis of data	• light collection optimization
Imperial College	• Finite elements • Calo. design • Readout: - photodiodes	• Test beam DAQ		
IPN Lyon	• Readout: - photodiodes - amplifiers			
ITEP	• Readout: - photodiodes			
LIP Lisboa				• Simulation: - Shashlik - Preshower
Rutherford Laboratory	• Finite elements • Calo. design • Readout: - photodiodes - amplifiers			

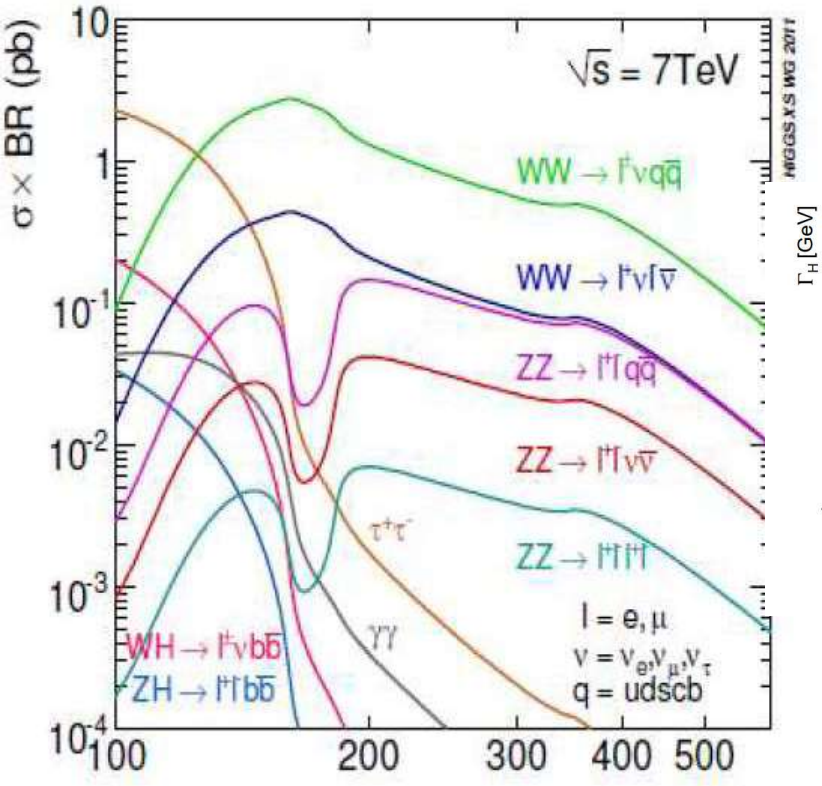
Table 10: Shashlik calorimetry activity sharing between the institutions involved in the R&D.

