

# Recent contributions to CMS experiment from METU Group

Project No. 2014TAEKCERN-A5.H6.F2.07

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on behalf of the METU-CMS group (in collaboration with Ozyegin Univ.,  
Anadolu Univ., Izmir IYTE, Izmir DEU)

***CERN Üniversitesi - Sanayi İşbirliği Konferansı  
14 Nisan 2016, TOBB, Ankara***

# METU Group participation in CERN experiments

- 1966-70 Magnetic Moment of Lambda Hyperon
- 1976-80 Investigation of Charm particles with WBB neutrino beam (WA17)
- 1987-91 UA8
- 1991-97 Charm II (WA75), CHORUS (WA95)
- 1996-on LHC CMS
- 2000-on OPERA
- 2011-on AMS

# Outline

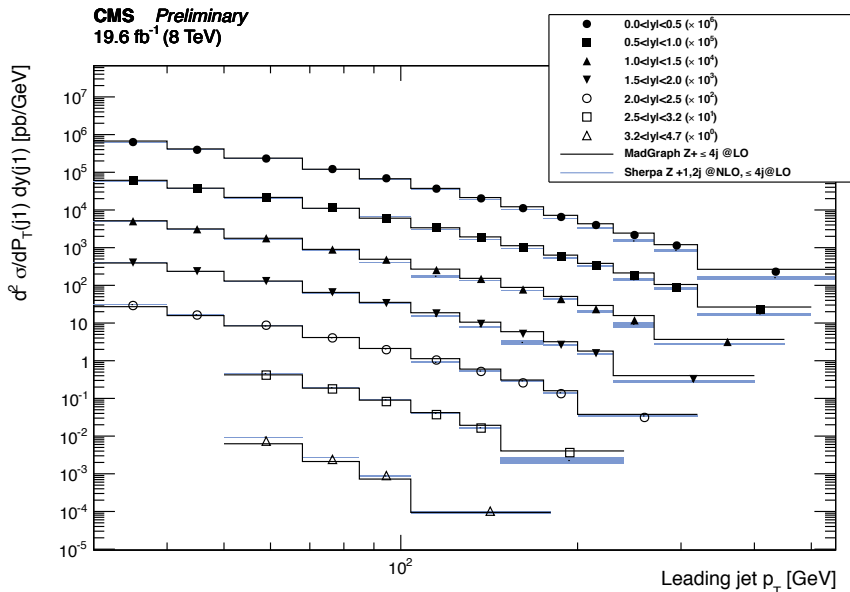
- Physics measurements
  - Standard model studies
    - measurement of Z+jets
    - $\Upsilon(1S) \Upsilon^*(1S) \rightarrow \mu^+ \mu^- e^+ e^-$
  - Top quark studies
    - Asymmetry studies
    - Underlying event measurements with  $t\bar{t}$  events
  - BSM searches
    - SUSY
    - Data scouting
    - Black hole searches
- Service work
  - Central shifts
    - DAQ
    - DCS
    - Trigger
  - HCAL Tasks within DPG group
    - L1 TP Development studies
    - HF calibration studies with Z->ee events
  - Tasks within TOP PAG group
- CESSAMag Project (FP7)
- Studies on  $^{43}\text{Sc}$  production
- Phase II Upgrade and HL-LHC 3

# Z+jets measurements

- Our group was involved in 8 TeV measurements of Z+jets cross section
  - Main contribution to multiple differential cross section measurements (CMS-PAS-SMP-14-009)
  - Will be a part of combined Z+jets legacy paper (SMP-14-013, PUB-Draft phase now, CWR soon)

