For postdoctoral research associate position for the project "Cluster of Excellence Quantum Universe"

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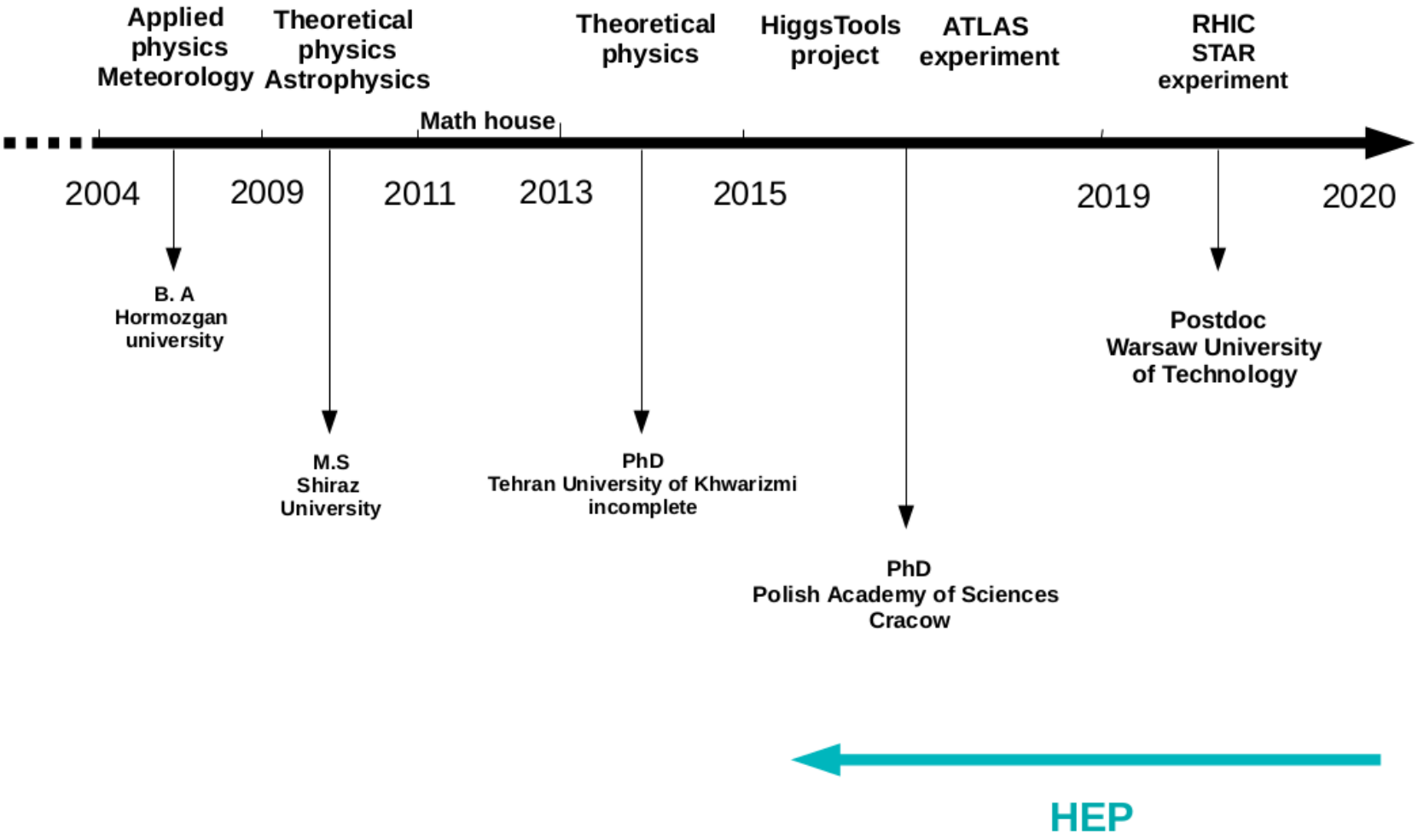
Warsaw University of Technology

August 20, 2020


Applied physics Meteorology
Theoretical physics Astrophysics
Theoretical physics
HiggsTools project
ATLAS experiment
RHIC STAR experiment
Math house
2004
2009
2011
2013
2015
2019
2020
B. A Hormozgan university
M.S Shiraz University
PhD Tehran University of Khwarizmi incomplete
PhD Polish Academy of Sciences Cracow
Postdoc Warsaw University of Technology
HEP

- Study the elastic and inelastic interaction of quarkonium with hadrons using femtoscopic correlations of J/ψ-hadron pairs.

$$C(\mathbf{P_a}, \mathbf{P_b}) = \frac{P_2(\mathbf{P_a}, \mathbf{P_b})}{P_1(\mathbf{P_a}) P1(\mathbf{P_b})}$$

$$C(k^*) = \int d^3r^* S(r^*) |\Psi_{(\mathbf{r^*}, k^*)}|^2$$

$$\Psi^S(\mathbf{r^*}, -k^*) \doteq e^{-i\mathbf{k^*}\cdot\mathbf{r^*}} + \frac{f^S(k^*)}{r^*} e^{ik^*\cdot r^*},$$

- Measurement of J/ψ breakup cross section due to its interaction with hadrons.

$$\sigma_{tot} = \sigma_{inel} + \sigma_{el} = \frac{4\pi}{k^*} \mathrm{Im}(f^S(k^*))$$

Lednicky and Lyuboshitz model

$$C(Q)=1+\sum_s \rho_s\left[\frac{1}{2}\frac{|f(k)|^2}{r_0^2}\left(1-\frac{1}{2\sqrt{\pi}}\frac{d_0}{r_0}\right)+\frac{\Re f(k)}{\sqrt{\pi}\,r_0}F_1(Qr_0)-\frac{\Im f(k)}{2r_0}F_2(Qr_0)\right]$$