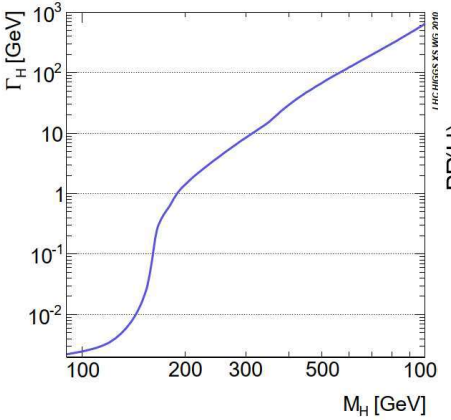


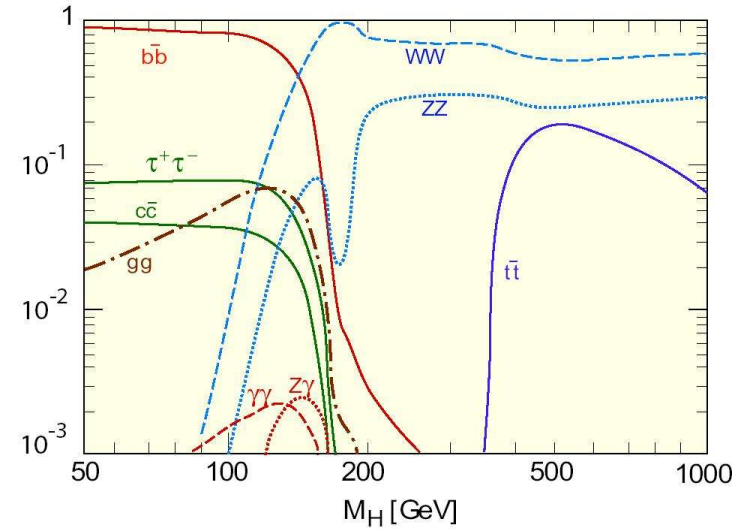



ECAL
Coil
HCAL
Tracker
Muon chambers

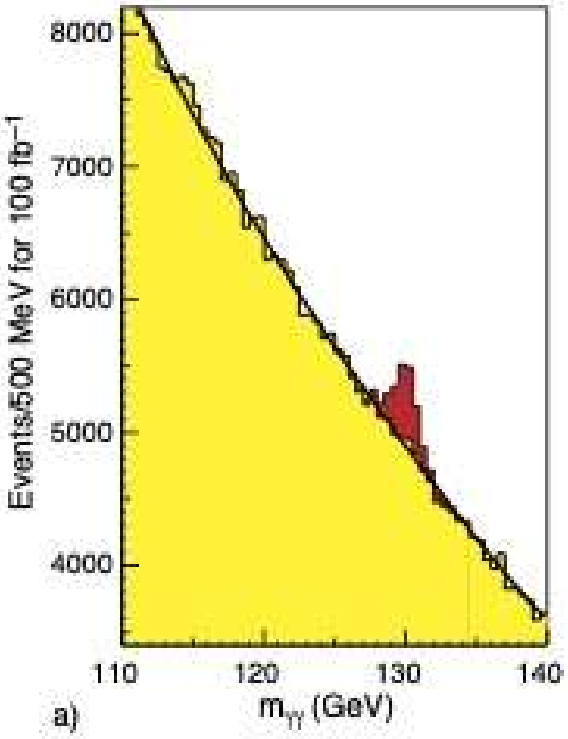

CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
