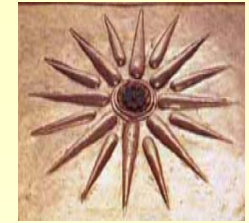




# The CASTOR Calorimeter Physics & Status



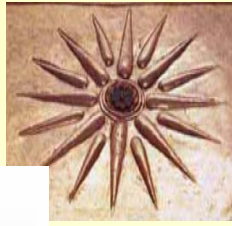
**Kerstin Borrás (DESY)**  
on behalf of the  
**CASTOR Group**

- **Where is CASTOR ?**
- **What is the physics of CASTOR ?**
- **What is the status of CASTOR ?**
- **What are the next steps for CASTOR ?**





# CASTOR in CMS @ LHC

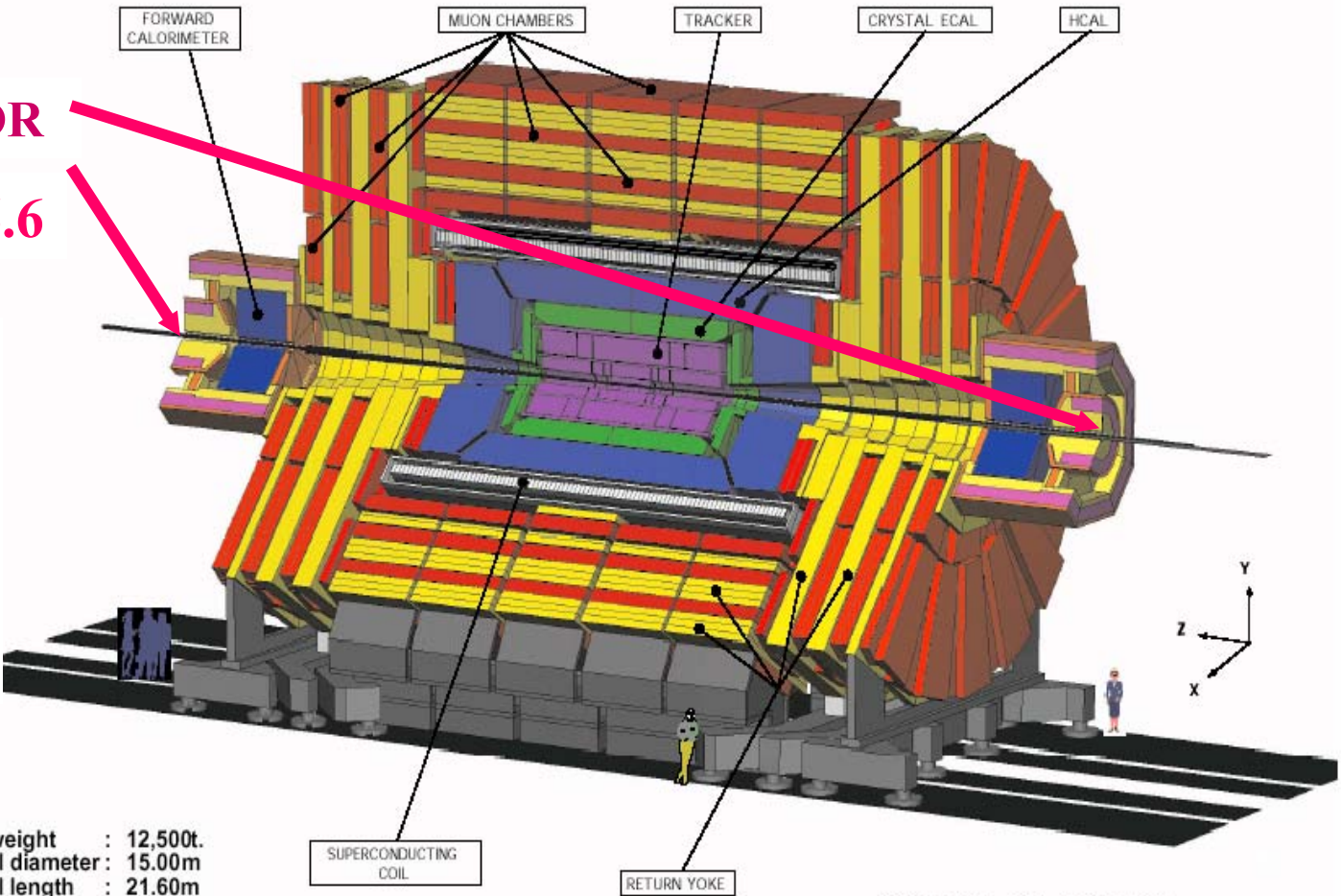


## CMS A Compact Solenoidal Detector for LHC

**CASTOR**

$5.15 < \eta < 6.6$

*Centauro  
And  
Strange  
Object  
Research*



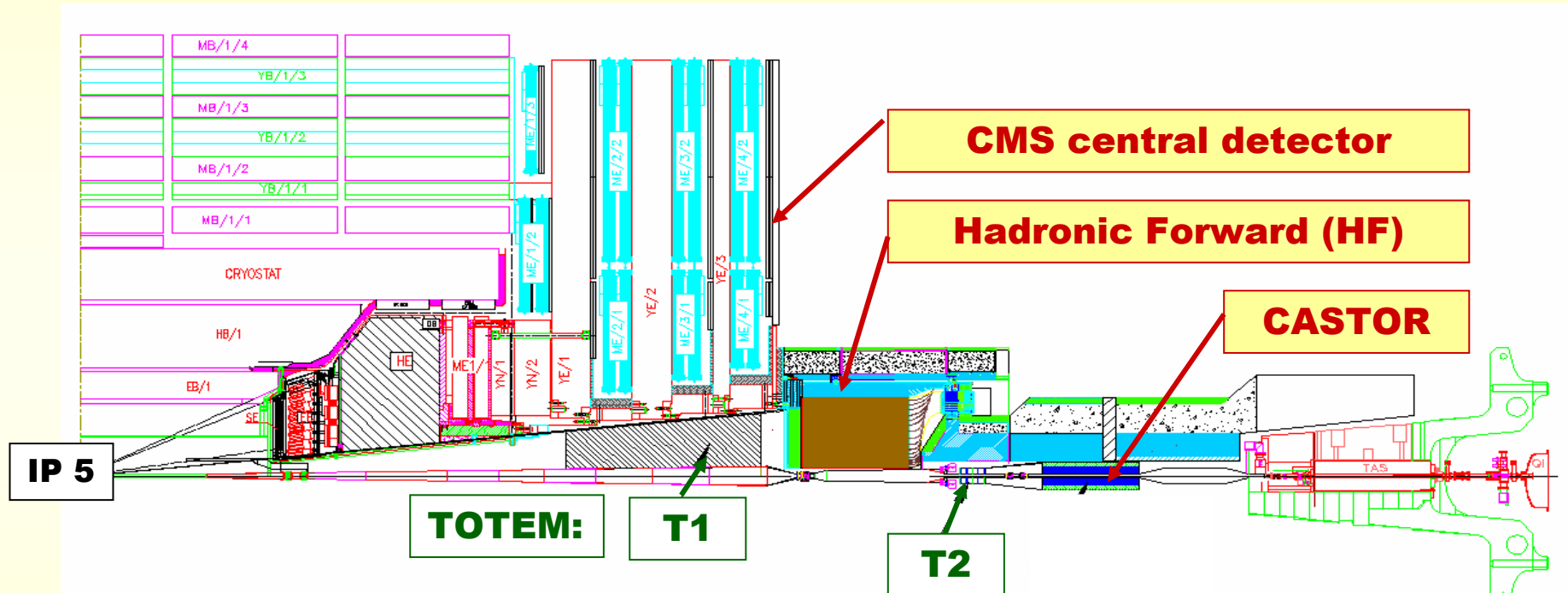
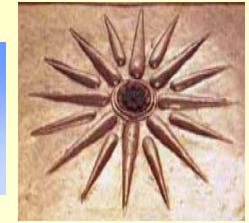
Total weight : 12,500t.  
 Overall diameter : 15.00m  
 Overall length : 21.60m  
 Magnetic field : 4 Tesla