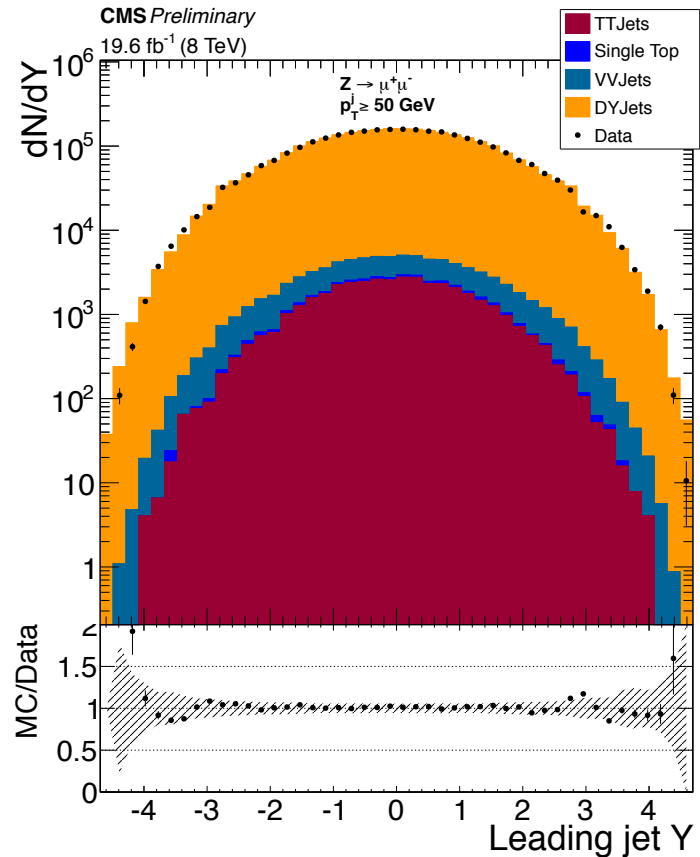


# Z+ jets measurements



2D differential cross section measurements  
 $\frac{d^2 \sigma}{dp_T^j dy^j}$

From CMS-PAS-14-009

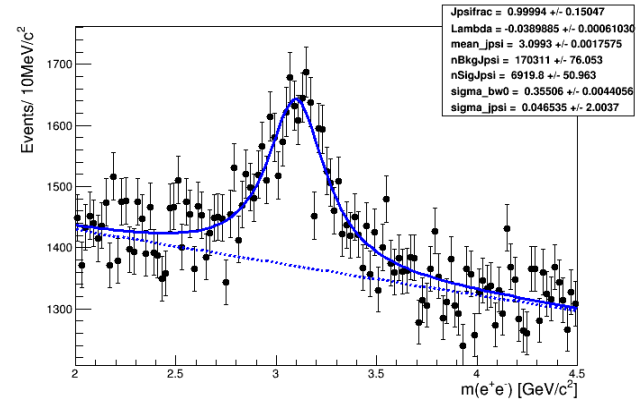
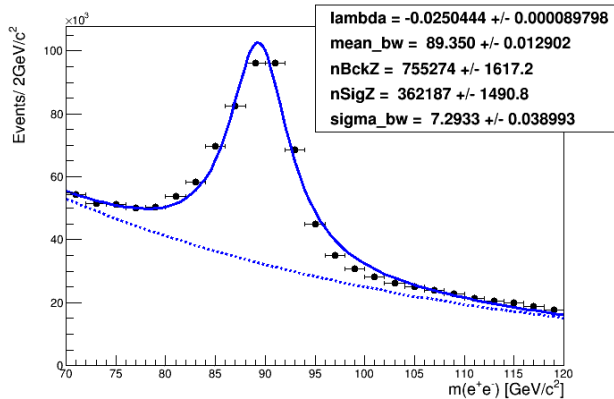


Detector level jet rapidity  
 This study is first including forward jets  
 in SMP V+jet measurements

$$Y(1S) Y^*(1S) \rightarrow \mu^+ \mu^- e^+ e^-$$

- Investigate the 4-lepton final state consisting of 2-muon and 2-electron in  $Y(1S)Y^*(1S)$  decays using the Run II data
- To investigate  $2 \mu 2e$  channel, we firstly validate dielectron mass spectra of Z boson and  $J/\psi$  meson

# $\Upsilon(1S) \Upsilon^*(1S) \rightarrow \mu^+\mu^-e^+e^-$



- Signal is fitted by Breit Wigner function
- Total PDF for signal +background
- Require both electrons with  $p_T > 10$  GeV
- **Z peak is observed  $\sim 90$  GeV in  $[70, 120]$  GeV**

- Signal is fitted by Breit-Wigner and Crystal-Ball function
- Exponential fit for background
- Total PDF for signal+background
- **J/ $\psi$  peak is observed  $\sim 3$  GeV in  $[2, 4.5]$  GeV**
- No Electron (Energy) Correction applied yet.

# $t\bar{t}$ asymmetry studies

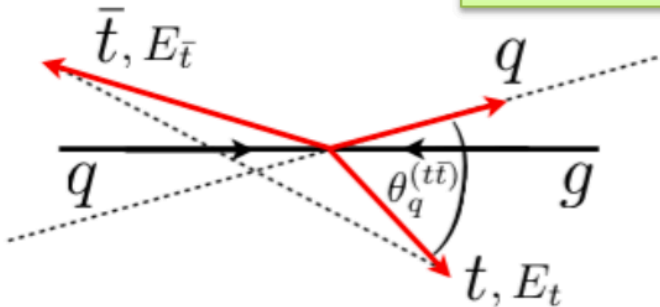
- Provide precise tests of the standard model
  - SM makes specific predictions on asymmetries
  - Test higher order QCD predictions
- Useful in searches for new particles
- Allow to measure some parameters of the SM and (new) particle properties.

# Asymmetry in $t\bar{t} + jet(s)$

- Huge gluon gluon background in measurements until now.
- At  $\sqrt{s} = 13$  (14) TeV, high parton luminosity for  $qg$  production
  - ◆ 20% of top pair events are from  $qg$  production.
  - ◆ Significant asymmetry in  $t\bar{t} + q$ -jet

S. Berge, S. Westhoff, JHEP07(2013)179

S. Westhoff, arXiv:1501.07477

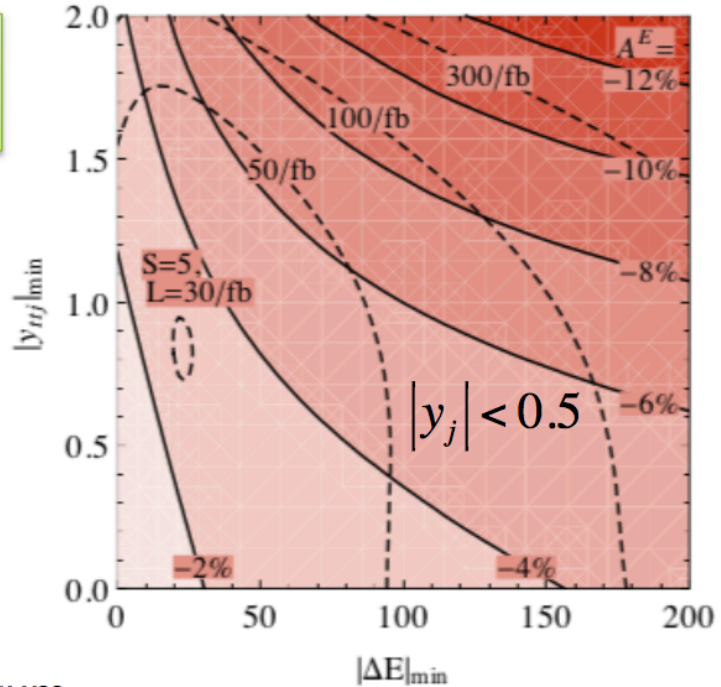


$\Delta E = E_t - E_{\bar{t}}$  in partonic CM frame.

$$A_E = \frac{\sigma_{t\bar{t}}(\Delta E > 0) - \sigma_{t\bar{t}}(\Delta E < 0)}{\sigma_{t\bar{t}}(\Delta E > 0) + \sigma_{t\bar{t}}(\Delta E < 0)}$$

$$\leftrightarrow \frac{\sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} < 0) - \sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} > 0)}{\sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} < 0) + \sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} > 0)}$$

due to momentum Conservation.



