AERES 2010, LPSC Grenoble, February 1st, 2010

Thématique 1 :

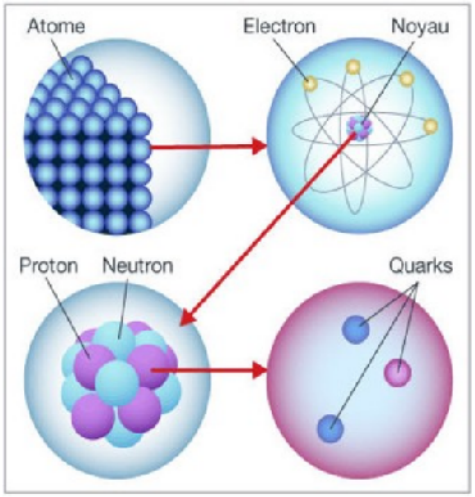
Quarks & Leptons, fundamental interactions

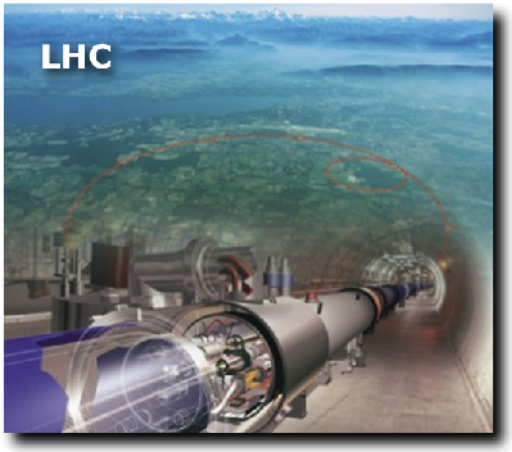
summarised by
Jan Stark

Quarks, leptons and fundamental interactions

Goals / open questions to be addressed

- What are the fundamental constituents of matter and the universe ? How do they interact ?
- How to describe the universe with a minimum of building blocks and a minimum of forces between them ?





Tools

- Particle colliders and the associated detectors
- Projects: DØ (Tevatron), ATLAS (LHC), ILC

- Experiments with ultra-cold neutrons
- Projects: nEDM (ILL-PSI), GRANIT (ILL)

15 tenured researchers, 3 post-docs, 6 students

HEP group (DØ/ATLAS/ILC) today

Physiciens permanents : 13

B. Clément (MCF)

J. Collot (Prof.)

S. Crépé-Renaudin (CR1)

P-A. Delsart (CR2)

J-Y. Hostachy (DR2)

F. Ledroit-Guillon (DR2)

A. Lleres (CR1)

A. Lucotte (CR1)

F. Malek (DR2)

F. Polci (CR2)

B. Trocmé (CR1)

G. Sajot (Prof.)

J. Stark (CR1)

Ingénieurs informatique : ATLAS + Tier3

S. Albrand, J. Fulachier, F. Lambert

C. Gondrand

Ingénieurs en micro-électronique : ILC

J. Bouvier, D. Dzahini , L. Gallin-Martel,

F. Rarbi, O. Rossetto, M. Yamouni…

Ingénieurs en mécanique : ILC

Y. Carcagno, J. Giraud, D. Grondin, J. Menu

+ atelier

Doctorants et postdocs

3 post-docs : H. Li (DØ), J. Donini (ATLAS), K. Krastev (ILC)

6 doctorants: T. Delemontex, E. Laisné, Le Bao T., J. Wang,

C. Weydert (ATLAS), L. Morin (ILC)

The DØ and ATLAS experiments

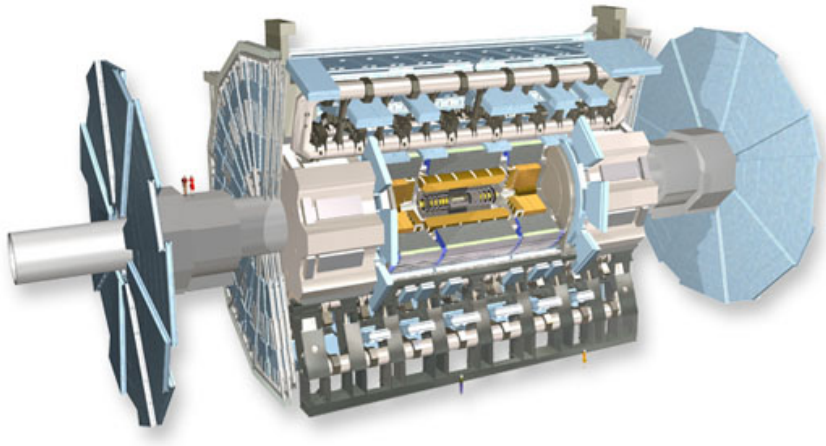
DØ

p pbar collisions at 2 TeV

Run II: taking data since 2002

~460 physicists

ATLAS



p p collisions at 14 TeV

first (low-energy) collisions: end of 2009

~2600 physicists

DØ: top quark physics

Physique du quark top : 2005 - 2008

2 thèses soutenues:

– Mesure de σ(tt) dans le canal “l+jets”

– Mesure de σ(tt) dans le canal dilepton ee, eμ, μμ

& Interprétations dans le cadre du Higgs chargé

Collaborations :

– co-tutelle de thèse avec ATLAS : Adaptation & transfert d’expertise acquise sur des données réelles

– Participation aux travaux du groupe “TeV4LHC”

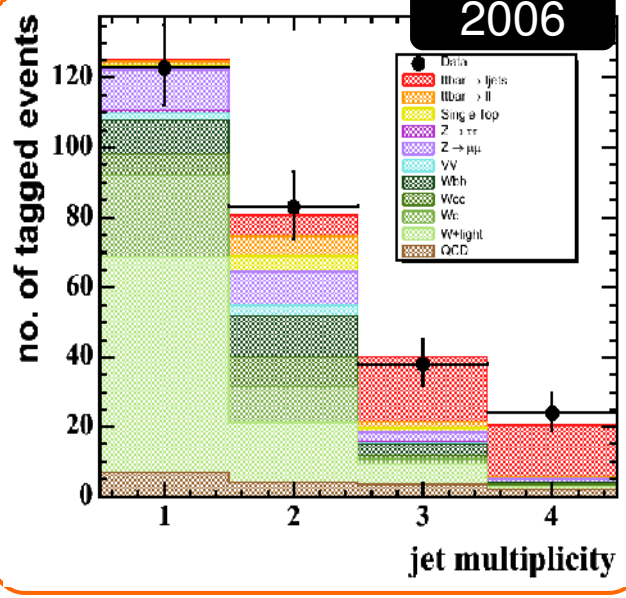
Y. Arnoud (-2008)

S. Crépé-Renaudin (-2008)

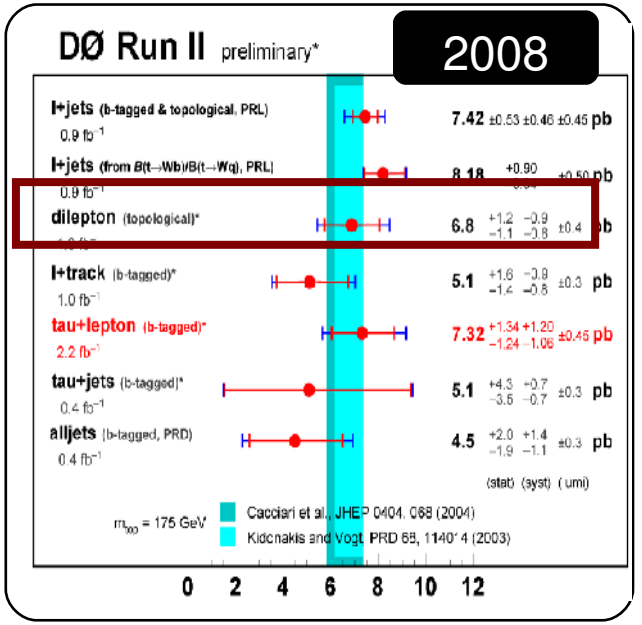
G. Sajot,

J. Stark

2006



2008



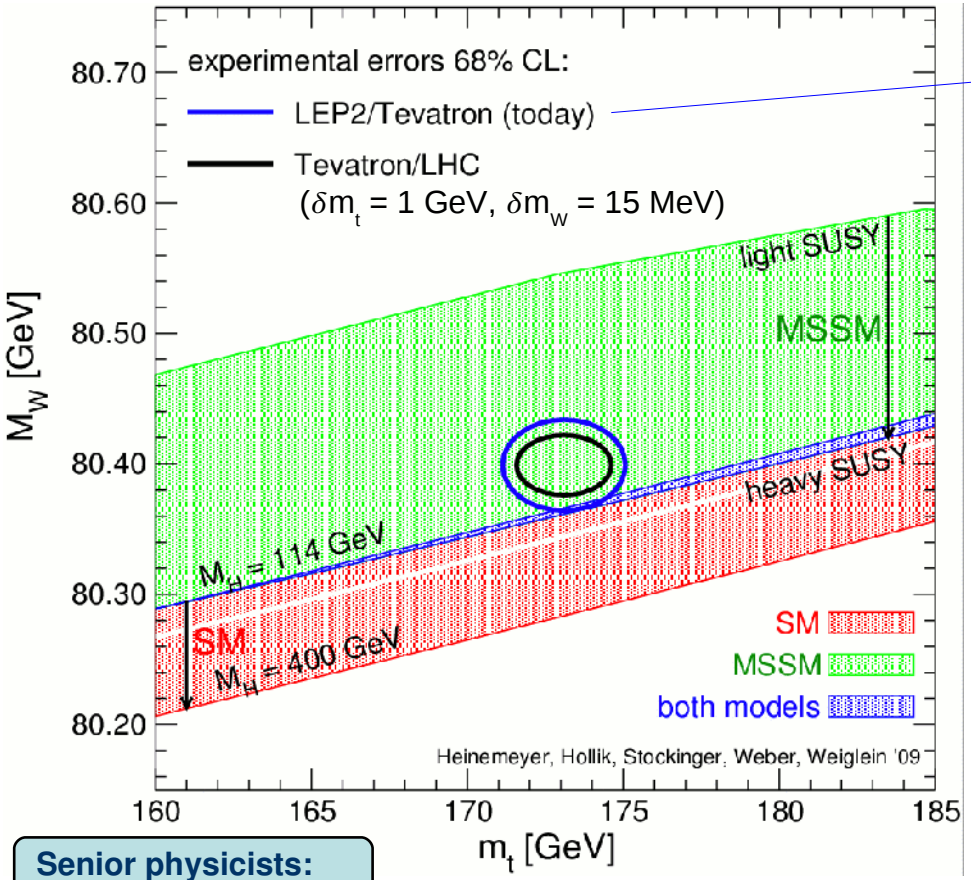
Thèses de:

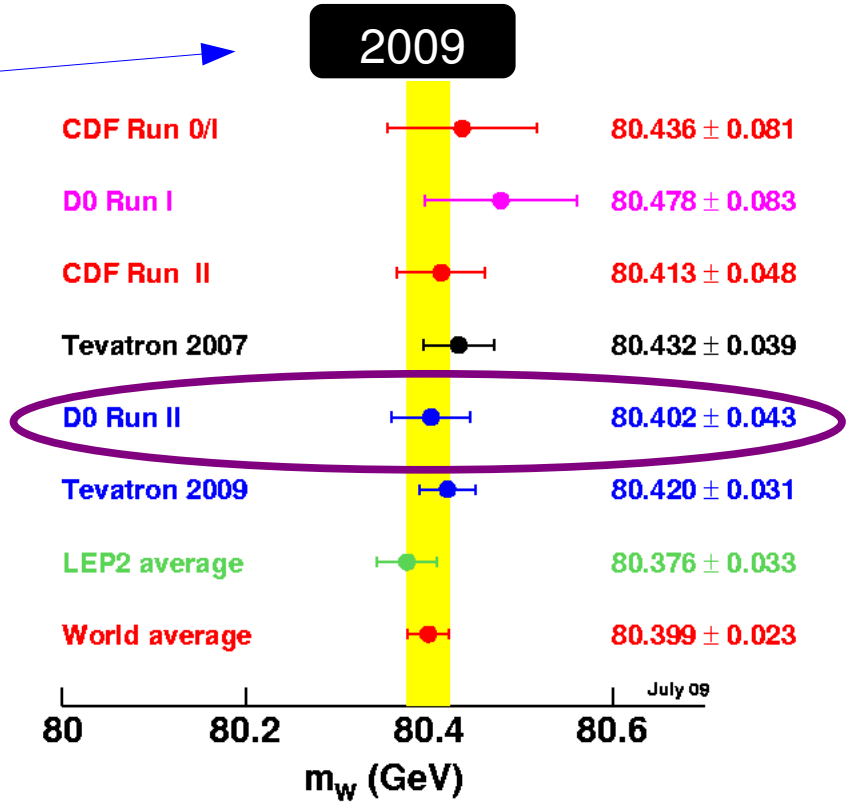
Florent Chevallier

Bertand Martin dit Latour

DØ: W boson mass

In the standard model, the mass of the (yet unobserved) Higgs boson can be predicted from measurements of the masses of the Top quark and the W boson.





DØ Run II (1 fb^{-1}): single most precise measurement. Presented for the first time at Moriond 09 and at Fermilab Wine&Cheese seminar in March 2009 by J. Stark. Published in PRL.

Senior physicists:
J. Stark (CNRS)
PhD students:
-

DØ: "*suite et fin*"

With 1 fb^{-1} uncertainties are mainly statistical (including 'systematics' from limited data control samples). Let's extrapolate:

source of uncertainties	1 fb-1	6 fb-1	10 fb-1	
Statistics	23	10	8	
Systematics				
Electron energy scale	34	14	11	
Electron resolution	2	2	2	
Electron energy offset	4	3	2	
Electron energy loss	4	3	2	
Recoil model	6	3	2	
Electron efficiencies	5	3	3	
Backgrounds	2	2	2	
Total Exp. systematics	35	16	13	
Theory				
PDF	9	6	4	
QED (ISR-FSR)	7	4	3	
Boson Pt	2	2	2	
Total Theory	12	8	5	
Total syst+theory	37	18	14	
(if theory unchanged)		20	17	
Grand total	44	21	16	(20)

At end of Run II, expect total uncertainty on W mass of 16 MeV from DØ alone.

Expect similar performance from CDF, and combined error of 12 MeV.

This legacy measurement will be in the textbooks for decades to come.

Could be an important contribution to getting the standard model into trouble:
with δm_W = 15 MeV, δm_t = 1 GeV
and m_W = 80.400 GeV

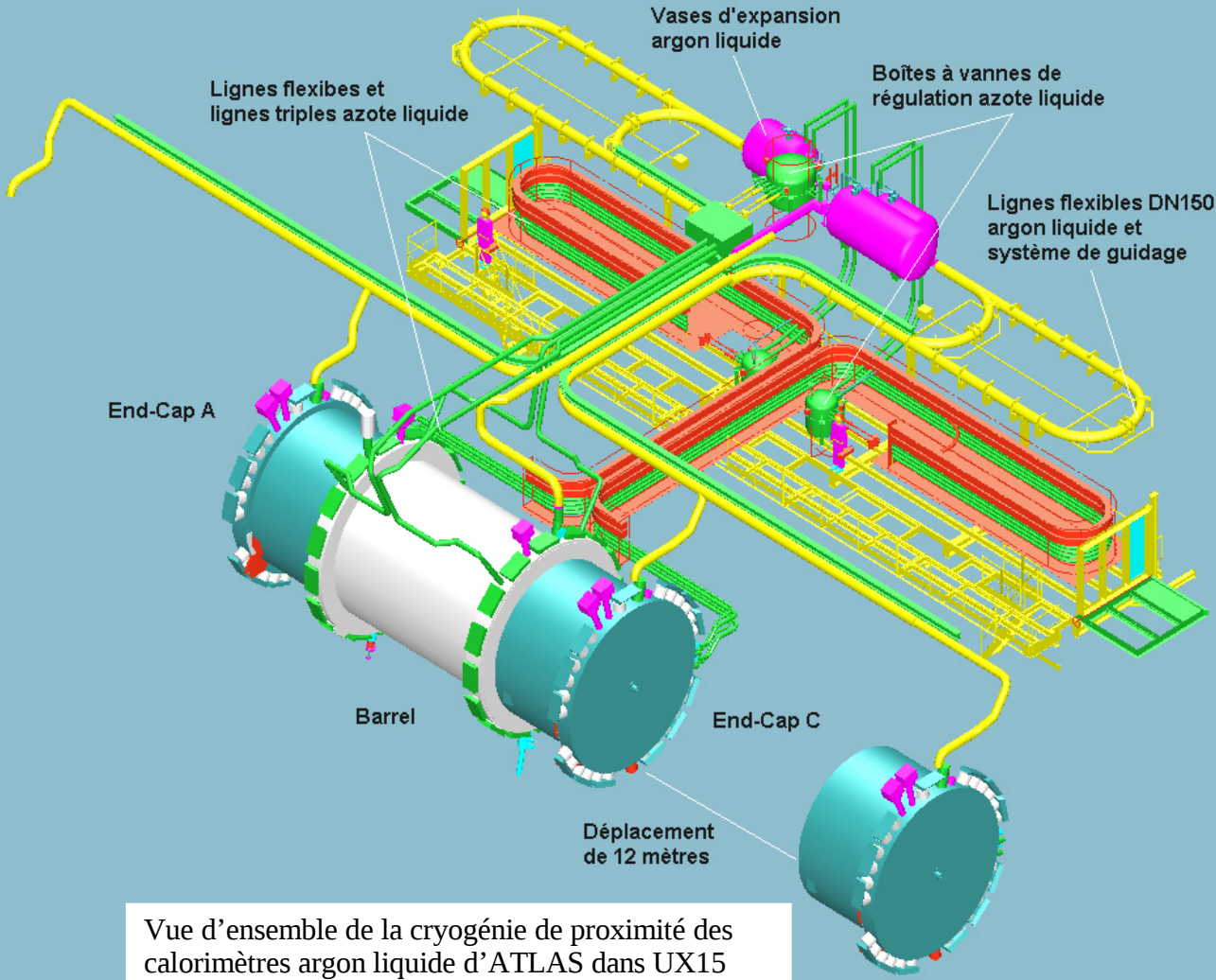
$$m_H = 71^{+24}_{-19}\ \text{GeV} \quad < 117\ \text{GeV}\ @\ 95\%\ \text{cl}$$

(P. Renton, ICHEP 2008)

Senior physicists:
J. Stark (CNRS)
H. Li (post-doc, since Dec 2009)

JS moving to ATLAS now
HL starting a year from now

ATLAS: LAr calorimeter
Proximity cryogenic system



Vue d'ensemble de la cryogénie de proximité des calorimètres argon liquide d'ATLAS dans UX15

Responsabilités:

conception,
construction
installation

- **Vases d'expansion**
- **Boîtes à vannes LN2**
- **Lignes rigides**
- **Lignes flexibles**
- **Systèmes vide**

fini en 2007

En 2008:

