



Chung-Yao
Chao
Fellowship
interview

F. Lemmi

The candidate

Past activities

Present
activities

Conclusions

Interview for the Chung-Yao Chao Fellowship

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June 5th, 2021

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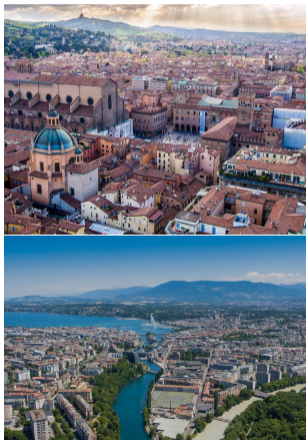
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- 30 years old, born in Reggio Emilia, Italy
- **Education:** scientific (PhD in HEP) and artistic (conservatory degree in piano performance)
- **PhD** at the **University of Bologna** in March 2021
- **Currently** in my **first postdoc** at IHEP Beijing
- Currently **based** at **CERN**
- Main **scientific interests:** **SM** physics, **Higgs** boson/**top** quark physics, **jets** physics

Past activities: $t\bar{t}$ cross section in all-hadronic final states ¹



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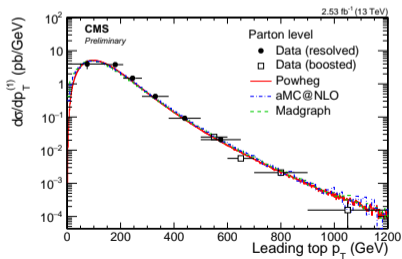
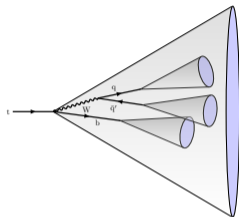
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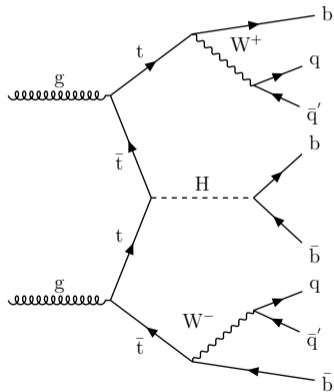
- Targeted both resolved and boosted all-hadronic decays
- **Novelty**: measured differential cross section in **fully-hadronic, fully-boosted** $t\bar{t}$ decays
- **Unfold** differential cross section at **parton-level**
- First differential p_T measurement up to the TeV scale
- Public result: [CMS PAS-TOP-16-013](#)
- Result was **showed at the LHCP2016 conference**

¹A. Castro, **F. Lemmi**, and K. Kousouris

PhD work: $t\bar{t}H$ in the fully-hadronic, boosted final state ²



- **Complementary approach to the previous CMS analyses**



- **At least 1 large-radius jet**
- **2 orthogonal channels:**
 - **Boosted Higgs channel (BHC):**
Higgs \rightarrow 1 large-radius jet
 - **Resolved Higgs channel (RHC):**
Higgs \rightarrow 2 well-resolved jets
- Use **2016 data sample** (35.9 fb^{-1})
- Extract signal strength $\mu_{t\bar{t}H}$
- **My contributions:** all the main steps of the analysis

²A. Castro, **F. lemmi**, K. Kousouris, G. Paspalaki, and Y. Tsiplitis

PhD work: $t\bar{t}H$ in the fully-hadronic, boosted final state



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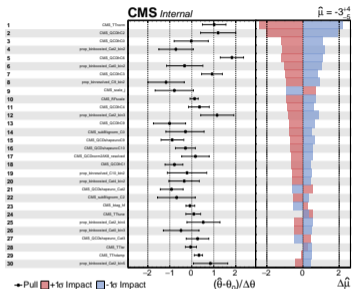
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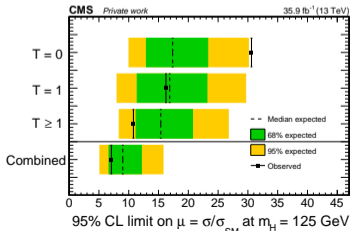
Conclusions



- Developed **MVA methods** to identify Higgs and top candidates
- **QCD** main background is **estimated completely from the data**

$$\hat{\mu}_{t\bar{t}H} = -3_{-5}^{+4}$$

- $\mu_{t\bar{t}H} < 7.1$ (9.0) at 95% CL
- **Results are compatible with the SM expectations**
- **First search for fully-hadronic $t\bar{t}H$ events in boosted topologies within CMS**



F. Lemmi (IHEP)

Chung-Yao Chao Fellowship interview

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Current projects: 4 top quarks in τ_h final states analysis ³



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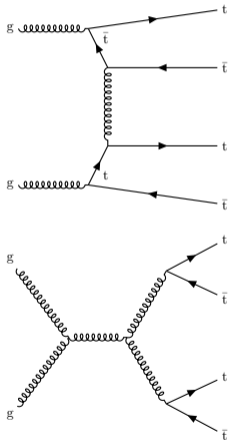
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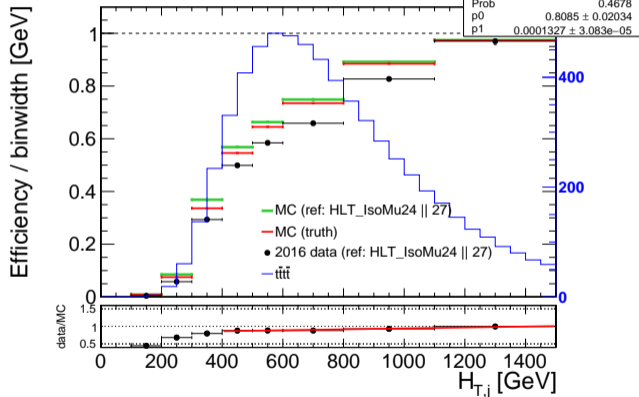
Conclusions