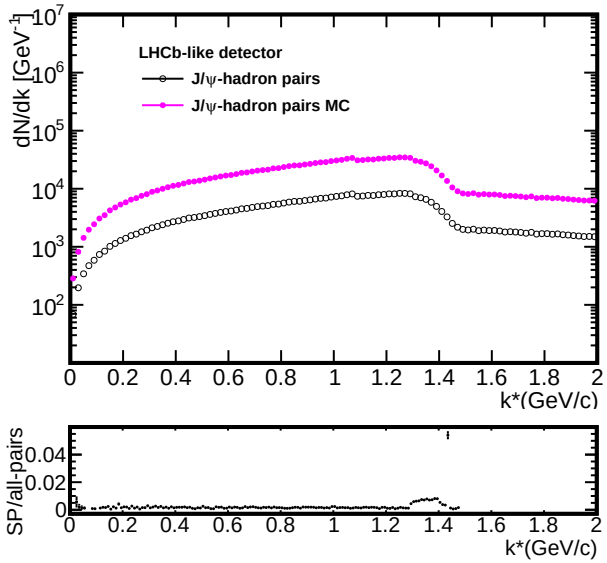
k = Q/2

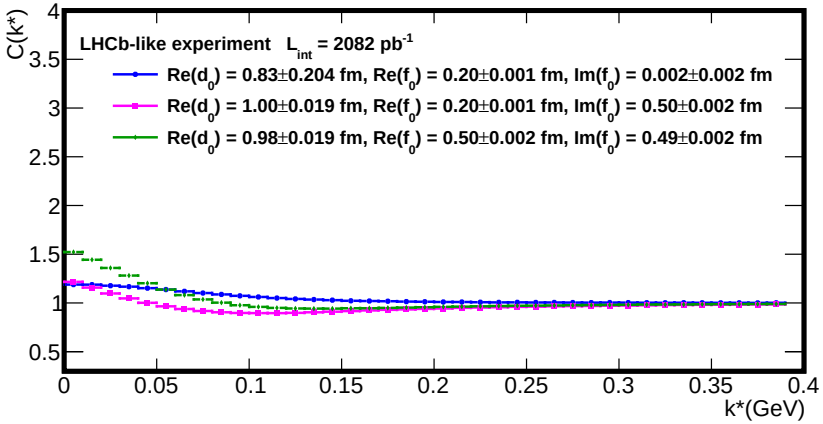
$$F_1(z)=\int_0^1 e^{x^2-z^2}/z\,dx \qquad F_2(z)=(1-e^{-z^2})/z$$

The s-wave scattering amplitude f(k) $f(k)=\left(\frac{1}{f_0}+\frac{1}{2}d_0k^2-ik\right)^{-1}$

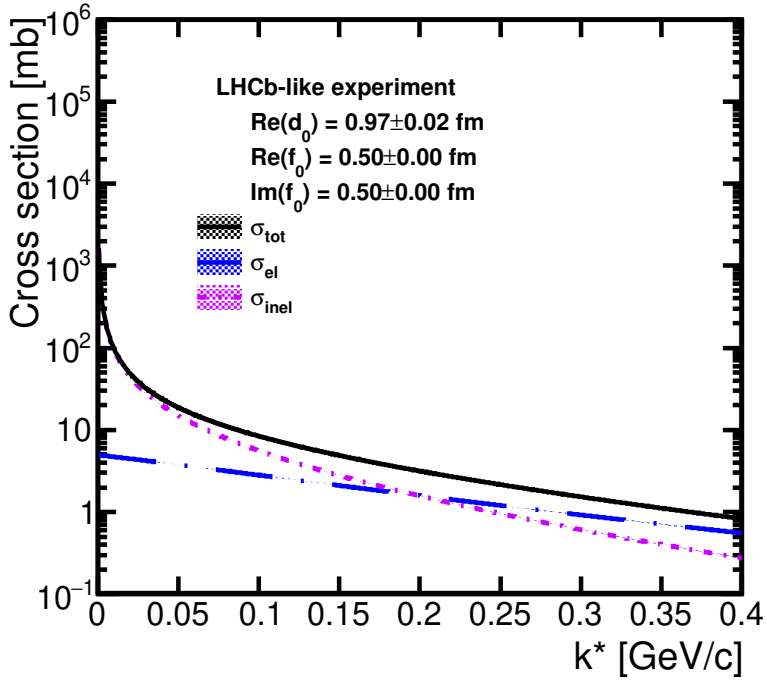
f_0 - the scattering length, d_0 - the effective range. r_0, f_0 and d_0 can be extracted from a fit of the LL formula to the experimental femtoscopic correlation function.

- Simulated sample with Pythia 8.2 configured within parameters of LHCb and STAR experiments(LHCb 8TeV and L_{int} 2082pb^{-1}, STAR 500GeV, L_{int} 400 and 2200 pb^{-1}).





J/ψ breakup cross section

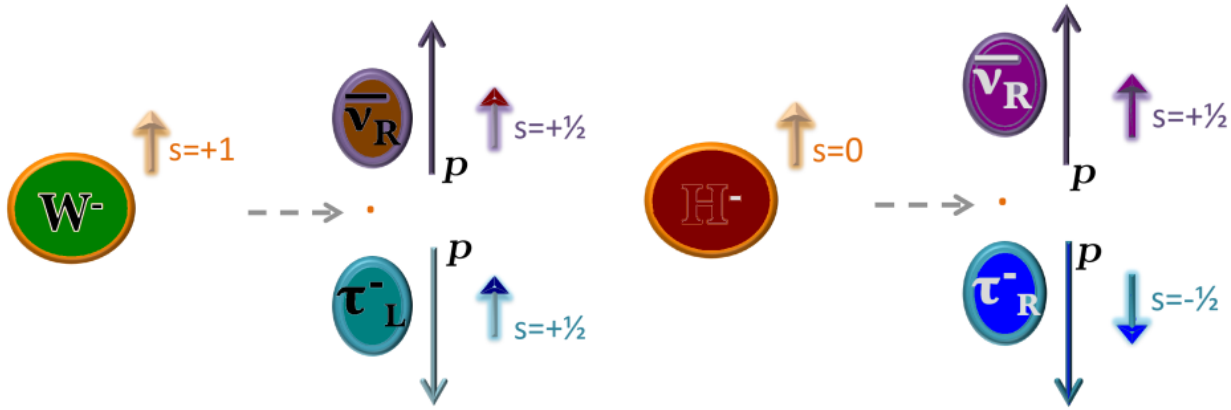


PhD projects

- Studies on tools and phenomenology were preformed in the context of the search for extended scenarios of electroweak symmetry breaking:
- Development and validation of `TauSpinner` program.
- Search for charged Higgs boson decaying via $H^{\pm} \to \tau\nu_{\tau}$ in the τ+jet and τ+lepton final state, using pp collision data at $\sqrt{s} = 13$ TeV with integrated luminosity of 36.1 fb^{-1}.
- Fake τ background estimation in the full Run-II data analysis.