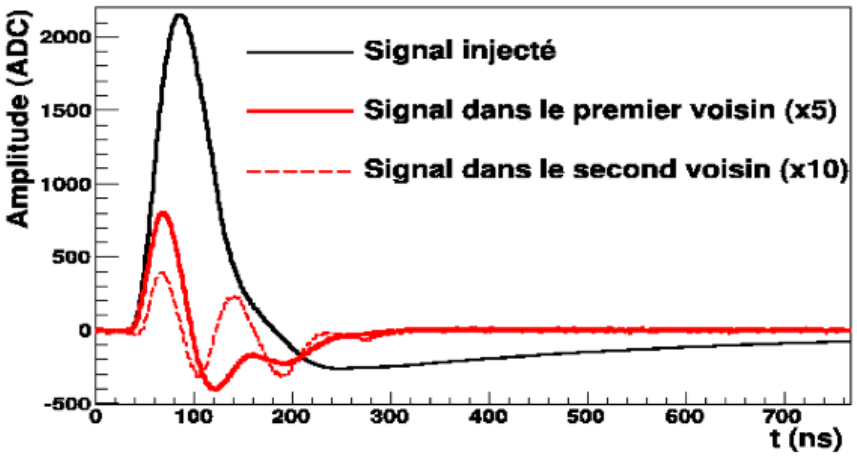
- **réhaussage ligne flexible**
- **Réparation ligne flexible (accident aimant)**

ATLAS: LAr calorimeter

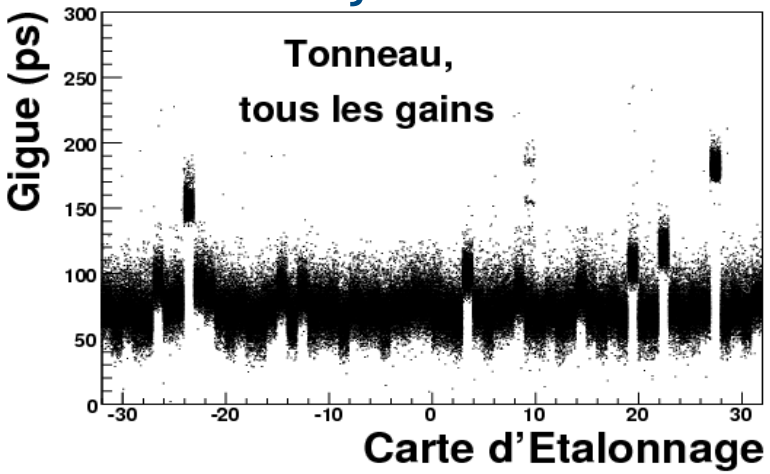
Calorimeter comissioning:
B. Trocmé (longer-term at CERN),
E. Laisné,
J. Labbé

Understanding hardware,
procedure for data quality assessment,
detailed analysis of pulser data,
...

Crosstalk measurement



Jitter



Precision on energy, position and time measurement are crucial for analysis

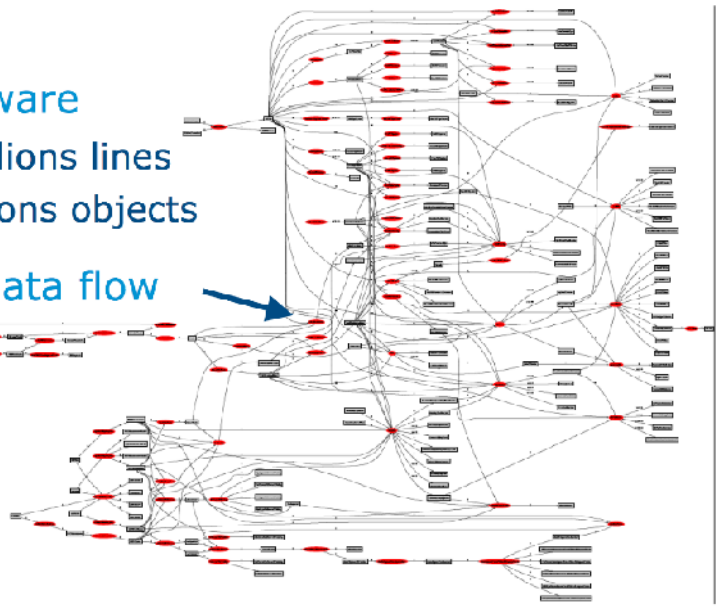
ex: $H \rightarrow \gamma\gamma$

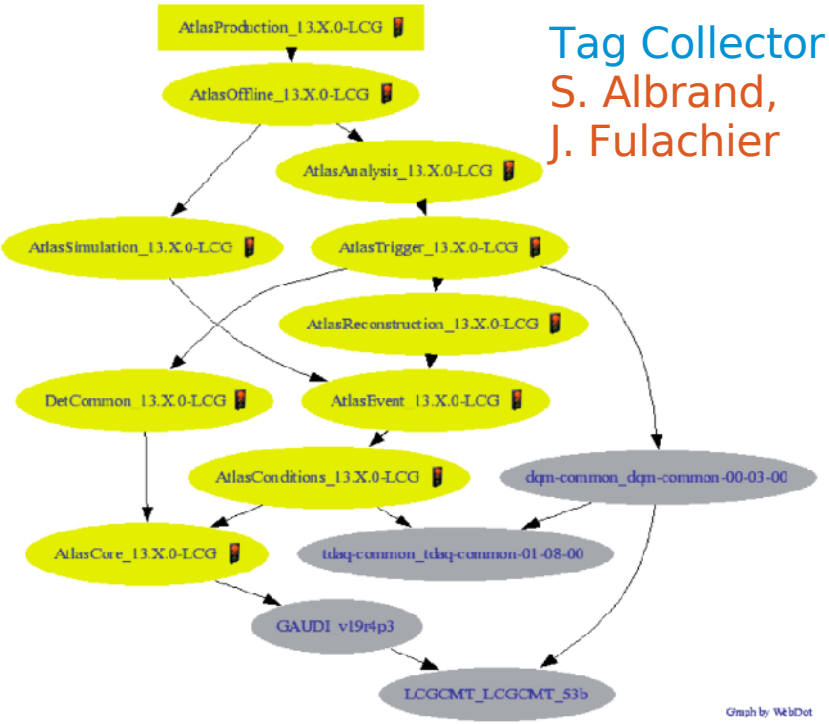
$$\frac{\sigma_m}{m} = \frac{1}{2}\left(\frac{\sigma_{E_1}}{E_1} \otimes \frac{\sigma_{E_2}}{E_2} \otimes \frac{\sigma_\alpha}{\tan(\alpha/2)}\right)$$

ATLAS: software and releases

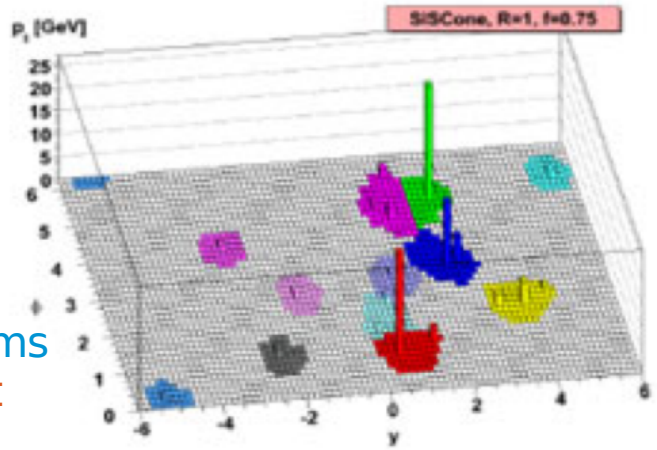
ATLAS software
- ≈ 5 millions lines
- 30 millions objects

Simplified data flow





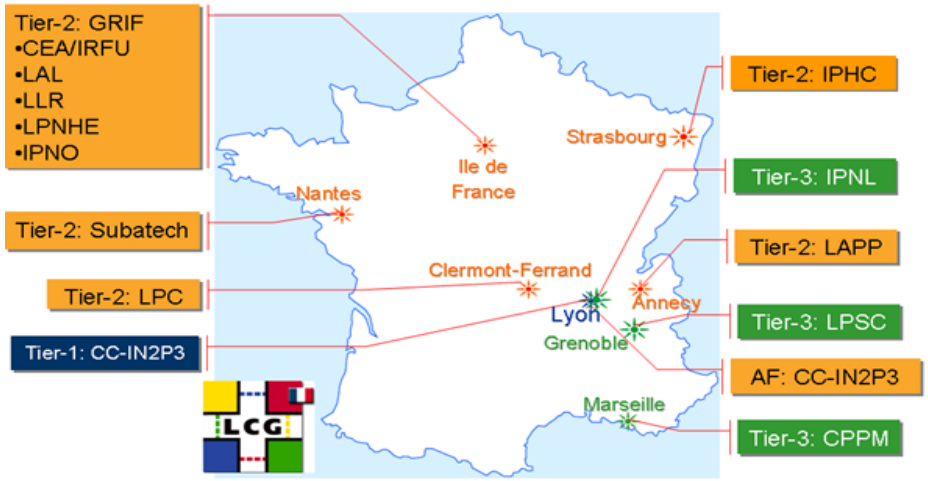
Tag Collector
S. Albrand,
J. Fulachier



Jet algorithms
P.A. Delsart

Package responsibility
Release build: shifts
J. Collot,
F. Ledroit,
A. Lucotte,
F. Polci

GRID computing / Tier 3



LCG: LHC Computing Grid
- LCG France
- (leader: F. Malek)

Tier 3 at LPSC

(scientific contact: S. Crépé):

CPU: 600 cores
(6000 HEP SPEC06)

Disk: 260 TB

ATLAS uses ~ 55%
(intended and used mainly for analysis needs of the group and for MC production)

Shifts: Tier 0 operations + data distribution (at CERN)
- F. Ledroit
- F. Malek

Shifts: data+MC production in "French Cloud"
- S. Crépé

Where to find ATLAS data ?

