# PROTON STRUCTURE AND PHYSICS AT THE LHC

**F. Barreiro**
**Universidad Autónoma de Madrid**
**CSIC, May 27th 2008**

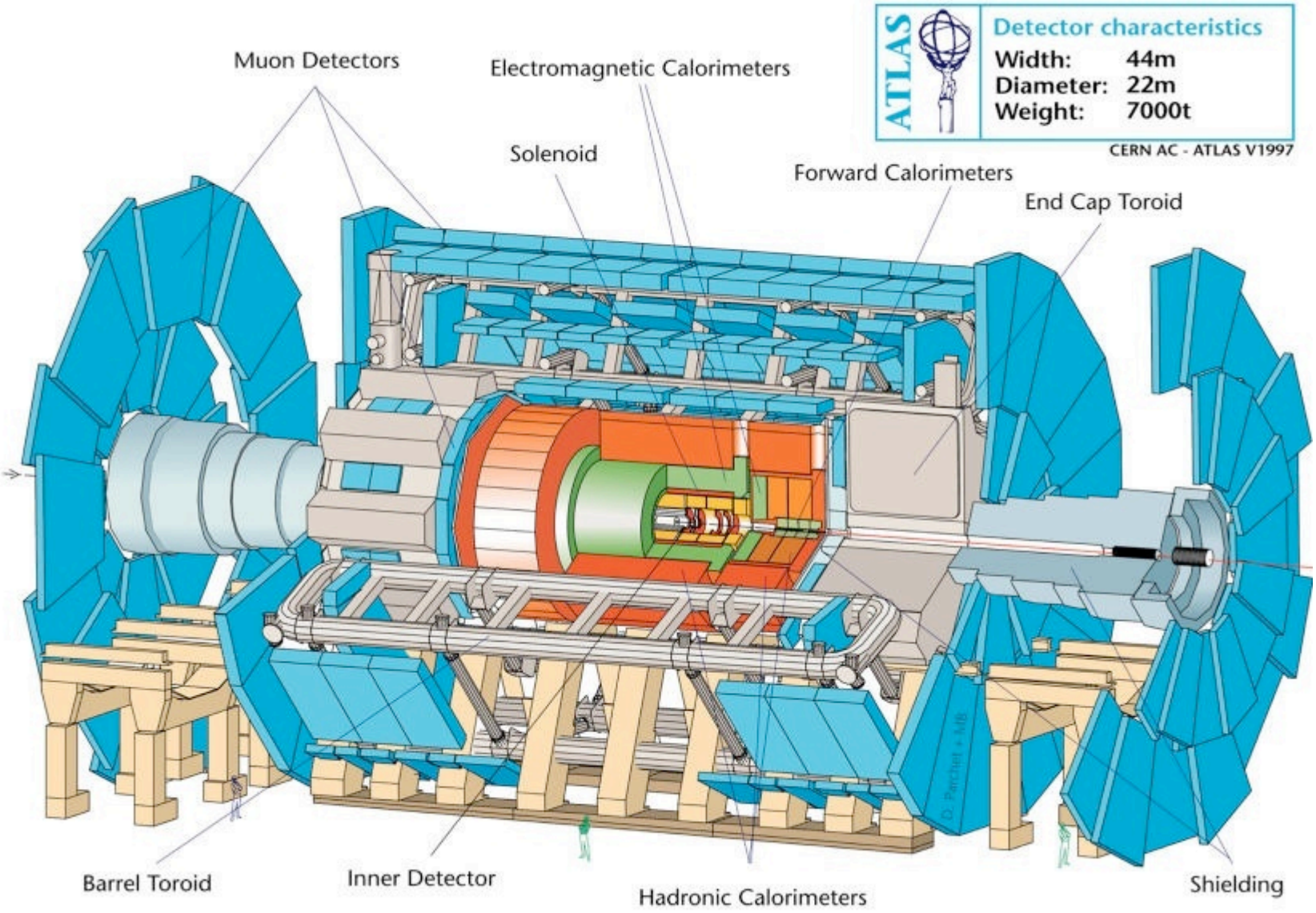
# Group Members

| | | |
|---|---|---|
| F. Barreiro | : | Professor |
| J. del Peso | : | Assoc. Prof. |
| J. Terron | : | Assoc. Prof. |
| C. Glasman | : | Assoc. Prof. |
| M. Soares | : | Assoc. Prof. |
| T. Lagouri | : | Postdoc Fellow |
| E. Ron | : | PhD Student |
| M. Jimenez | : | PhD Student |
| E. Nebot | : | PhD Student |
| C. Gabaldon | : | PhD Student |
| J. Cantero | : | PhD Student |
| F. Gallardo | : | Technician |

In the past years, two lines of research:

i) Construction of ATLAS LAr EMEC

ii) Analysis of ZEUS data at HERA


ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

For standard model Higgs (H) searches, the detector has to be sensitive (with **l=e** or $\mu$) to:

i) **H → $\gamma\gamma$ for Higgs boson masses below 170 GeV**
ii) **H → ZZ →4l** in the mass range **130 GeV < $m_H$ < 2 $m_Z$**
iii) **H →ZZ →4l** or **2l** + **2**$\nu$´s for **$m_H$ > 2$m_Z$**
iv) **H → WW**, **ZZ →** l + $\nu$ + **2jets** or **2l** + **2jets** for Higgs masses up to **1 TeV**

Another important issues like

i) detailed studies for top production and decays

ii) investigation of CP violation in b decays

iii) searches for heavy Z and W like objects

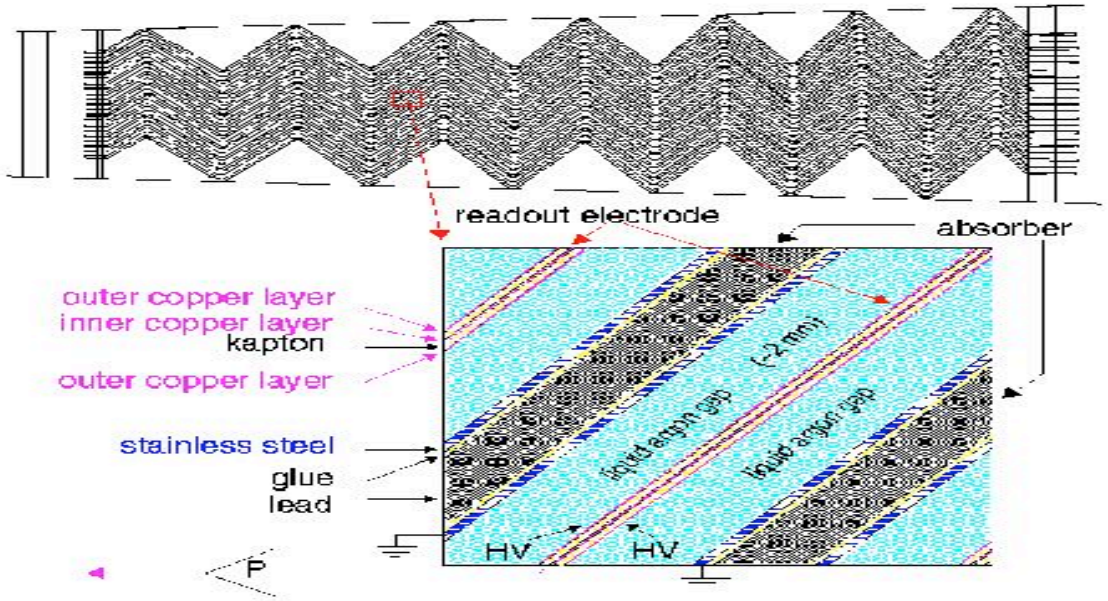
iv) searches for supersymmetric particles

v) searches for compositeness of the fundamental fermions

indicate the importance of identifying electrons and photons at the LHC.

# Introduction

- the LAr Em calorimeter is based on the accordion geometry.
- accordion-shaped lead absorbers interleaved with electrodes.
- the honeycomb spacers separate absorbers and electrodes.
- gap filled with liquid argon.

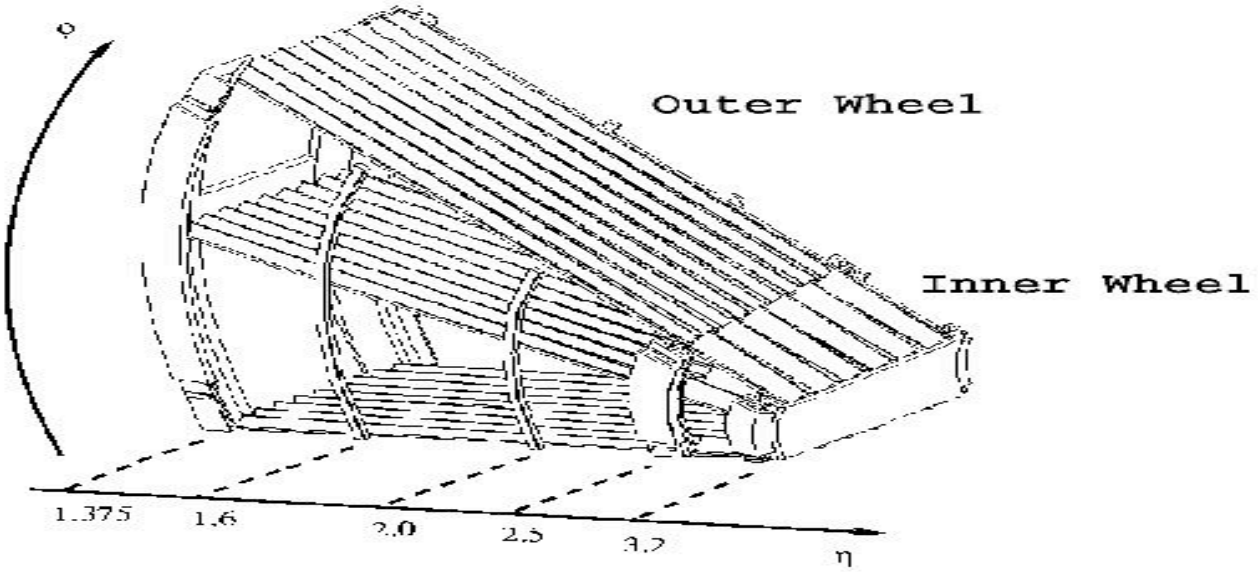



The calorimeter is split up into three parts:

- a cylinder (barrel)
- two wheels (end-caps).

# Introduction_tris: End-cap

- two wheels (crack at $\eta = 2.5$) on each side of the electromagnetic barrel.
- pseudorapidity range from $\eta = 1.375$ to $\eta = 3.2$.
- 8 modules per end-cap.
- 96 (32) absorbers and electrodes by module in the outer (inner) wheel.




- gap varies with the radius.

# Absorbers production

| | Barrel | | End-cap | |
|---|---|---|---|---|
| | $\eta < 0.8$ | $\eta > 0.8$ | Outer W. | Inner W. |
| Lead plates | 1.53 mm | 1.13 mm | 1.7 mm | 2.2 mm |
| Stainless steel | 0.2 mm | | 0.2 mm | |
| glass-fibre prepreg adhesive | 0.135 mm | 0.335 mm | 0.15 mm | |
| Nominal thickness absorber | 2.2 mm | | 2.4 mm | 2.9 mm |

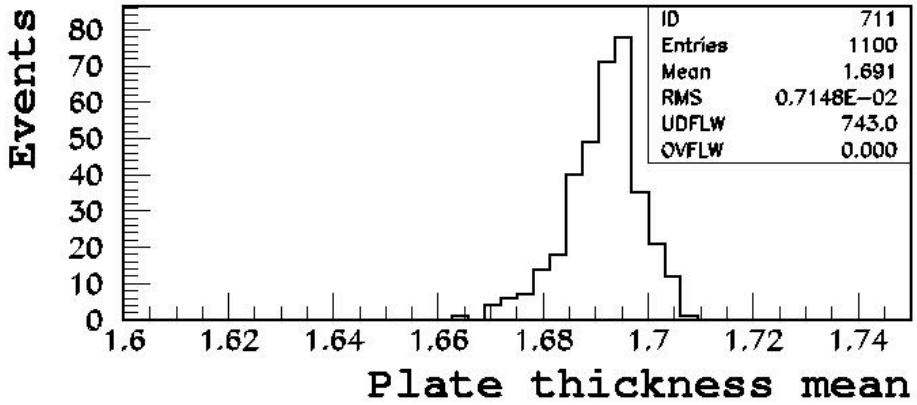
- to minimise the contribution of the passive material to the **constant term** in the energy resolution, **stringent tolerances** on the **lead plate thickness** must be imposed.
- all the plates were thickness mapped using a technique based on ultrasound.
- in the barrel (lead thickness only):

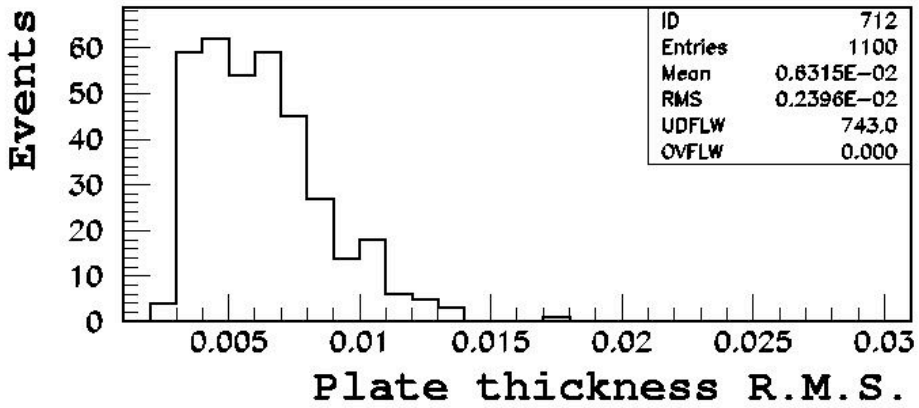
| | $\eta < 0.8$ | $\eta > 0.8$ |
|---|---|---|
| contribution to the constant term | 0.12% | 0.18% |

- in the end-cap:

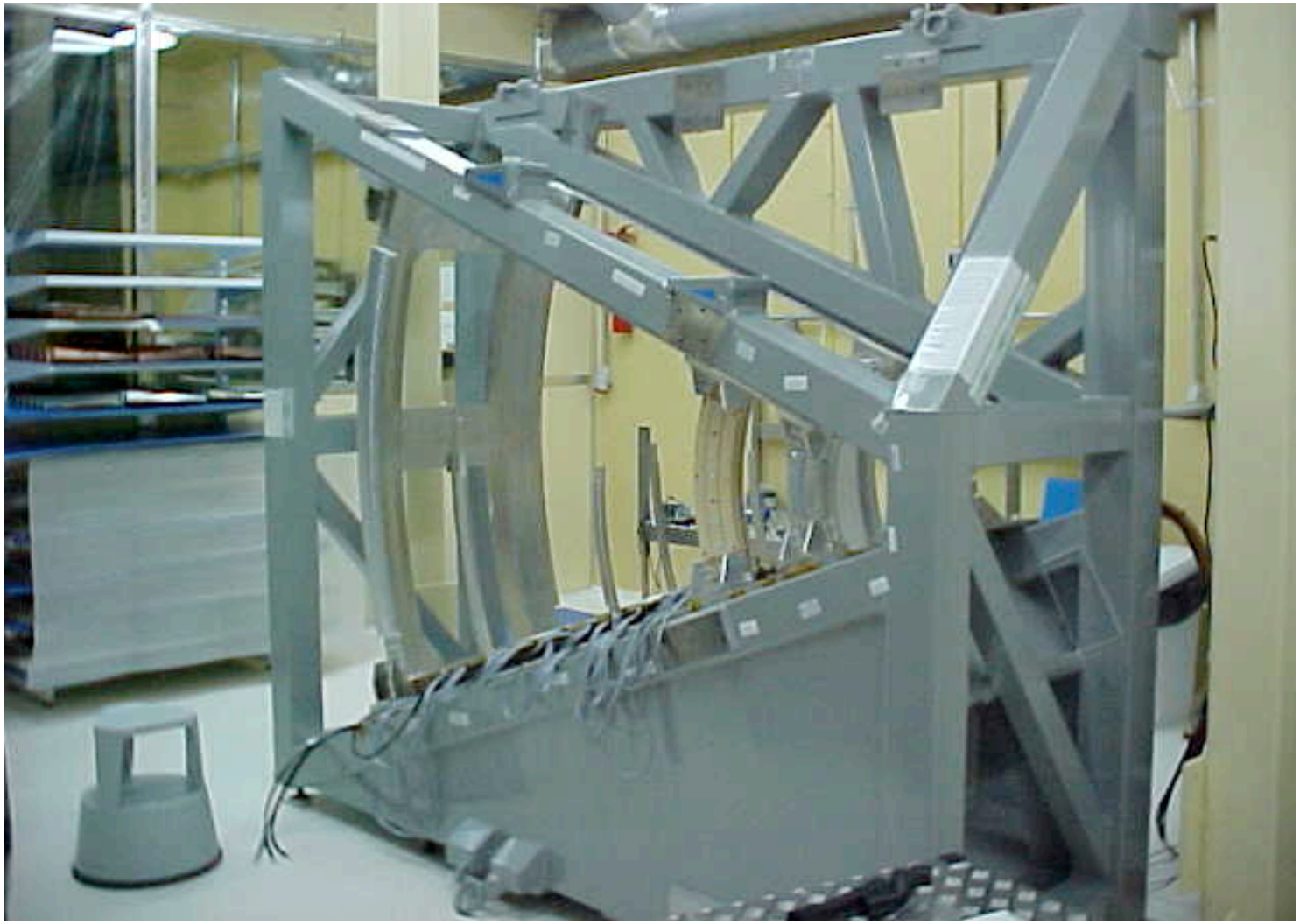
| | OW | IW |
|---|---|---|
| contribution of 0.2% to the constant term | $17\mu m$ | $22\mu m$ |
| for all measurements | $9\mu m$ | $9\mu m$ |

# 15 Modules


Events
80
70
60
50
40
30
20
10
0
1.6
1.62
1.64
1.66
1.68
1.7
1.72
1.74
Plate thickness mean
ID 711
Entries 1100
Mean 1.691
RMS 0.7148E−02
UDFLW 743.0
OVFLW 0.000

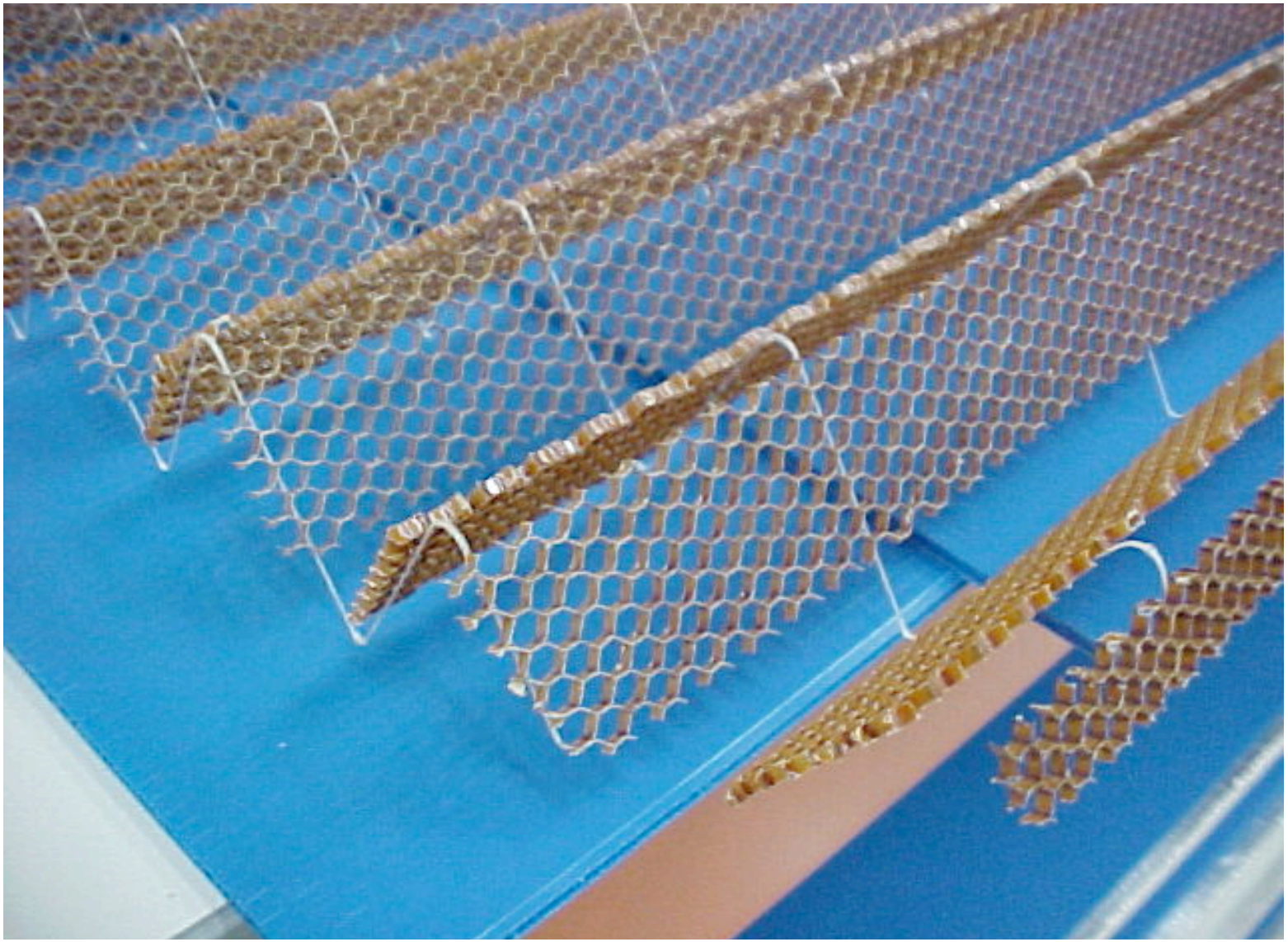

Events
60
50
40
30
20
10
0
0.005
0.01
0.015
0.02
0.025
0.03
Plate thickness R.M.S.
ID 712
Entries 1100
Mean 0.6315E−02
RMS 0.2396E−02
UDFLW 743.0
OVFLW 0.000

# Stacking Frame

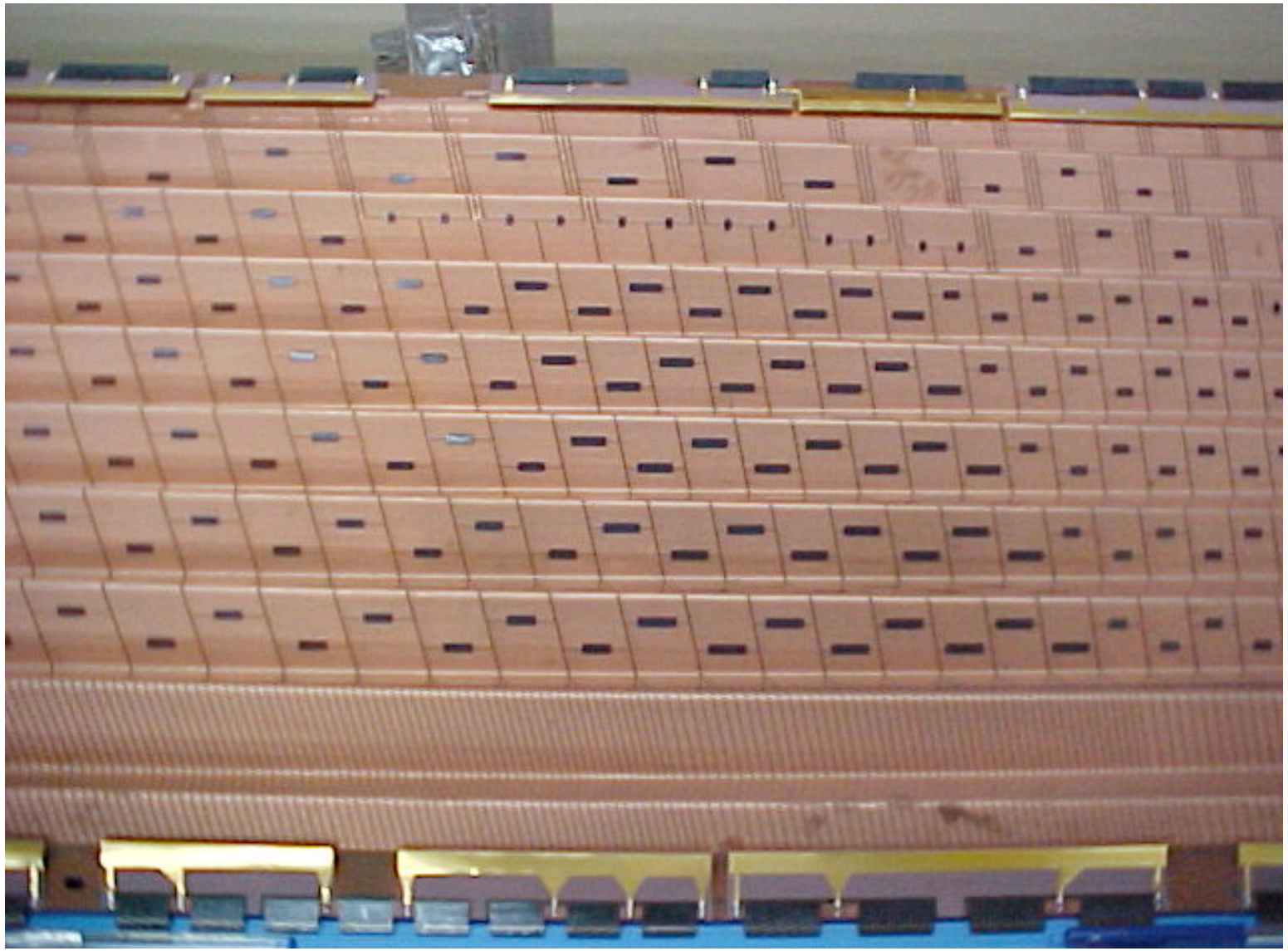


# Inner and outer wheel absorbers

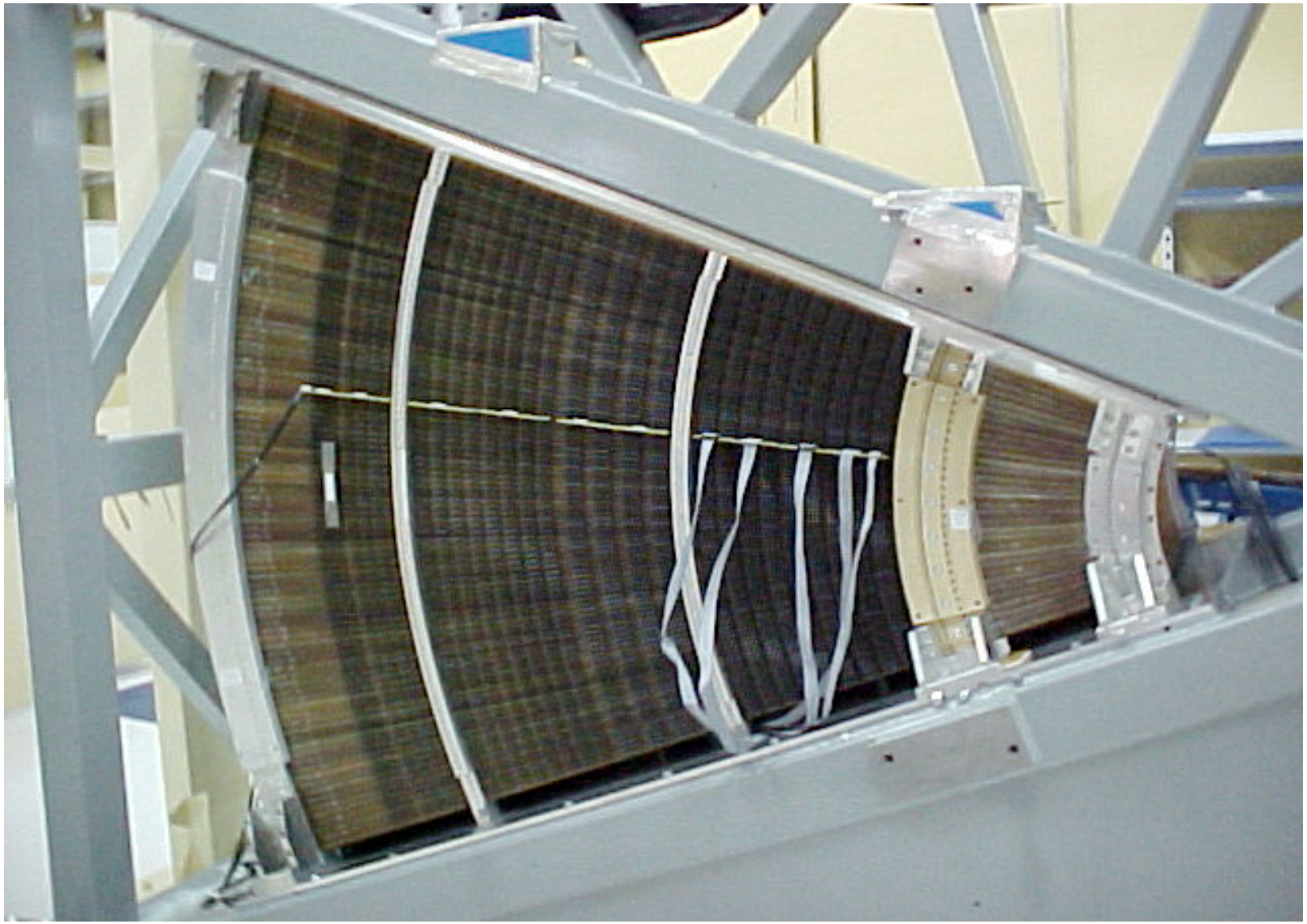
# D-Spacer



# Detail of an electrode



# Module stacked



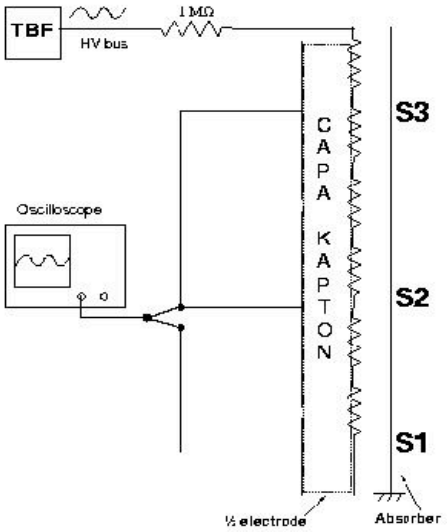
# Low frequency test

Goal

To check the continuity of:

- the electrical circuit,
- the electrode connections including the high voltage distribution.