Highest asymmetry for boosted  $t\bar{t}$  events and when the jet is perp. to the beam.

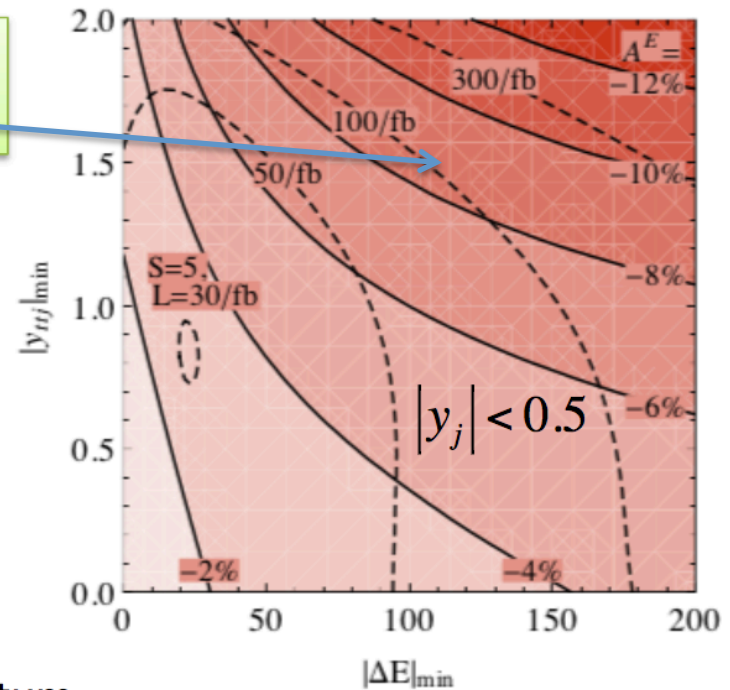
05/03/15  
 $A_{FR}$  of quark-jet in top pair rest frame

# Asymmetry in $t\bar{t} + jet(s)$

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S. Berge, S. Westhoff,  
JHEP07(2013)179

NEEDS  $\sim 100$  /fb of data  
for asymmetry values of  
7% (with  $DE > 150$  GeV  
and  $|y_{ttj}| > 1.0$ )  
Will need full Run II data



due to momentum  
Conservation.

Highest asymmetry for boosted ttj  
events and when the jet is perp. to  
the beam.

$$A_E = \frac{\sigma_{t\bar{t}}(\Delta E > 0) - \sigma_{t\bar{t}}(\Delta E < 0)}{\sigma_{t\bar{t}}(\Delta E > 0) + \sigma_{t\bar{t}}(\Delta E < 0)}$$

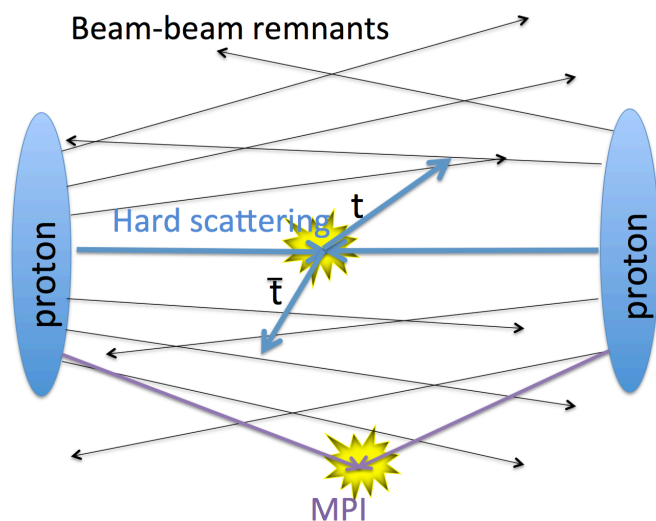
$$\leftrightarrow \frac{\sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} < 0) - \sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} > 0)}{\sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} < 0) + \sigma_{t\bar{t}}(\cos\theta_q^{(t\bar{t})} > 0)}$$

05/04/15

$A_{FR}$  of quark-jet in top pair rest frame.

# Study of Underlying Event with $t\bar{t}$

→ One important ingredient in simulations: the underlying event (UE).



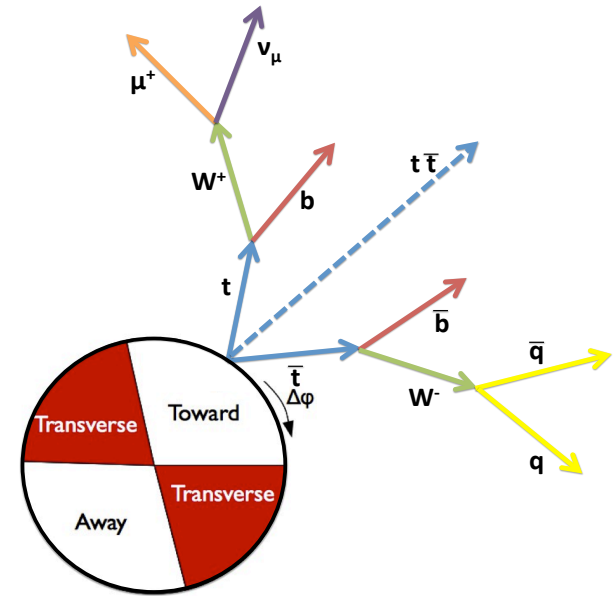
→ UE = the beam-beam remnants + the Multiple Parton Interactions (MPI) that accompany the hard scattering.  
 → Not fully described by pQCD.  
 → Relies on phenomenological models whose parameters can be “tuned”.