Home Searches Tools Bookmarks ?

Datasets Selection ATLAS

atlas Login

Overview of catalogued datasets

(valid = 92577 , total = 135375)

Catalogue	Datasets	Series	Start Date	Manager	Status
data08_001-real_data	(Browse) 45151	All (Browse)	2008-3-4	nairz	open
mc08-production	(Browse) 6922	All (Browse)	2008-2-19	amiadmin	open
fdr08-real_data	(Browse) 2030	All (Browse)	2008-2-1	amiadmin	open
data07_cosM5-real_data	(Browse) 7126	All (Browse)	2007-11-5	Nairz	open
Cos07_M4_01-real_data	(Browse) 2529	All (Browse)	2007-9-24	Nairz	open
StreamTest_2007-production	(Browse) 1215	All (Browse)	2007-1-31	Hinchliffe	open
csc-production	(Browse) 6051	All (Browse)	2006-9-26	hoecker	open
POOL_Cond-2007	(Browse) 31	All (Browse)	2006-8-30	Hawkings	open
LArCalorimeter-real_data	(Browse) 89	All (Browse)	2006-7-3	Hong	closed
mc11-production	(Browse) 8293	All (Browse)	2006-4-10	Hinchliffe	open
mc11test-production	(Browse) 1146	All (Browse)	2006-3-15	nevski	open
CTB_RealData-reconstruction	(Browse) 5505	All (Browse)	2005-5-16	Farilla	closed
CTB_MonteCarlo-reconstruction	(Browse) 632	All (Browse)	2005-5-16	Farilla	closed
CTB_MonteCarlo-simulation	(Browse) 762	All (Browse)	2005-5-16	Farilla	closed
CTB_MonteCarlo-digitization	(Browse) 718	All (Browse)	2005-5-16	Farilla	closed
CTB_EC2-testbeam	(Browse) 2963	All (Browse)	2005-5-16	Albrand	archive
DC2-production	(Browse) 63	All (Browse)	2005-3-16	Albrand	archive
ID_CTB_MonteCarlo-simulation	(Browse) 387	All (Browse)	2004-8-1	Albrand	archive
ID_CTB_MonteCarlo-digitization	(Browse) 387	All (Browse)	2004-8-1	Albrand	archive
DC1-generation	(Browse) 440	All (Browse)	2003-3-16	Albrand	archive

AMI

S. Albrand

J. Fulachier

F. Lambert

Top and Single Top physics

Top Physics activity started in 2004…

Motivation: New physics in Top events

Top quark production rate is large @ LHC

→ Precision measurements of σ_t, σ_{tt}: indirect search for extra bosons ($H^{\pm}$, W '), anomalous couplings

→ Search for new resonance Z'

Two major axes

1) Single-top cross-section :

Analyses in the 3 channels (s-, t-, W+t)

2) Top pair cross-section :

Polarisation measurements

Search for Z'→tt

Senior physicists:

B. Clément (MCF)

S. Crépé-Renaudin (CNRS)

J. Donini (postdoc)

A. Lleres (CNRS)

A. Lucotte (CNRS)

PhD students:

F. Chevallier (2007)

J. Labbé (2009)

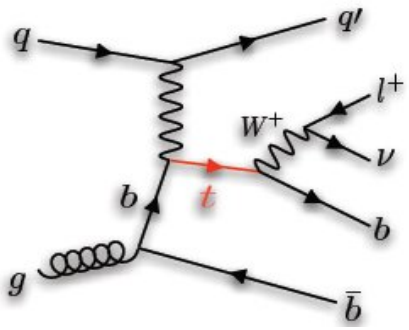
C. Weydert (PhD in 2011)

T. Delemontex (PhD in 2012)

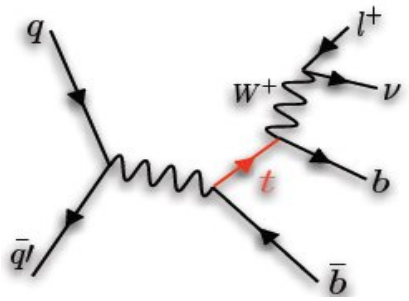
J. Wang (PhD in 2012)

Single top physics at LPSC

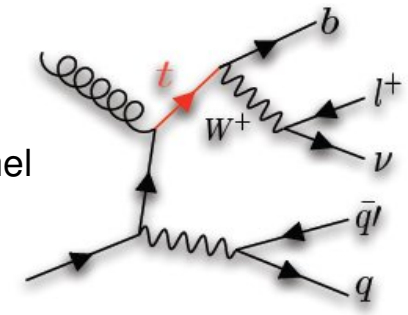
t-channel



s-channel



W+t channel



Single-top analyses at LPSC

1) Measurement of the t-channel cross-section
   →1 PhD + 2 staff physicists
2) Measurement of the W+t channel « in l+jets »
   →1 PhD students + 1 staff physicist
3) Search for dilepton single-top events
   →1 PhD student + 1 staff physicist

Key aspects with direct LPSC involvement:

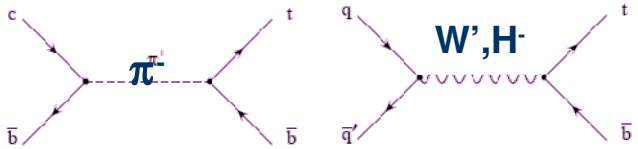
1) Centralized Production of Data:
   →Resposability for the central software & production
2) B-tagging performance: efficiency vs mistag
   →2 PhD students + 3 permanent physicists
3) MVA validation and optimisation :
   →1 PhD student + 2 permanent physicists

Single top: motivations

Interpretations Beyond SM

Single top as probe to NP
- Cover a large spectrum
- in top production or decay
- in V_{tb} or new particles

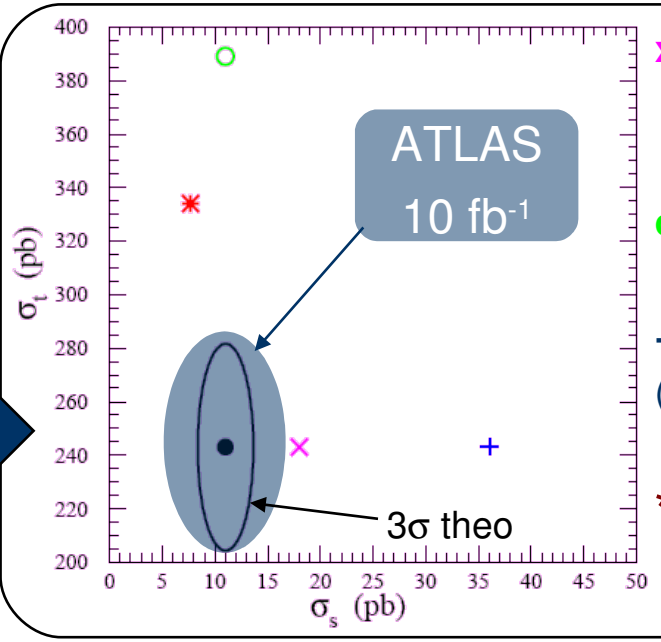
s-channel sensitive to:
- W' in GUT/ED
- $H^{\pm}$ in NMSM or MSSM
- Techni-pion

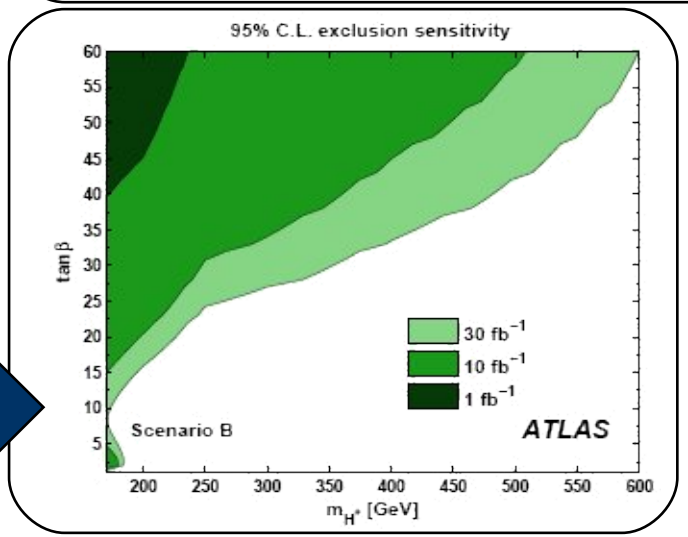


t-channel sensitive to:
- Anomalous couplings
- Anomalous polarisation

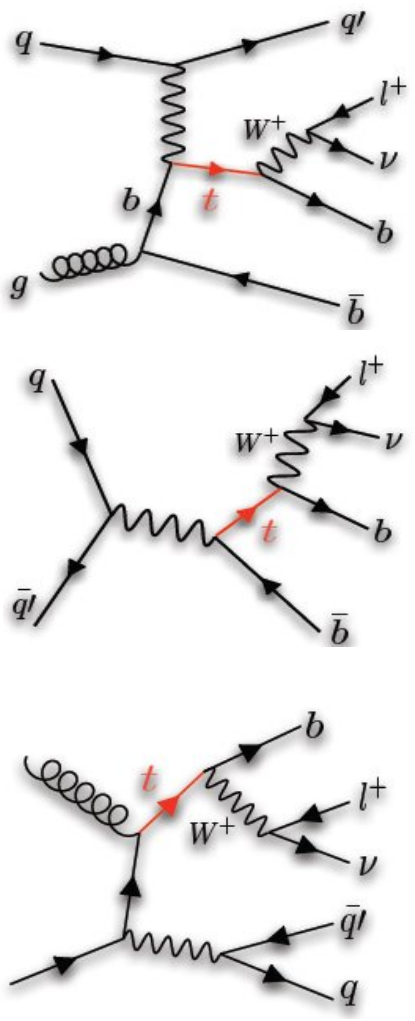
W+t channel :
- $H^{\pm}$ search !