- The τ polarization is a measure of the degree of parity violation in the interaction.

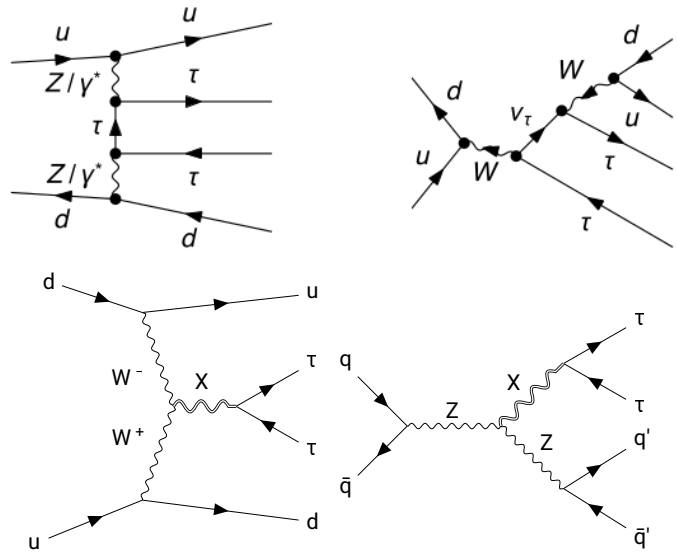
$$P_\tau = \frac{N_R - N_L}{N_R + N_L} = \frac{\sigma_\tau(\lambda = 1) - \sigma_\tau(\lambda = -1)}{\sigma_\tau(\lambda = 1) + \sigma_\tau(\lambda = -1)}$$

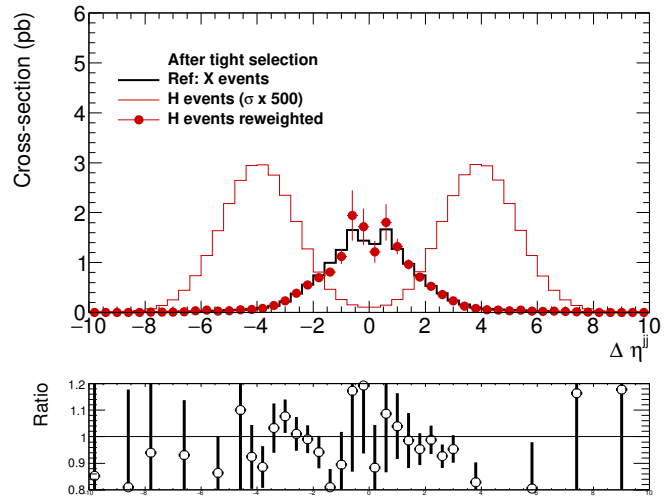


- TauSpinner is a tool for modifying τ spin effects in any MC generated samples or data containing τ leptons.
- The program can be used to calculate appropriate events weights, whereby spin effects can be included into or removed from a sample.

TauSpinner development

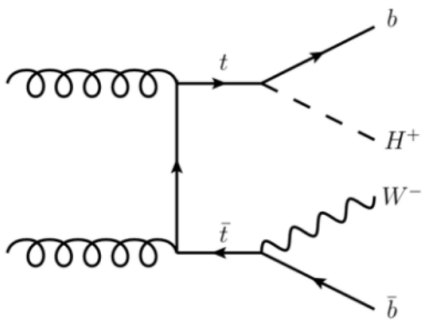
- TauSpinner 2→4: to study samples with 2 τs and 2 jest at the final state.
  - Evaluation of systematic uncertainties of TauSpinner for variation of its input parameter.Acta Phys.Pol.B48,1455 (2017)
- A non-SM process with an intermediate spin-2 X-state is implemented in TauSpinner.
- The matrix element of non-SM X were generated by Madgraph and modified in order to be implemented.
- Test of matrix element and reweighting in TauSpinner has been preformed Eur.Phys.J.C(2018)78:10.



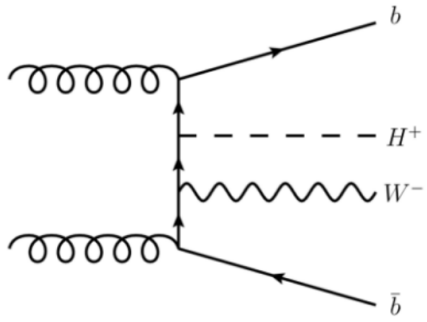


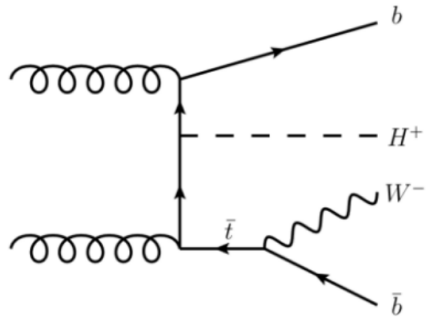
Search for charged Higgs boson

- Any extension to the Higgs sector, beyond adding a single scalar, implies existence of charged scalars (2HDM, NMSSM, Triplet, ect.)
- At LHC $H^{\pm}$ produced mainly in top-quark decays or in association with top-quark.
- We look for $H^{\pm}$ decays to $\tau\nu$ in τ+jets ($t \to bq$) and τ+lepton ($t \to bl\nu$) channels.
- The τ+jets channel is sensitive to high $H^{\pm}$ mass (high BR of $t \to bqq$).
- The τ+lepton channel is sensitive to low and intermediate $H^{\pm}$ mass (leptonic trigger).