→ Using topological structure of hard hadron-hadron collisions, the UE activity in  $t\bar{t}$  events is studied.

→ Important to verify the “universality” of the UE tunes in hard process events.

# Study of Underlying Event with $t\bar{t}$

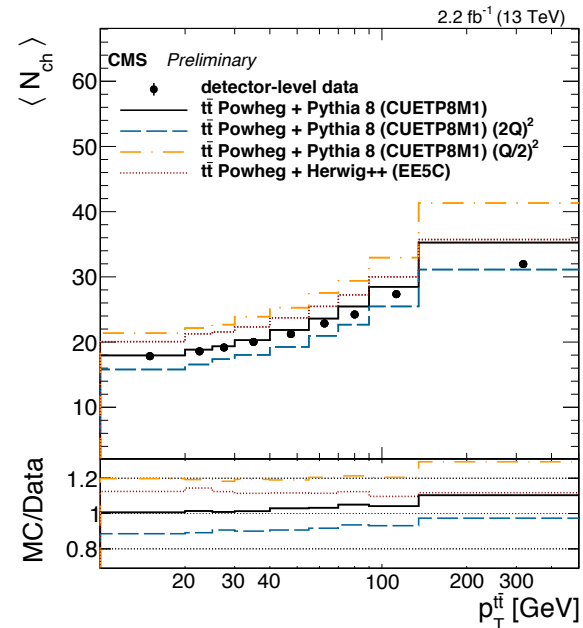
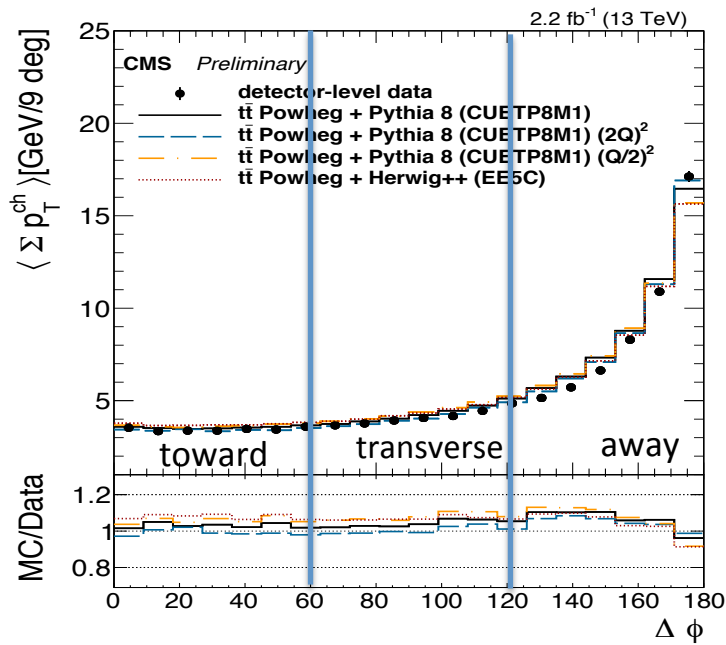
- $t\bar{t}$  system is used as the leading object.
  - UE regions described wrt the  $\Delta\phi(ch, t\bar{t})$
- UE is measured @13 TeV in lepton+jet channel
- Number of charged particles,  $N_{ch}$ ,
- scalar sum of charged particle transverse momenta,  $\Sigma p_T^{ch}$ ,
- average transverse momentum per particle  $\bar{p}_T^{ch}$  are measured.





# Charged $p_T$ flux measured with respect to the $t\bar{t}$ flight direction

13 TeV l+jets



- Transverse is the most sensitive region to UE activity.
- Away region contains contents of hard jets accompanying  $t\bar{t}$ .

- $\langle N_{ch} \rangle$  profiled wrt  $p_T^{t\bar{t}}$
- Comparison to scale up and down variations.
  - Better description of the data by scale up sample.

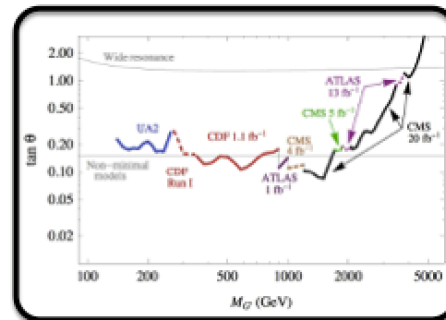
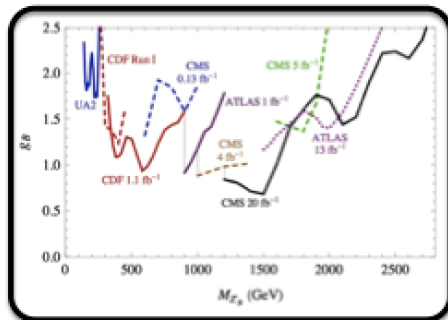
# SUSY searches

- Search for SUSY with topological variables at the LHC\*:
  - the effects of topological variables, namely W-transverse mass and topness
    - on the signal significance to be used in SUSY searches in single lepton channels at the LHC and in the future collider experiments are studied.