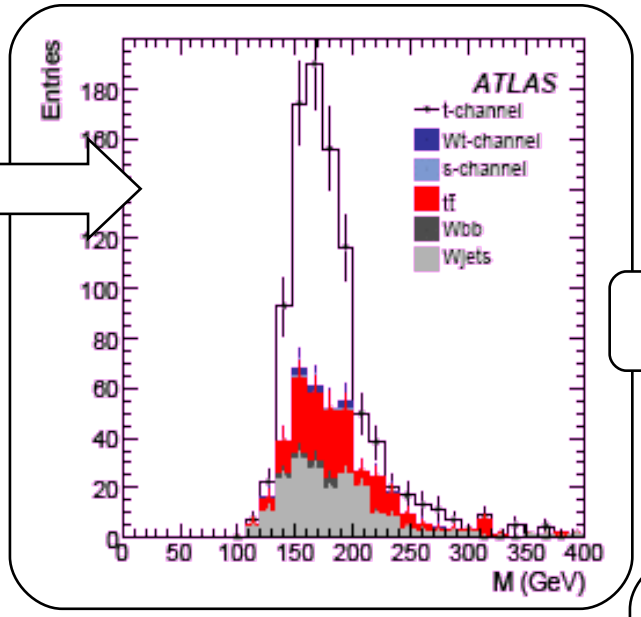
  pp → $H^{\pm}$t → blv τvb



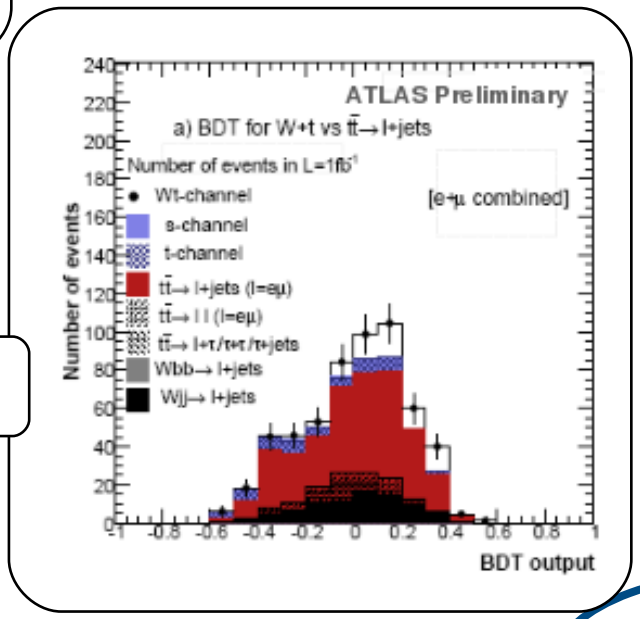


Single top in ATLAS: LPSC results





t-channel analysis



W+t channel

ATLAS: Z' → e^+ e^-

Z' discovery or exclusion

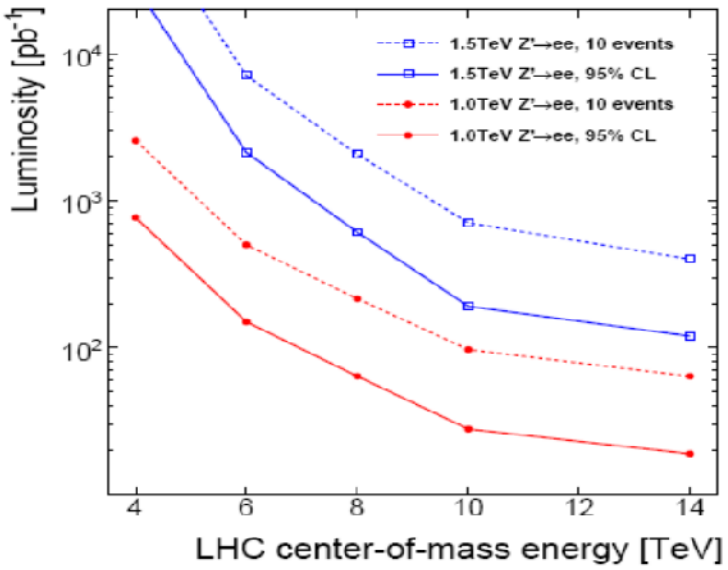
Good potential beyond Tevatron reach, even with 'low' integrated luminosity.

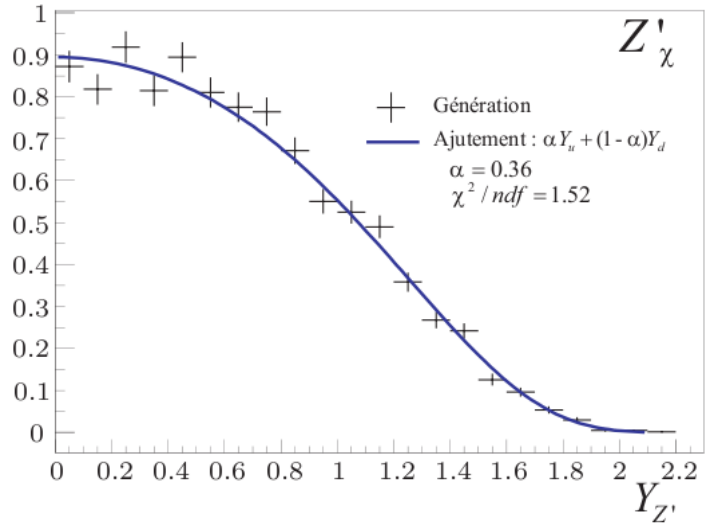
Distinction between models (discovery case !)

Width x cross section,
F-B asymmetry measurement,
fits to rapidity distributions

Now: very high p_T electrons in early data

Data quality, determination of ID performance (efficiency, backgrouds), energy scale and resolution, ... from collision data.





Senior physicists:

B. Trocmé (CNRS)

F. Ledroit-Guillon (CNRS)

PhD students:

J. Morel (2008)

E. Laisné (PhD in 2012)

ATLAS: H → $\gamma\ \gamma$

Key channel for Higgs masses just above the LEP limit

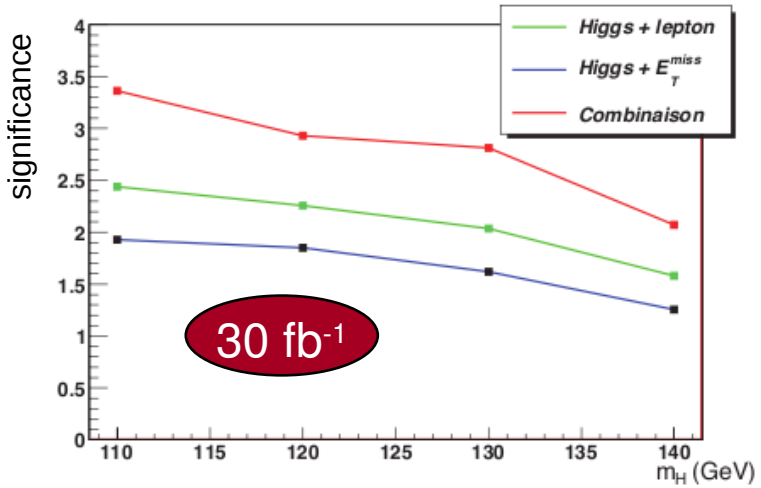
... *i.e.* for the Higgs masses that are favoured by global Electroweak fits and which are difficult (in terms of sensitivity) both at the Tevatron and the LHC.

Small branching fraction; main production mode: g g → H
Recent thesis has focussed on additional production mode: H associated with W or Z

Three final states:

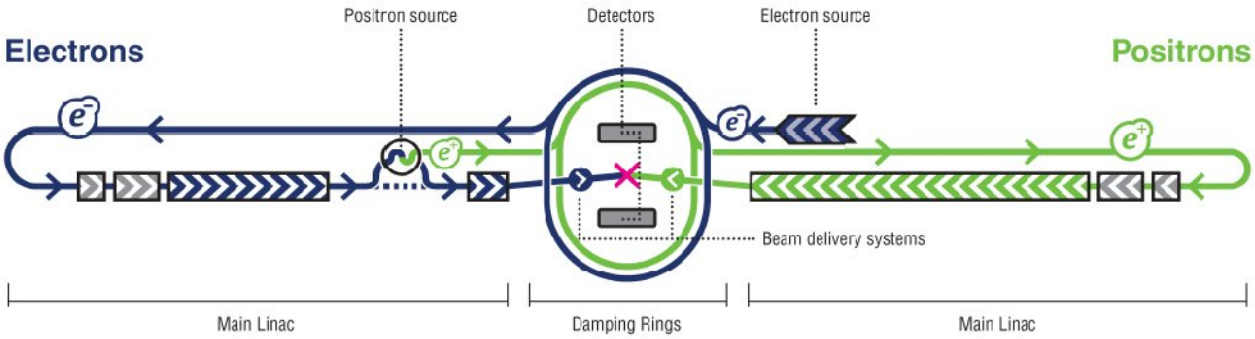
diphoton + isolated lepton + missing E_T	(WH → e ν $\gamma\gamma$)
diphoton + missing E_T	(ZH → $\nu\nu$ $\gamma\gamma$)
diphoton + jets	(hadronic W/Z decays)

Senior physicists:
F. Malek (CNRS)
F. Polci (CNRS)
PhD students:
B. Brélier (2008)
proposal Oct 2010 (PhD in 2013)