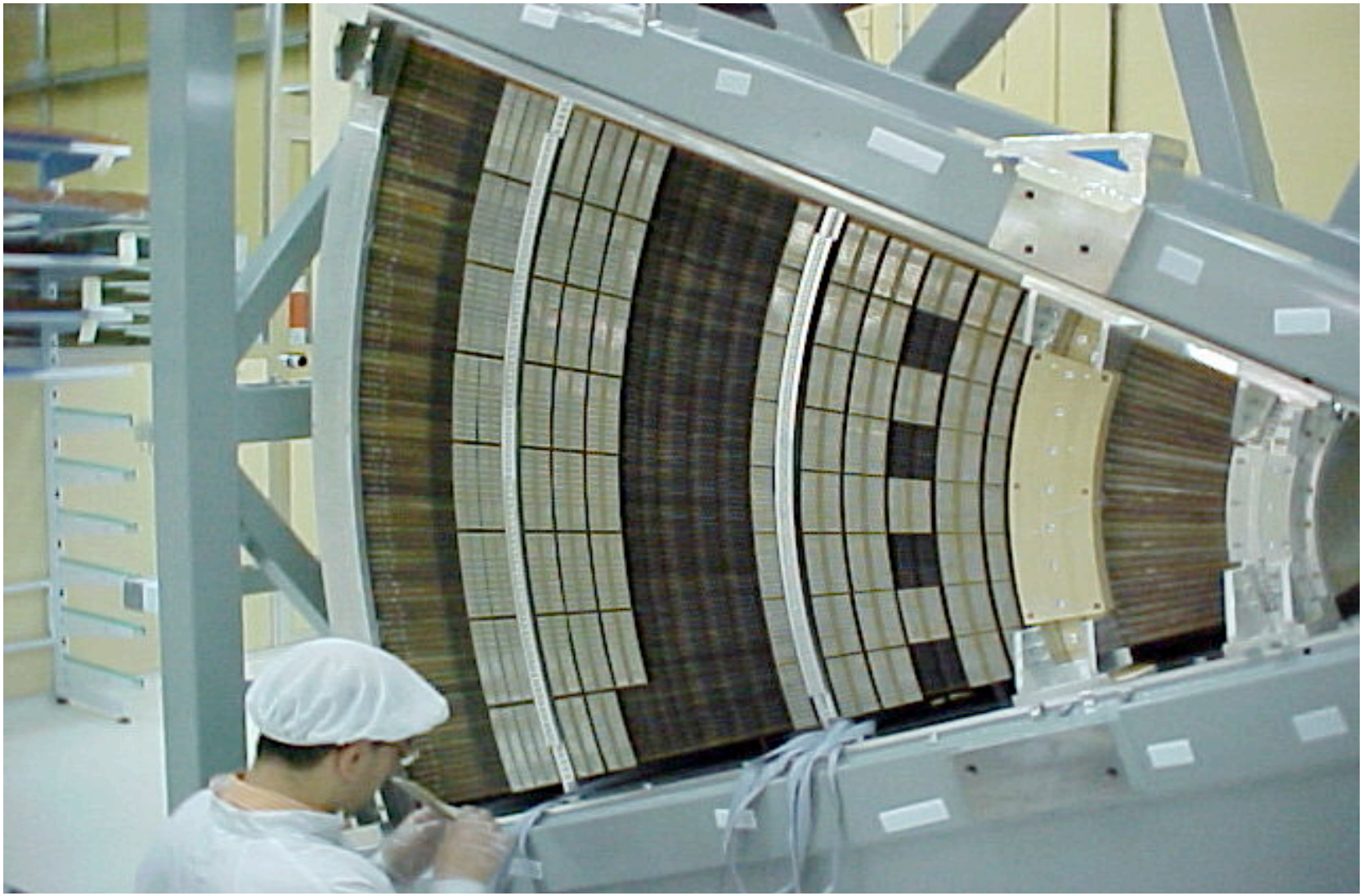
principle



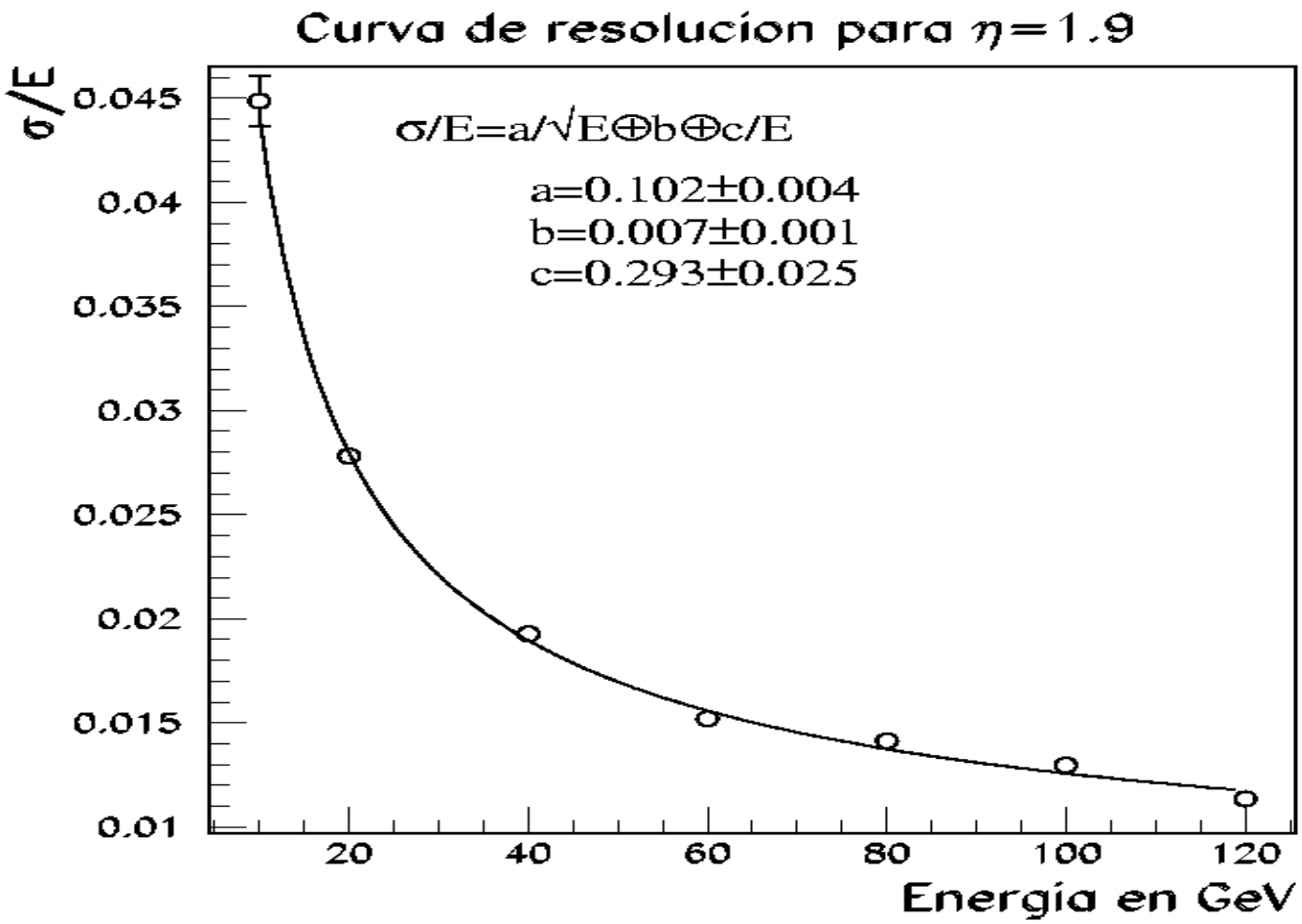

- a low frequency sinusoïdal signal is injected on the HV lines.
- a current is induced on the signal layer.
- the decoupling capacitance is calculated.