\* In collaboration with A. Cakir (ITU, DESY)

# CMS data-scouting and a search for low-mass dijet resonances

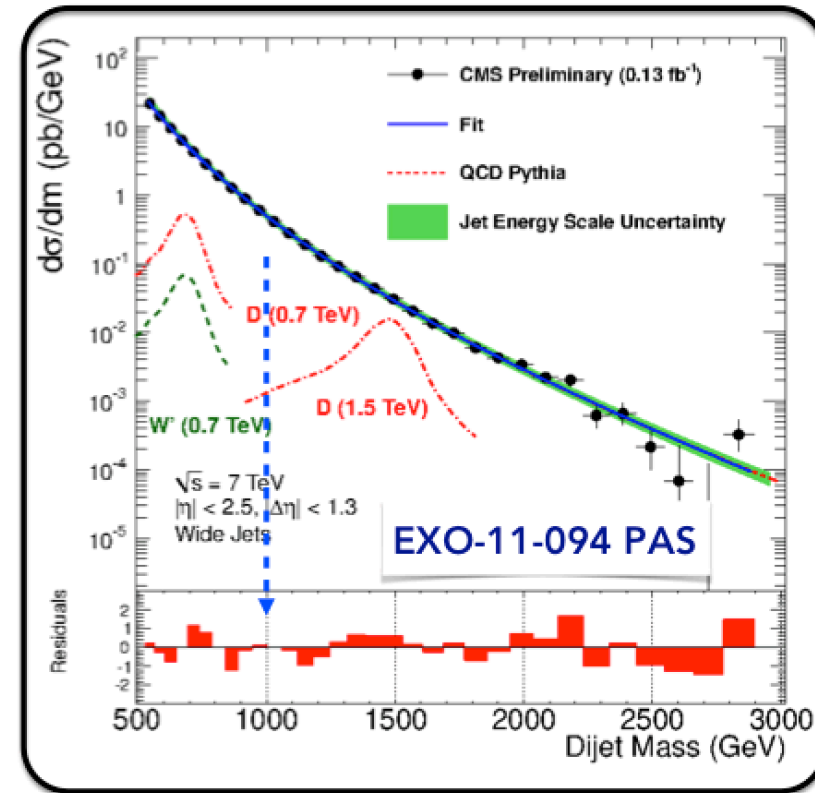
- LHC instantaneous luminosity increased during 8 TeV run.
- As an inevitable consequence, there are events not collected in main stream due to trigger constraints.
- **That does not mean that they are not interesting** to be investigated.
- As an example
  - the search for bumps in the dijet mass ( $m_{ij}$ ) spectrum starts at  $m_{ij} \approx 0.9$  TeV (trigger efficiency  $\approx 100\%$ ).
  - A standard analysis approach **leaves** the mass region  $m_{ij} < 1$  TeV **unexplored**.



## IV. CONCLUSIONS

We urge the experimental collaborations to present limits (or contours if a signal is observed) on dijet resonances in the coupling-versus-mass plane of a “baryonic”  $Z'_B$ , as in Figure [1] (or a coloron as in Figure [2], if the search is sensitive primarily to large signals arising from heavy resonances). This coupling-mass mapping, while be-

Bogdan A. Dobrescu, Felix Yu  
<http://arxiv.org/abs/arXiv:1306.2629>

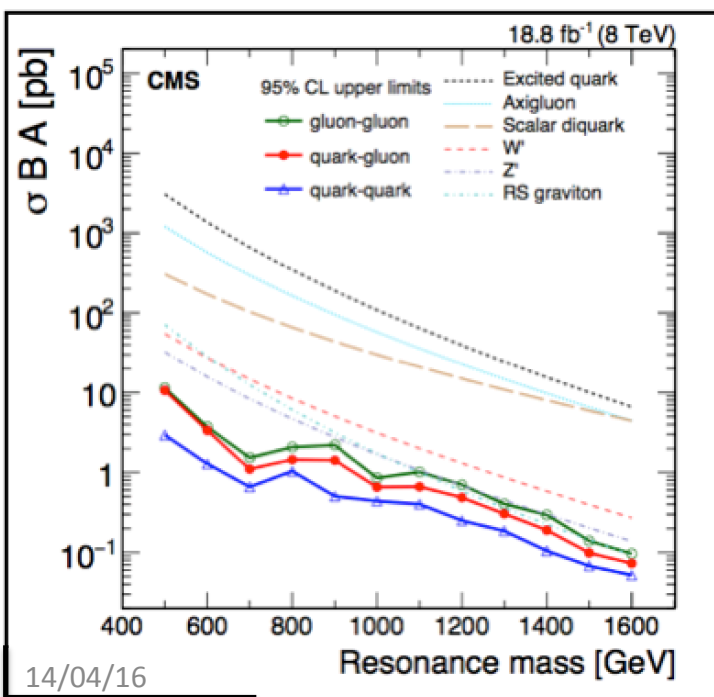


## Scouting approach extended the dijet search below 1 TeV

The dataset from 2012 has much higher potential:  
 18.8 fb<sup>-1</sup>, 8 TeV, and triggers with lower threshold than in 2011 (we could go even below the 500 GeV shown in that plot).

# Results and Publications

- The most stringent limits to date in the dijet final state for resonance masses between about 500 and 800 GeV were set.
- Interest is growing with the structure observed around 750 GeV.
- PAS has already been cited for 53 times.  
<http://cds.cern.ch/record/2063491>
- 13 TeV studies have already been started with the more developed data scouting record with PF jets.
- The analysis is in Final Reading process, and will be submitted to PRL.