$m_{H^{\pm}} < m_{top}$





$m_{H^{\pm}} \geq m_{top}$

Analysis Overview

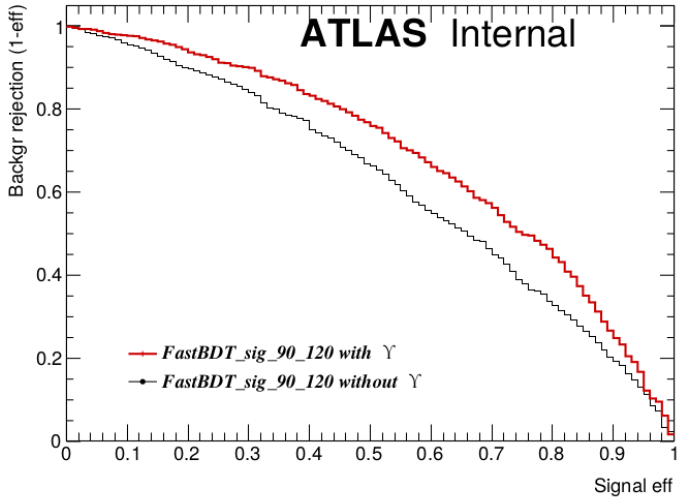
- Search for $H^{\pm}$ over wide mass range (90-2000 GeV), using pp collision data at $\sqrt{s} = 13$ TeV with integrated luminosity of 36.1 fb^{-1}, recorded by ATLAS J.High Energ.Phys.(2018)2018:139.
  - low mass range (90-160 GeV), Intermediate mass range (first time ever!) ($m_H \approx m_t$), High mass range (200-2000 GeV)
- Analysis technique (MVA).
- Background with prompt hadronic τ.
  - Top, V+jets and VV : modeled with MC.
- Background with fake τ
  - Fake $j \rightarrow \tau$ estimated with data driven fake factor method.
  - Fake $l \rightarrow \tau$ estimated with MC.
- Discriminating variable: BDT score. m_T was used before.

$$m_T = \sqrt{2 p_T^{\tau} E_T^{miss} (1 - \cos\Delta\phi_{\tau,miss})}$$

- MVA input variables

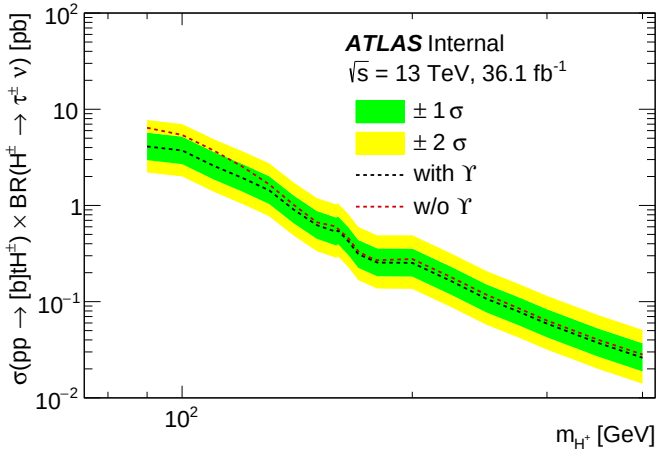
MVA input variable	τ+jets	τ+lep
$E_{\mathrm{T}}^{\mathrm{miss}}$	✓	✓
p_{T}^{τ}	✓	✓
$p_{\mathrm{T}}^{b\text{-jet}}$	✓	✓
p_{T}^{ℓ}		✓
$\Delta\phi_{\tau,\mathrm{miss}}$	✓	✓
$\Delta\phi_{b\text{-jet},\mathrm{miss}}$	✓	✓
$\Delta\phi_{\ell,\mathrm{miss}}$		✓
$\Delta R_{\tau,\ell}$		✓
$\Delta R_{b\text{-jet},\ell}$		✓
$\Delta R_{b\text{-jet},\tau}$	✓	
$\Upsilon = 2\frac{p_{\mathrm{T}}^{\tau\text{-track}}}{p_{\mathrm{T}}^{\tau}} - 1$	✓*	✓*

(* only used for 1p τ, 90-400 GeV)



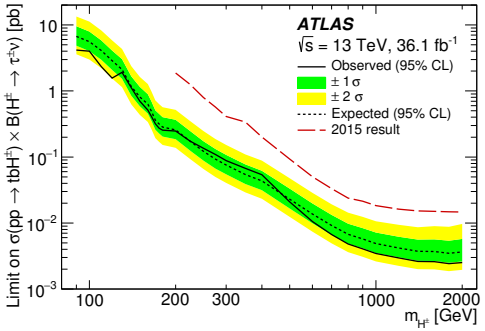
- The Υ variable, sensitive to τ polarization, the most important at low $H^{\pm}$ mass, while at high mass the m_T constituents mostly discriminating.

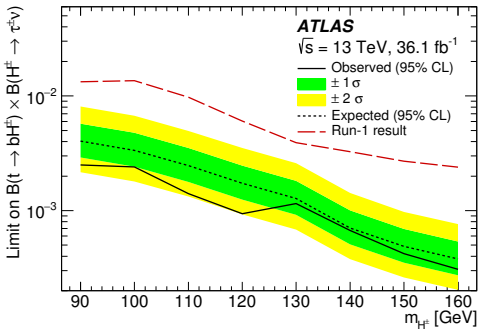
$$\Upsilon = \frac{E_T^{\pi^{\pm}} - E_T^{\pi^0}}{p_T} \approx 2\frac{p_T^{trk}}{p_T} - 1$$