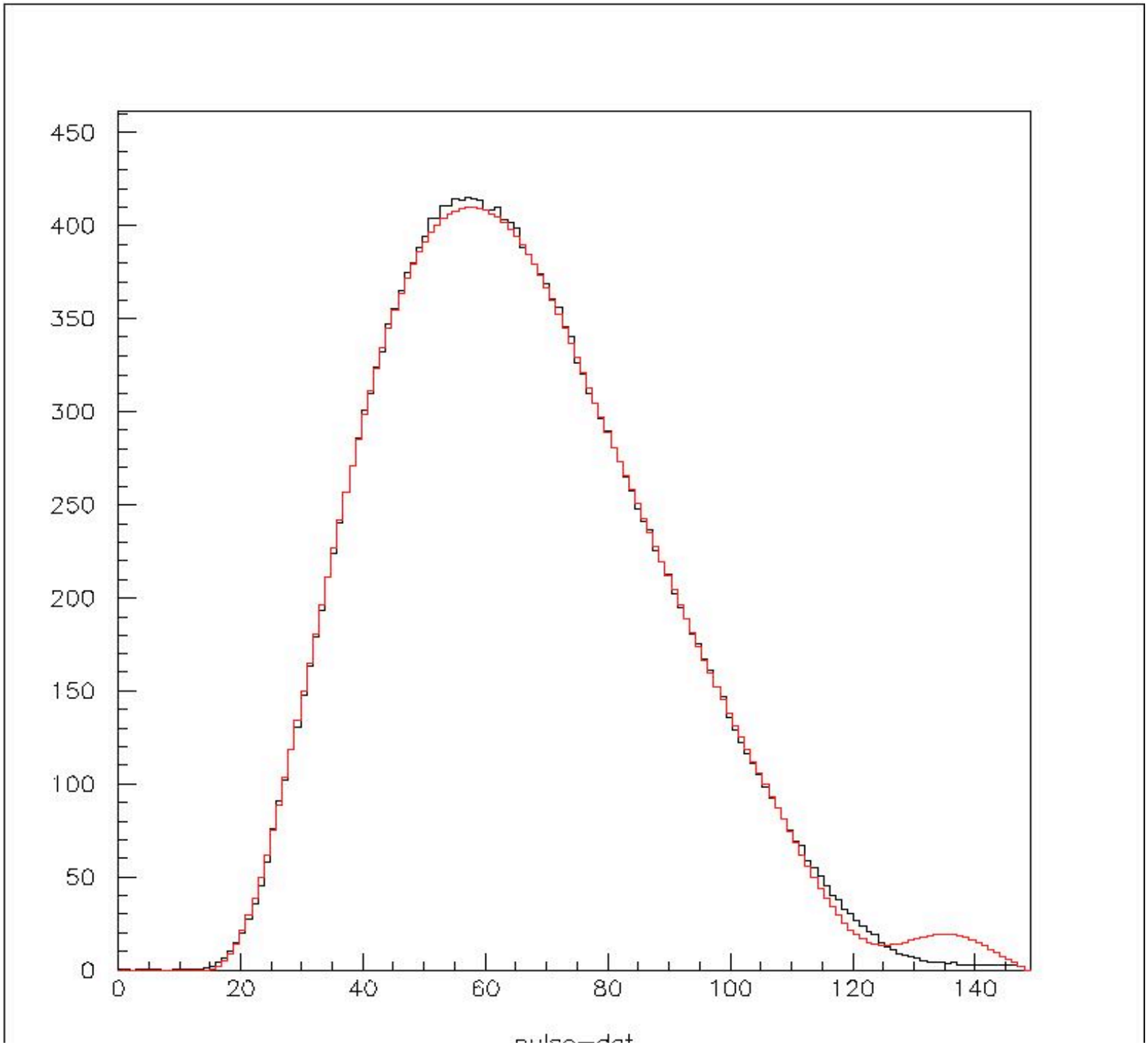
# Jose and Pablo at work

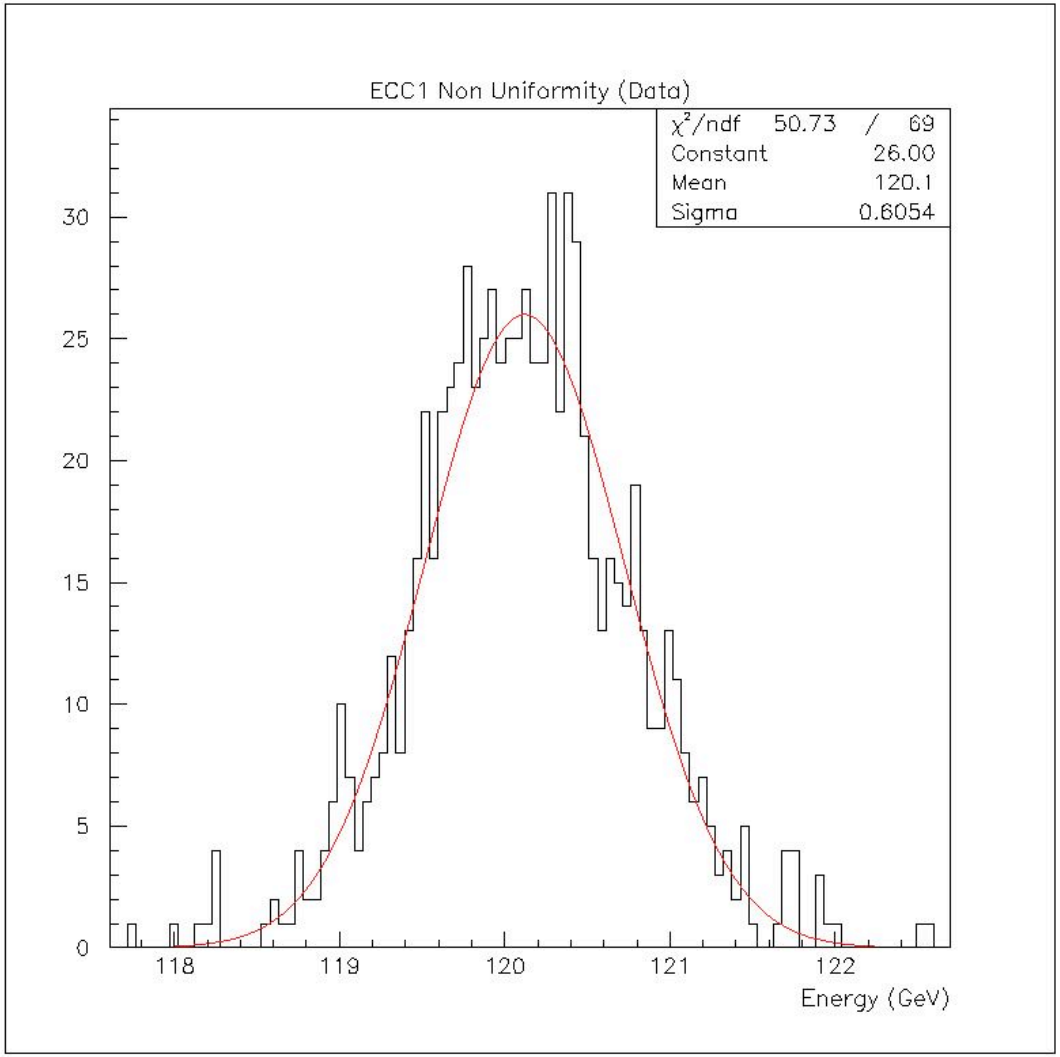
# Equiping summing boards

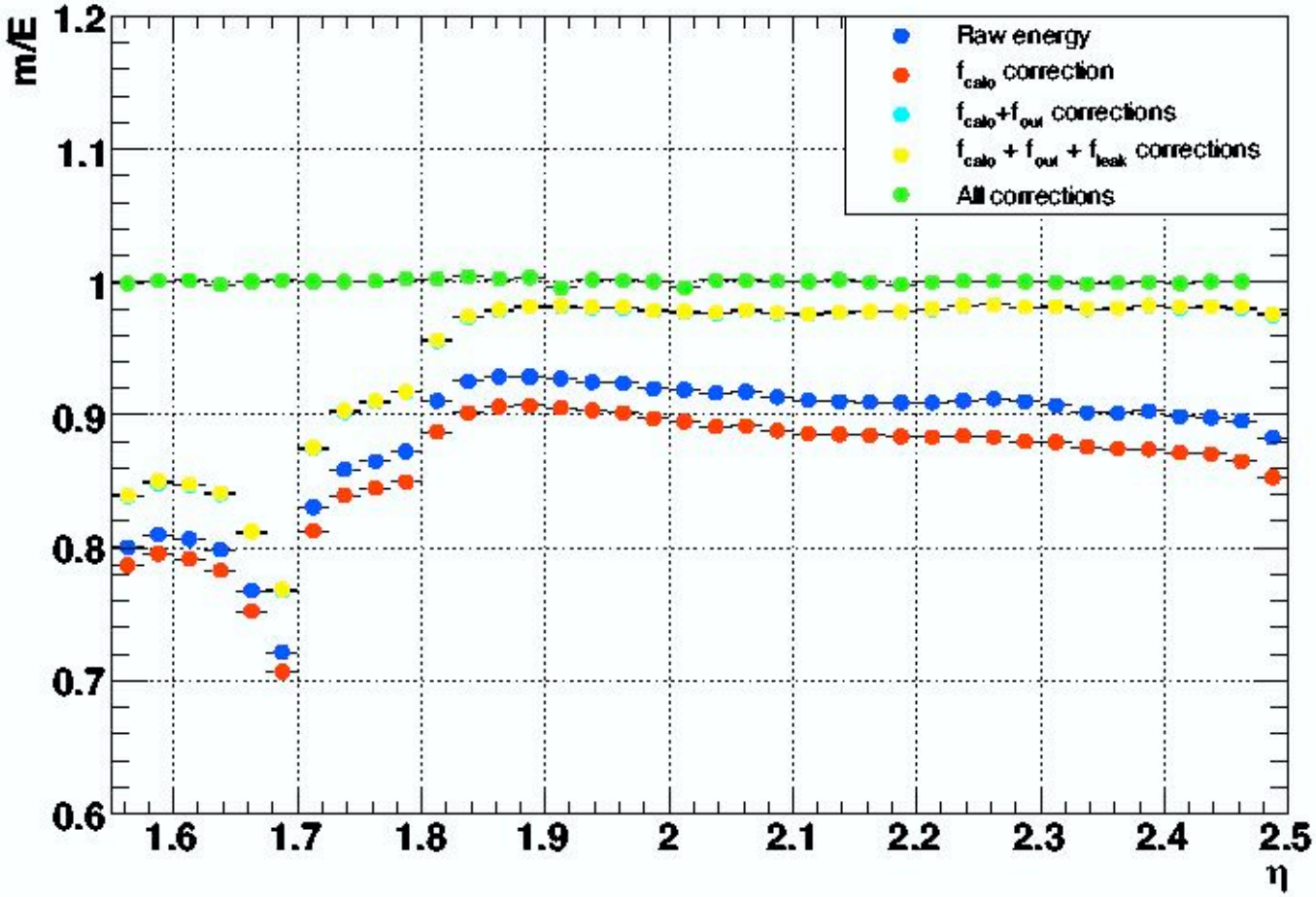


ATELIERS ROCHE
15, Bd Marcelin Berthelot
REIMS FRANCE
Date de Fab. : AVRIL 2002
MPI
Wuppertal


Curva de resolucion para $\eta=1.9$
$\sigma/E=a/\sqrt{E}\oplus b\oplus c/E$
a=0.102±0.004
b=0.007±0.001
c=0.293±0.025
σ/E
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
20
40
60
80
100
120
Energía en GeV


450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140


ECC1 Non Uniformity (Data)
χ²/ndf 50.73 / 69
Constant 26.00
Mean 120.1
Sigma 0.6054
30
25
20
15
10
5
0
118
119
120
121
122
Energy (GeV)


m/E
1.2
1.1
1
0.9
0.8
0.7
0.6
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
η
Raw energy
$f_{calo}$ correction
$f_{calo}$+$f_{out}$ corrections
$f_{calo}$ + $f_{out}$ + $f_{leak}$ corrections
All corrections

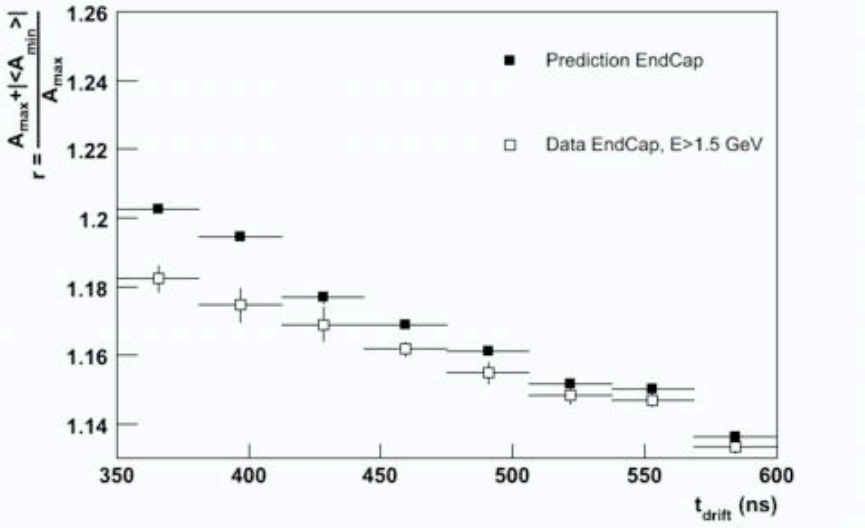
# Validation of $t_{drift}$ using cosmic data

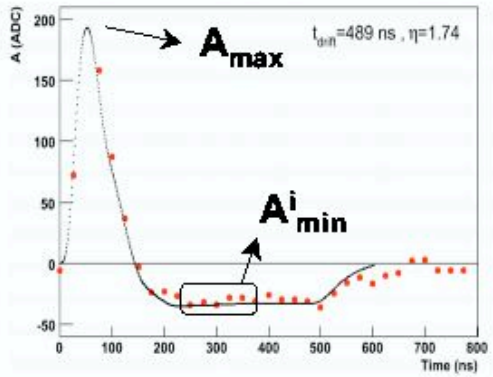
- **Otra The following quantity is sensitive to $t_{drift}$ :**

$$r = \frac{A_{max}^{OFC_{5s}} + |\frac{1}{n}\sum_{i=1}^{n} A_{min}^{i}|}{A_{max}^{OFC_{5s}}}$$

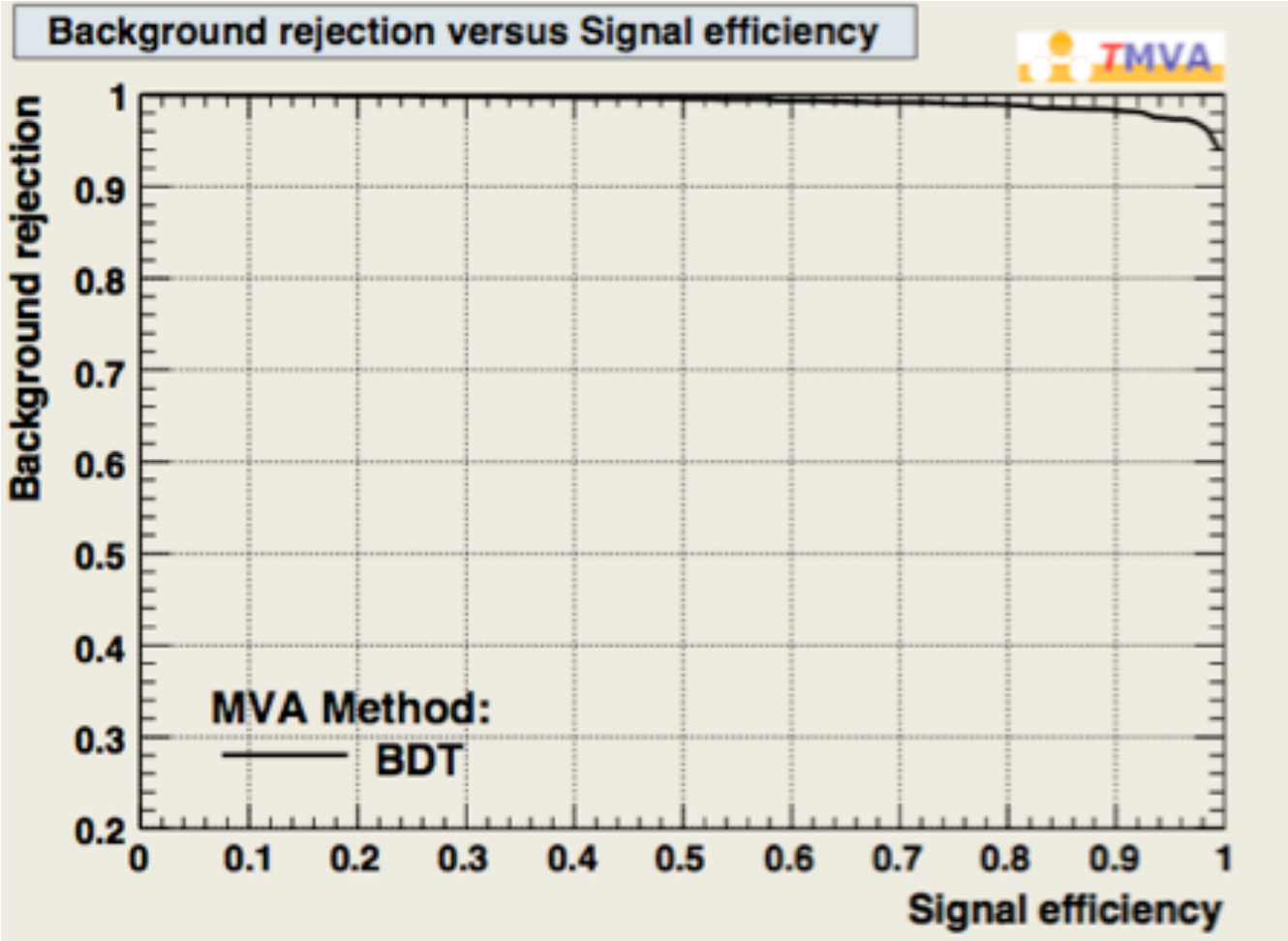
- **$A_{max}$** : Amplitude obtained using 5 "samples" OFC
- **$A^{i}_{min}$** : "samples" to estimate undershoot
- **n = 5** : "number of samples used