International Journal of High-energy Physics

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Nov 13, 2015

#### CMS data-scouting and a search for low-mass dijet resonances



Proton beams crossed inside each of the CMS and ATLAS detectors 20 million times a second during the 2012 LHC proton-proton run. However, the physics programme of CMS is based on only a small subset of these crossings, corresponding to about 1000 events per second for the highest

beam intensities attained that year. This restriction is due to technological limitations on the speed at which information can be recorded. The CMS detector has around 70 million electronics channels, yielding up to about half-a-million bytes per event. This volume of data makes it impossible to record every event that occurs. A so-called trigger system is used in real time to select which events to

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- ▶ Another important step for the AWAKE experiment
- ▶ When trees break
- ▶ TPS exceeds design goal of 500 mA stored current
- ▶ From the April 1973 issue
- ▶ CMS hunts for supersymmetry in uncharted territory

Available on the CERN CDS information server

CMS PAS EXO-14-005

## CMS Physics Analysis Summary

Contact: [cms-pag-conveners-exotica@cern.ch](mailto:cms-pag-conveners-exotica@cern.ch)

2015/10/29

### Search for Resonances Decaying to Dijet Final States at $\sqrt{s} = 8$ TeV with Scouting Data

The CMS Collaboration

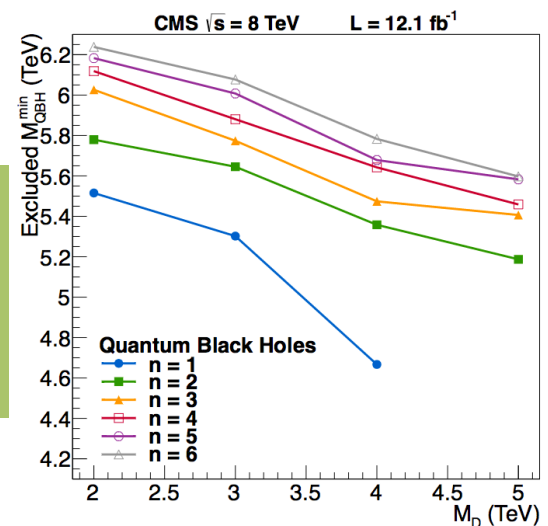
#### Abstract

A search for resonances decaying to dijet final states is performed in pp collisions at a center-of-mass energy  $\sqrt{s} = 8$  TeV. Using a loose online data selection and a reduced data format collected with a novel technique called *data scouting*, the search extends to low-mass values, testing previously unprobed low couplings. No evidence for a signal is found. The result is interpreted as upper limits on the production cross section as a function of the resonance mass. These limits are translated into an upper limit on the resonance coupling, allowing a comparison with results obtained in the same mass region at lower collision energies.

# Black Hole searches

- Was involved in 7 & 8 TeV black hole searches in scope of Quantum Black Holes
  - Worked on generating MC samples for different benchmarks
  - 13 TeV analysis uses the same set-up.

Lower quantum black hole mass limits at 95% CL as functions of the fundamental Planck scale MD for various QBH black hole models with a number  $n$  of extra dimensions from one to six



# Central shifts

- DAQ shifts
  - Taken by our group members since 2010
  - Will also be done in 2016
- DCS shifts
  - Done in 2014 by our group members
- Trigger shifts
  - Taken by our group members since 2014

# HCAL Tasks within DPG

- L1 TP Development studies
  - Joined the task force in 2014 to solve the discrepancies between TP emulations and data.
  - Continuing working on L1 TP developments for Upgrade.
- HF calibration studies with  $Z \rightarrow ee$  events
  - Method relies on reconstructing Z boson where one electron is in central and the other in Forward (HF)
  - Currently working on trigger development to cope with prescales of single electron triggers

# Tasks within TOP DQM group

- Serving as TOP/DQM-PdmV contact person
  - Responsible for interactions between two groups
  - Responsible in maintaining the DQM codes of the TOP group
    - Recently made the code available to run on miniAOD
    - Bug-fixing to old package coping with changes in CMSSW
      - B-tag related changes etc.



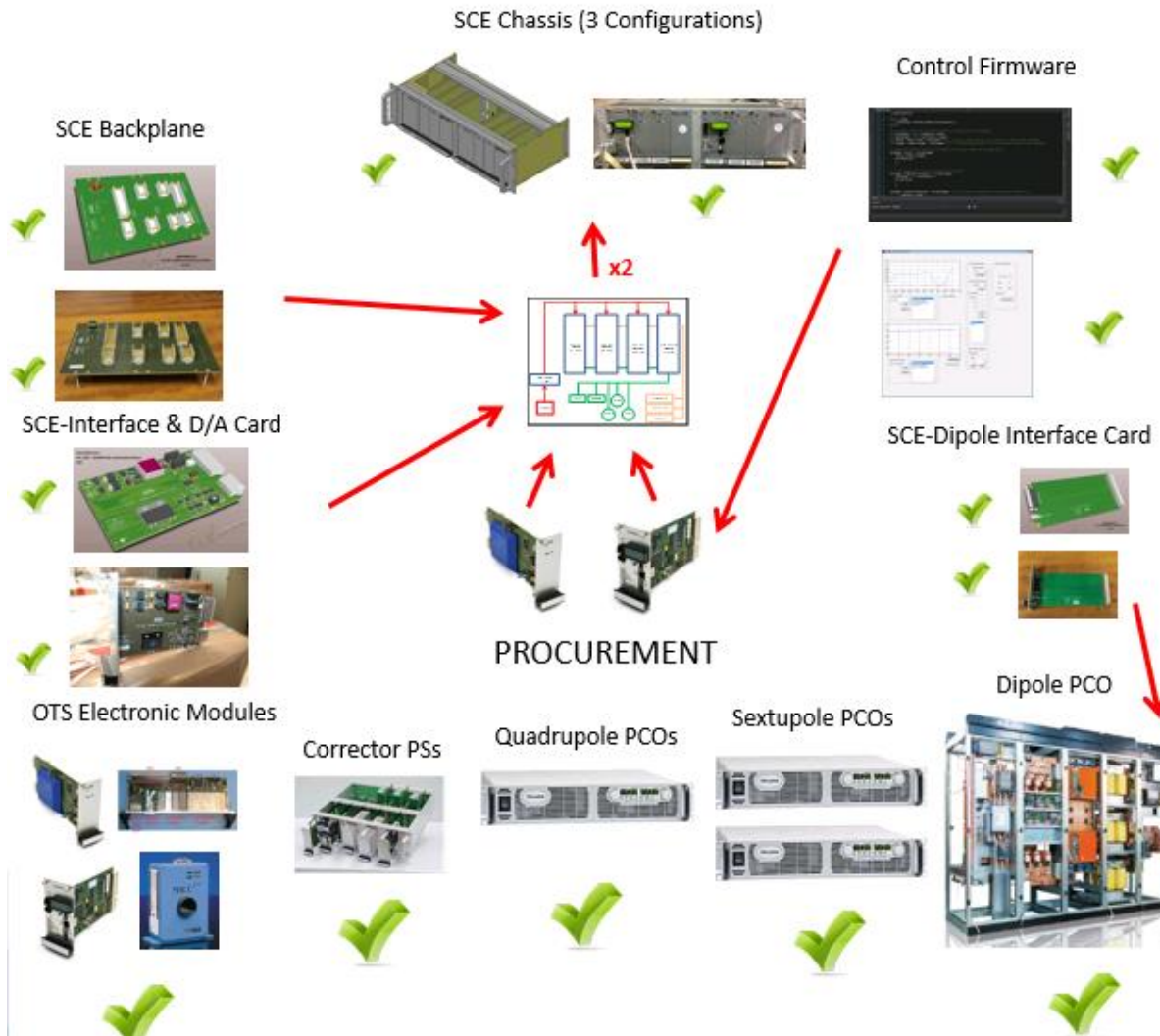
# CESSAMag Project (FP7)