γ1
ECAL Surface
γ2

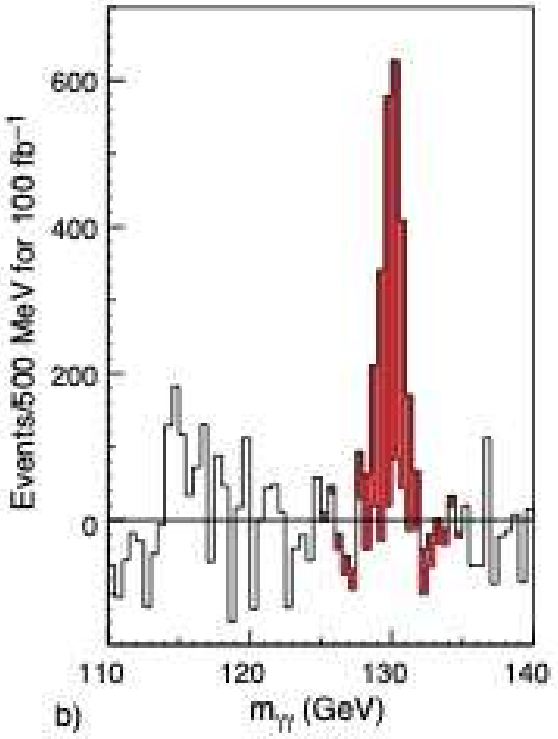


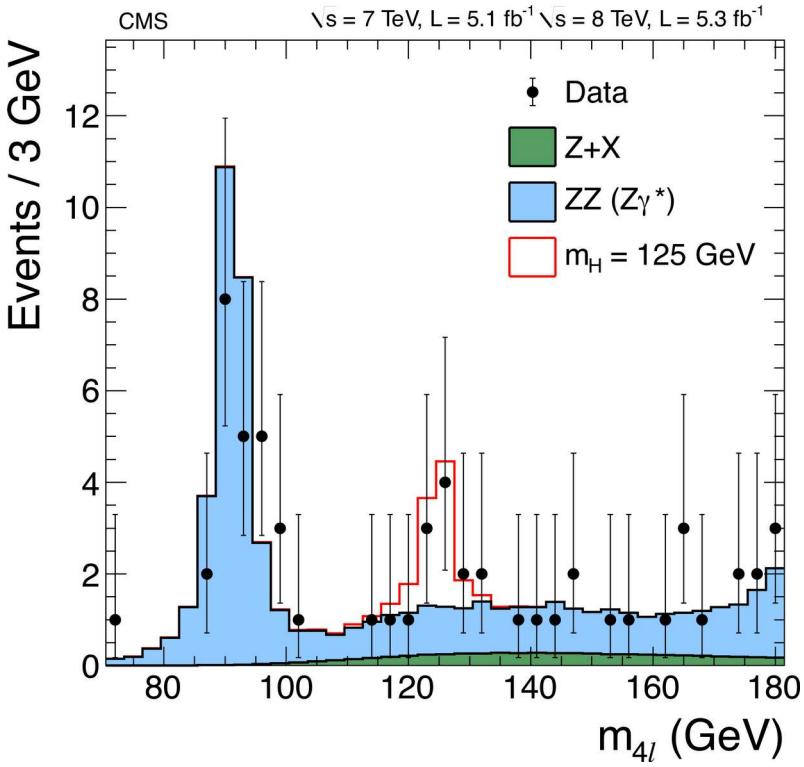


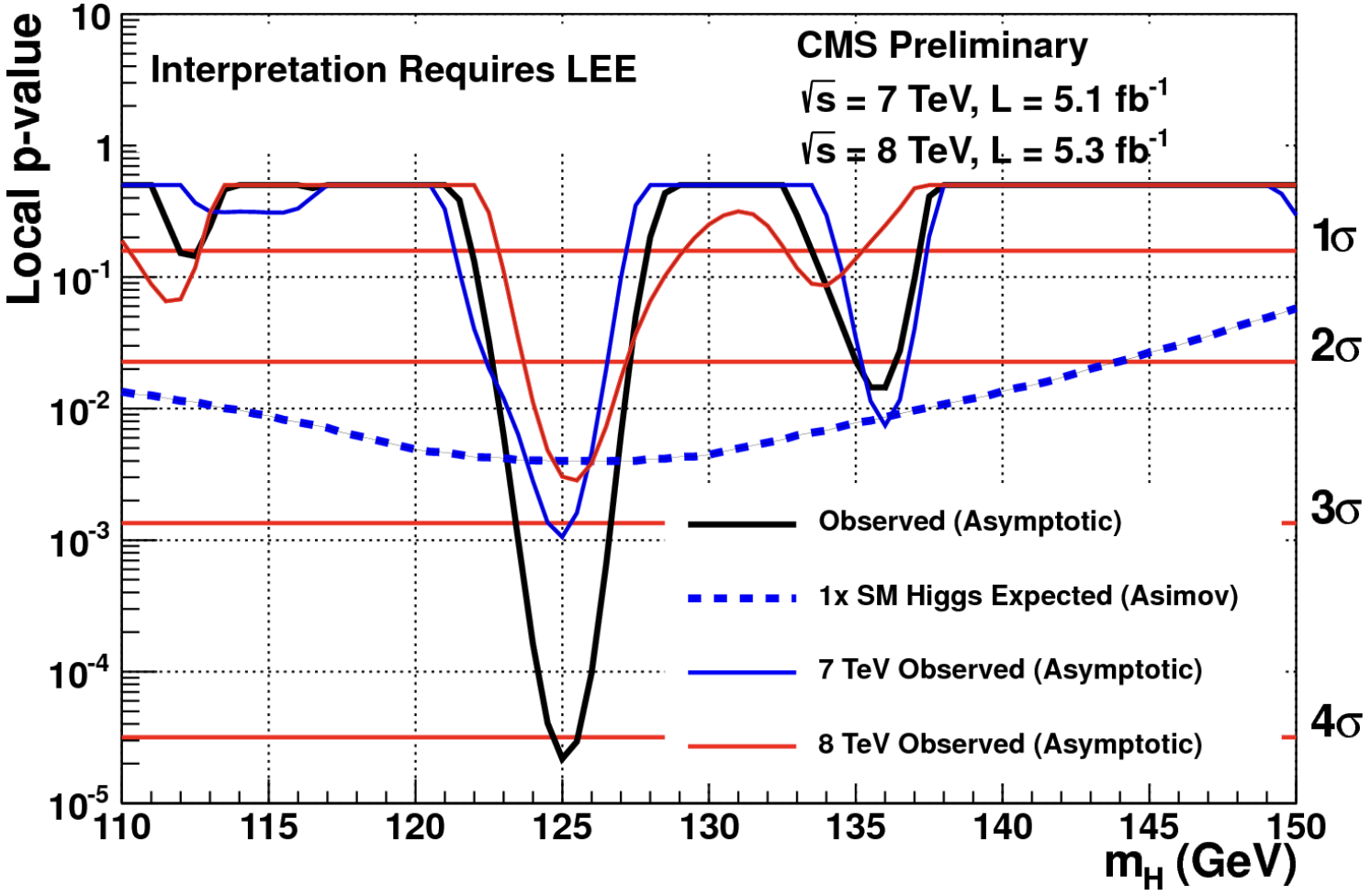


Yellow Report CERN-2011-002 (for the LHC start-up energy)