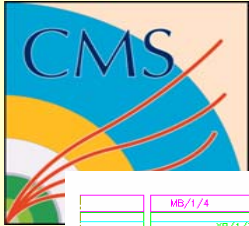
CMS-PARA-001-11/07/97 JLB.PP



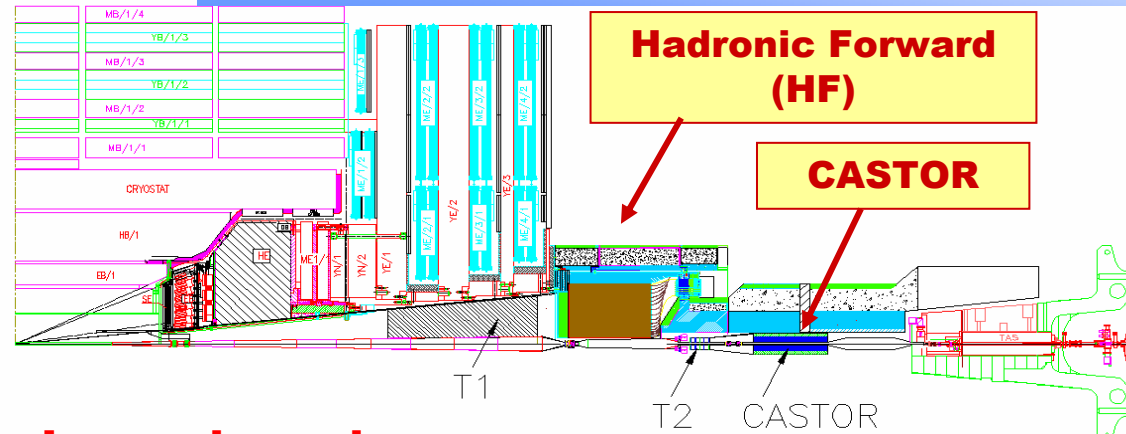


# Forward Region around CMS IP

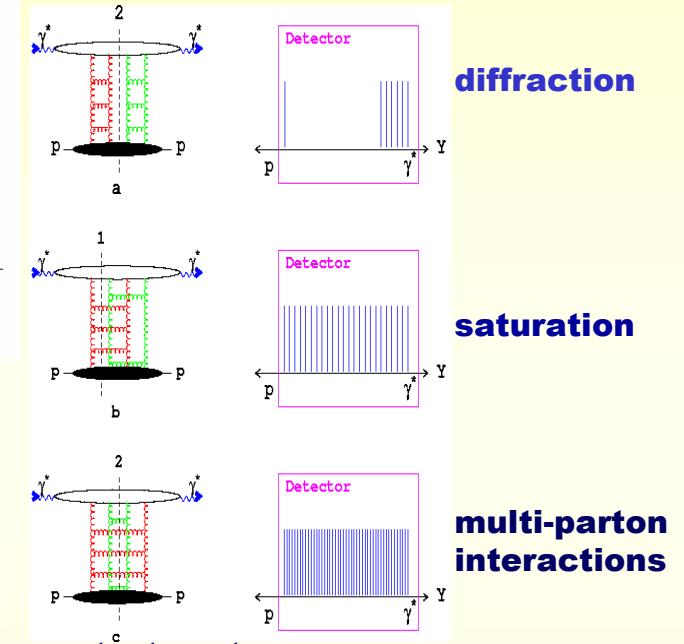




# Physics with CASTOR



## IN QCD: (AGK-Cutting rules)

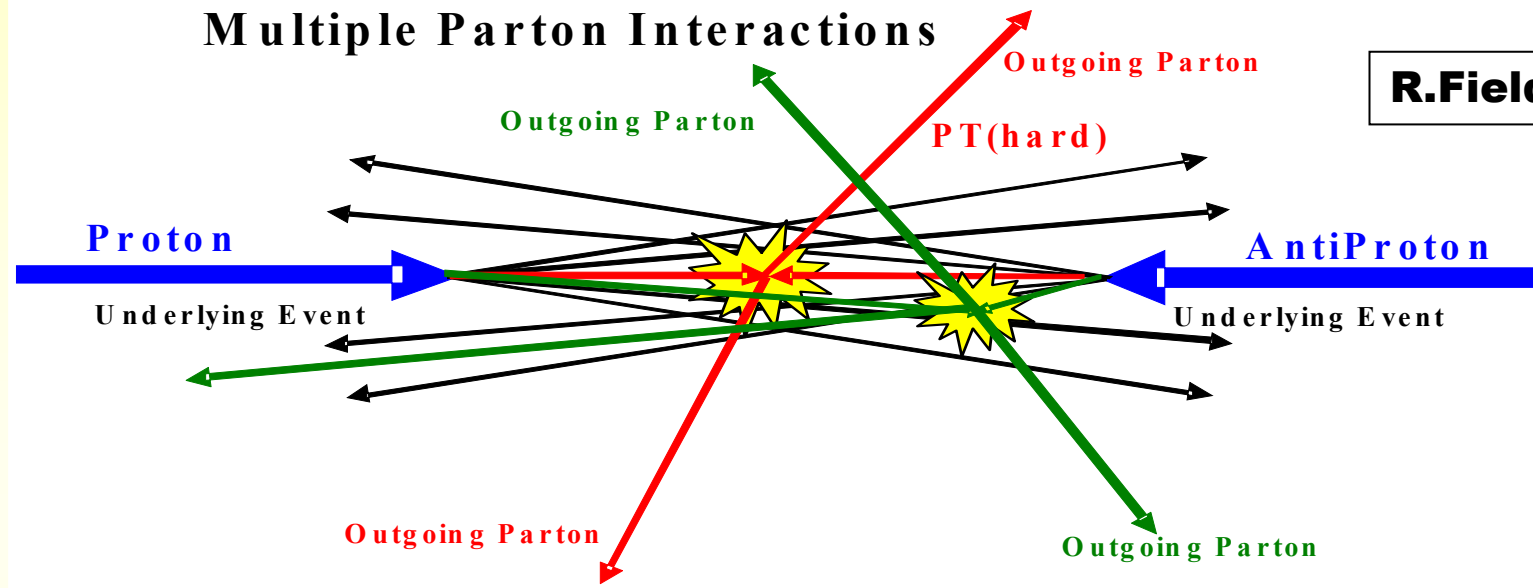
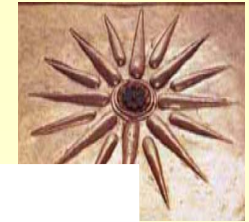


- **Low-x dynamics**
  - **proton structure, BFKL/CCFM/DGLAP dynamics**
  - **parton saturation**
  - **multi-parton scattering and underlying event**
- **Diffraction**
- **Measurements for cosmic ray data analysis**
  - **Forward energy and particle flows, minimum bias event structure**
- **Two-photon interactions and peripheral collisions**
- **QED processes to determine the luminosity to O(1%),**  
e.g.  $pp \rightarrow pp ee$  and  $pp \rightarrow pp \mu\mu$
- **Forward physics in pA and AA collisions**
- **New forward physics phenomena**
  - **Disoriented Chiral Condensates, incoherent pion emission, Centauro's, Strangelets....**





# Multiple Interactions and Underlying Event



In addition to the single **hard interaction with large  $p_T$** :

- **(soft) interactions with low  $p_T$**  → **Underlying Event**  
(remnant-remnant interactions and parton showers ...  
→ additional energy offset)
  - **more hard interactions** → **Multi - Parton Interactions**  
(see evidence from CDF 1997: need > 50% double parton interaction for  $\gamma + 3 \text{ jet}$  )
- important for jet analyses (additional UE energy) or  
 $pp \rightarrow W+H+X$  with  $W \rightarrow l+\nu$  and  $H \rightarrow bb$  (MI:  $pp \rightarrow W+X_W + bb+X_b$  without any Higgs!)

**Underlying event and Multi - Parton Interactions  
crucial for all precision measurements !**





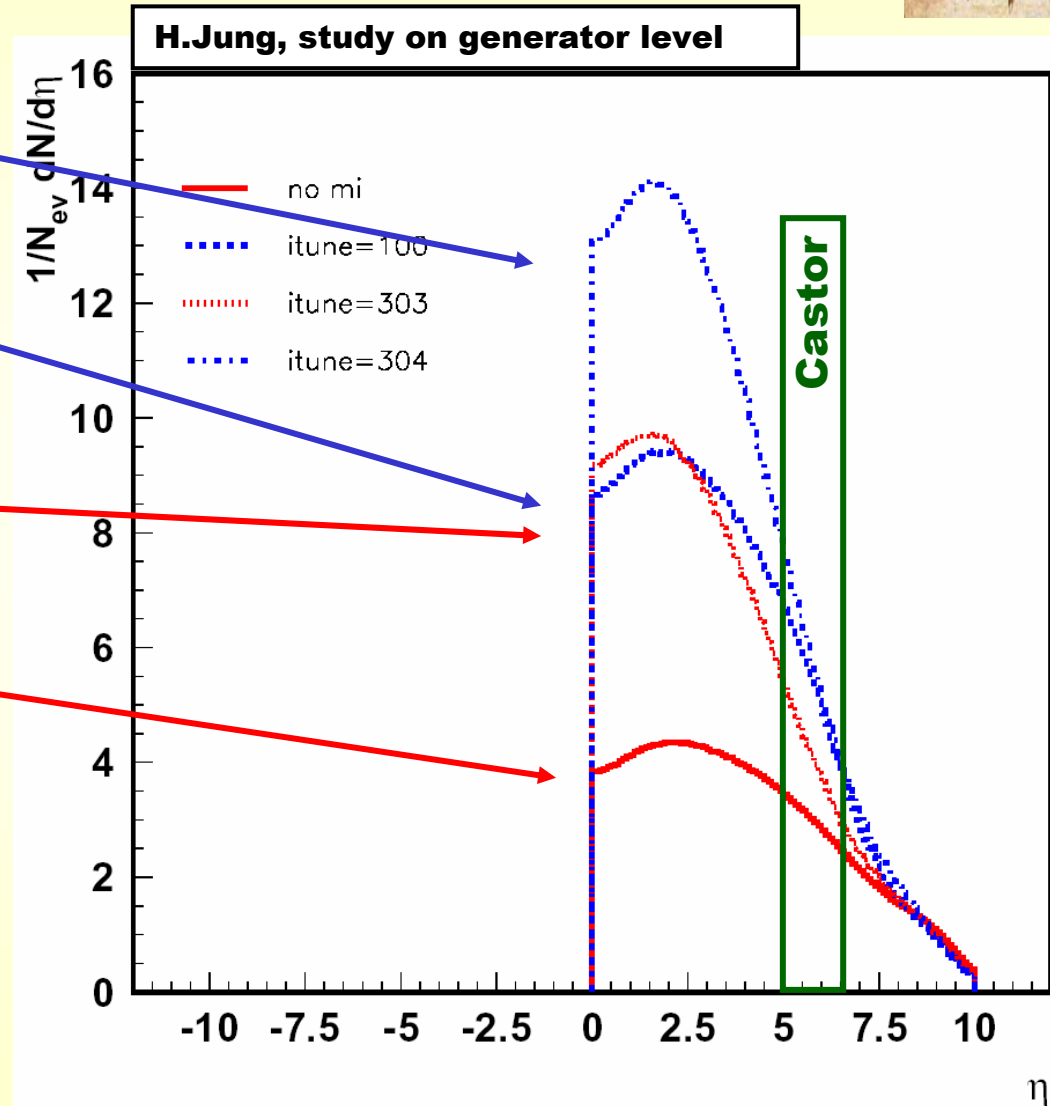


# Particle Flow



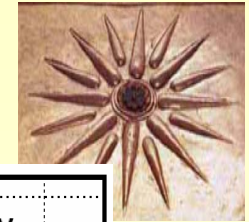
## Different models:

- extreme model (energy dependence of  $p_T$  - cut)
- realistic models:
  - Pythia: Tune A (Rick Field)
  - new Pythia: ~Tune A (Sandhoff-Skands)  
new parton shower  
→ new MI treatment
- no Multiple Interactions
- Multiplicities in CASTOR different
- Multiplicities in central region pretty similar  
→ enhancement by triggering on CASTOR ?