## CERN EC Support to SESAME Magnets

- SESAME Storage Ring Magnet Power Supply System were to be designed. This system is responsible from regulating the storage ring magnets' current to desired levels. The conducted work included the following:
  - Storage Ring Magnet Power Supply System Requirements Management
  - Design and Validation of SESAME Control Electronics (SCE) Chassis
  - Design and Validation of SCE Backplane Board (SCE-BKP)
  - Design and Validation of SCE Dipole Interface Board (SCE-DIF)
  - Contribution to design and validation of SCE Data Acquisition Board (SCE-DAQ)

# CESSAMag Project (FP7)

## DESIGN



# Studies on $^{43}\text{Sc}$ production for PET scan

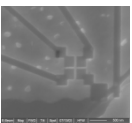
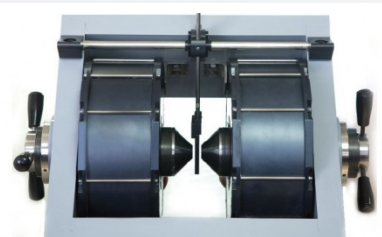
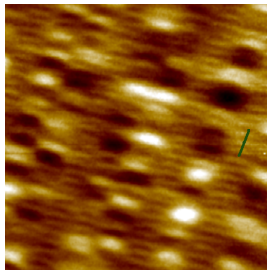
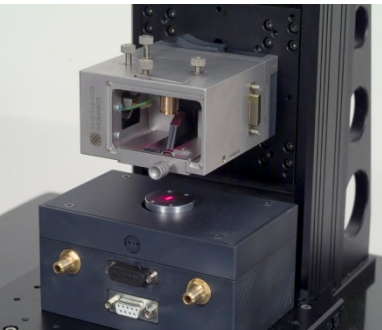
- Studies on  $^{43}\text{Sc}$  production cross section with Calcium and Titanium targets at 18 MeV Bern Medical Cyclotron (IBA).
- Production of novel PET radionuclide with longer life-time, low gamma-ray and positron energy.

# CMS Phase II Upgrade and HL-LHC

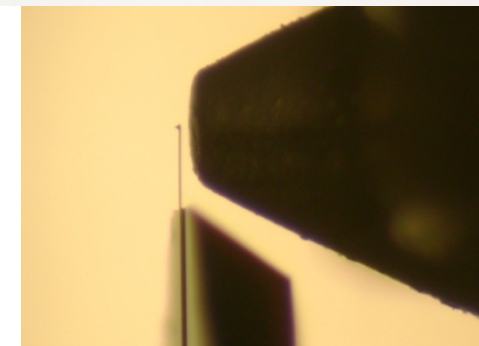
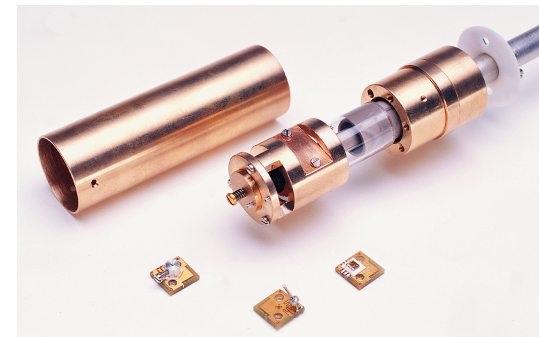
- We envisage contribution to R&D, qualification, assembly in the following areas/items:
  - Electronics and software
  - Mechanical manufacturing
  - Optical design, fiber optics and systems
  - Laser systems
  - Low temperature measurements and characterization
  - Ultra High Vacuum Systems
- Identified two medium size company:
  - Nanomagnetics Instruments Ltd.
  - Kenar Muhendislik Ltd.