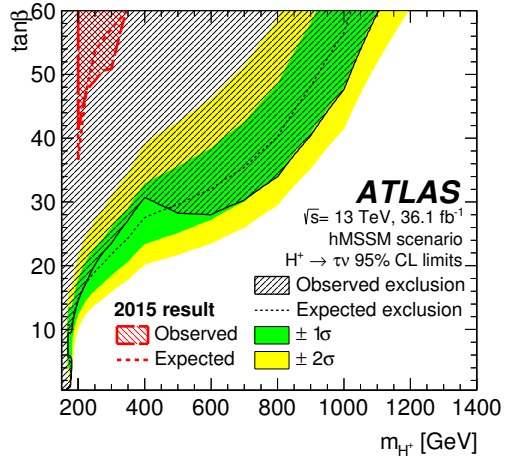


Observed limit and Statistical interpretation of result

- Combined limits as a function of $H^{\pm}$ mass:
  - $\sigma(pp \to tbH^{+}) \times \mathcal{B}(H^{+} \to \tau\nu)$ for full $H^{\pm}$ mass (top): 4.2 pb - 2.5 fb
  - $\mathcal{B}(t \to bH^{+}) \times \mathcal{B}(H^{+} \to \tau\nu)$ for low $H^{\pm}$ mass (middle): 0.25% - 0.031%
- Interpretation of result in context of hMSSM scenario
- Mass range $H^{\pm} < 160$ GeV excluded where theoretical prediction exists
- Significant gain with respect to 2015 data.







Fake τ background in full Run-II

- Background containing $j \to \tau$ fakes are estimated from data using fake factor method.

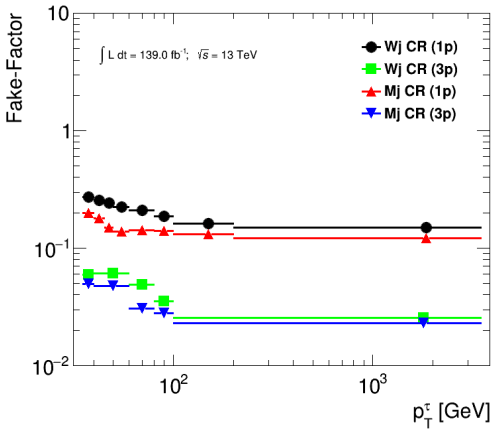
$$\mathrm{FF} = \frac{\mathrm{N}^{\mathrm{CR}}_{\tau_{\mathrm{had-vis}}}}{\mathrm{N}^{\mathrm{CR}}_{\mathrm{anti}-\tau_{\mathrm{had-vis}}}}$$

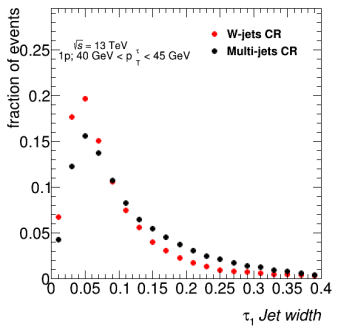
- FF measured in multi-jet (gluon-initiated jets) and W+jets(quark-initiated jets) regions
- Parametrization: p_T^{τ} and number of tracks

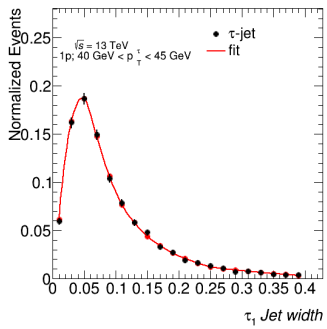
- The FFs are combined using template fit method

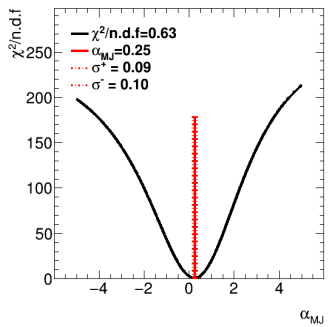
$$\mathrm{FF}^{\mathrm{comb}}(\mathrm{i}) = \alpha_{\mathrm{MJ}}(\mathrm{i}) \times \mathrm{FF}^{\mathrm{multi-jet}}(\mathrm{i}) + [1 - \alpha_{\mathrm{MJ}}(i)] \times \mathrm{FF}^{\mathrm{W+jets}}(\mathrm{i})$$

- The discriminating variables for 1-prong $\tau_{\text{had-vis}}$ candidates: τ jet width and for 3-prong candidates: transformed $\tau_{\text{had-vis}}$ BDT score



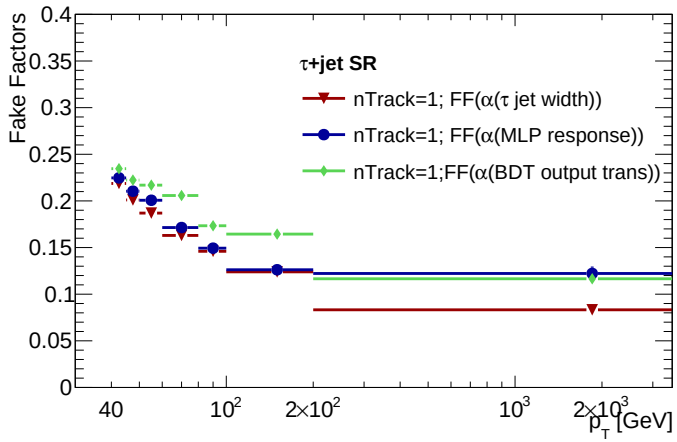


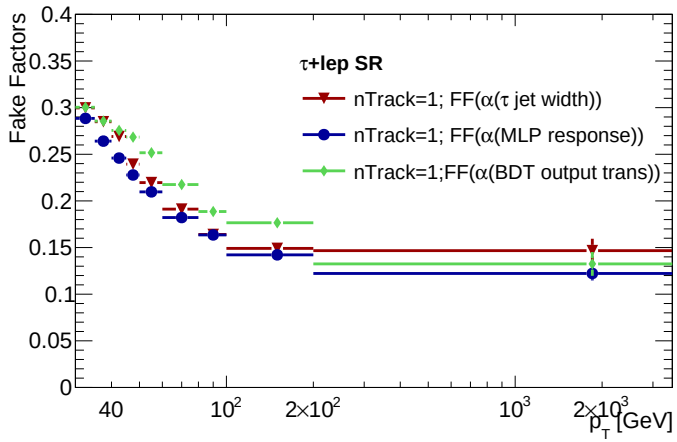




Alternative discriminating variable for template fit

- MVA analysis Neural Network (MLP) was trained on 2018 data in the W+jets and multi-jet control regions.
- Three variables, the $\tau_{\text{had-vis}}$ jet width, the transformed BDT score and p_T^{τ} were used for training.
- Comparison of combined FFs for 1-prong candidate estimated by template fit method using $\tau_{\text{had-vis}}$ jet width, the MLP response and the transformed BDT score as discriminating variables:



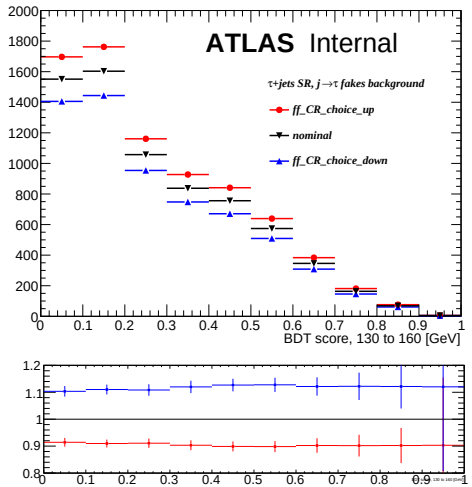


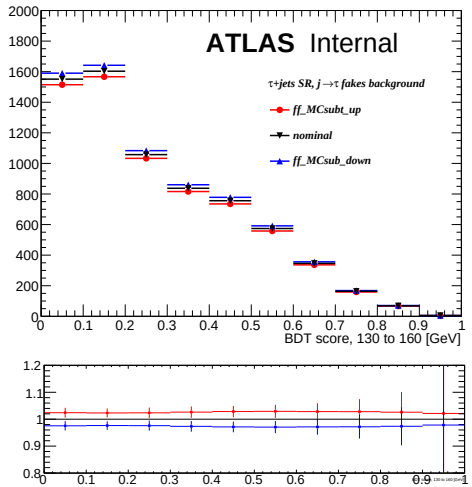
- MLP universally applicable to both 1-prong and 3-prong in the entire p_T range and results in somewhat smaller uncertainties.

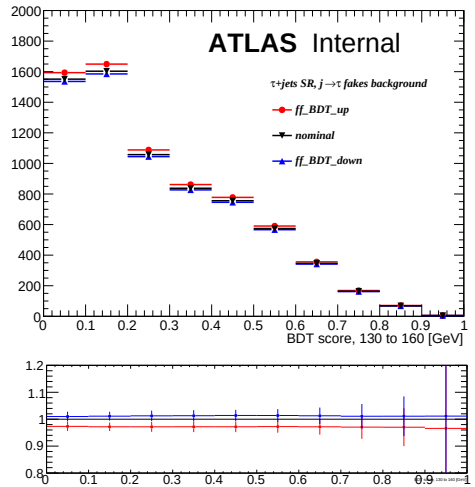
Systematic uncertainties of the fake factor method

	$\tau_{had-vis}$+jets		$\tau_{had-vis}$+lepton	
Source of uncertainty on FF	Effect on yield	Shape	Effect on yield	Shape
Jet composition	4.6%	✓	2.8%	✓
Statistical uncertainties	0.62 %	✗	0.73%	✗
True $\tau_{had-vis}$	3.0%	✓	4.5%	✓
α_{MJ} uncertainty	1.60%	✓	4.20%	✓
Control region choice	8.4 %	✓	7.9%	✓
Smirnov transform.	0%	✓	0%	✓

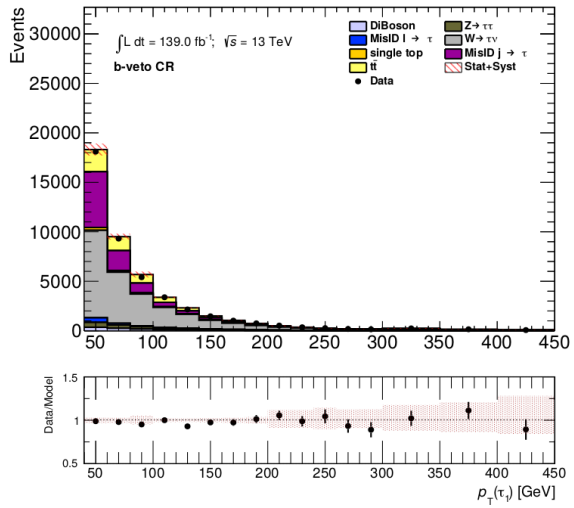
- Effect of systematic variations on the BDT score in the H^+ mass range 130-160 GeV in the $\tau_{\text{had-vis}}$+jets SR