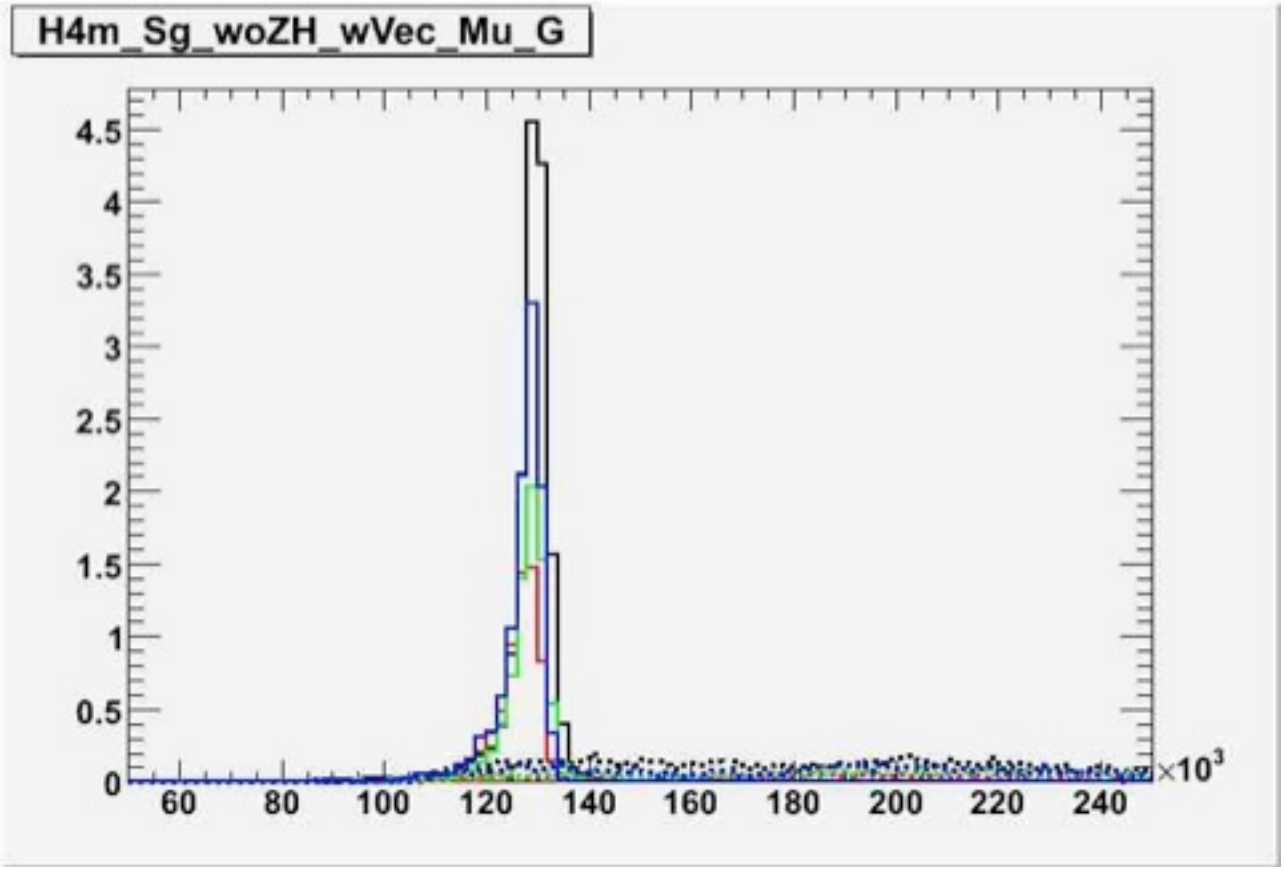
- **An increase of r translates in an increase of $t_{drift}$**




→ ***Data suggest an overestimation of the*** **$t_{drift}$ values used in the prediction**


Background rejection versus Signal efficiency
TMVA
Background rejection
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Signal efficiency
MVA Method:
BDT


H4m_Sg_woZH_wVec_Mu_G
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
60
80
100
120
140
160
180
200
220
240
×10³

# Presentations at Conferences

J. Fernandez, Construction and tests of the ATLAS Lar EMEC,CALOR99, Lisbon.

S. Rodier: LAr EMEC: Construction and Uniformity of response, CALOR 2002, Caltech.

L.Labarga : Construction and test results of the LAr EMEC, 8th Topical Seminar on Particle Detectors, Siena, October 2002

C. Oliver: Uniformity of response in the ATLAS LAr EMEC, 9th ICATPP, Villa Olmo, 2005

C. Gabaldon :Commissioning the ATLAS Lar detector with cosmic muon signals, CALOR2008, Padova

# PhD THESIS

**P. Romero: Design and construction of the ATLAS LAr EMEC**

**G. Garcia : Two cases of calorimetry: the ZEUS plug calorimeter and the ATLAS LAr EMEC**

**C. Oliver : Uniformity of the ATLAS LAr EMEC**

**S. Rodier : Construction and tests of the ATLAS LAr EMEC**

# PUBLICATIONS

**C. Gabaldon, J. del Peso : Signal reconstruction in the EMEC and check with cosmic data, ATLAS-LAr-PUB-2008-001**

**E. Nebot, J. del Peso: Electron energy recosntruction for the Lar EMEC using calibration hits, ATLAS-COM-Larg-2008-05**

**T. Lagouri, F Barreiro, J. del Peso: Hto4lEV in the ATLAS Eventview analysis framework, submitted to IESS-NSS-08**

**C. Oliver, J. Del Peso : Uniformity of the ATLAS LAr EMEC, ATLAS-LARG-PUB-2005_02**

# List of Publications

May 22, 2008

## References


[1] Result from a new combined test of an electromagnetic liquid argon calorimeter with a hadronic scintillating-tile calorimeter.

ATLAS Coll., S. Akhmadalev et al. *Nucl. Inst. and Meth. A449 (2000) 461-477.*

[2] Hadron energy reconstruction for the ATLAS calorimetry in the framework of the nonparametrical method.

ATLAS Coll., S. Akhmadalev et al., *Nucl. Inst. and Meth. A480 (2002) 508-523.*

[3] Performance of the ATLAS electromagnetic calorimeter barrel module 0.

ATLAS EM LAr Cal Group, B. Aubert et al., *Nucl. Inst. and Meth. A500 (2003) 202-231*

[4] Performance of the ATLAS electromagnetic calorimeter endcap module 0.

ATLAS EM LAr Cal Group, B. Aubert et al., *Nucl. Inst. and Meth. A500 (2003) 178-201*

[5] Hadronic calibration of the ATLAS Liquid argon endcap calorimeter in the pseudorapidity region $1.6 \leq \eta \leq 1.8$ in beam tests.

ATLAS LAr EMEC/HEC Coll., C. Cojocaru et al., *Nucl. Instrum. Meth.A 531 (2004):481-514.*

[6] Position resolution and particle identification with the ATLAS electromagnetic calorimeter.

ATLAS LAr Coll., J. Colas et al., *Nucl. Instrum. Meth.A 550 (2005):96-115.*

[7] Response Uniformity of the ATLAS Liquid Argon Electromagnetic Calorimeter.

J. Colas et al., *Nucl. Inst. and Meth. A582 (2007) 429-455.*

0503010069178

# MINISTERIO DE EDUCACIÓN Y CIENCIA

**Secretaría de Estado de Universidades e Investigación**
**Secretaría General de Política Científica y Tecnológica**
Dirección General de Investigación

INDIVIDUAL

## Resumen de la documentación de la solicitud de Proyecto Individual

## Plan Nacional de I + D + I (2004-2007)

**El investigador :** Fernando Barreiro Alonso

**Ha presentado la solicitud de código :** 3010

**En el Programa Nacional :** Programa Nacional de Física de Partículas

**Con los siguientes anexos :**

**Memoria técnica (Inglés)**

--

**Memoria técnica**

MEMORIA.DOC

**Curricula**

Investigador Principal :

Curriculum Fernando Barreiro Alonso 31179875V.PS

Otros Investigadores :

| Nombre Investigador | Curriculum |
|---|---|
| Luis Labarga Echeverria | 16527494Q.PS |
| Jose del Peso Malagon | 02707084F.PS |
| Stephane David Rodier - | X2678690H.PS |
| Juan Pablo Fernandez Ramos | 05415703P.PS |

0503010069178

## 1.6. AYUDA SOLICITADA

**Entidad Solicitante:** UNIVERSIDAD AUTONOMA DE MADRID

| | | Caso de costes marginales | Caso de costes totales | |
|---|---|---|---|---|
| | | Ayuda solicitada | Presupuesto total | Ayuda solicitada |
| | | EURO | EURO | EURO |
| Costes de personal | Personal | 120.000,00 | | |
| | Complementos salariales (*) | 0 | | |
| Costes de ejecución | Pequeño equipamiento y material bibliográfico | 36.000,00 | | |
| | Material fungible | 27.000,00 | | |
| | Viajes y Dietas | 220.000,00 | | |
| | Varios | 240.000,00 | | |
| Costes Directos Totales(A) | | 643.000,00 | | |
| Costes Indirectos (0,19 x A) | | 122.170,00 | | |
| **Coste Total del Proyecto(B)** | | 765.170,00 | | |

| | |
|---|---|
| **EDP DEL GRUPO INVESTIGADOR COMPLETO DE LA ENTIDAD SOLICITANTE:** P = P1 + P2 | **P = 5** |
| **EDP TOTAL DEL EQUIPO DE PROYECTO:** Q = P1 + P2 + P3 | **Q = 5** |
| | **EURO** |
| **Indicador de coste anual:** | **51.011,33** |

(*) Los costes de personal han sido incrementados con los complementos salariales si se han solicitado (Solo Centros Públicos de I+D. Máximo 2100xP EURO por Año).

**REFERENCIA:** FPA2005-03010/
**INVESTIGADOR PRINCIPAL:** FERNANDO BARREIRO ALONSO

**ORGANISMO:** UNIVERSIDAD AUTONOMA DE MADRID
**CENTRO:** DPTO. FISICA TEORICA
**TITULO:** CONSTRUCCION DEL CALORIMETRO ELECTROMAGNETICO DE ATLAS
**DURACIÓN:** 3 **AÑO/S**

LA DIRECCIÓN GENERAL DE INVESTIGACIÓN, en el ejercicio de las competencias que le atribuye la Orden ECI/4073/2004, y la resolución de convocatoria de 28 DE DICIEMBRE DE 2004, por la que se establecen las bases y se hace pública la convocatoria de concesión de ayudas para la realización de proyectos de investigación en el marco de algunos Programas Nacionales del Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica 2004-2007 y, por otra parte, las derivadas del Real Decreto 553/2004, de 17 de abril, de reestructuración de los departamentos ministeriales, del Real Decreto 562/2004, de 19 de Abril, por el que se establece la estructura orgánica del Ministerio de Educación y Ciencia y, del Real Decreto 1553/2004, de 25 de Junio, por el que se desarrolla la estructura orgánica básica del Ministerio de Educación y Ciencia y antes de proceder a la Resolución de concesión de ayuda da traslado de la siguiente NOTIFICACIÓN DE SUBVENCIÓN/ANTICIPO REEMBOLSABLE.

Pone en su conocimiento que la Comisión de selección del Programa Nacional de Física de Partículas, tras seguir el procedimiento descrito en el apartado noveno de la citada Orden y Convocatoria, ha propuesto la financiación del proyecto de referencia, en los términos siguientes (y, en su caso, con las observaciones reseñadas en el Informe de la Comisión de selección):

Subvención que se propone conceder con (si procede) un crédito-anticipo reembolsable

**PROPUESTA DE FINANCIACIÓN TOTAL POR CONCEPTOS (Euros)**

| | |
|---|---|
| **PERSONAL (1)** | **120000** |
| **COSTES DE EJECUCIÓN** | **470000** |
| **COSTES DIRECTOS** | **590000** |
| **Nº DE BECAS PROPUESTAS PARA ASIGNACIÓN AL PROYECTO** | **1** |
| **Nº DE TÉCNICOS PROPUESTOS PARA ASIGNACIÓN AL PROYECTO** | **1** |
| | |
| **Puntuación del proyecto** | **96** |
| **Puntuación de corte en su programa/subprograma** | **50** |

(1) La financiación de Personal que se muestra no incluye los complementos salariales que puedan concederse, que no están sometidos a trámite de audiencia, y serán incluidos en la resolución definitiva.

La distribución anual será aproximadamente: 1º año: 30%, 2º año: 40%, y 3º año: 30%, para los proyectos con tres años de duración. En el caso de proyectos a costes marginales, la entidad beneficiaria recibirá un 19% adicional de la financiación concedida, (incluidos los complementos salariales, si los hubiese).

Estas ayudas podrán estar cofinanciadas por el FEDER, que contribuye en las regiones Objetivo 1 con el 70% de la ayuda total y en las zonas elegibles de las regiones Objetivo 2 con el 50%.

**Observaciones de la Comisión de Selección sobre la propuesta de financiación (si las hubiere):**

# HEP-UAM group at ZEUS

- **Previous funding by CICYT and MCyT**

| Project Number | Project leader | Funding | Duration |
|---|---|---|---|
| FPA2005-02272 | J. Terron | 289000 Euros | 2005-2008 |
| FPA2002-0915 | L. Labarga | 255660 Euros | 2002-2005 |
| AEN99-0384 | L. Labarga | 272859,49 Euros | 1999-2002 |
| AEN96-1996-C02-01 | L. Labarga | 41.7 Mpesetas | 1996-1999 |
| AEN93-0077 | F. Barreiro | 53.0 Mpesetas | 1993-1996 |
| ..... | ..... | ..... | ..... |

- **Scientific outcome:**
  - → **ZEUS internal notes: ≈ 100**
  - → **Publications on instrumentation from ZEUS R& D: 12**
  - → **ZEUS physics publications: 182**
  - → **ZEUS physics publications lead by UAM members: 47**
  - → **Theses done by UAM members in ZEUS: 14**
  - → **Publications in collaboration with theoreticians: 6**

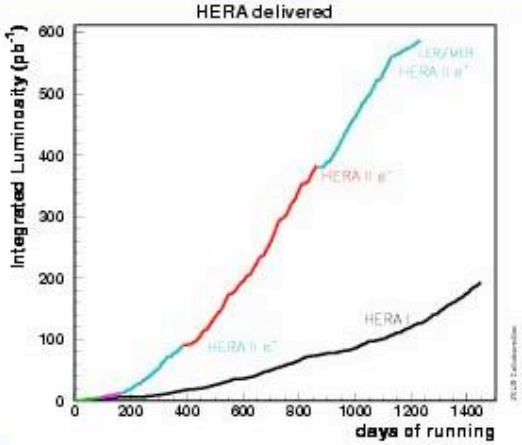
# HERA II Performance

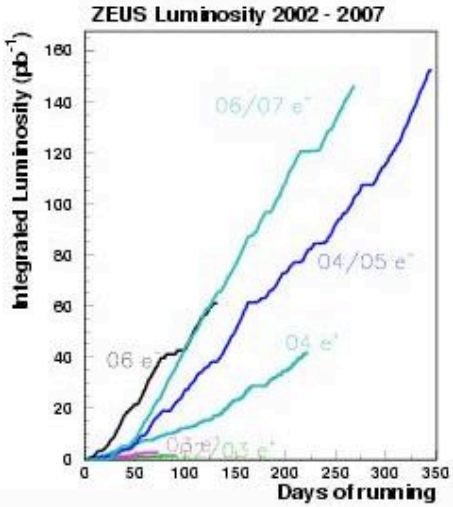
- Luminosity and detector upgrade
- Long run period until 2007
- Installation of spin rotators in collider experiments: H1 and ZEUS
- Longitudinally polarised $e^{\pm}$ beams

→ New window into Electroweak Sector

- High Energy Running ($\sqrt{s} = 300 - 320$ GeV)
  - → ended on March 20th, 2007
  - → luminosity delivered by HERA: 758 $\text{pb}^{-1}$
  - → ZEUS physics luminosity : $\sim 504$ $\text{pb}^{-1}$
- Low Energy Running ($E_p = 460$ GeV) and Medium Energy Running ($E_p = 575$ GeV) afterwards
  - → measurement of $F_L$

⇒ HERA stopped operation on June 30th, 2007



## Main Areas of Research

- **Jet Production and QCD**
- **Diffraction**
- **Heavy Quarks**
- **Structure Functions, Electroweak Interactions and Searches**