# NANOMAGNETICS INSTRUMENTS

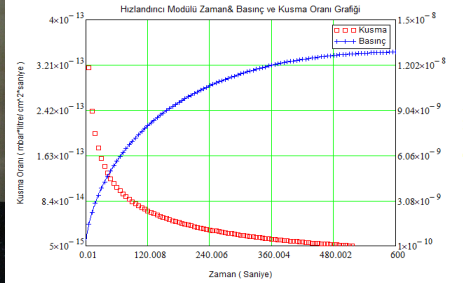


- Low Temperature Scanning Probe Microscopes
  - 10mK-300K
- Atomic Force Microscopes
  - ezAFM
  - High Performance AFM
  - *UltraFast* AFM
- Hall Effect Measurement Systems 10mK-1273K
- Magnetic Susceptibility Measurement Systems
- Vibrating Sample Magnetometer
- AC-DC Electrical Transport Measurement systems
- Ultra Low Noise Fiber Interferometers: 1fm/√Hz
- Contract R&D, Low Noise Electronics and Precision mechanical manufacturing
- 35 Employees, 5 with PhD



**(Pictures and Graph shows the products manufactured and designed for Turkish Accelerator Technologies Institute**

**ULTRA HIGH VACUUM CHAMBERS and MANIPULATORS**

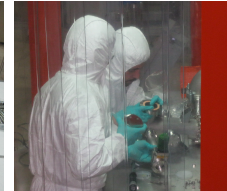


Outgassing Rates  $<10^{-13}$  mbar\*L/ cm<sup>2</sup>\*sec

Vacuum Pressure  $<2 \cdot 10^{-10}$  mbar

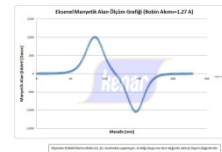
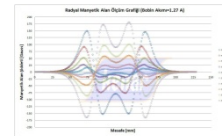
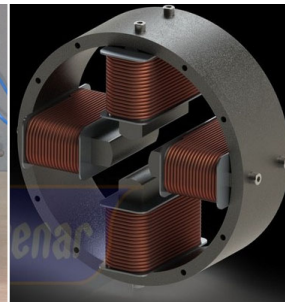
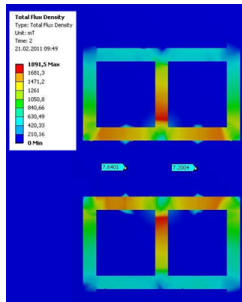
Chamber Volume  $< 1000$  L

**ELECTRON & ION GUNS**



Design Voltage  
 $> 300$  kV DC

**ELECTRO-MAGNETS**



Faraday – Coil (500-2000 Gauss)

Quadrupole (1-50 Gauss/m)

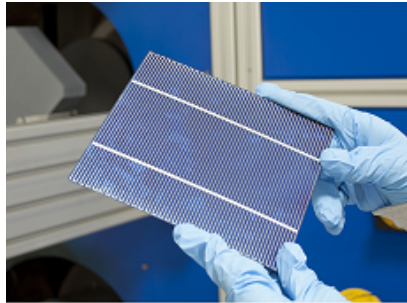
Hexapole



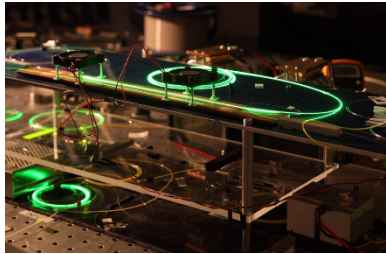
# R&D: Understanding Behavior at the Quantum Level



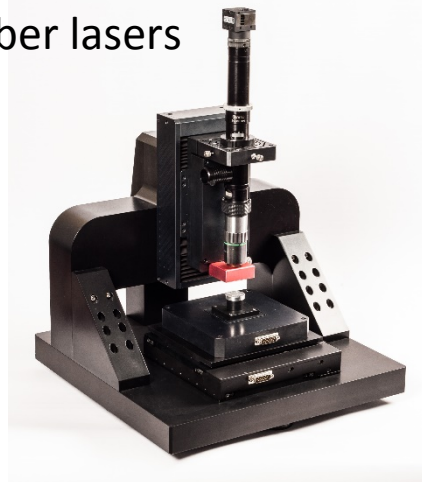
MIDDLE EAST TECHNICAL UNIVERSITY  
DEPARTMENT OF PHYSICS



Solar Cell Production

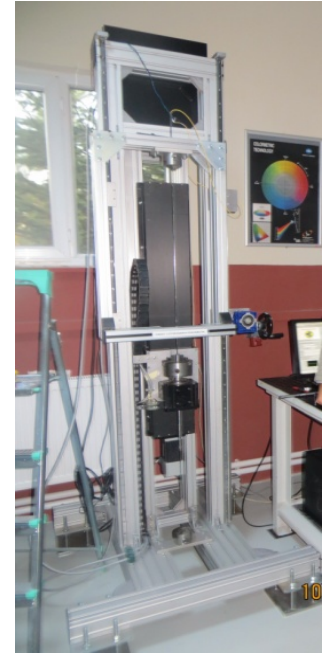


Fiber lasers



High Performance AFM

- Develop novel techniques to understand energies of systems from the nano-scale to bulk (*Non-linear Optics, Nano-Photonics, Plasmonics, Terahertz Research, Plasma Physics, Atomic Scale Imaging, Computational Physics*)
- Develop and characterize tools that benefit both industry and scientific community needs (*AFM, Optical Metrology, THz Spectroscopy and Imaging, Ultrafast Fiber Laser Development*)
- Develop technologies to efficiently harness energy from the sun (*1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> Generation Solar Cells, )*



Laser Gun Barrel Measurement System



MMW UGV

# Exploring A Wide Range of Energetic Phenomena

- 0.3-10THz
- Energy: 1.2 - 40meV
- Potential for unique studies

- UV-IR Solar Cells
- UV-Vis-IR Nanophotonics, Plasmonics, Detectors
- Plasma Diagnostics

- XRD: Growth of Crystals for LWIR detectors
- XRD: Polymer Research

- Test space qualified materials