- Yet **unobserved** process
- Hadronic taus **final states unexplored in CMS**
- **Very rare** SM process: $\sigma_{\text{tttt}}^{\text{SM}} \simeq 12 \text{ fb}$
- Phase space split in signal categories based on τ_h , ℓ , jets, b-jets multiplicities
- **My contributions** so far:
 - Revision of the code
 - **Trigger studies**
 - **Tau ID studies**
- **Plans**: publish a **combined result** with other CMS channels with **EFT interpretation**

³H. Hua, **F. Lemmi**, H. Liao, H. Okawa, and Y. Zhang

An example of my work: trigger efficiency



- Final state with high jet multiplicity \implies use multijet triggers
- **Plot efficiency in data and MC**
- **Fit the ratio with a straight line**
- **Also plotted H_T distribution for signal**
- Apply $H_{T,j} > 400$ GeV cut

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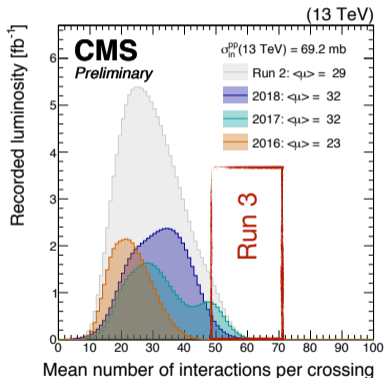
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Current projects: PU mitigation with ML techniques ⁴



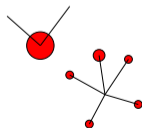
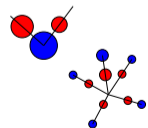
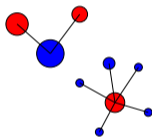
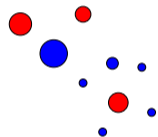
- **PU** will **increase** in Run3 ($\langle n_{PU} \rangle = 60$) and in HL-LHC ($\langle n_{PU} \rangle = 140$)
- Will severely **degrade quality of observables** (jet multiplicity, jet substructure, lepton isolation, ...)
- Current PU mitigation technique for Run3: **PUPPI**: a cut-based algorithm
- **Idea**: use **ABCNet** to combine information from all particles in the event
- **Main idea behind ABCNet**: graph neural network combined with attention-based mechanisms

⁴L. Gouskos, **F. Lemmi**, S. Liehti, B. Maier, V. Mikuni, and H. Qu

Optimal transport concepts for a loss function



- We inherit an idea from **optimal transport**



- The **Earth Mover's Distance** is the minimum work to move **earth** to fill some **holes**

$$EMD(\vec{x}, \vec{y}) = \min_f W(f, \vec{x}, \vec{y})$$

- With the EMD you can **match distributions** (e.g. earth-holes)
- Take two identical samples, with and without PU
- Match the 3D (p_T, η, ϕ) distributions for the noPU particles and **PU particles weighted by an ABCNet weight**

PU mitigation: current status



- Apply **ABCNet weights** to particles 4-momenta and **recluster jets**;
- ABCNet is comparable to PUPPI in hard observables (e.g., leading jet p_T)
- ABCNet leads to **huge improvement in soft observables** (e.g., uncl. MET)

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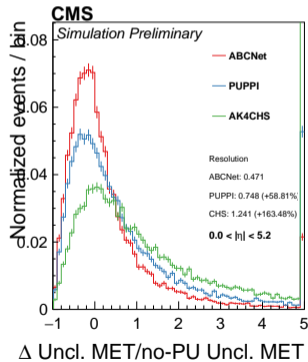
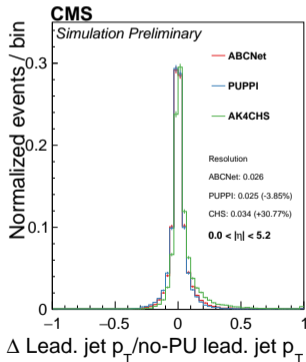
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- **Plans:** try to improve resolution for hard observables

Final considerations



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- I am involved in both **analysis-** and **objects-related activities**
 - 4 tops with τ_h final states (TOP PAG)
 - PU mitigation with advanced ML techniques (JME POG)
- Also recently joined a $t\bar{t}$ resonance analysis (B2G PAG)
 - **Importing** latest **top taggers** in the analysis framework
- **Detector activities:** I am completing my training as a technical shifter at CMS Point5
- I also **plan** to get involved in **HGCal-related activities** at CERN

Thanks a lot for your attention and consideration



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Backup slides

Talks/posters and awards



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- **Talks/posters** given at conferences:
 - **Higgs boson physics review**, talk at the CMSItaly2020 annual meeting (online)
 - **Latest measurements in single top quark with the CMS experiment**, parallel talk at the LHCP2019 conference (Puebla, Mexico)
 - **Measurement of the inclusive and differential $t\bar{t}$ cross sections at 13 TeV in the all-jets boosted regime with CMS**, communication at the 102nd congress of the Italian Physical society (Padua, Italy)
 - **Associated $t\bar{t}H$ production in the all-jets final state with the CMS experiment**, poster at Meetings on High Energy Physics 2019 (Naples, Italy)
- **Awards:**
 - **Marco Polo fellowship** on *Development of tools for the CMS Drift Tubes Control System for upgrade and longevity studies* (3 months stay at CERN)
 - **INFN CERN Associate scholarship** on *Search for $t\bar{t}H$ production in the boosted, all-jets final state with CMS in pp collisions at 13 TeV*, (one year stay at CERN)