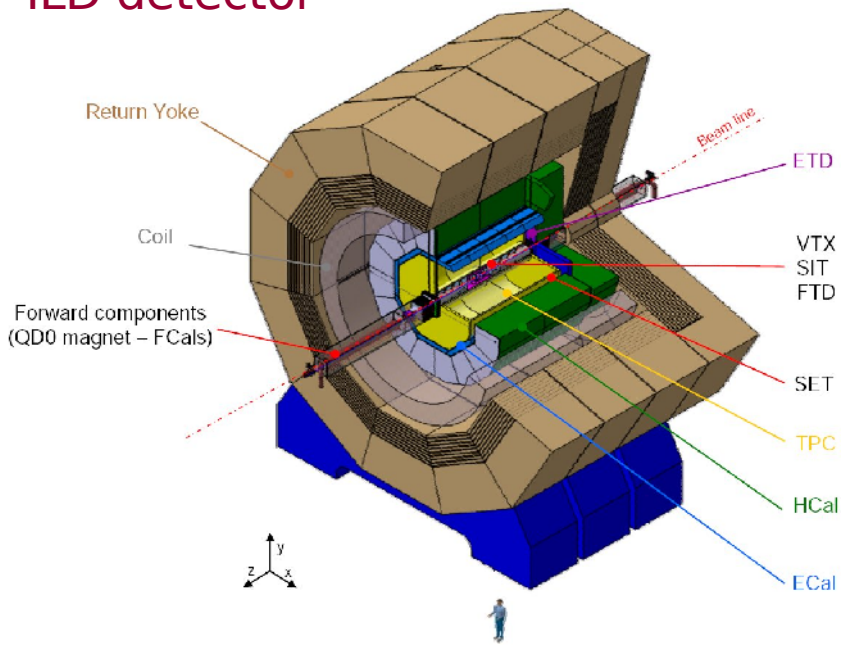
ILC: introduction

ILC collider (e^+e^-)



Senior physicists:
J.Y. Hostachy (CNRS)
K. Krastev (postdoc, -> Dec 2010)
PhD student:
L. Morin (-> Feb 2010)

ILD detector



R&D project -> VTX detector + EM calorimeter

The CALICE Collaboration
Calorimeter for ILC

Calorimeter R&D for the ILC

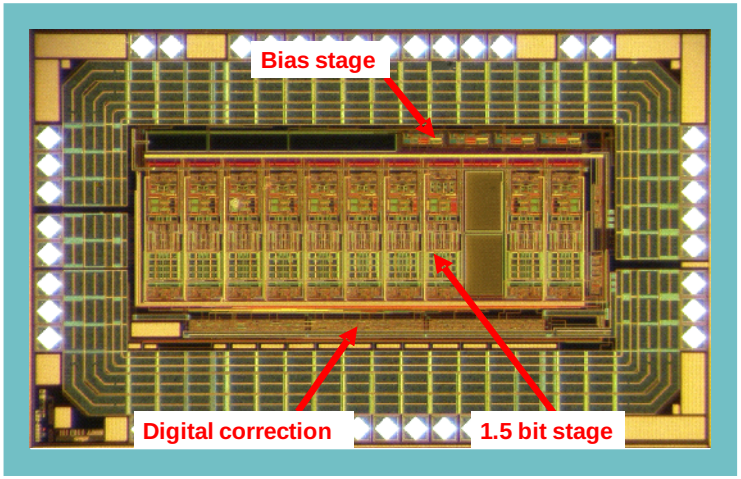
~293 physicists/engineers from 51 Institutes and 13 Countries from 4 Continents

- Integrated R&D effort
- Benefit/Accelerate Detector Development due to *common* approach

ILC: technical contributions

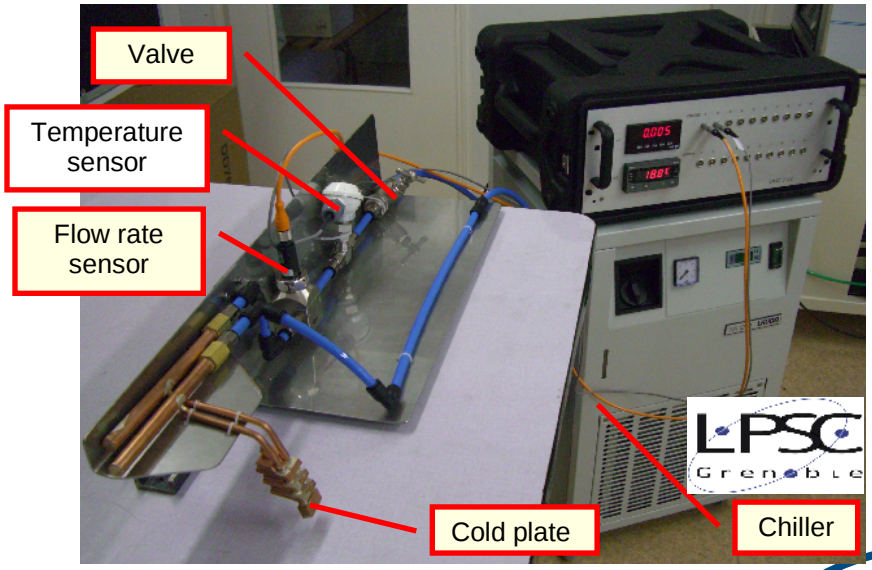
Micro-electronics:

- ADC for readout of VTX (pixel) detector
  (prototypes tested;
  next: integrate with Si detectors
  in monolithic circuit)
- ADC for EM calorimeter readout
  (prototypes tested; low power consumption,
  large dynamic range)
- DAC for EM calorimeter readout
  (prototypes tested)

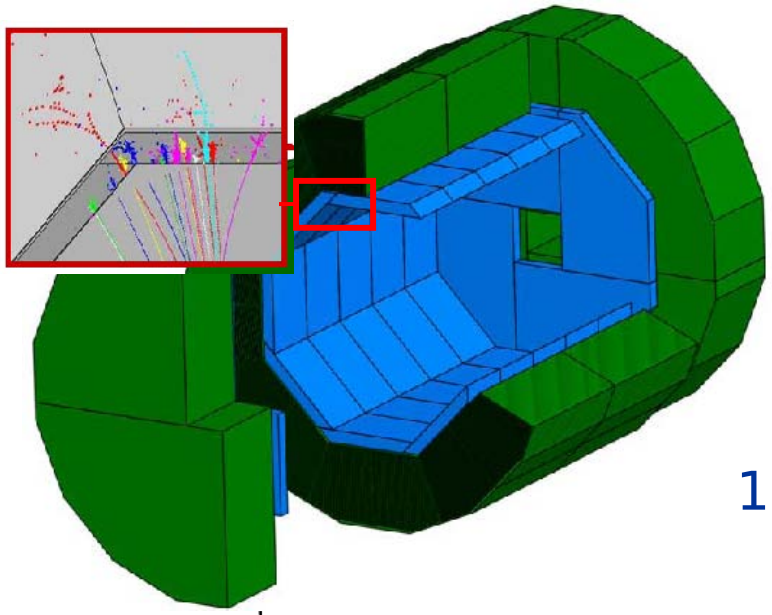


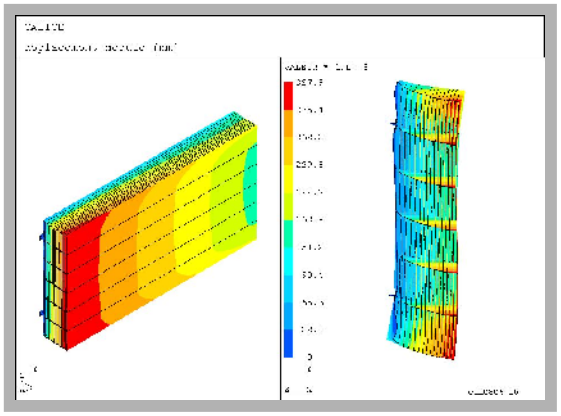
Mechanics:

- Cooling system for EM calorimeter
  (heat from electronics for the large
  number of readout channels !)
- Fastening system for EM calorimeter
  (suspend the EM calo [heavy Tungsten !]
  from HAD calorimeter)
- General layout of EM end-cap calorimeter