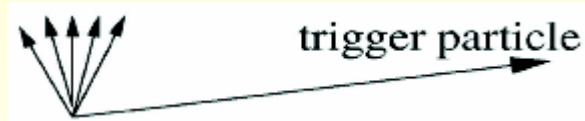




# Long Range Correlations



**central** **forward**



**no correlation**



**long range correlation**

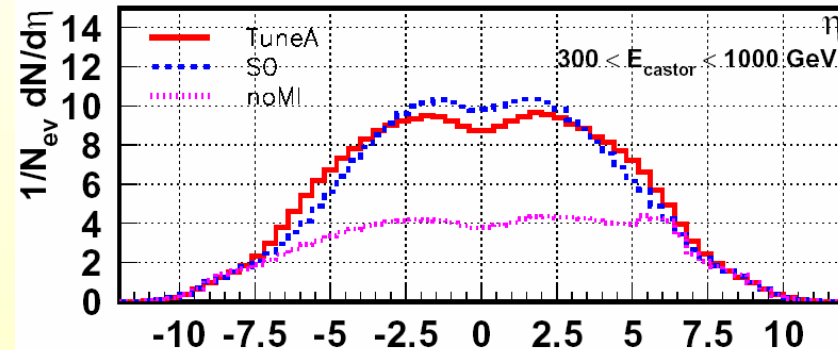
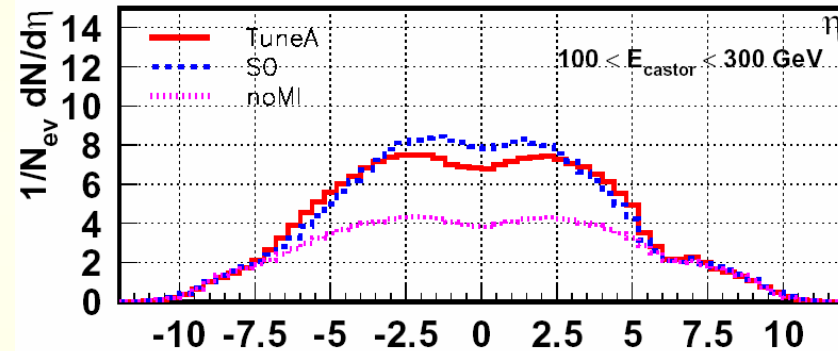
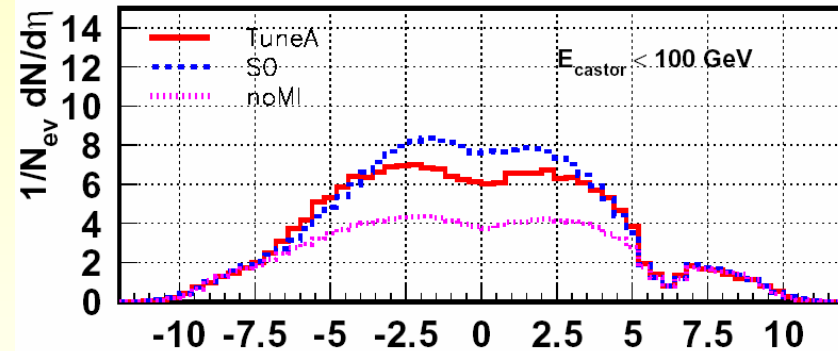


**Pythia without MI → no correlation**

**Pythia with MI:**

→ **long range correlations, trigger enhancing differences in the central region**

→ **discriminative power**



**H.Jung, study on generator level**







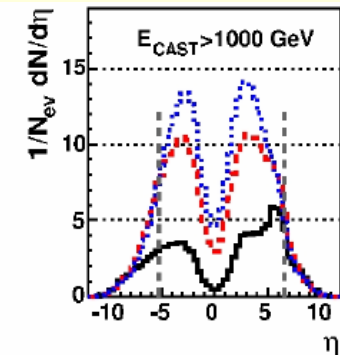
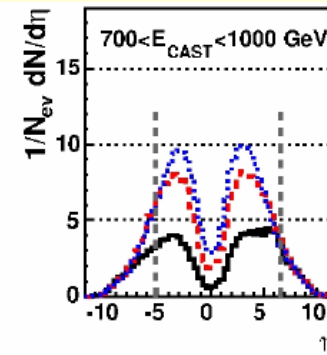
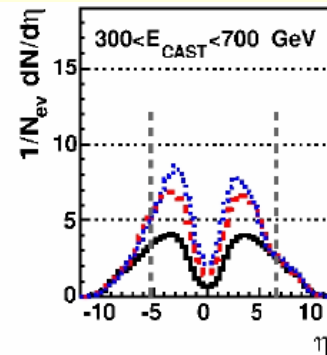
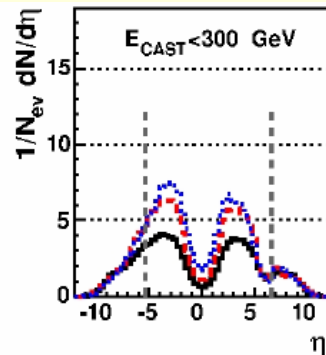
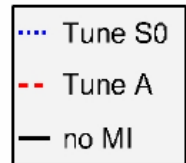
# Multiple Interaction Study



## Charged Particle Multiplicities ( $E_{part} > 1\text{GeV}$ )

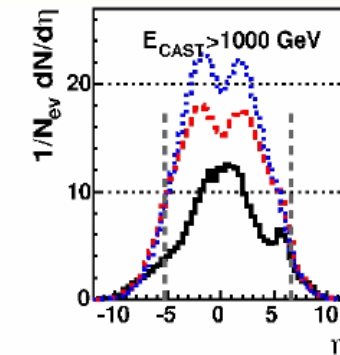
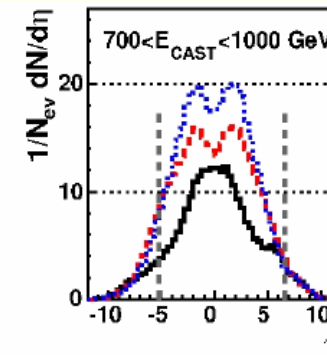
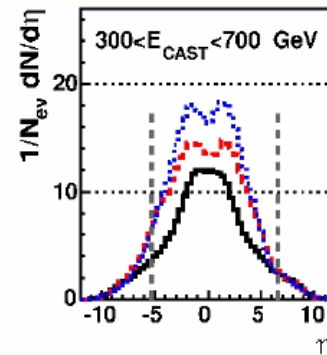
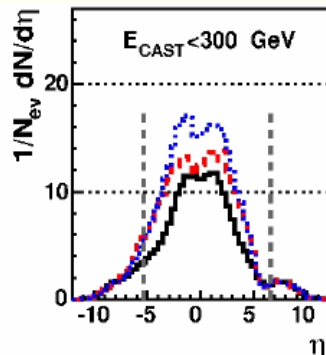
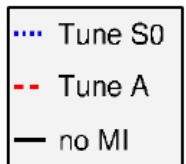
Z.Rurikova, this workshop

**QCD:**



**no MI → no correlation ; large energy in CASTOR → high multiplicities; trigger in CASTOR enhances differences in models**

**top:**



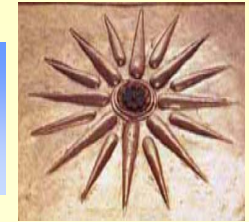
**In top production much higher underlying event activity;**