Events/500 MeV for 100 fb⁻¹
8000
7000
6000
5000
4000
110
120
130
140
a)
m_γγ (GeV)


Events/500 MeV for 100 fb⁻¹
600
400
200
0
110
120
130
140
b)
m_γγ (GeV)


CMS
√s = 7 TeV, L = 5.1 fb⁻¹ √s = 8 TeV, L = 5.3 fb⁻¹
Data
Z+X
ZZ (Zγ*)
m_H = 125 GeV
Events / 3 GeV
0
2
4
6
8
10
12
80
100
120
140
160
180
m_4l (GeV)


Interpretation Requires LEE
CMS Preliminary
√s = 7 TeV, L = 5.1 fb-1
√s = 8 TeV, L = 5.3 fb-1
Local p-value
10
1
10-1
10-2
10-3
10-4
10-5
1σ
2σ
3σ
4σ
Observed (Asymptotic)
1x SM Higgs Expected (Asimov)
7 TeV Observed (Asymptotic)
8 TeV Observed (Asymptotic)
110
115
120
125
130
135
140
145
150
mH (GeV)

Cost Estimate Reference	Deliverables	CERN	China	Croatia	Cyprus	France - CEA	France - IN2P3	Greece	India	Italy	Portugal	RDMS - Russia	RDMS - Dubna Member States	Switzerland - ETHZ	Switzerland - PSI	Taipei	United Kingdom	USA - DOE	USA - NSF	Assigned Funds
3.1.1	Crystals	24.16%			0.22%		1.12%			2.91%				71.59%						22,350
3.1.2	Electronics	6.27%		0.84%	1.46%	2.93%	16.77%			5.23%	2.97%			33.46%	7.19%			14.45%	8.43%	23,910
3.1.3	Mechanics	13.19%					29.86%			20.38%				36.57%						8,340
3.1.4	Assembly & Installation	25.64%				8.55%								65.81%						5,850
3.1.5	Monitoring					71.82%												28.18%		1,810
3.1	Barrel	15.26%		0.32%	0.64%	4.02%	10.84%			5.78%	1.14%			49.63%	2.76%			6.37%	3.24%	62,260
3.2.1	Crystals	13.07%												81.70%			5.23%			7,650
3.2.2	Electronics										6.04%			79.79%			14.17%			6,705
3.2.3	Mechanics											58.97%					41.03%			1,950
3.2.4	Assembly & Installation											26.67%					73.33%			750
3.2.5	Monitoring					100.00%														500
3.2.6	Preshower	34.57%						17.41%	12.80%			9.60%	5.12%			20.49%				7,810
3.2	Endcaps	14.59%				1.97%		5.36%	3.94%		1.60%	8.28%	1.58%	45.73%		6.31%	10.64%			25,365
3.	ECAL	15.06%		0.23%	0.46%	3.42%	7.70%	1.55%	1.14%	4.11%	1.27%	2.40%	0.46%	48.50%	1.96%	1.83%	3.08%	4.52%	2.30%	87,625

THESE

Pour l'obtention du Diplôme de

DOCTEUR DE L'UNIVERSITE PARIS 7
Spécialité : Physique et Technologie des Grands Instruments

Présentée et soutenue publiquement

par

Véronique DA PONTE PUILL

le 13 décembre 1999

Participation à l'étude de la calibration du calorimètre électromagnétique
de l'expérience CMS
et
à l'étude de photodiodes à avalanche