R&D: end-cap geometry

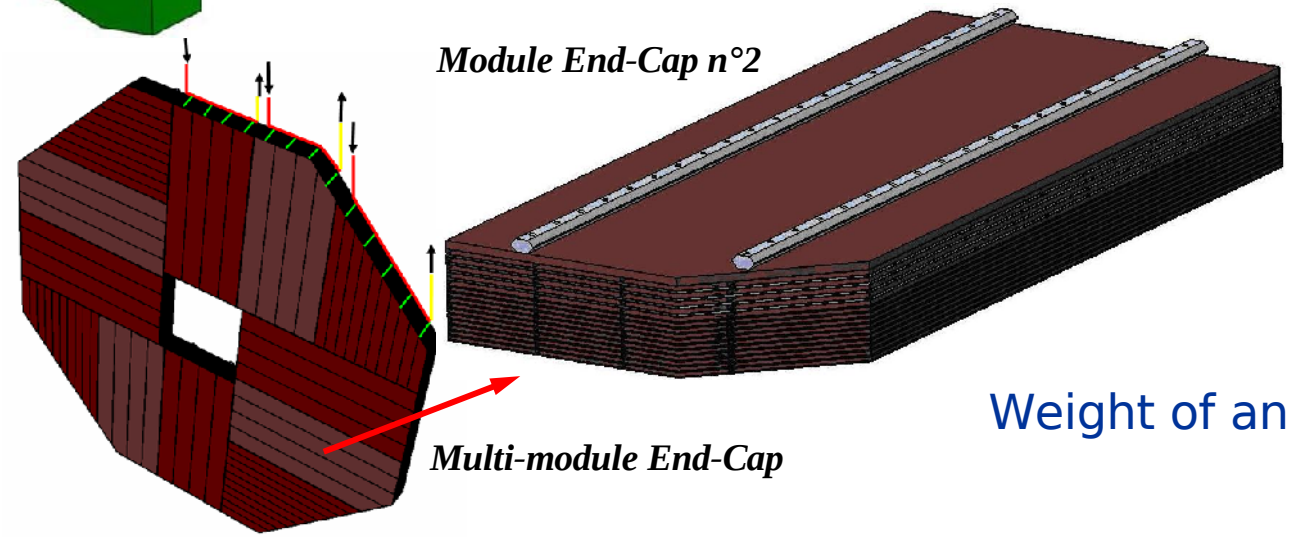




End-Cap module
Configuration 90°

Simulation: Global displacements and localisation of high-stress zones

12 modules of 3 different types / end-cap

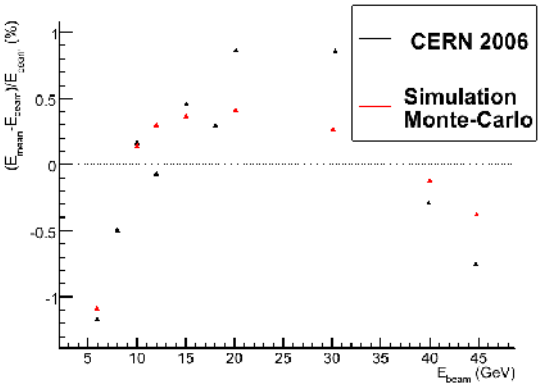


Weight of an end-cap ~ 16 T

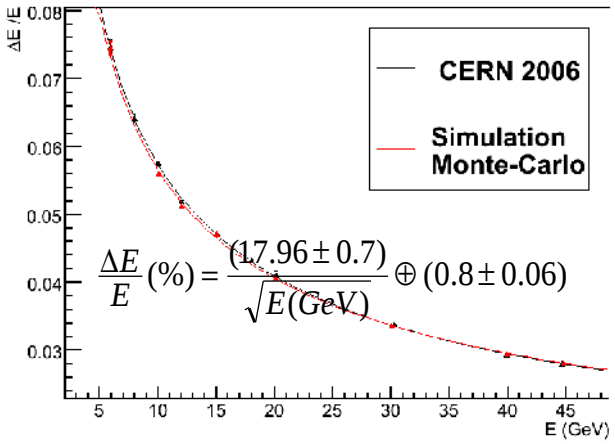
Beam tests, analysis, simulation

Participation in all test campaigns since July 06 (CERN+Fermilab) with a Si-W EM calorimeter prototype:

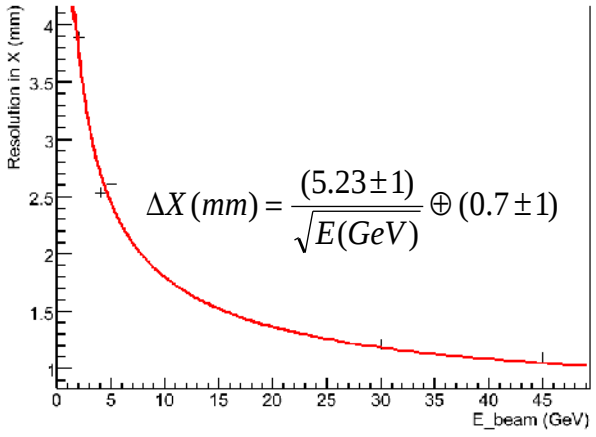
Linearity



Energy resolution

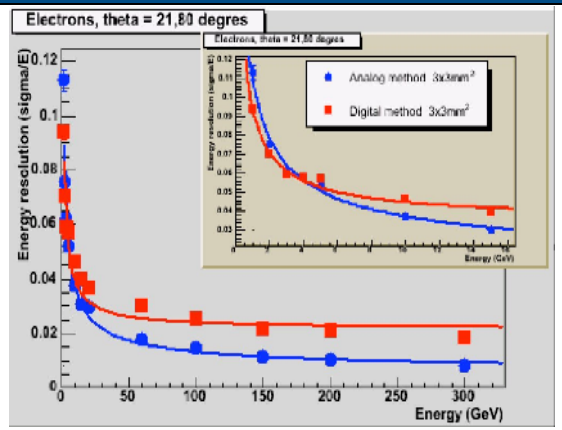


Spatial resolution

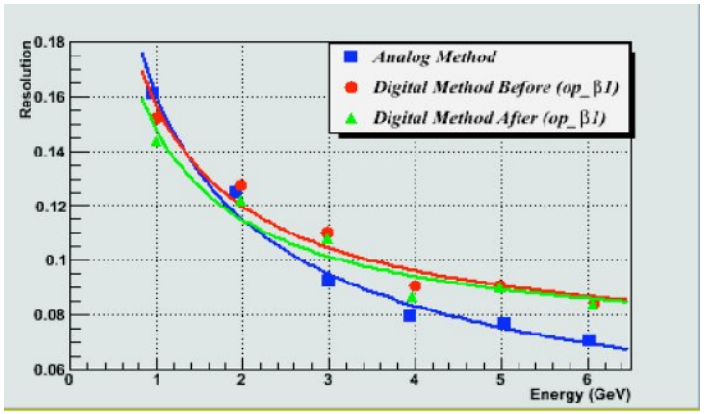


Future: New beam tests foreseen with the EUDET module (1.50 m long)

Simulation, physics



Simulations

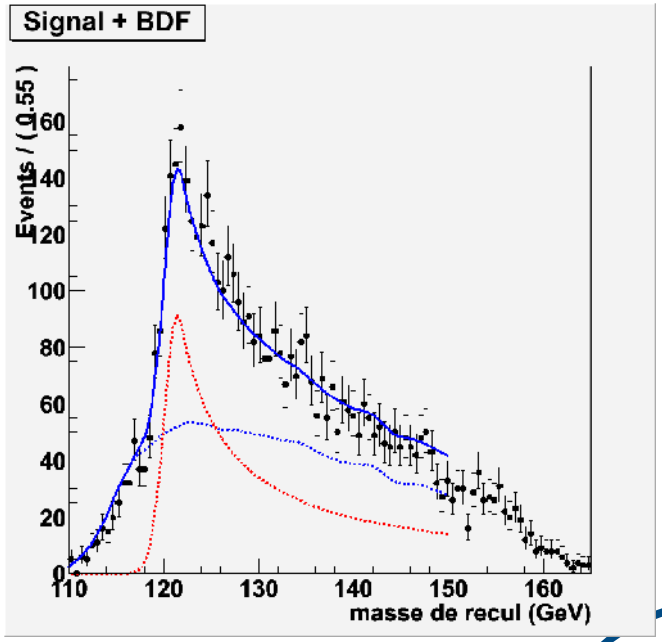


Experimental data

Comparison between digital and analog methods (Collaboration with University of Casablanca)

Measurement of the Higgs mass in the channel:
$e^+e^- \rightarrow ZH \rightarrow e^+e^- + X$

Possibility to observe the Higgs boson from its production mode (via: $Z \rightarrow e^+e^-$)
Luminosity = 250 fb^{-1}
(Here M_H = 120 GeV)
Accuracy of the measurement: ~150 MeV



UCN group

UCN = ultra-cold neutrons

Physiciens permanents : 3

F. Naraghi (MCF)

K. Protasov (Prof)

G. Quéméner

(CNRS, 2005 – march 2009)

D. Rebreyend (CNRS)

Doctorants

G. Pignol (2006-2009)

S. Roccia (2006-2009)

Ingénieurs en instrumentation :

R. Faure, M. Marton, M. Migliore, P. Stassi,

O. Zimmermann

Ingénieurs en micro-électronique :

O. Bourrion, R. Foglio, E. Lagorio, S. Muggeo,

J.-P. Scordilis, C. Vescovi

Ingénieurs en mecanique :

Y. Caragno, D. Fombaron, C. Geraci,

D. Grondin, J.-C. Malacour, E. Perbet,

S. Roni, S. Roudier, F. Vezzu

Ingénieur informatique :

G. Dargaud

Physique fondamentale avec les neutrons de basse énergie (UCN)

- **Objectif:** pousser les limites d'expériences de précision avec des neutrons de basse énergie pour observer des signaux d'une physique au-delà du modèle standard.
- **Outils:** UCN (Ultra Cold Neutron) E ≈ 100 neV

  → ILL : source la plus intense au monde (~10 UCN/cm^3)

  → PSI : démarrage nouvelle source en 2010 (~1000 UCN/cm^3)
- **Expériences:**
  - Etude des états quantiques de neutrons piégés dans le champ gravitationnel

    → Projet GRANIT à l'Institut Laue Langevin (ILL)
  - Mesure du moment électrique dipolaire du neutron

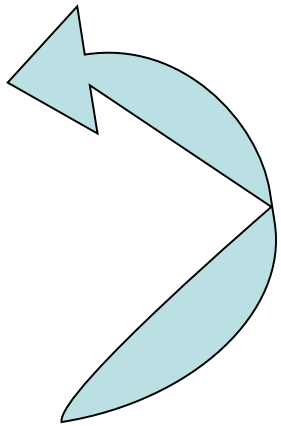
    → Projet nEDM à l'Institut Paul Scherrer (PSI)

Le moment électrique dipolaire du neutron et la violation de CP

nEDM ≠ 0 ⇒ $\not{T}$ et $\not{CP}$

Asymétrie baryonique de l'Univers (BAU ~ 5.1×10^{-10})
« impose » existence de nouvelles sources de violation de CP

- MS (CKM) : BAU ~ 10^{-20} → $d_n \sim 10^{-31}$ *e* cm
- MSSM baryogénèse : $d_n > 10^{-27}$ *e* cm
- GUT baryogénèse: $d_n > 1.5\ 10^{-26}$ *e* cm



Baryogénèse/
leptogénèse ?