# Jet Production and QCD

- Past

1. Observation of hard scattering in photoproduction at HERA, PLB297 (1992) 404-416
2. Observation of two-jet production in DIS at HERA, PLB306 (1993) 158-172
3. Observation of direct processes in photoproduction at HERA, PLB322 (1994) 287-300
4. Inclusive jet differential cross sections in photoproduction at HERA, PLB342 (1995) 417-432
5. Dijet angular distribs. in direct and resolved photoproduction at HERA, PLB348 (1996) 401-413
6. Measurement of jet shapes in photoproduction at HERA, EPJC2 (1998) 61-75
7. High-$E_T$ inclusive jet cross sections in photoproduction at HERA, EPJC4 (1998) 591-606
8. Measurement of jet shapes in high $Q^2$ DIS at HERA, EPJC8 (1999) 367-380
9. Measurement of dijet prodn. in NC DIS at high $Q^2$ and determination of $\alpha_s$, PLB507 (2001) 70-88
10. Dijet production in neutral current DIS at HERA, EPJC23 (2002) 13-27
11. High-mass dijet cross sections in photoproduction at HERA, PLB531 (2002) 9-27
12. Inclusive jet cross sects. in the Breit frame in NC DIS and determ. of $\alpha_s$, PLB547 (2002) 164-180
13. Study of the azimuthal asymmety of jets in NC DIS at HERA, PLB551 (2003) 226-240
14. Measurement of subjet multiplicities in NC DIS at HERA and determ. of $\alpha_s$, PLB558 (2003) 41-58

## Jet Production and QCD (continued)

15. Scaling violations and determ. of $\alpha_s$ from jet prodn. in $\gamma p$ at HERA, PLB560 (2003) 7-23
16. Jet production in charged current deep inelastic $e^+p$ scattering at HERA, EPJC31 (2003) 149-164
17. The dependence of dijet prodn. on photon virtuality in $ep$ at HERA, EPJC35 (2004) 487-500
18. Substructure dependence of jet cross sections at HERA and determ. of $\alpha_s$, NPB700 (2004) 3-50

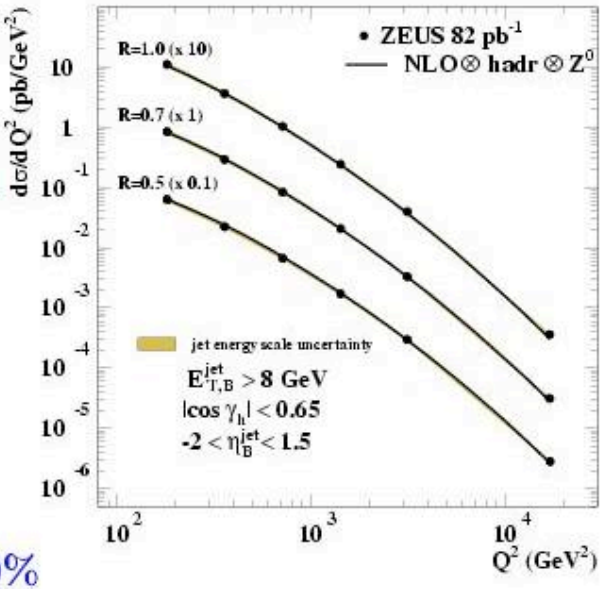
- Current Project (2005-2008):

19. Forward jet production in DIS and low-$x$ parton dynamics at HERA, PLB632 (2006) 13-26
20. Event shapes in deep inelastic scattering at HERA, NPB767 (2007) 1-28
21. Measurement of prompt photons with associated jets in $\gamma p$ at HERA, EPJC49 (2007) 511-522
22. Inclusive-jet and dijet cross sections in DIS at HERA, NPB765 (2007) 1-30
23. Forward-jet production in deep inelastic $ep$ scattering at HERA, EPJC52 (2007) 515-530
24. Jet-radius dependence of inclusive-jet cross sections in DIS at HERA, PLB649 (2007) 12-24
25. Three- and four-jet final states in photoproduction at HERA, NUPB792 (2008) 1-47

# Inclusive Jet Cross Sections in NC DIS at $Q^2 > 125$ GeV$^2$

PLB649 (2007) 12-24

- New measurement of inclusive jet cross sections in the kinematic region defined by $Q^2 > 125$ GeV$^2$ and $|\cos\gamma| < 0.65$ for jets with $E^B_{T,jet} > 8$ GeV and $-2 < \eta^B_{jet} < 1.5$ using $\mathcal{L} = 81.7$ pb$^{-1}$
  - → for different values of the radius-like parameter (R) of the $k_T$-cluster algorithm: $R = 0.5, 0.7, 1$
- Advantages:
  - → infrared insensitivity (no dijet cuts!)
  - → smaller theoretical uncertainties than for dijet
- Small experimental uncertainties:
  - → jet energy scale (1% for $E_{T,jet} > 10$ GeV)
    - $\Rightarrow \sim \pm 5\%$ on the cross sections
- Small parton-to-hadron corrections ($C_{had}$): $< 10\%$




- NLO QCD calculations ($\mathcal{O}(\alpha_s^2)$) using $\mu_R = E^B_{T,jet}$, $\mu_F = Q$ and the ZEUS-S parametrisations of the proton PDFs describe the measurements well

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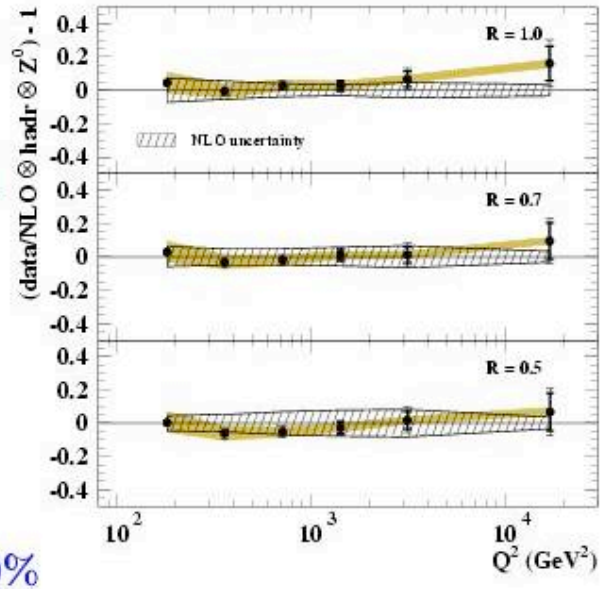


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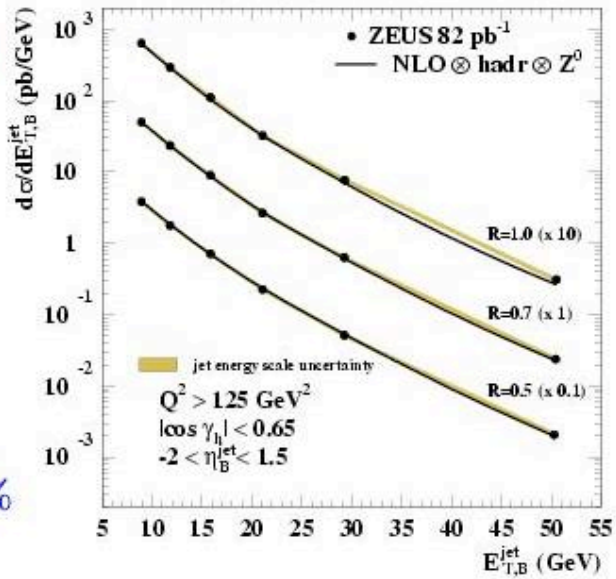
# Inclusive Jet Cross Sections in NC DIS at $Q^2 > 125$ GeV$^2$

- New measurement of the inclusive jet cross section $d\sigma/dE^B_{T,jet}$ in the kinematic region defined by $Q^2 > 125$ GeV$^2$ and $|\cos\gamma| < 0.65$ for jets with $E^B_{T,jet} > 8$ GeV and $-2 < \eta^B_{jet} < 1.5$

PLB649 (2007) 12-24




- Small theoretical uncertainties ($R = 1$):
  - → higher-order terms (> NLO); varying $\mu_R$ between $\frac{1}{2} \cdot E^B_{T,jet}$ and $2 \cdot E^B_{T,jet}$ ⇒ $\pm 5\%$
  - → uncertainties on the proton PDFs; ⇒ $\pm 3\%$
  - → uncertainty on $\alpha_s(M_Z)$ ($\pm 0.0010$); ⇒ $\pm 2\%$
  - → hadronisation corrections; ⇒ $\pm 1.4\%$

- NLO QCD calculations ($\mathcal{O}(\alpha_s^2)$) using $\mu_R = E^B_{T,jet}$, $\mu_F = Q$ and the ZEUS-S parametrisations of the proton PDFs describe the measurements well

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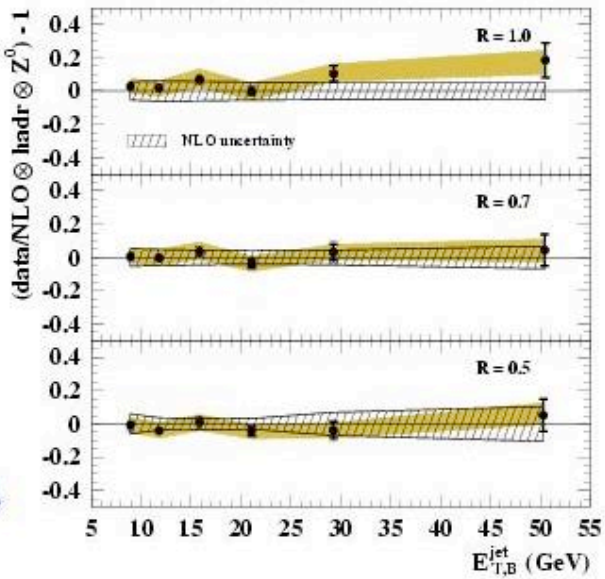
PLB649 (2007) 12-24

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# Inclusive Jet Cross Sections and extraction of $\alpha_s$ (ZEUS)

- The inclusive jet cross section $d\sigma/dQ^2$ at $Q^2 > 500$ GeV$^2$ has been used to extract $\alpha_s(M_Z)$

$$\alpha_s(M_Z) = 0.1207 \pm 0.0014\ (\text{stat.})^{+0.0035}_{-0.0033}\ (\text{exp.})^{+0.0022}_{-0.0023}\ (\text{th.})$$

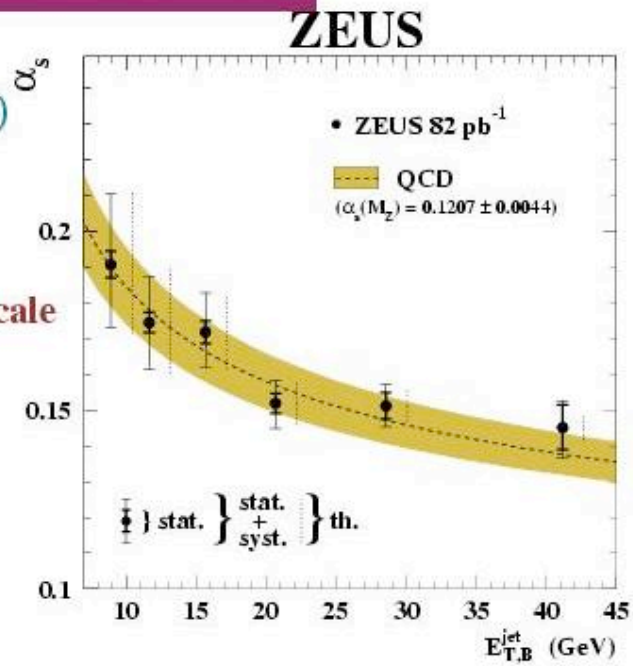
- Experimental uncertainties: 2% from jet energy scale
- Theoretical uncertainties:

→ terms beyond NLO $\Delta\alpha_s(M_Z) = 1.5\%$

→ uncertainties proton PDFs $\Delta\alpha_s(M_Z) = 0.7\%$

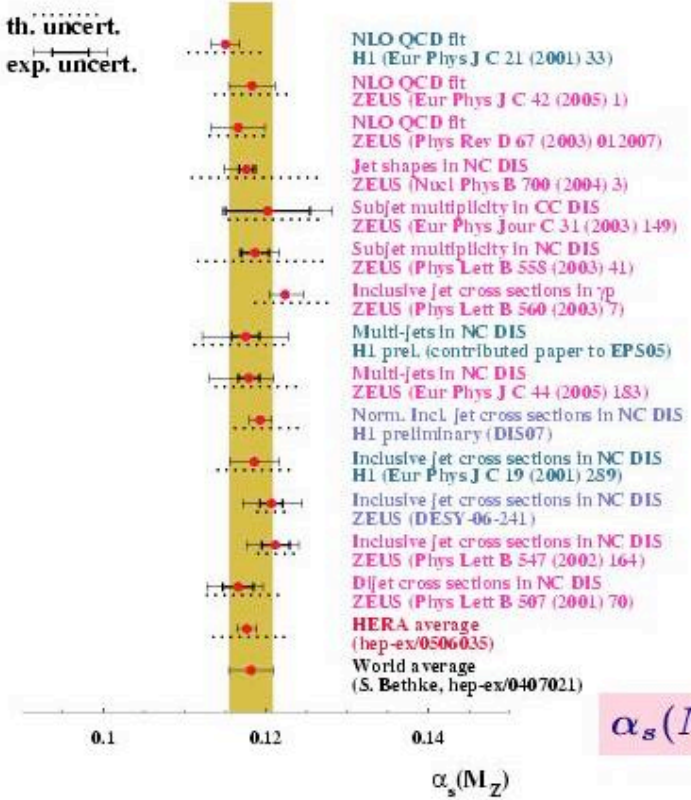
→ hadronisation corrections $\Delta\alpha_s(M_Z) = 0.8\%$

- Consistent with other determinations of $\alpha_s$
- Very precise determination of $\alpha_s(M_Z)$!




