Higgs → ττ analysis in the CMS

Michał Olszewski

On behalf of the CMS Collabaration

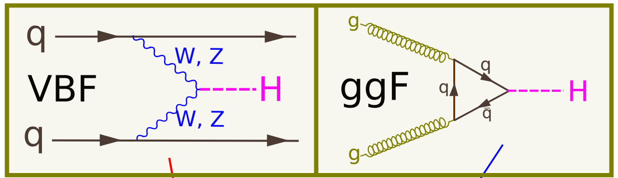
young researches session

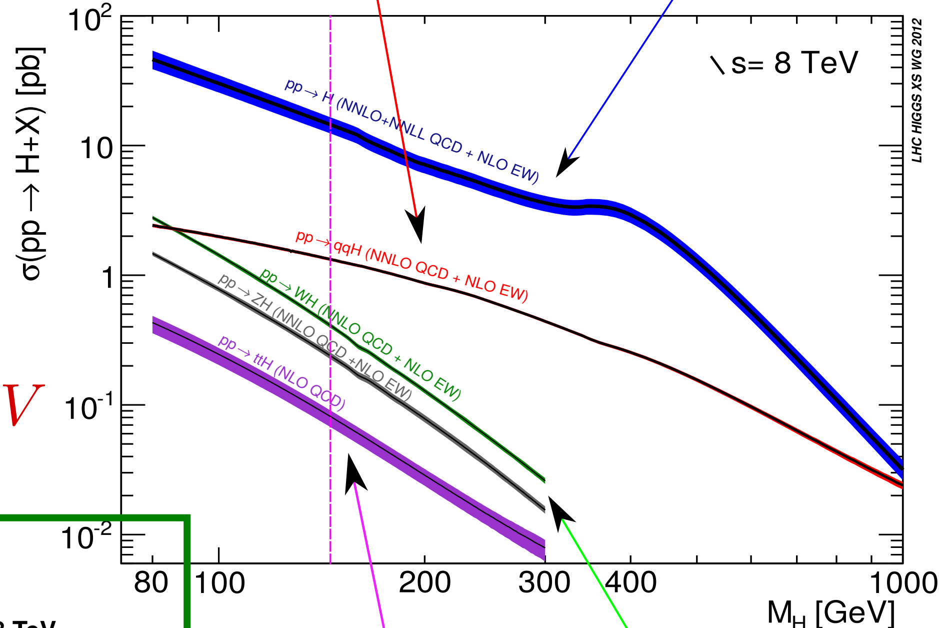
Faculty of Physics
University of Warsaw

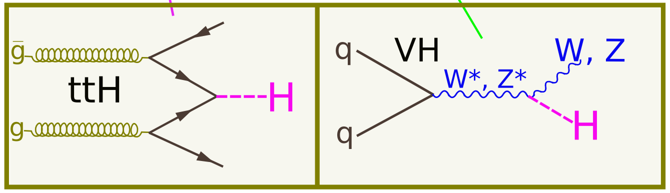
1. Higgs analyses during Run I of the LHC
2. Higgs into taus analysis overview
3. The tau reconstruction improvements for Run II

After the Higgs boson discovery

channel	production	Signif. (epx.)
$H \to ZZ$	ggF, VBF	6.8σ (6.7σ)
$H \to \gamma\gamma$	ggF, VBF	5.7σ (5.2σ)
$H \to WW$	ggF, VBF	4.3σ (5.8σ)
$H \to \tau\tau$	ggF, VBF,VH	3.2σ (3.7σ)
$H \to bb$	VH,VBF	2.6σ (2.7σ)