**When requesting a central jet with  $E_T > 40\text{GeV}$  in MinBias → difference to top production disappears**

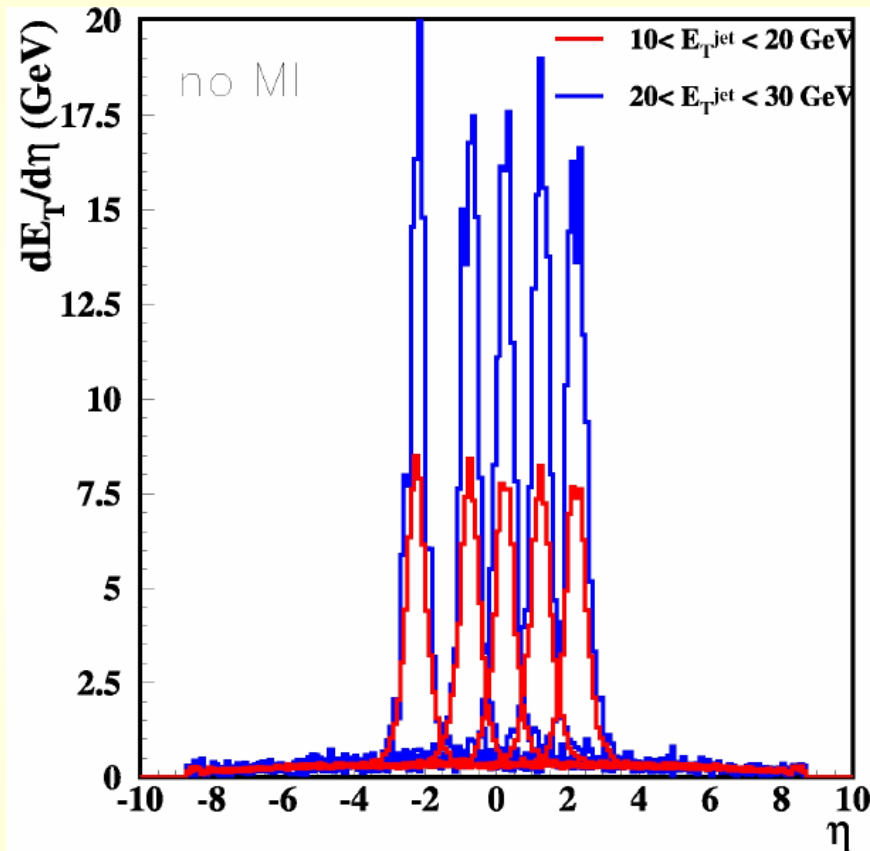




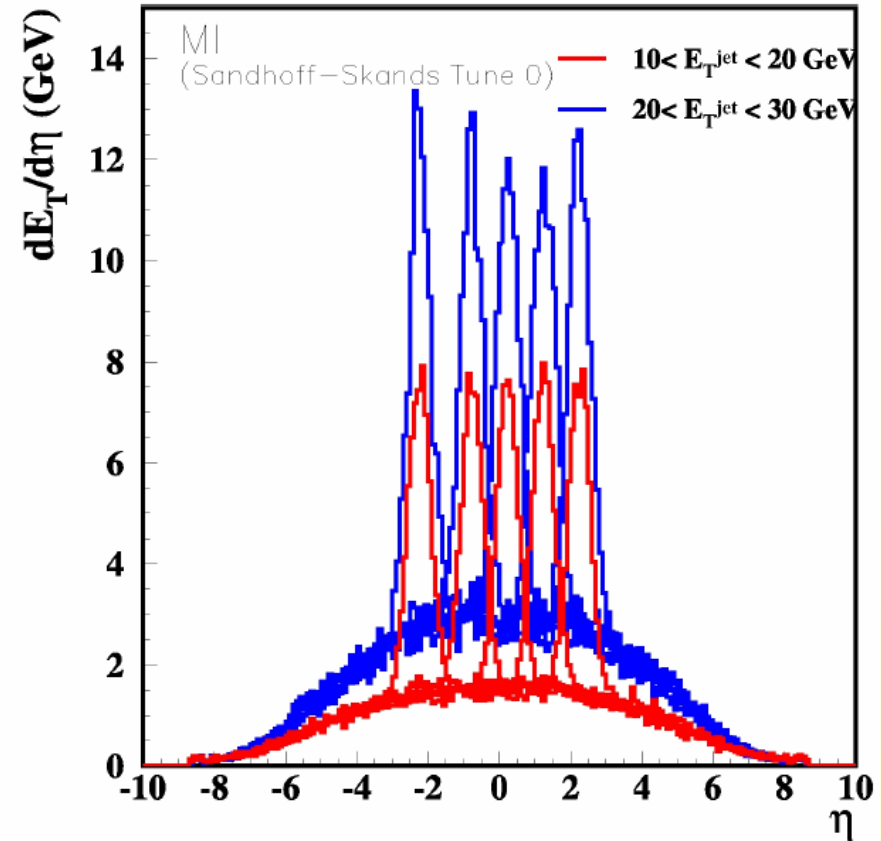
# Jet-Pedestals through MI



A.Bunyatyan, this workshop



**No MI → no pedestal**

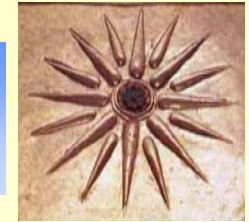


**MI → pedestal;  
Pedestal independent on  $\eta(\text{jet})$   
 $E_T(\text{jet})$  larger → pedestal larger**

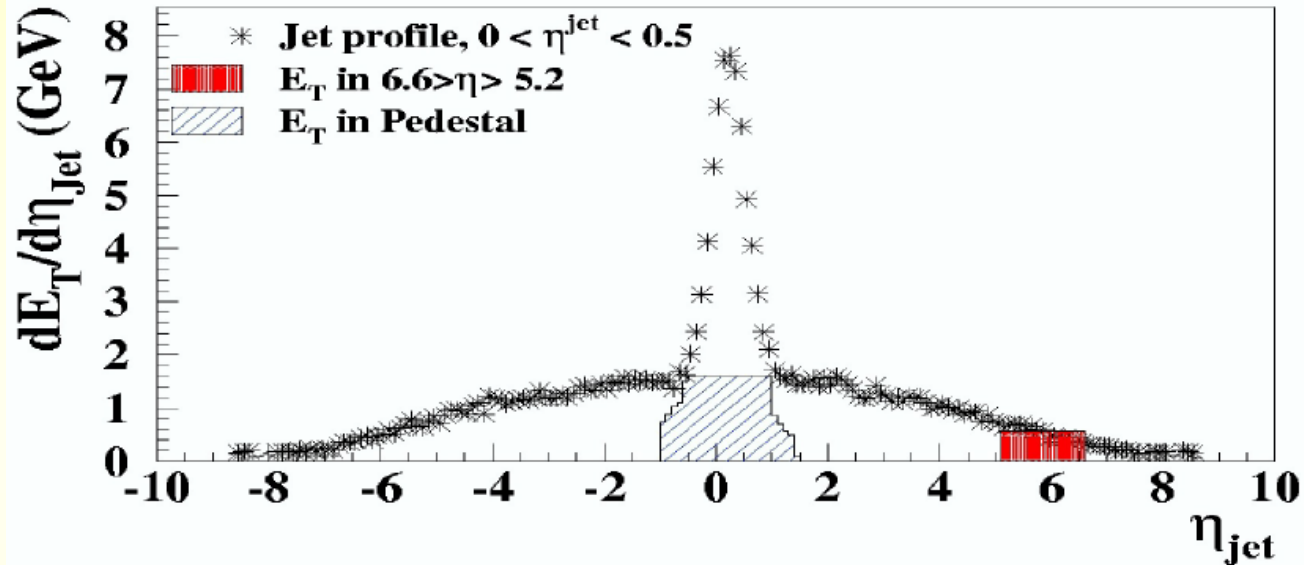




# Determination of True Jet $E_T$

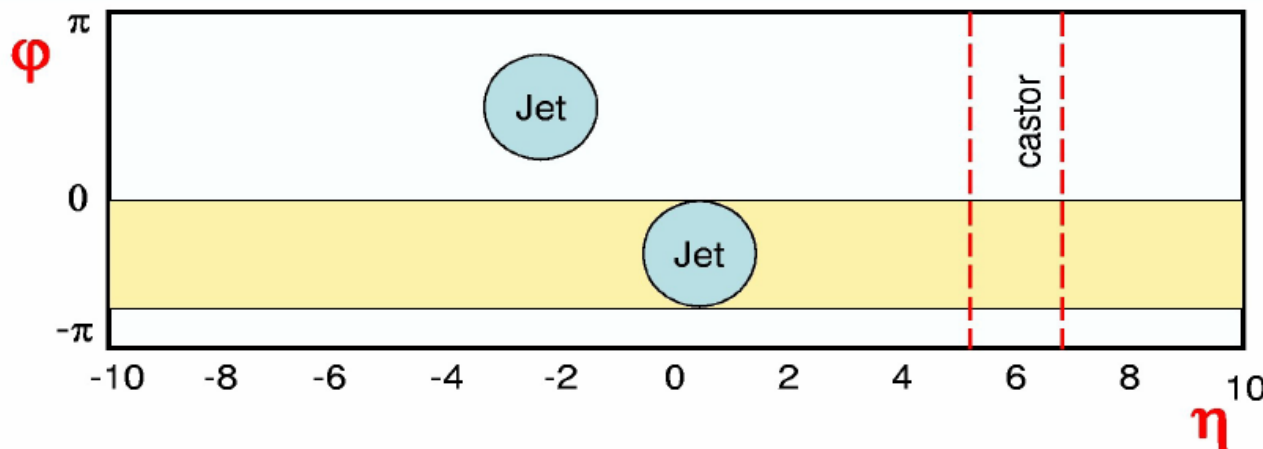


A.Bunyatyan, this workshop



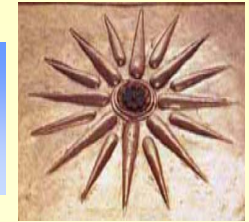
$$f(\eta) = \frac{A}{1 + B \cdot e^{|\eta|-4}}$$

→ Determine true jet  $E_T$  by measuring pedestal in forward  $\eta$  → **CASTOR and HF**





# Small - x and Saturation



**Goal: study the parton evolution at small-x in HF ( $3 < \eta < 5$ ) and CASTOR ( $5.3 < \eta < 6.6$ ):**

Common CMS-TOTEM Note on Prospects of Forward Physics

→ **DGLAP, BFKL, CCFM**

→ **investigate possible saturation effects**

## Forward Jets

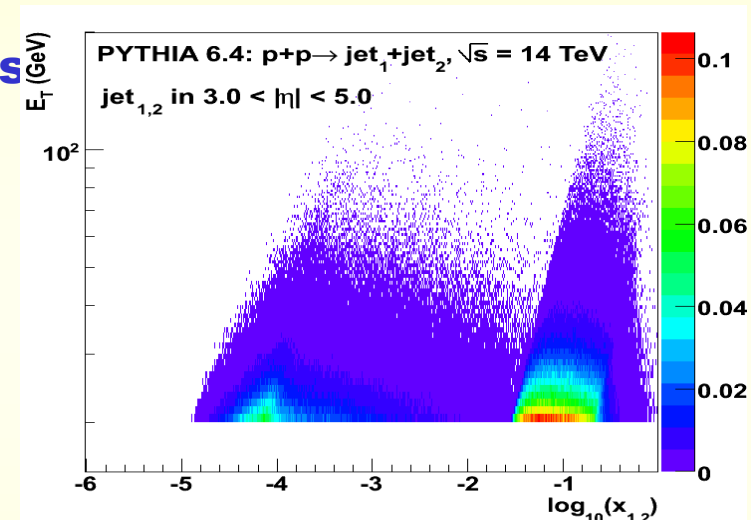
→ **dijet events with at least one jet in HF probe  $x_1 \sim 10^{-4}$ - $10^{-5}$  and  $x_2 \sim 10^{-1}$  (two units in  $\eta \rightarrow$  one order of magnitude in  $x$ )**

• **single inclusive jet cross section with low  $E_T \sim 20\text{GeV} - 100\text{ GeV}$  constrain the low-x proton pdf**

• **Mueller-Navelet dijet cross section with one jet in each of the two HF are sensitive to BFKL dynamics and saturation effects.**

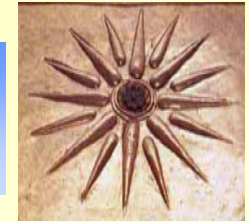
## Drell-Yan pairs:

→ **probes the pdf down to  $x_1 \sim 10^{-7}$  if produced mass  $M$  is large**