M. Jean-François Montagne Hamamatsu FR

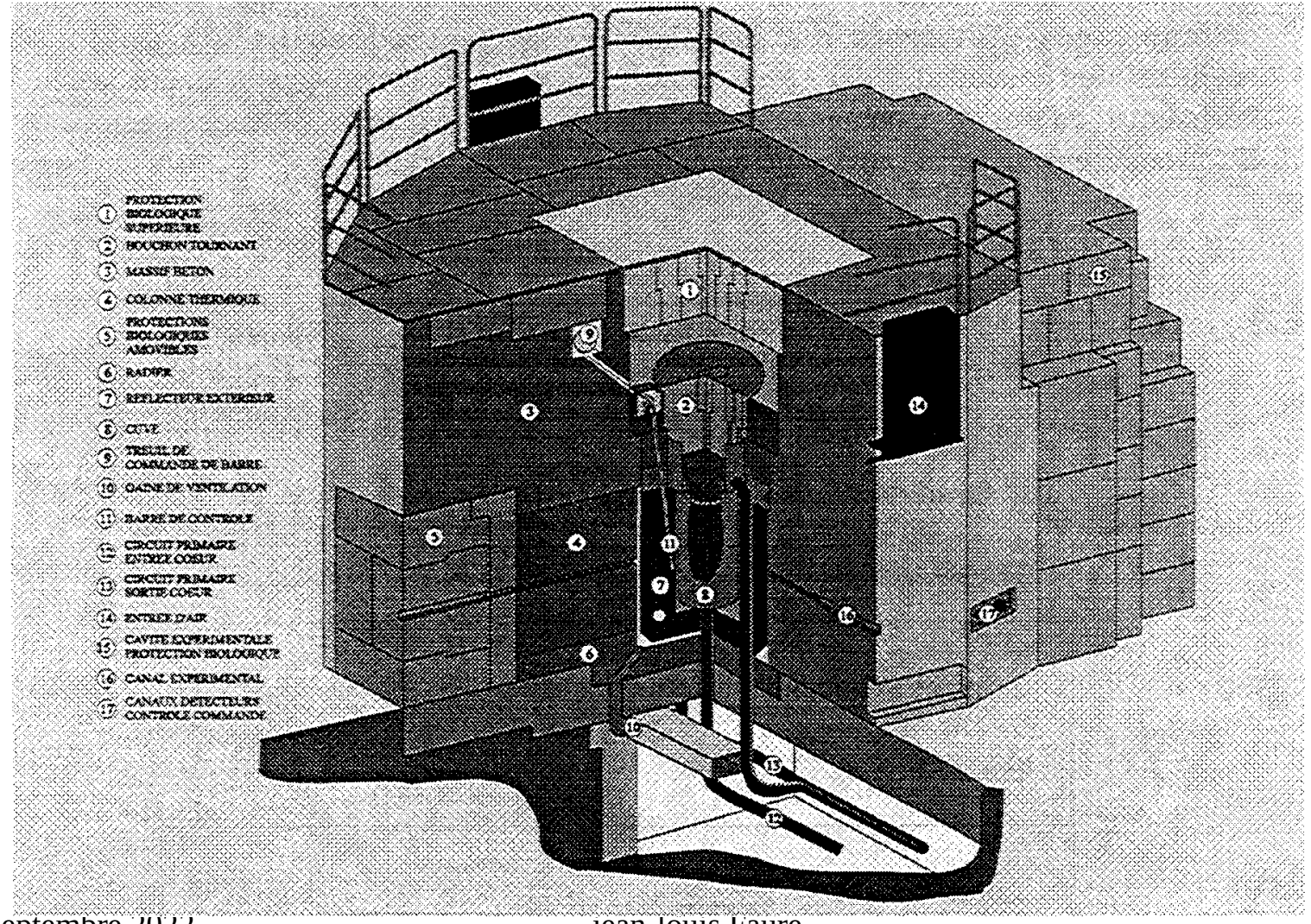

1 PROTECTION BIOLOGIQUE SUPERIEURE
2 BOUCHON TOURNANT
3 MASSIF BETON
4 COLONNE THERMIQUE
5 PROTECTIONS BIOLOGIQUES AMOVIBLES
6 RADIER
7 REFLECTEUR EXTERIEUR
8 CUVE
9 TREUIL DE COMMANDE DE BARRE
10 GAINE DE VENTILATION
11 BARRE DE CONTROLE
12 CIRCUIT PRIMAIRE ENTREE COEUR
13 CIRCUIT PRIMAIRE SORTIE COEUR
14 ENTREE D'AIR
15 CAVITE EXPERIMENTALE PROTECTION BIOLOGIQUE
16 CANAL EXPERIMENTAL
17 CANAUX DETECTEURS CONTROLE COMMANDE

Table 1.7: Radiation dose in CMS Calorimeters for an integrated luminosity of 500 fb^{-1} ($\approx$ 10 years).