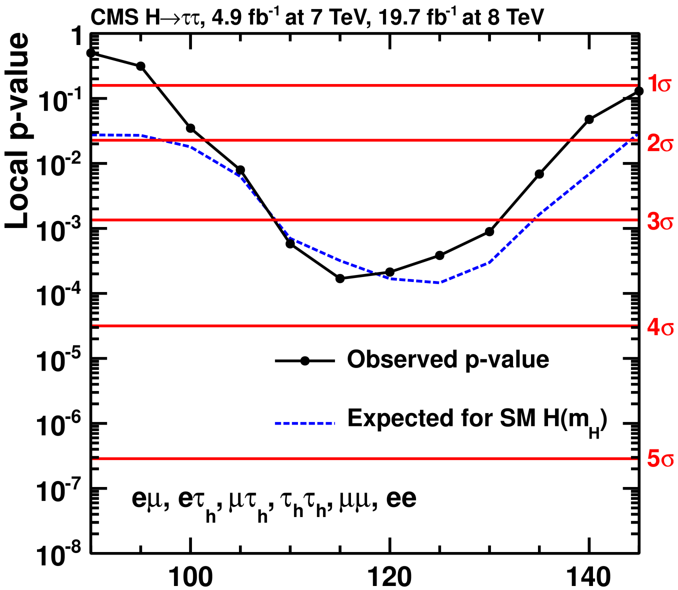




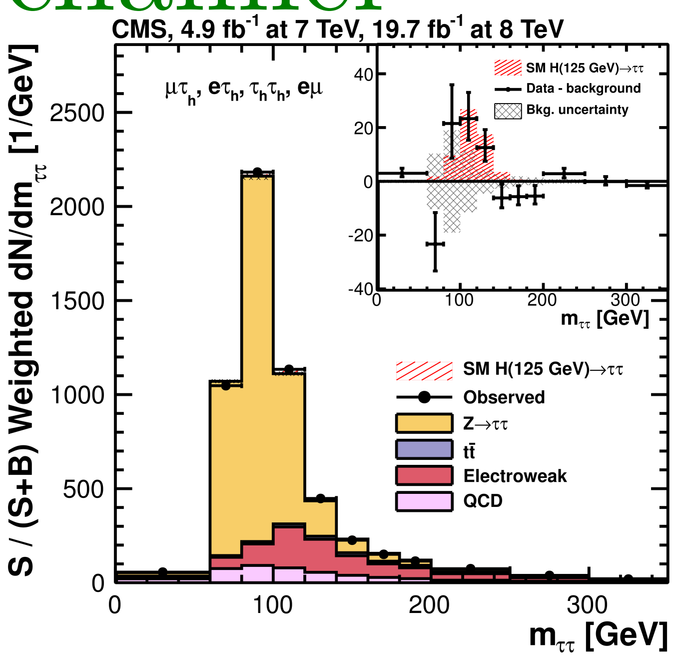
Mass (CMS+ATLAS) PRL 114, 191803 (2015):