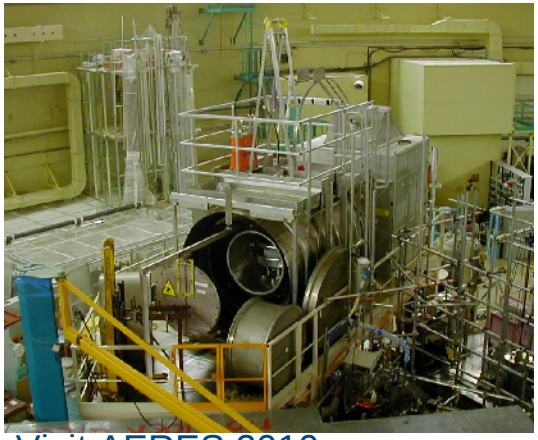
Limite expérimentale:

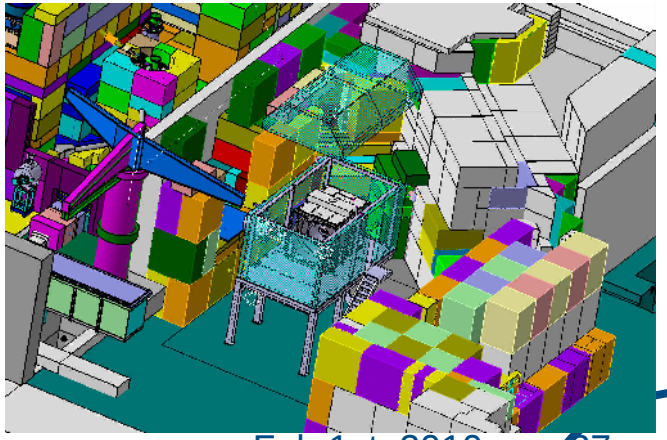
- RAL-Sussex-ILL (2006) : $d_n < 3.\ 10^{-26}$ *e* cm
- Prochaine génération (2015) : ~ 10^{-28} *e* cm

Le projet nEDM au PSI

Atteindre une sensibilité de 5×10^{-28} *e* cm à l'horizon 2020

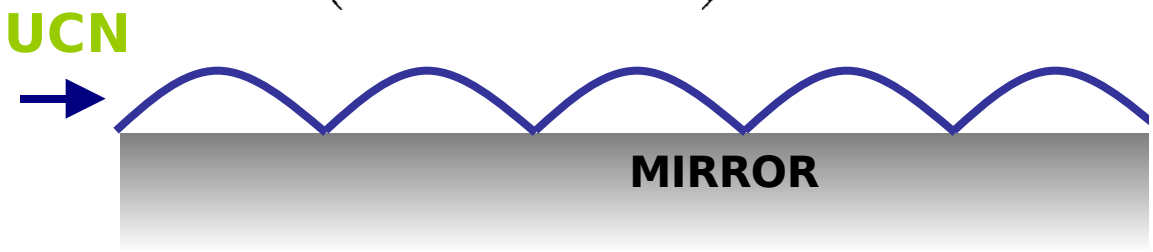
- Le projet:
  - Collaboration ~ 40 personnes (Suisse, Allemagne, France, Pologne…)
  - Mesure avec spectro RAL-Sussex au PSI (2010-2012) → 5×10^{-27} *e* cm
  - Objectif final avec nouveau dispositif (2013-2018)
- Faits marquants:
  - Fin de la phase R&D avec spectro RAL-Sussex à l'ILL (2005-2008)
  - Déménagement spectro RAL-Sussex ILL→PSI début 2009.
  - Premières prises de données au PSI en 2010.
  - Publications: Limites sur oscillation neutron-neutron miroir (PRL 08) et couplage exotique de neutrons avec champ cosmique (PRL 09).

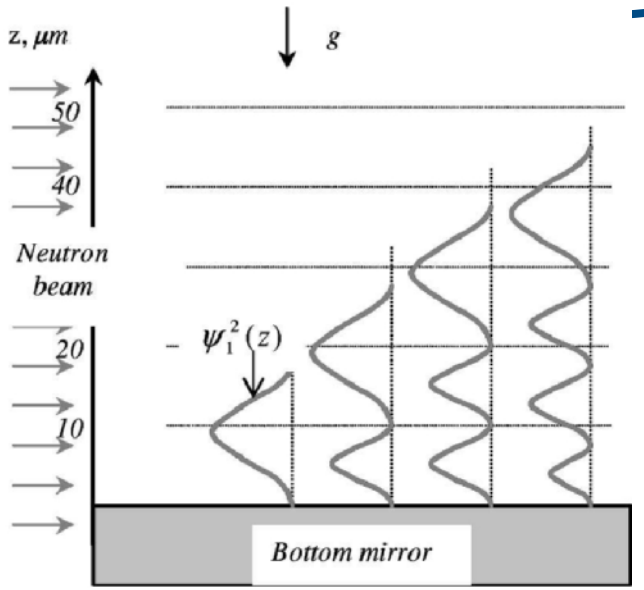




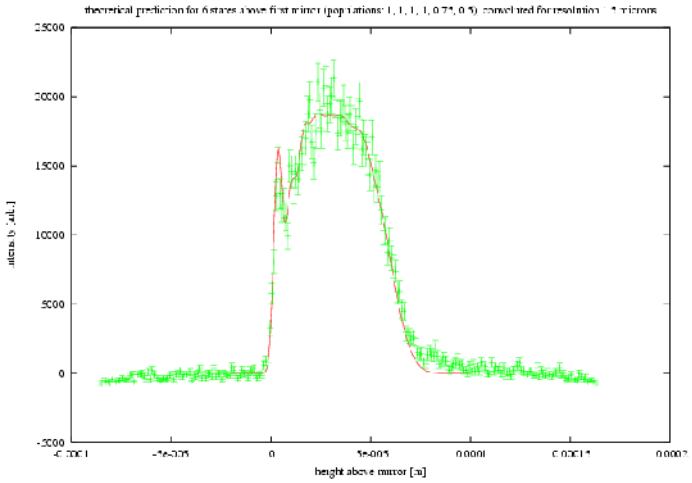
Des neutrons piégés par le champ gravitationnel

$$\left(-\frac{\hbar^2}{2m}\frac{d^2}{dz^2}+mgz\right)\psi = E\,\psi$$





- Système quantique unique:
  - Un des rares systèmes ou la gravitation peut être étudiée dans le cadre de la MQ
  - Dimensions macroscopiques ~10 μm
  - Énergie ~ peV
- Première observation ILL en 2000 (V. Nesvizhevsky et al, Nature 2002)
- Limites sur des nouvelles interactions (Class. Quant. Grav. 2004, PR C 2007)



Le projet GRANIT

(GRAvitational Neutron Induced Transitions)

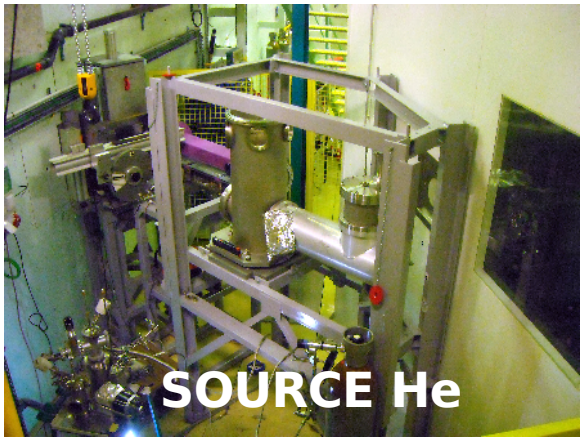
Mesure de l'énergie des *transitions* entre niveaux
(sensibilité x100 / premières expériences)

Le projet:

- Collaboration ILL-LPSC-LMA + contributions labos russes et allemands.

Faits marquants:

- Nouvelle ligne de faisceau neutrons installée et testée en 2009.
- Installation au niveau C de l'ILL pratiquement finalisée
  →premières données en 2010.



Major leadership roles in the international collaborations

DØ:
- Convener of Calorimeter Algorithms group (JS, 2004-2006)
- Convener of W mass physics group (JS, 2005-2009)
- Convener of Electroweak physics group (JS, since 2009)

ATLAS:
- Convener of Exotics physics group (F. Ledroit, 2006-2008)
- Convener of Single Top physics group (A. Lucotte, since 2008)
- Leader of Barrel LAr hardware commissioning effort (B. Trocmé, 2006-2007)
- Convener of LAr Data Quality group (B. Trocmé, since 2008)

nEDM:
- Technical coordinator (D. Rebreyend, until 2009)

GRANIT:
- IN2P3 representative (K. Protasov)

Conclusions

- Rich and diverse physics programme.
  Efficient resource management: well-selected topics where LPSC is at the forefront of science.
- Strong support from all of our governing agencies.
- Continuity of research program, *e.g.*
  DØ (finalising legacy results) → ATLAS (analysing first data) → ILC (design of future experiments).
- Physics that develops quickly.
  Currently in a phase where new experiments start to produce first data and results: nEDM, GRANIT, ATLAS !
- An exciting period for physics: *e.g.* legacy precision measurements from DØ are cornering the standard model, completely unexpected results like the "Neutron whispering gallery" (Nature Physics 2010), and who knows what else ATLAS/LHC and GRANIT have in store for us ?