Pseudorapidity (η)	ECAL Dose (kGy)	HCAL Dose (kGy)	ECAL Dose Rate (Gy/h)
0–1.5	3	0.2	0.25
2.0	20	4	1.4
2.9	200	40	14
3.5	–	100	–
5	–	1000	–

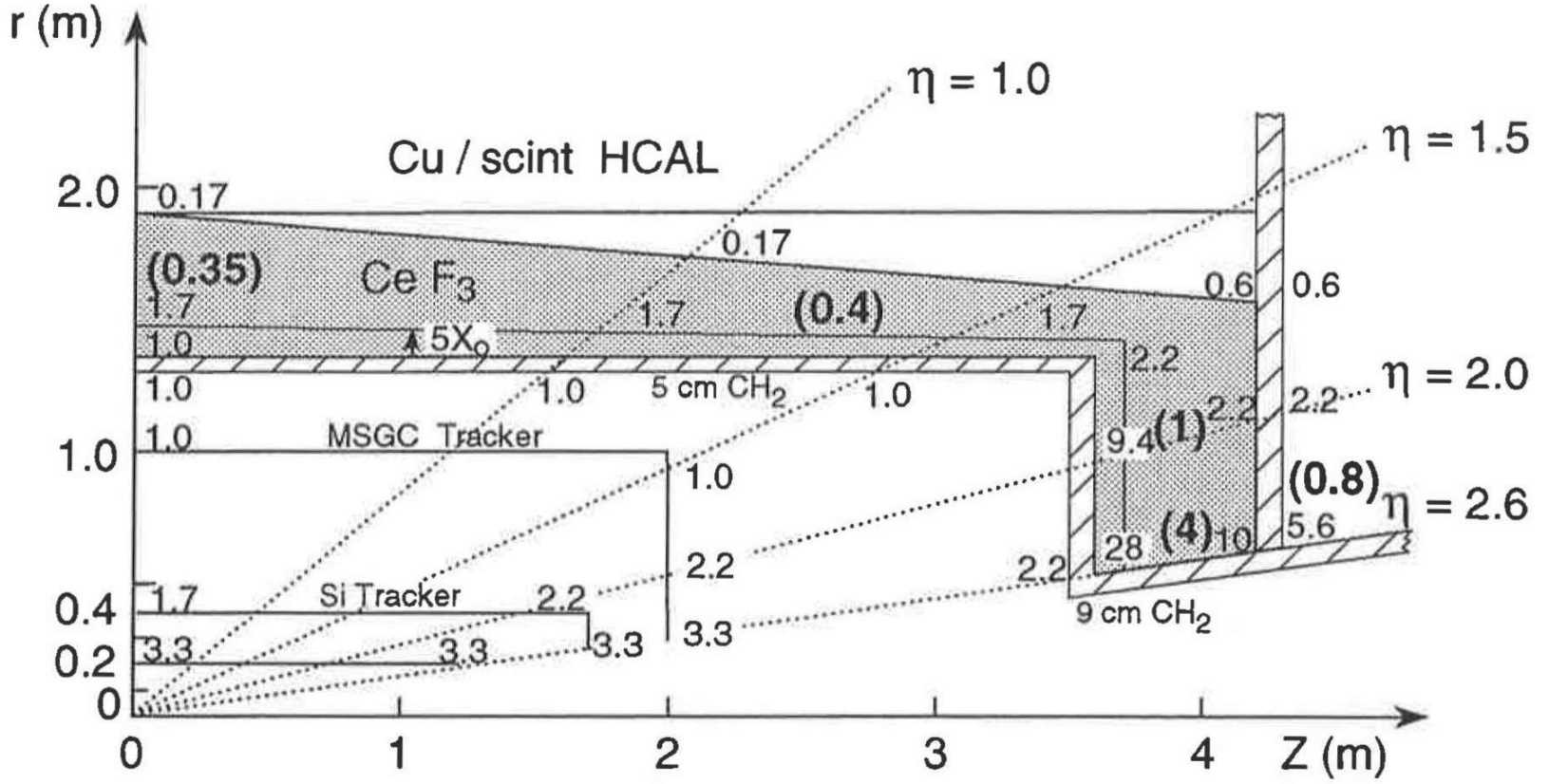


Fig. 1.4 : Neutron fluence and dose in CMS. The numbers in the figure are the fluence in units of 10^{13} n/cm^2. Numbers in bold are the dose in Mrads. These numbers are given for an integrated luminosity of L = 10^{42} cm^{-2}, corresponding to 10 years of running at design luminosity .