- Study of the scale dependence of $\alpha_s(E^B_{T,jet})$: mahoganyfrom the measured $d\sigma/dE^B_{T,jet}$ $E^B_{T,jet}$ region → $\alpha_s(< E^B_{T,jet} >)$ is extracted
- The measurements are consistent with the running of $\alpha_s$ predicted by perturbative QCD

# Summary of $\alpha_s$ determinations




- Wealth of determinations of $\alpha_s$ at HERA from a variety of observables:

→ NLO QCD analyses of structure functions

→ Inclusive jet production in NC DIS

→ Dijet production in NC DIS

→ Tri-jet/Dijet rate in NC DIS

→ Jet substructure in NC DIS

→ Jet substructure in CC DIS

→ Inclusive jet photoproduction

- Theoretical uncertainties are dominant

→ Biggest contrib. from terms beyond NLO

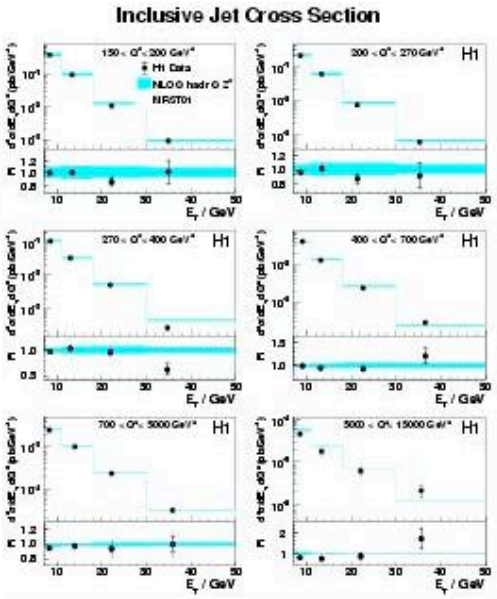
- Average of HERA determinations (2004)

$$\alpha_s(M_Z) = 0.1186 \pm 0.0011(\text{exp.}) \pm 0.0050(\text{th.})$$

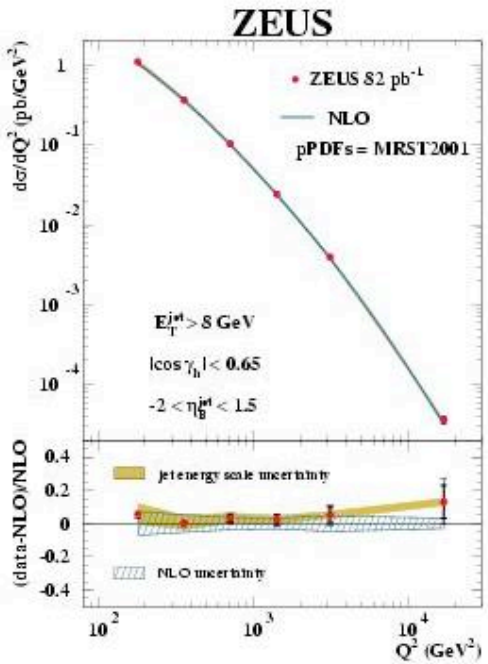
(most recent ones not yet included)

# New HERA $\alpha_s(M_Z)$ combination

- New $\alpha_s(M_Z)$ combination from inclusive-jet cross sections in NC DIS:
  simultaneous fit to ZEUS and H1 data sets which yield the most precise $\alpha_s(M_Z)$ values
  (instead of combining $\alpha_s(M_Z)$ values)




H1 Collab. PLB653 (2007) 134-144




ZEUS Collab. PLB649 (2007) 12-24

# New HERA $\alpha_s(M_Z)$ combination

- Fit to 30 measurements of inclusive-jet cross sections in NC DIS:

→ 24 H1 data points from double-differential cross section ($150 < Q^2 < 15000$ GeV$^2$)

→ 6 ZEUS data points from single-differential $Q^2$ cross section ($125 < Q^2 < 10^5$ GeV$^2$)

- NLO QCD calculations at $\mathcal{O}(\alpha_s^2)$
- Uncertainties on combined $\alpha_s(M_Z)$:

→ Experimental: $\pm 0.0019$ (Hessian method)

→ Theoretical: $\pm 0.0026$ (Jones et al. method)

- HERA combined 2007 $\alpha_s(M_Z)$ value:

$$\alpha_s(M_Z) = 0.1198 \pm 0.0019\ (\text{exp.}) \pm 0.0026\ (\text{th.})$$

with a total uncertainty of 2.7%

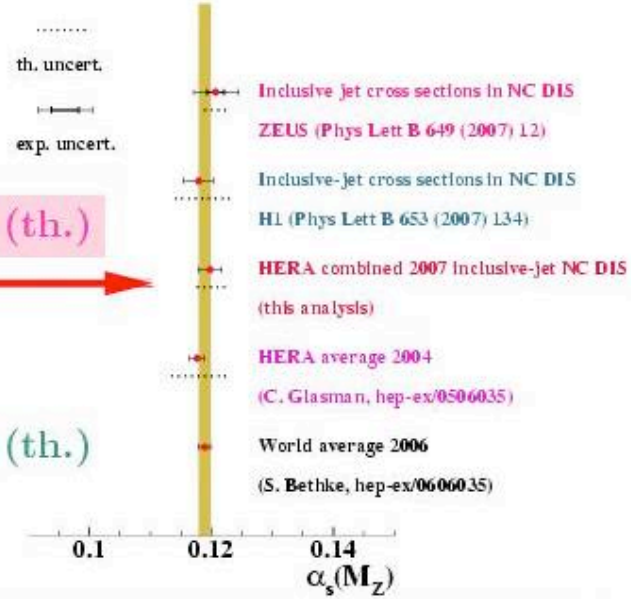
- To be compared with

→ HERA average 2004 (4.8%)

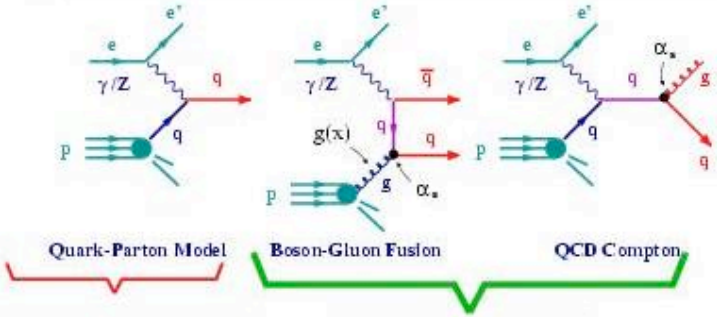
$$\alpha_s(M_Z) = 0.1186 \pm 0.0011\ (\text{exp.}) \pm 0.0050\ (\text{th.})$$

→ World average 2006 (0.8%)

$$\alpha_s(M_Z) = 0.1189 \pm 0.0010$$



# Measurements of Jet Substructure in NC DIS

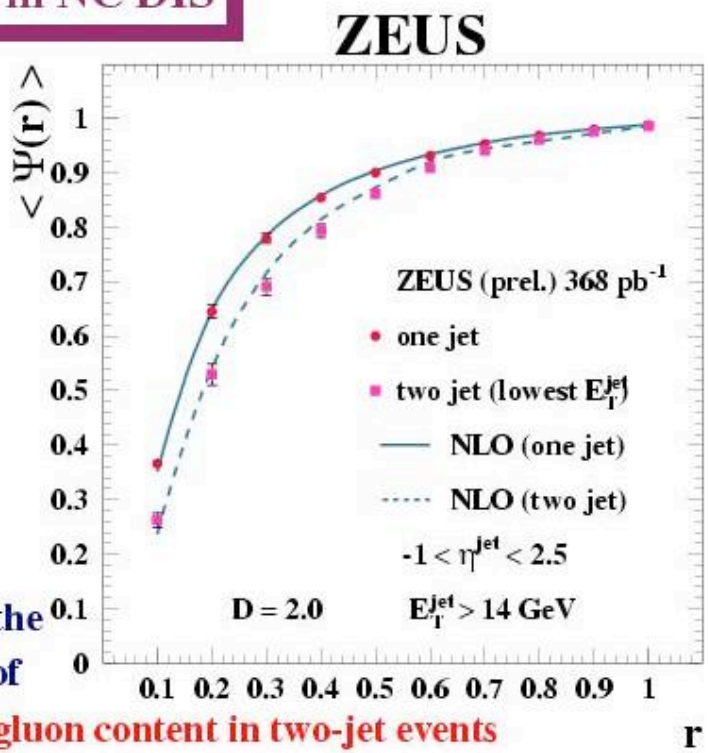



**One-jet events**

- Enriched in quark jets

**Two-jet events**

- Higher content of gluon jets




- The observation that the lowest-$E_T^{jet}$ jet in the two-jet event sample is BROADER than that of the one-jet sample is consistent with a higher gluon content in two-jet events

NLO QCD calculations corrected for hadronisation effects ($< 10\%$ for $r \geq 0.4$) reproduce the data reasonably well; in particular, the difference in jet shape between the two samples

# Diffraction

- Past

1. Observation of jet production in DIS with a large rapidity gap at HERA, PLB332 (1994) 228-243
2. Observation of hard scattering in photop. events with a LRG at HERA, PLB346 (1995) 399-414
3. Diffractive hard photop. and evidence for the gluon content of the pomeron, PLB356 (1995) 129-146
4. Event Shape Analysis of DIS Events with a Large Rapidity Gap at HERA, PLB421 (1998) 368-384
5. Diffractive Dijet Cross Sections in Photoproduction at HERA, EPJC5 (1998) 41-56
6. The ZEUS Forward Plug Calorimeter with Lead-Scintillator Plates and WLS Fiber Readout, NIMA450 (2000) 235
7. Three-jet production in diffractive deep inelastic scattering at HERA, PLB516 (2001) 273-292

- Current Project (2005-2008):

8. Leading neutron energy and $p_T$ distributions in DIS and $\gamma p$ at HERA, NPB776 (2007) 1-37

# Heavy Quarks

- Past

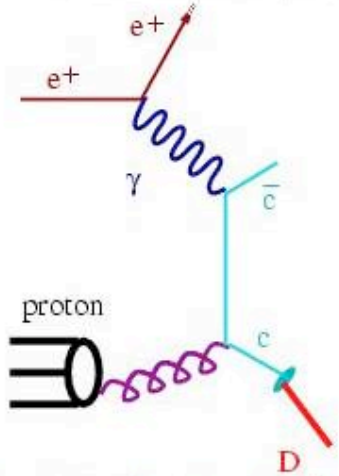
1. Study of $D^*(2010)^{\pm}$ production in $ep$ collisions at HERA, PLB349 (1995) 225-237
2. Neutral strange particle production in deep inelastic scattering at HERA, ZPC68 (1995) 29-42
3. Differential cross sections of $D^{*\pm}$ photop. in $ep$ collisions at HERA, PLB401 (1997) 192-206
4. $D^*$ production in deep inelastic scattering at HERA, PLB407 (1997) 402-418
5. Charged particles and neutral kaons in photoproduced jets at HERA, EPJC2 (1998) 77-93
6. Measurement of $D^{*\pm}$ prodn. and the charm Contribn. to $F_2$ in DIS at HERA, EPJC12 (2000) 35-52
7. Beam.test of silicon strip sensors for the ZEUS microvertex detector, NIMA501 (2003) 340-358
8. Measurement of $D^{*\pm}$ production in deep inelastic $e^+p$ scattering at HERA, PRD69 (2004) 012004

- Current Project (2005-2008):

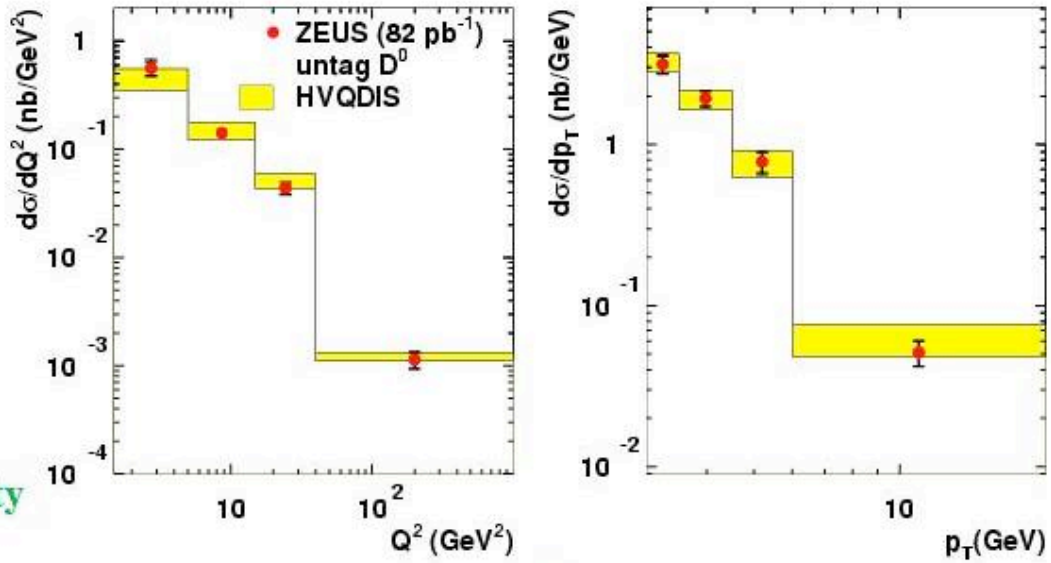
9. Measurement of $D$ mesons production in deep inelastic scattering at HERA, JHEP 07 074 (2007)

# $D$ mesons production in Neutral Current DIS ($1.5 < Q^2 < 1000$ GeV$^2$)

JHEP 07 074 (2007)




$D^{*+}$, $D^0$, $D^+$ and $D_s^+$ (+c.c.) charmed mesons




Luminosity 82 pb$^{-1}$

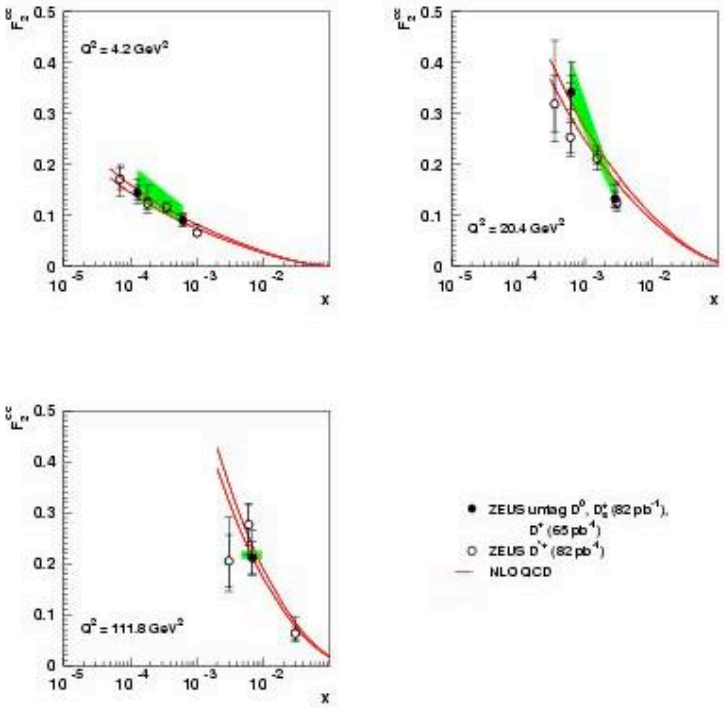
Sensitive to gluon density in the proton

- Precise measurements of differential cross sections for $D$-mesons production are well described by NLO QCD calculations with the parametrisations of the proton PDFs as determined by the ZEUS NLO QCD fit (FFNS) $\Rightarrow$ Input for future QCD fits of the p PDFs