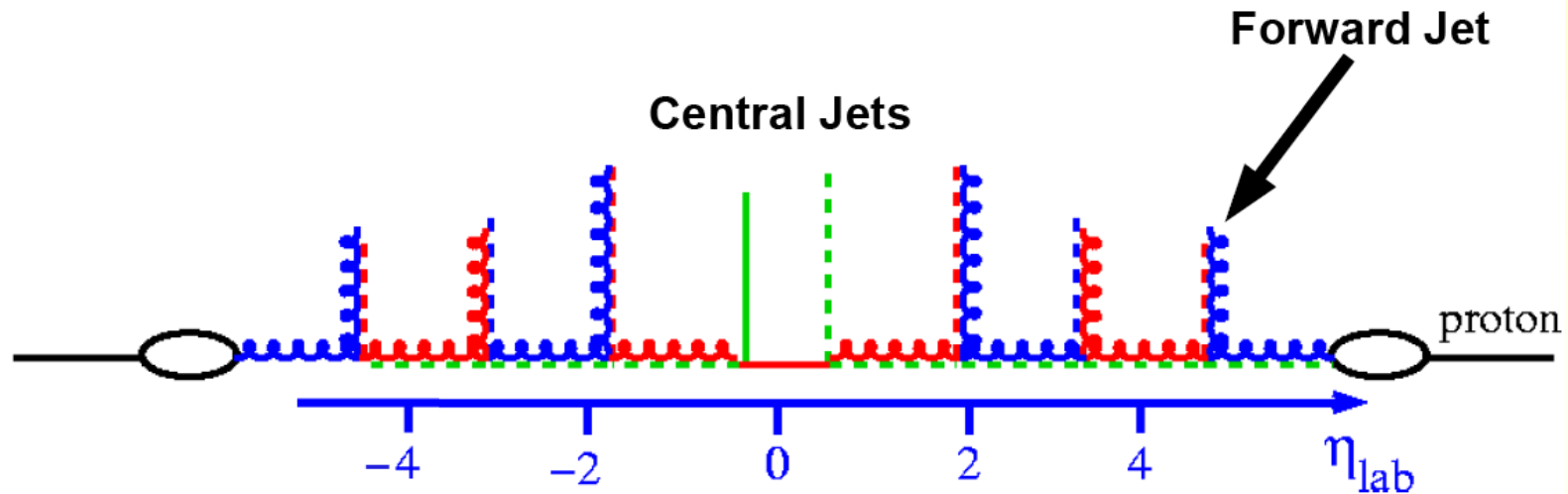




# Parton Dynamics with Jets



A.Knutsson, this workshop



Hard jet or particle in forward region,  
large rapidity range between ME and forward jet

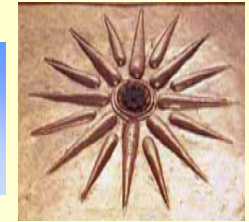
- Opens up phase space for emissions, higher order reactions
- **Small  $x$**  physics
- Gain information of the **full evolution**

→ **Tool to learn about higher order QCD reactions**



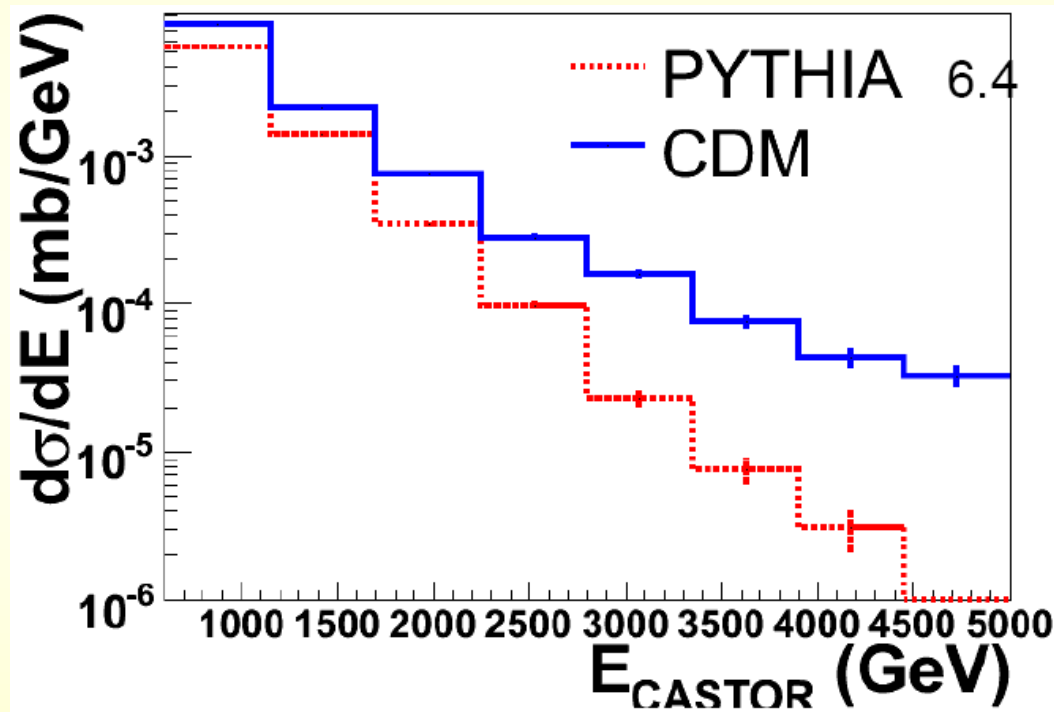


# Parton Dynamics with Jets



A.Knutsson, this workshop

**2 central jets, 1 forward jet in CASTOR**  
**with  $E_T > 10$  GeV**



## Detector features applied:

- Energy smearing of particles according to beam test results
- Noise cut ( $E > 10$  GeV)
- Energy sum in most active phi-segment plus neighbors

**→ With jets in CASTOR we can distinguish different parton dynamic schemes**





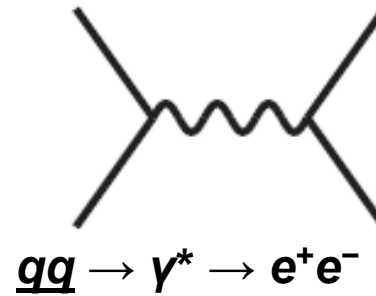
# Parton Dynamics with Lepton Pairs



**Forward lepton pairs:**

**Shadowing in CASTOR:  
EHKQS: “saturated” pdf with nonlinear terms in gluon evolution**

[A. Dainese et al., HERA-LHC Workshop proc.]



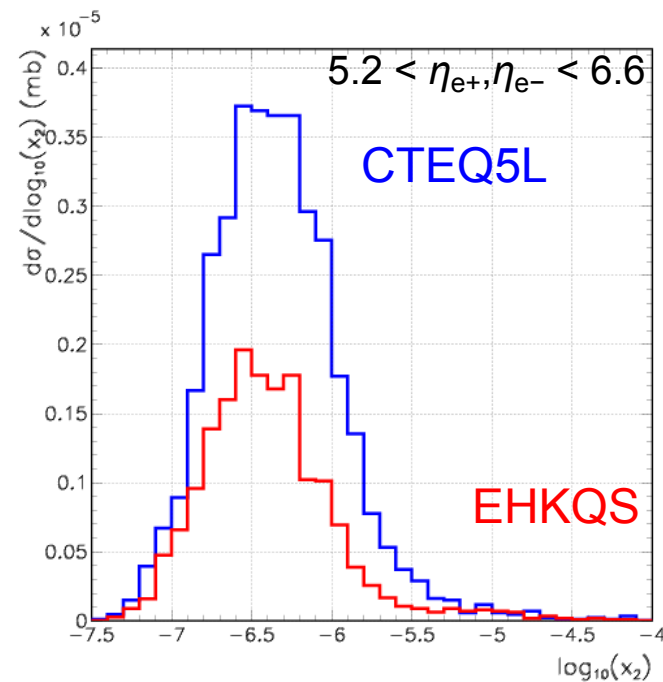
P.v.Mechelen,  
DIS'08 workshop

**→ Cross section reduced by factor 2!**

**In summary:**

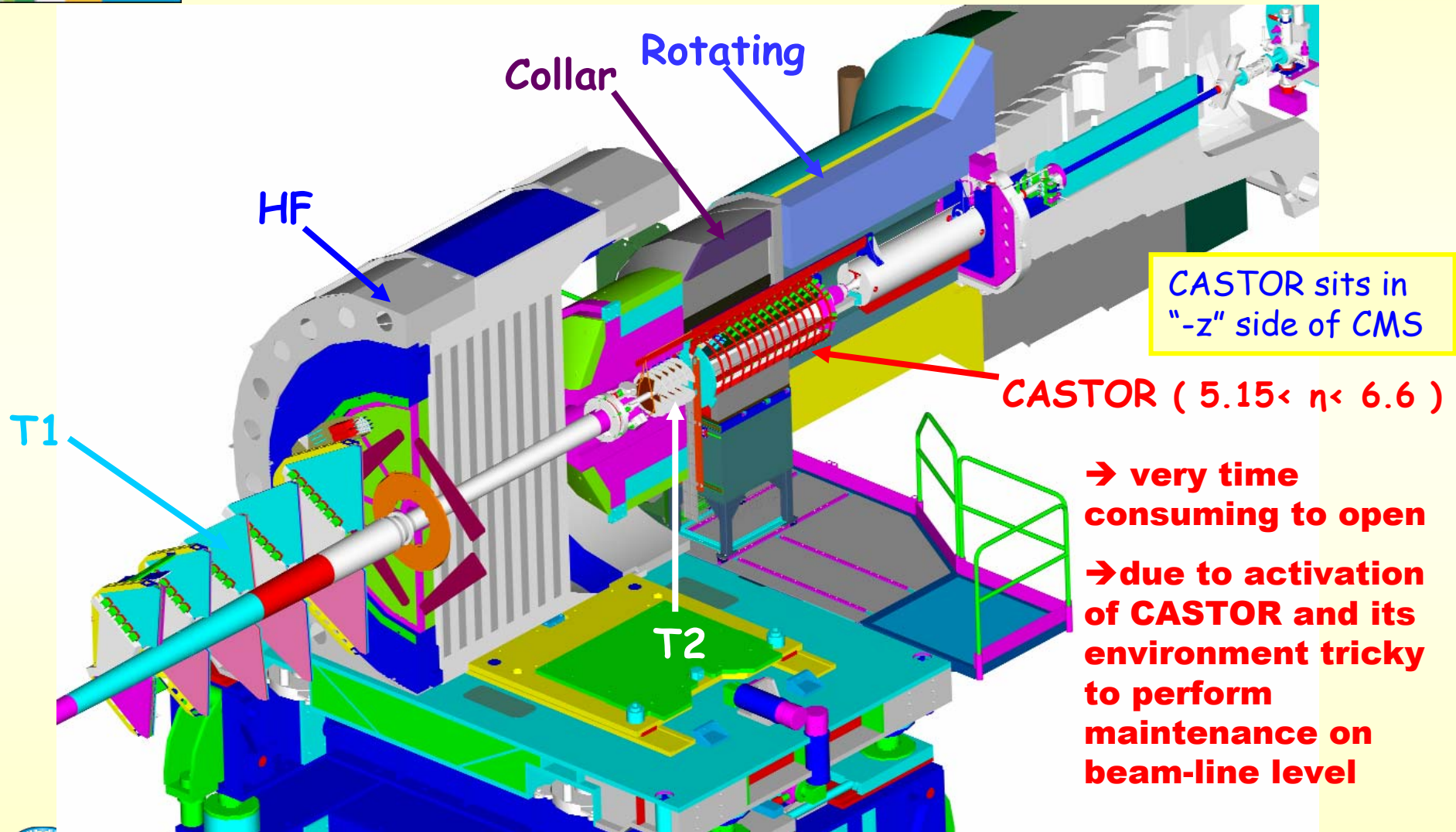
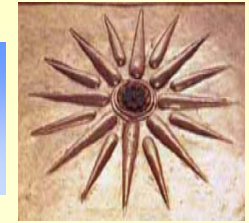
**Rich menu for physics with the CASTOR Calorimeter**