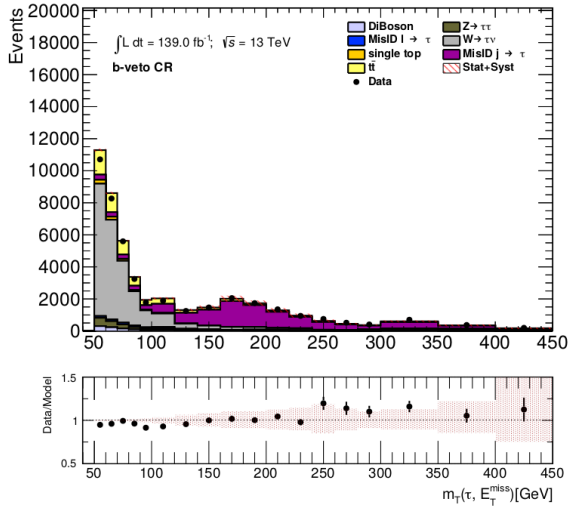


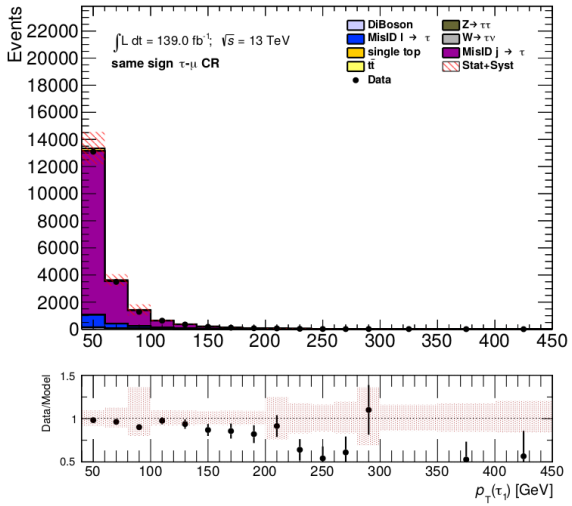


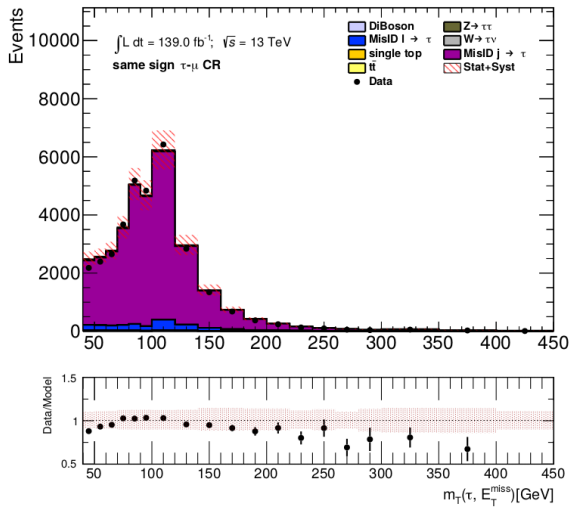


Validating of the fake τ background estimation



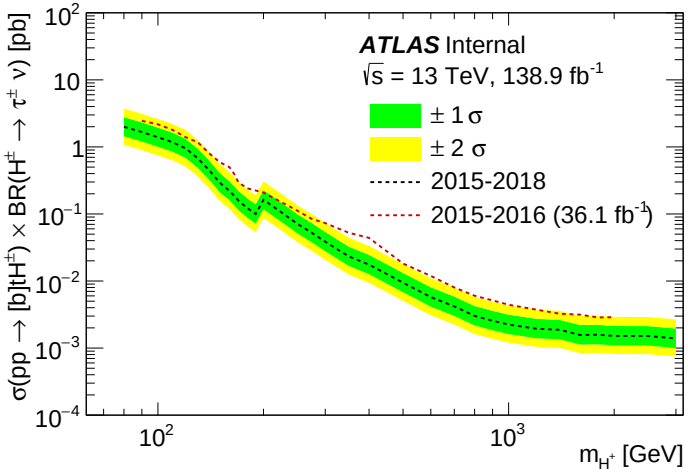


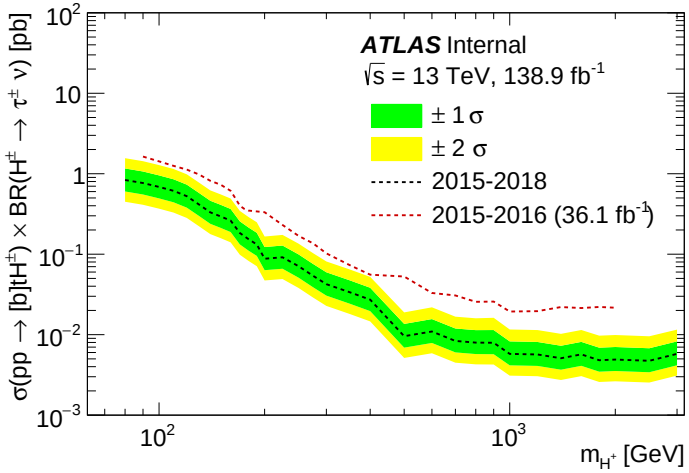




Modified discriminant in the full Run-II analysis (preliminary)

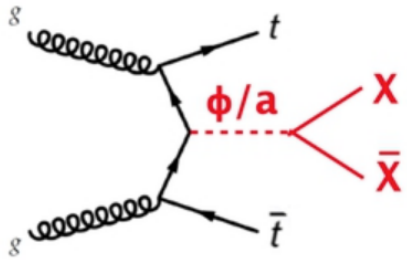
- Discriminating variable BDT output by using new variable for both channels, $\Delta\phi_{\tau,miss}/\Delta\phi_{jets,miss}$, where $\Delta\phi_{x,miss}$ is the difference in azimuthal angle between a detector object x and the direction of the missing transverse momentum
- The training of the BDT is preformed using the Scikit learning tool.
- The expected limit for the full Run-II and 2015 and 2016 analysis for both channels.



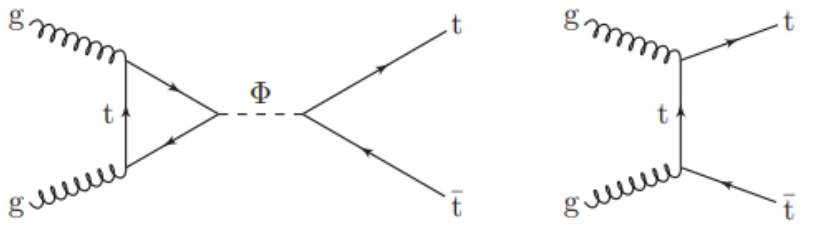


Research interest and plans for future: being part of HEP community, CMS experiment, LHC.