# Open-charm contribution to $F_2$(proton) ($1.5 < Q^2 < 1000$ GeV$^2$

JHEP 07 074 (2007)

Measured cross sections for untag $D^0$, $D^+$ and $D_s^+$ (+c.c.) in the visible range and in $(Q^2, y)$ bins were extrapolated to the full phase space using NLO QCD calculations




→ Steep rise at low $x$

• $F_2^{c\bar{c}}$ data are generally well described by the prediction of the ZEUS NLO QCD fit of the p PDFs

Open-charm contribution to $F_2$(proton) at low $x$ and high $Q^2 \rightarrow F_2^{c\bar{c}}/F_2 \sim 30\%$

# Structure Functions, Electroweak Interactions and Searches

- Past

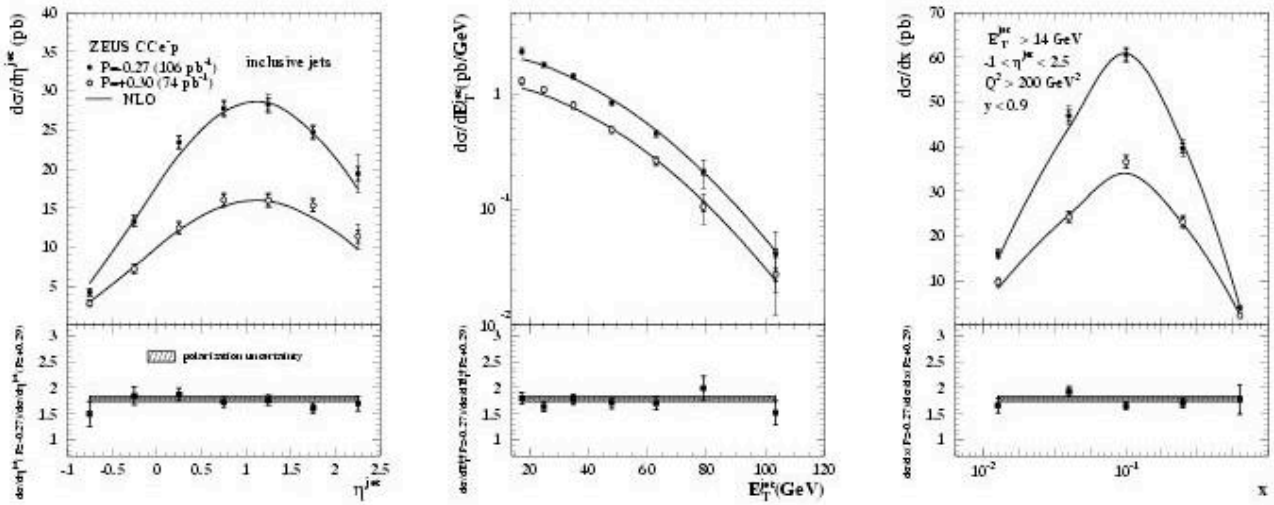
1. Initial Study of deep inelastic scattering with ZEUS at HERA, PLB303 (1993) 183-197
2. Study of CC $ep$ at $Q^2 > 200$ GeV$^2$ with the ZEUS detector at HERA, ZPC72 (1996) 47-64
3. Search for single-top production in $ep$ collisions at HERA, PLB559 (2003) 153-170
4. An NLO QCD analysis of inclusive cross-section and jet-production data from the ZEUS experiment, EPJC42 (2005) 1-16

- Current Project (2005-2008):

5. Multi-jet cross sections in charged current $e^{\pm}p$ scattering at HERA, Preprint DESY-08-024, accepted in PRD

# Multi-jet cross sections in charged current $e^{\pm}p$ scattering at HERA

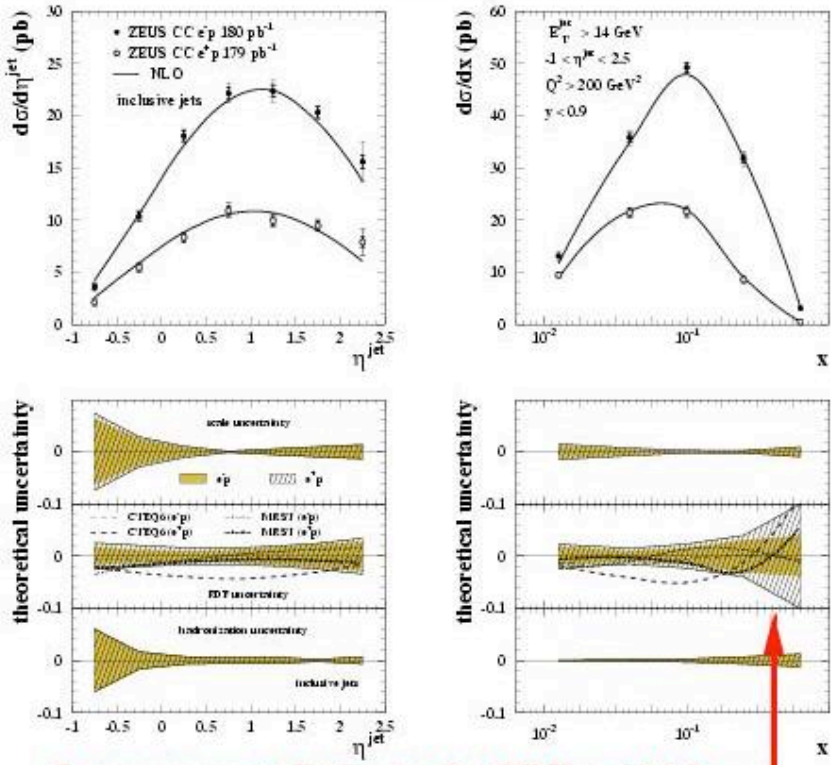
- **Measurement of inclusive-jet, dijet and trijet cross sections in CC DIS with longitudinally polarised $e^{\pm}$ beams using 359 pb$^{-1}$ (first paper that makes use of all HERA II data!)**

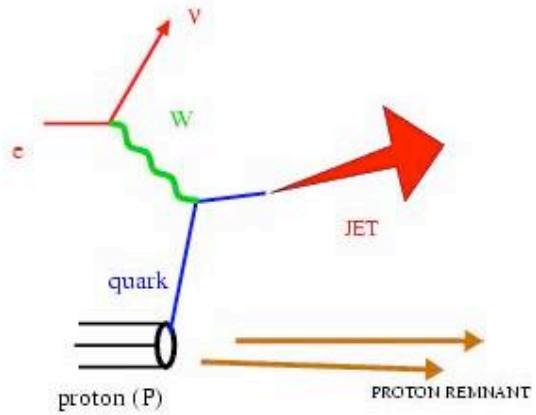



- **Measurements of inclusive-jet cross sections for CC DIS in $e^{-}_{L,R}p$ collisions:**

**→ the measured ratio $\sigma(e^{-}_{L}p)/\sigma(e^{-}_{R}p)$ is in good agreement with the measured polarization ratio as predicted by the chiral structure of electroweak interactions**

# Multi-jet cross sections in charged current $e^{\pm}p$ scattering at HERA




**The measurements are sensitive to the valence flavor content of the proton: $W^{-(+)}$ couples to up-like (down-like) quarks in the proton**

**Large uncertainties in the PDFs at high $x$:**

**the measurements will help to constrain the flavor content of the proton at high $x$**

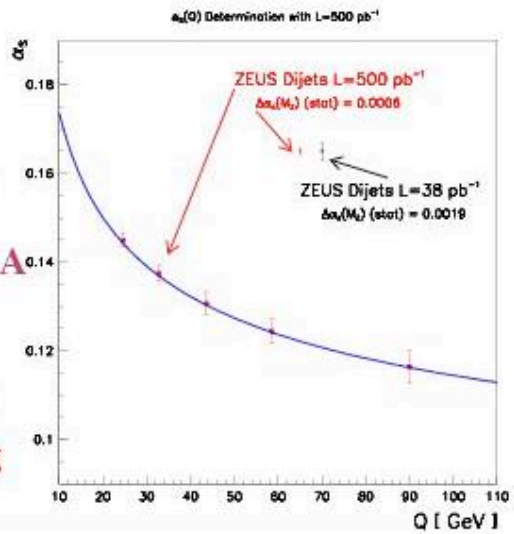
# Plans

1. Measurements of jet production in the Breit frame of NC DIS in an extended kinematic region and using $\mathcal{L} = 0.5\ \mathrm{fb}^{-1}$
   → stringent test of pQCD and a more precise determination of $\alpha_s$ and of its running
   → improved determination of the proton PDFs, in particular the gluon density through a combined analysis of jet cross-section measurements and structure functions

2. Measurements of three-jet production in NC DIS and photoproduction:
   → extraction of the colour factors through the measurement of angular correlations between the jets

3. Search for single-top production in $ep$ collisions at HERA
   → stringent test of the electroweak couplings of the top

4. Measurement of prompt-photon production in CC DIS:
   → test of the $WW\gamma$ coupling, particularly by measuring the tail of the $E_T^\gamma$ distribution



**REFERENCIA:** FPA2005-02272/
**INVESTIGADOR PRINCIPAL:** JUAN TERRON CUADRADO

**ORGANISMO:** UNIVERSIDAD AUTONOMA DE MADRID
**CENTRO:** DPTO. FISICA TEORICA
**TITULO:** ESTUDIO DE LA DISPERSION ELECTRON PROTON CON ZEUS EN HERA
**DURACIÓN:** 3 **AÑO/S**

LA DIRECCIÓN GENERAL DE INVESTIGACIÓN, en el ejercicio de las competencias que le atribuye la Orden ECI/4073/2004, y la resolución de convocatoria de 28 DE DICIEMBRE DE 2004, por la que se establecen las bases y se hace pública la convocatoria de concesión de ayudas para la realización de proyectos de investigación en el marco de algunos Programas Nacionales del Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica 2004-2007 y, por otra parte, las derivadas del Real Decreto 553/2004, de 17 de abril, de reestructuración de los departamentos ministeriales, del Real Decreto 562/2004, de 19 de Abril, por el que se establece la estructura orgánica del Ministerio de Educación y Ciencia y, del Real Decreto 1553/2004, de 25 de Junio, por el que se desarrolla la estructura orgánica básica del Ministerio de Educación y Ciencia y antes de proceder a la Resolución de concesión de ayuda da traslado de la siguiente NOTIFICACIÓN DE SUBVENCIÓN/ANTICIPO REEMBOLSABLE.

Pone en su conocimiento que la Comisión de selección del Programa Nacional de Física de Partículas, tras seguir el procedimiento descrito en el apartado noveno de la citada Orden y Convocatoria, ha propuesto la financiación del proyecto de referencia, en los términos siguientes (y, en su caso, con las observaciones reseñadas en el Informe de la Comisión de selección):

Subvención que se propone conceder con (si procede) un crédito-anticipo reembolsable

**PROPUESTA DE FINANCIACIÓN TOTAL POR CONCEPTOS (Euros)**

| | |
|---|---|
| **PERSONAL (1)** | **39000** |
| **COSTES DE EJECUCIÓN** | **250000** |
| **COSTES DIRECTOS** | **289000** |
| **Nº DE BECAS PROPUESTAS PARA ASIGNACIÓN AL PROYECTO** | **0** |
| **Nº DE TÉCNICOS PROPUESTOS PARA ASIGNACIÓN AL PROYECTO** | **0** |
| | |
| **Puntuación del proyecto** | **84** |
| **Puntuación de corte en su programa/subprograma** | **50** |

(1) La financiación de Personal que se muestra no incluye los complementos salariales que puedan concederse, que no están sometidos a trámite de audiencia, y serán incluidos en la resolución definitiva.

La distribución anual será aproximadamente: 1º año: 30%, 2º año: 40%, y 3º año: 30%, para los proyectos con tres años de duración. En el caso de proyectos a costes marginales, la entidad beneficiaria recibirá un 19% adicional de la financiación concedida, (incluidos los complementos salariales, si los hubiese).

Estas ayudas podrán estar cofinanciadas por el FEDER, que contribuye en las regiones Objetivo 1 con el 70% de la ayuda total y en las zonas elegibles de las regiones Objetivo 2 con el 50%.

**Observaciones de la Comisión de Selección sobre la propuesta de financiación (si las hubiere):**

SPID2008000602V0

GOBIERNO DE ESPAÑA | MINISTERIO DE EDUCACIÓN Y CIENCIA

# MINISTERIO DE EDUCACIÓN Y CIENCIA

**Secretaría de Estado de Universidades e Investigación**
**Secretaría General de Política Científica y Tecnológica**
Dirección General de Investigación

## 1.6. SOLICITUD DE INCLUSIÓN EN EL PROGRAMA DE FORMACIÓN DE INVESTIGADORES(FPI)

¿Solicita que este subproyecto sea incluido en el Programa de Formación de Investigadores? ☑ SI ☐ NO

Número de investigadores que solicita: 2

## 1.7. SOLICITUD DE INCLUSIÓN EN EL PROGRAMA DE FORMACIÓN DE TÉCNICOS:

¿Solicita que este subproyecto sea incluido en el Programa de Formación de Técnicos? ☑ SI ☐ NO

Número de técnicos que solicita: 2

## 1.8. ¿Existe alguna EPO, española o extranjera, interesada en los resultados del Proyecto de Investigación?(La presencia de EPO es obligatoria para ser incluido en el Programa de Formación de Técnicos y recomendable en el Programa de Formación de Personal Investigador)

☑ SI ☐ NO

Super Micro Computer Spain S.L. CIF: B82868878 Tipo Vinculación: Participación activa

## 1.9. ANTÁRTIDA

¿Su proyecto se va a desarrollar en las Bases Antárticas? ☐ SI ☑ NO

## 3.9 PRESUPUESTO DE COSTES MARGINALES

### . PRESUPUESTO DESGLOSADO POR CONCEPTOS

| CONCEPTO | | Ayuda que se solicita |
|---|---|---|
| | | EURO |
| CONCEPTO | COSTE IMPUTABLE | |
| ıtes de personal | 400000.0 | |
| nplementos Salariales | 0.0 | |
| TOTAL COSTES DE PERSONAL CON CARGO AL PROYECTO | | 400.000 |
| CONCEPTO | COSTE IMPUTABLE | |
| ıueño equipamiento y material bibliográfico (a) | 100000.0 | |
| erial Fungible (b) | 0.0 | |
| es y Dietas (c) | 560000.0 | |
| ios (d) | 460000.0 | |
| TOTAL COSTES DE EJECUCIÓN(a+b+c+d) | | 1.120.000 |
| **TOTAL COSTES DIRECTOS** | | 1.520.000 |
| **TOTAL COSTES INDIRECTOS** | | 319.200 |
| **TOTAL COSTES DIRECTOS (Directos + Indirectos)...** | | 1.839.200 |