**→ look at the status of the hardware ...**





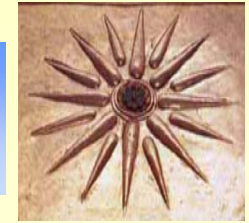
# CASTOR Calorimeter Integration



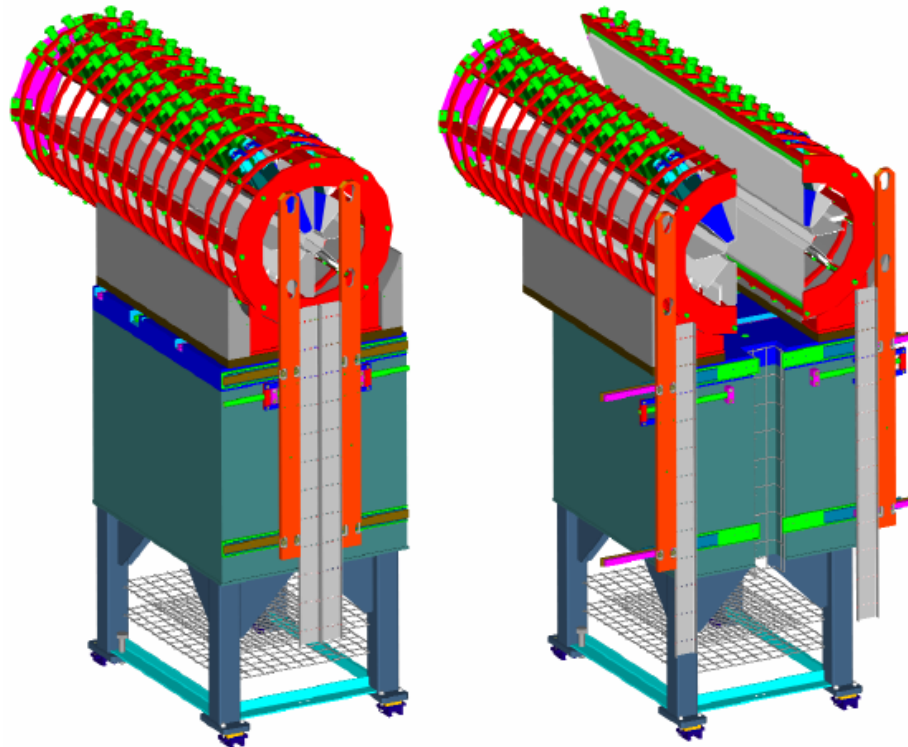




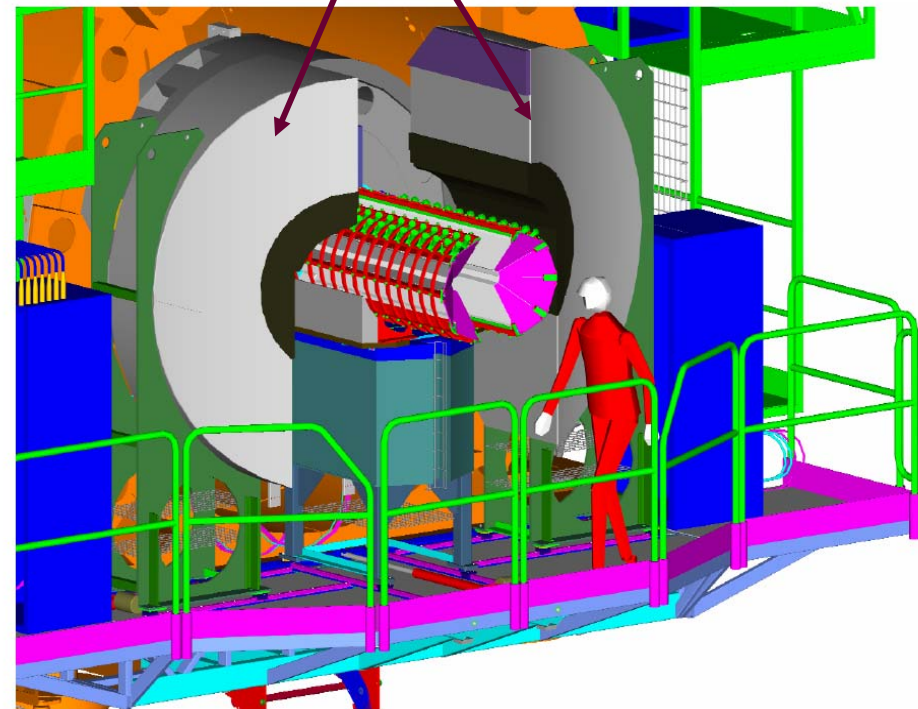
# Integration of CASTOR



CASTOR halves

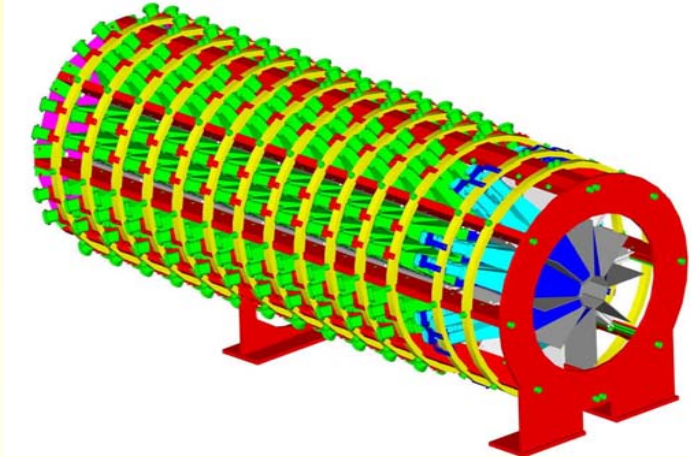
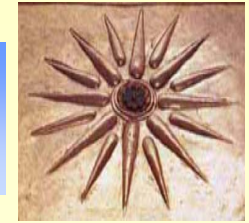


Collar shielding



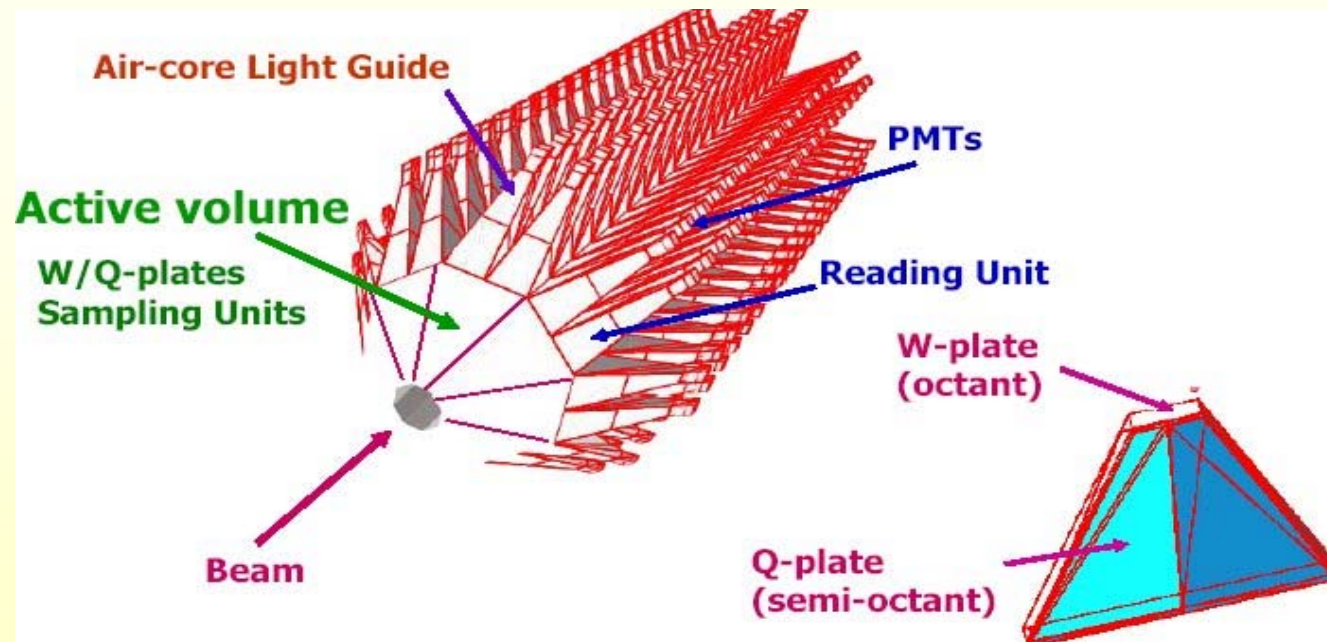


# CASTOR Components



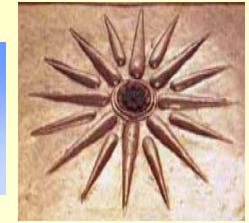
## Sampling Calorimeter:

- **absorber material: Tungsten**  
+ small XO and small  $\lambda$ int  
+ lower activation than copper
- **active medium: Quartz plates**  
+ radiation hard  
+ compact showers (Cherenkov threshold)