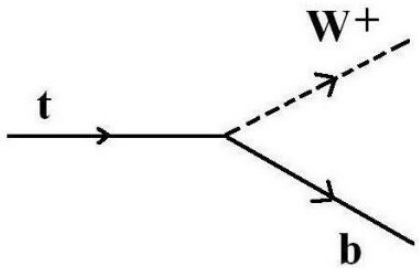
- Direct searches for BSM, looking for Dark matter
  - Searching for heavy Higgs

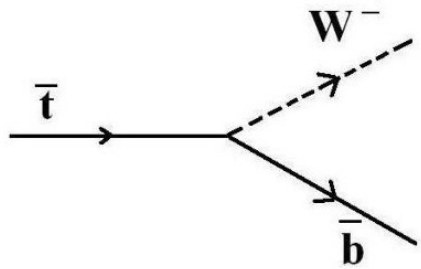


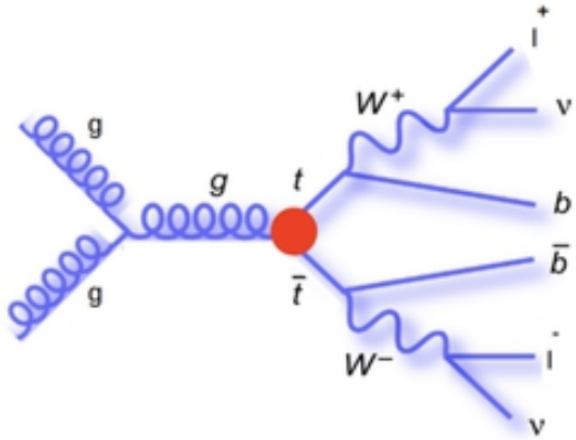
  - Search for dark matter with top quark events



- Indirect searches, precision measurement of SM, any deviation is a hint for new physics
  - Top quark decay
  - Top quark pair spin correlation and top quark polarisation
  - Search for Effective Field Theory (EFT) Couplings

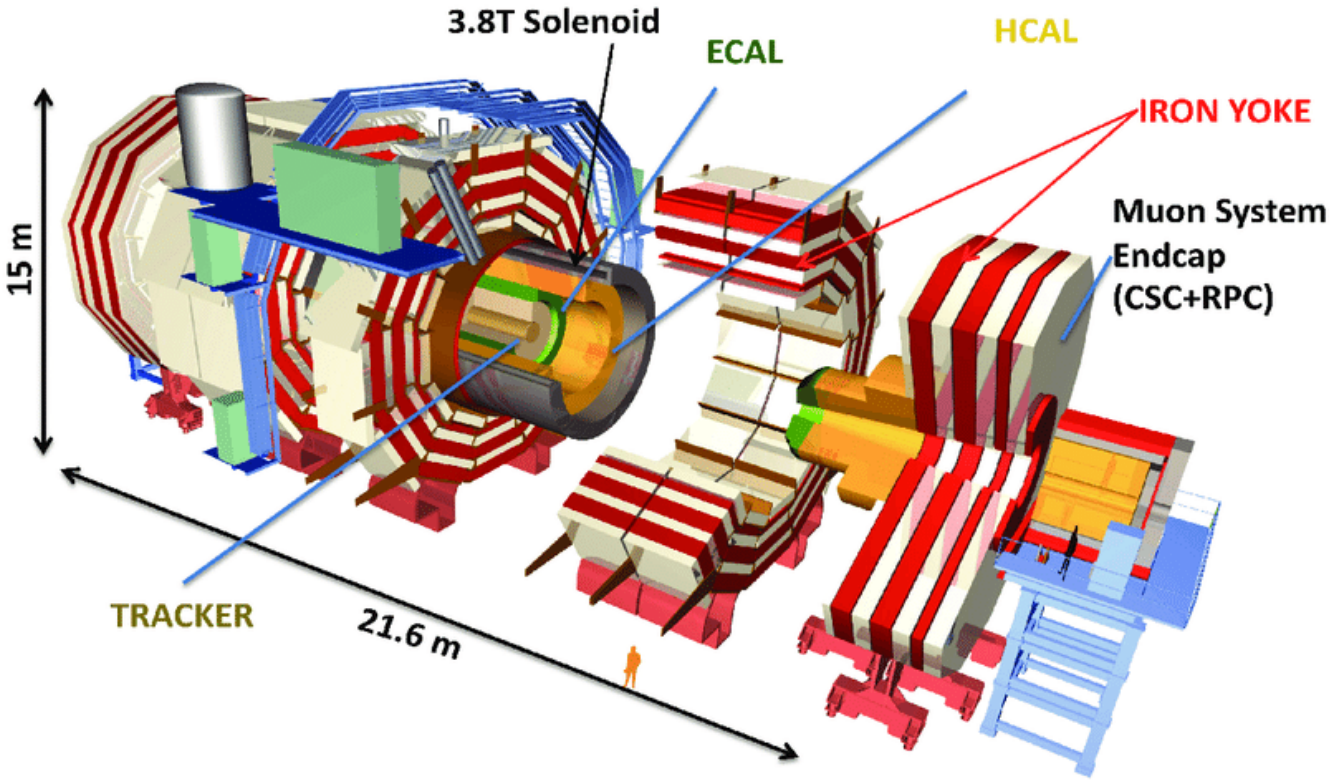






Career development plans

- Improve my skills of software development, data analysis and machine learning techniques, phenomenological approaches.
- If there will be possibility to develop skills on detector operation




THANK YOU FOR
YOUR ATTENTION!

Questions

For our location in Hamburg we are seeking:

Postdoctoral research associate for the project "Cluster of Excellence Quantum Universe"

DESY

DESY is one of the world's leading research centres for photon science, particle and astroparticle physics as well as accelerator physics. More than 2400 employees work at our two locations Hamburg and Zeuthen in science, technology and administration.

The Cluster of Excellence "Quantum Universe" performs research to understand mass and gravity at the interface between quantum physics and cosmology. The research team includes leading scientists from mathematics, particle physics, astrophysics, and cosmology at Universität Hamburg and DESY. Postdoctoral research associates will become members of the Quantum Universe research school (QURS) and through this receive offers for academic training, soft skills, and career planning. In addition, they will receive individual budgets, meant to enable them to attend conferences or other educational and supporting measures. Additional travel money for project-duties will be made available via the hosting research groups. Postdoctoral research associates may participate in the supervision of doctoral students, teaching at the University, and in the organization of the Cluster via an early career council.

The position is limited to 2 years.
Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. Handicapped persons will be given preference to other equally qualified applicants. DESY operates flexible work schemes. DESY is an equal opportunity, affirmative action employer and encourages applications from women. Vacant positions at DESY are in general open to part-time-work. During each application procedure DESY will assess whether the post can be filled with part-time employees.