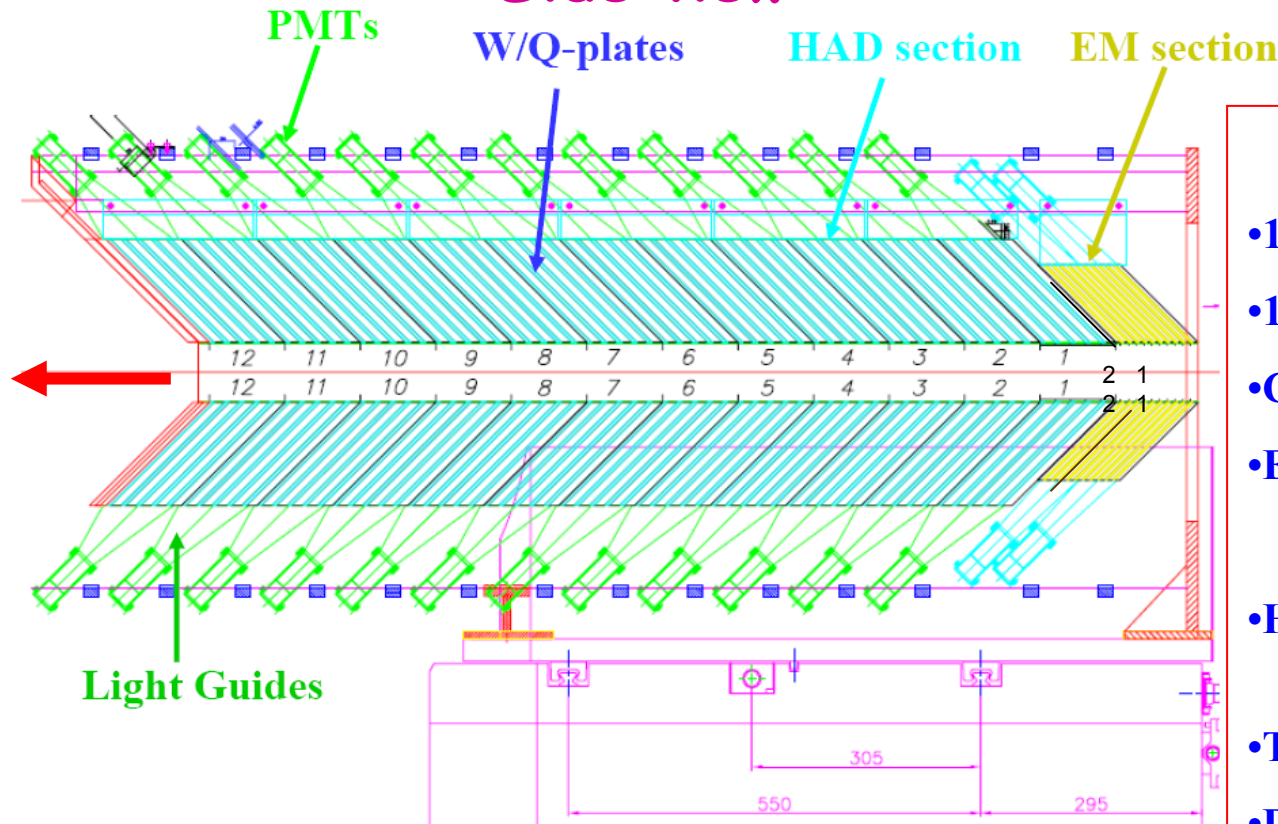




# CASTOR Layout



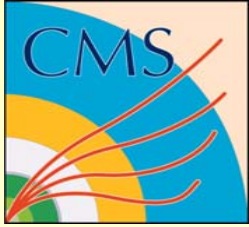
## Side view



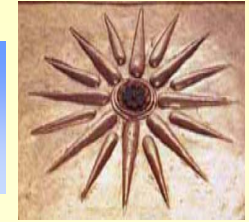
## Design Parameters

- 16-fold azimuthal segm<sup>n</sup>
- 14-fold longitudinal segm<sup>n</sup>
- Channels = 16 x 14 = 224
- EM-section: 2 x 10 X<sub>0</sub> → 0.77 λ<sub>1</sub>  
W/Q-plates = 5/2mm
- HD-section: 12 x 0.77 λ<sub>1</sub> → 9.24 λ<sub>1</sub>  
W/Q-plates = 10/4mm
- Total Length = 1616 mm
- Diameter = 560 mm





# Some History



**~2003 CASTOR project came from ALICE to CMS (Greece politics)**

**Design modification to adapt to the new environment,  
forming a group with new collaborators from CMS to realize  
the project: technical coordinator, electronics coordinator ...**

**Jan 2007 First CASTOR workshop @ CERN**

**Feb 2007 CMS Review of all projects in the forward region**

**May 2007 CMS Review of CASTOR project**

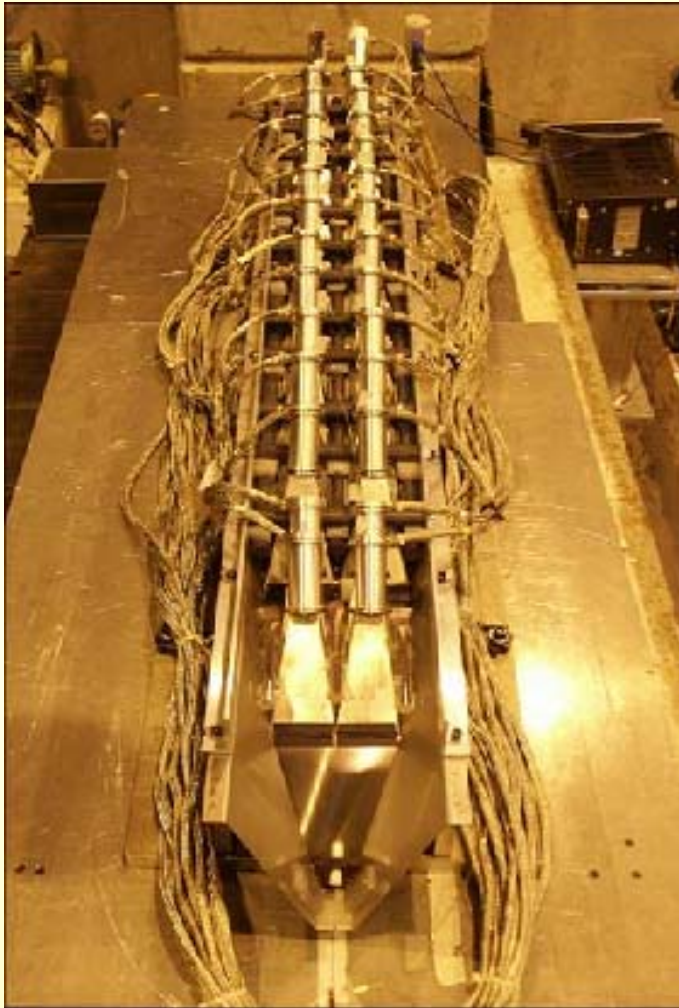
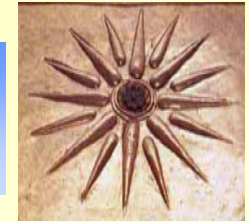
**→ CASTOR approved as CMS component**

**Aug 2007 Test beam measurements with one octant at CERN**



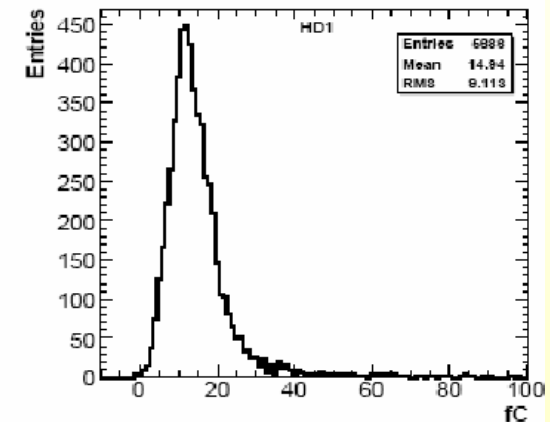
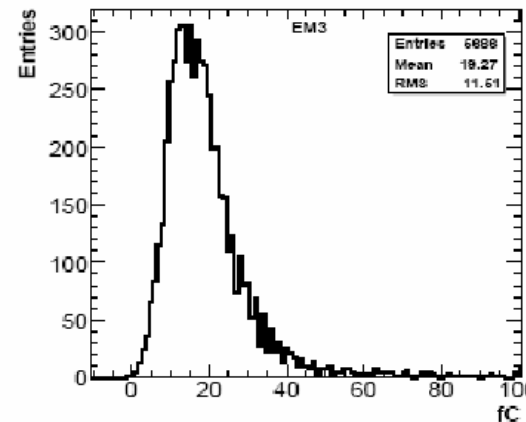
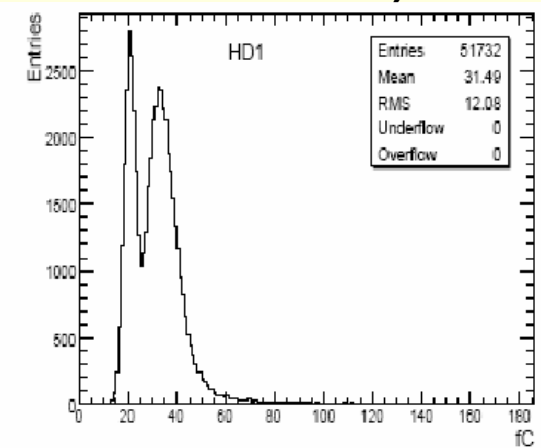
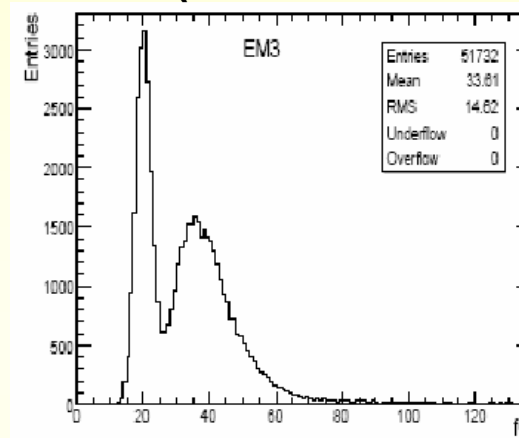


# Beam Test 2007



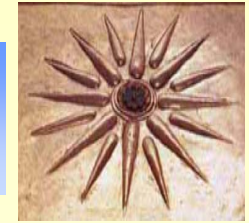
## Muon Signals

(without and with pedestal subtracted)

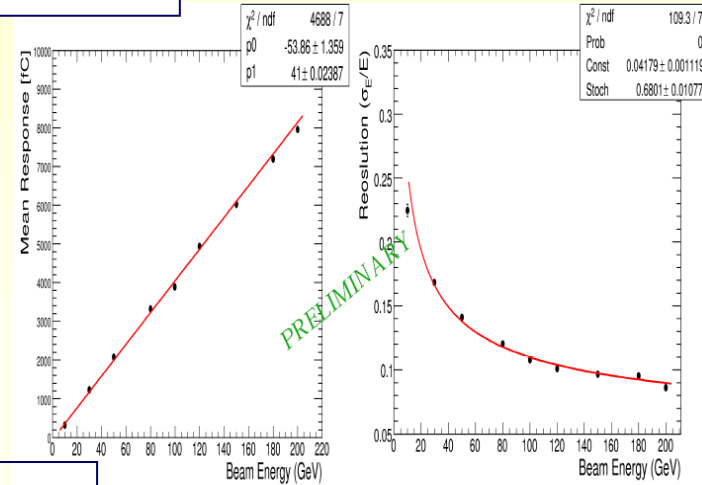
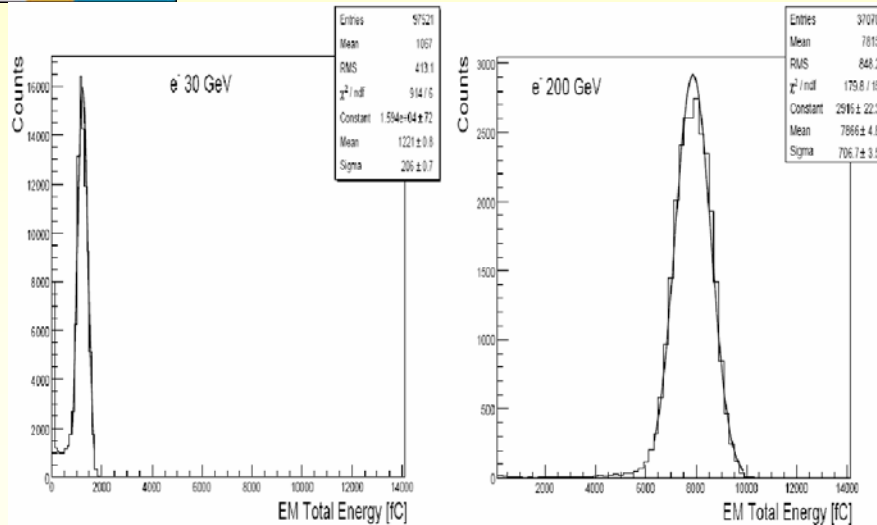




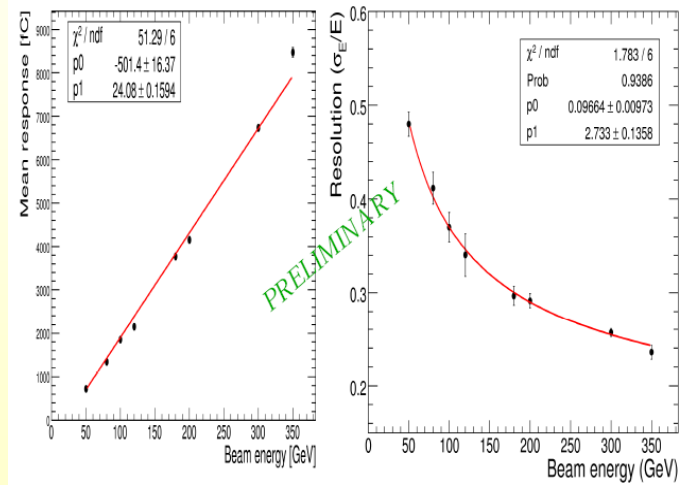
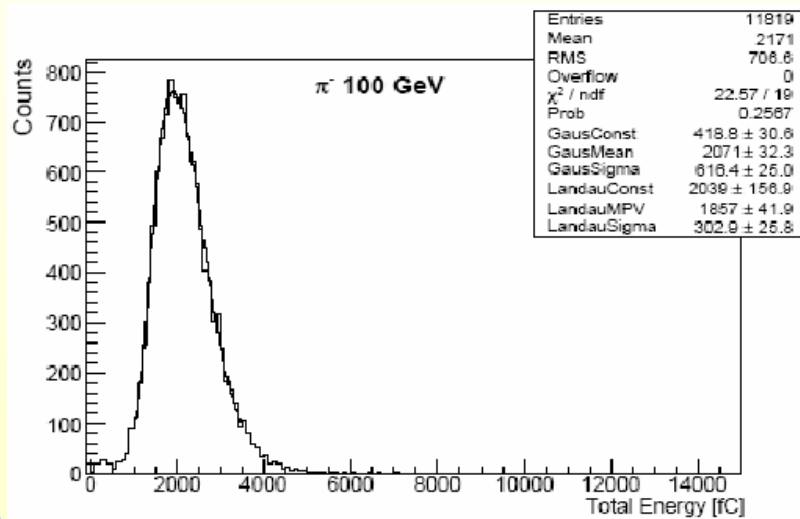
# Beam Test 2007

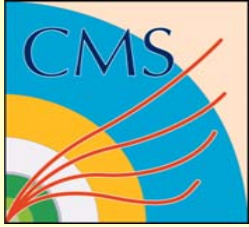


## Electrons

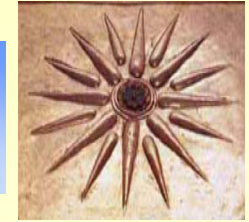


## Pions





## Some History (cont.)



**~2003 CASTOR project came from ALICE to CMS (Greece politics)**

**Design modification to adapt to the new environment and forming a group with new collaborators from CMS to realize the project: technical coordinator, electronics coordinator ...**

**Jan 2007 First CASTOR workshop @ CERN**

**Feb 2007 Review of all projects in the forward region**

**May 2007 Review of CASTOR project  
→ CASTOR approved as CMS component**

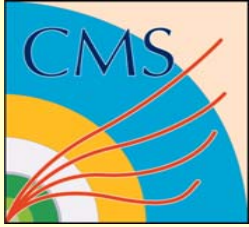
**Aug 2007 Test beam measurements with one octant at CERN**

**Oct 2007: Successful completion of Engineering Design Review (EDR)**

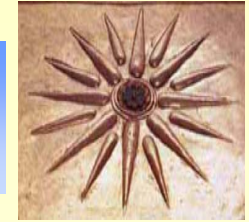
**Jan 2008: successful follow-up EDR for integration/installation  
threshold of necessary funding reached**

**→ start production and procurements**





# CASTOR Institutes



## 6. Resources

### 6.1. Collaborating Institutes & Tasks

- Antwerp: PMTs, trigger, DAQ, funding; Electronics coordination
- Athens: Design, Q-plates, SW-MC, funding; Project management
- CERN: Beam test / EDR reports; SW-Physics coordination
- Cukurova: PMT testing, assembly
- DESY: FEA calculations, construction, electronics, funding; Project management
- JINR Dubna: Design; Technical coordination
- INR, Moscow: Light guides & 2mm Q-plates (funding)
- ITEP, Moscow: Laser/LED calibration system
- MSU, Moscow: Electronics, DCS/data base, MC , physics (all within HRJRG with DESY)
- Northeastern: Readout devices, MC-SW, construction
- U Iowa: Potentially construction & integration





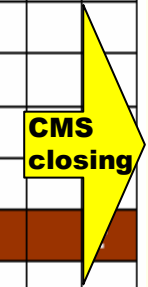


# Schedule



## Construction & Commissioning Schedule for (1/2) Calorimeter V2.1 (28-04-08)

			Month	A	P	R	I	L		M	A	Y	J	U	N	E	J	U	L	Y
			Week	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	<b>TASKS</b>																			
1	Construction-assembly 1/2 -skeleton	Started		█	█	█	█	█	█	█	█	█	█							
2	Fabrication 560 Q-plates (4+2 mm)	Started		█	█	█	█	█	█	█	█	█								
3	Fabrication 490 W-plates	Started		█	█	█	█	█	█	█	█	█								
4	Fabrication 112 light guides									█	█	█								
5	Delivery/testing 125 PMTs + bases	Started		█	█	█	█	█	█	█	█	█	█							
6	1/2 [FE/Trigger/DAQ] electronics	Started		█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
7	Assembly 1/2 calorimeter													█	█	█				
8	Testing																█	█		
9	Installation cables & services	Ordered								█	█									
10	Installation in beam line 1/2 calo																		█	█



**TB  
08**

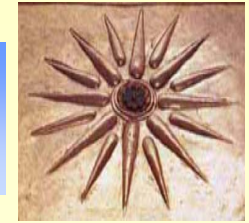
**Very ambitious schedule and test beam in addition → very tight if LHC starts up in July → a lot of work/commissioning clustering in June/July → Challenging times have reached us !**

**This is what keeps us alive ☺**





# Plans for the near Future



## Goals for 1/2 CASTOR in 2008:

- **Produce 1/2 CASTOR calorimeter**
- **Exercise installation procedure (safety & control systems)**
- **DAQ, LED/LASER calibration**
- **Investigate monitoring with halo-muons**
- **Possibly learn how first physics signals look like ☺**

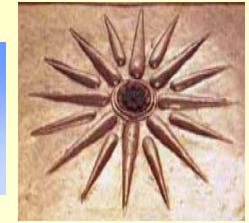
## After (during) 2008 data taking:

- **Produce another 1/2 CASTOR calorimeter with radiation hard Quartz plates**
- **Take out first 1/2 CASTOR, replace DELPHI Quartz-Plates**
- **Finalize electronics (esp. trigger)**
- **Install full CASTOR calorimeter on -z side**
- **Analyze test beam and LHC data**
- **Optimize performance as preparation for real data taking in 2009 ☺**





# Summary



**CASTOR had/has a very exciting time:**

**Successfully approved as CMS detector component**

**Successfully passed the EDR and the follow-up EDR's**

**Funding raised to a decent level (not yet for rad-hard Quartz → DELPHI Quartz)**

- **Procurements out, early deliveries arrived**
  - **Construction of ½ CASTOR calorimeter underway**
  - **Test beam 07 analyses progressing well**
  - **Test beam 08 preparations underway**
  - **Software needs to speed up considerably**
  - **Physics preparations need to catch up**
- **pretty ambitious schedule**

**Rich physics menu makes it worth**

**CASTOR is on its way and running against the time to master all obstacles !**