$m_H = 125.09 \pm 0.24(i.e \pm 0.21_{stat} \pm 0.11_{syst}) GeV$

$H \to \tau\tau$ channel



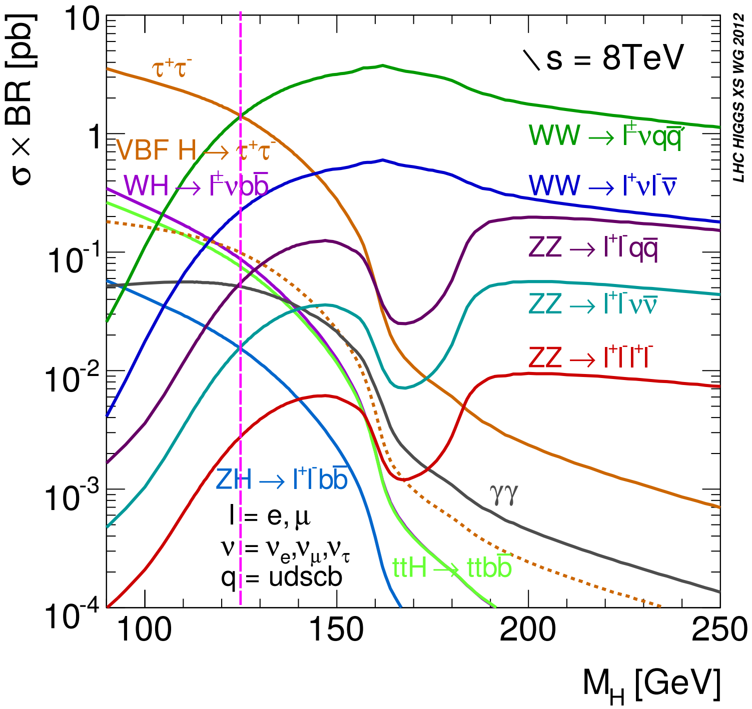
JHEP 05 (2014) 104

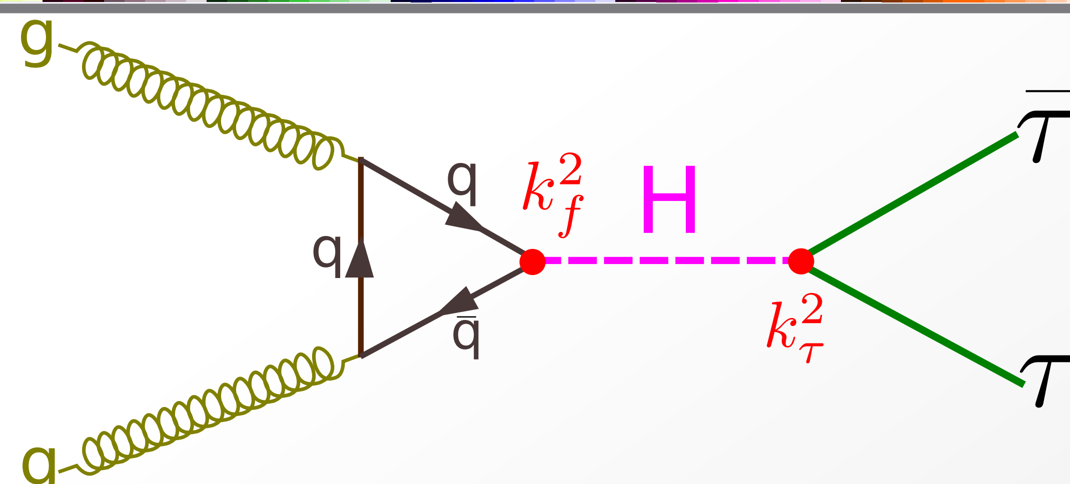


Higgs into taus

MICHAŁ OLSZEWSKI EPIPHANY 2016

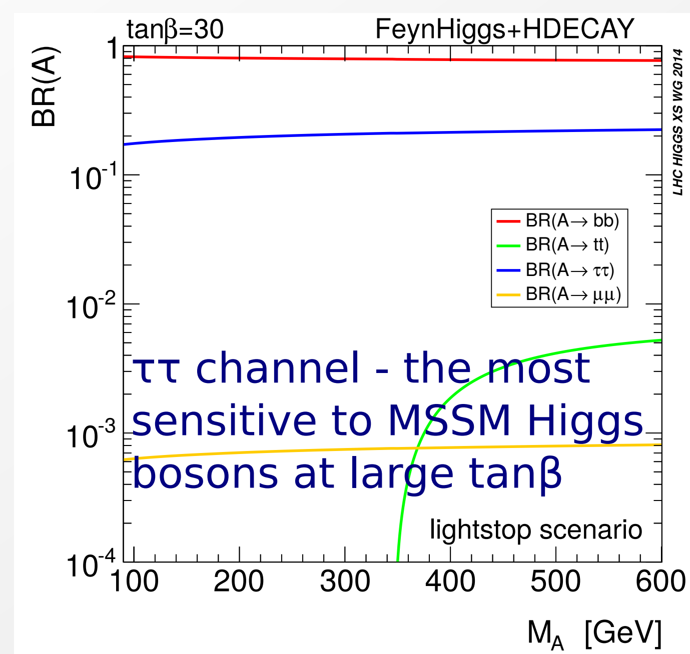
high signal yield
(~6,3% BR in SM)





direct measure of couplings to fermions

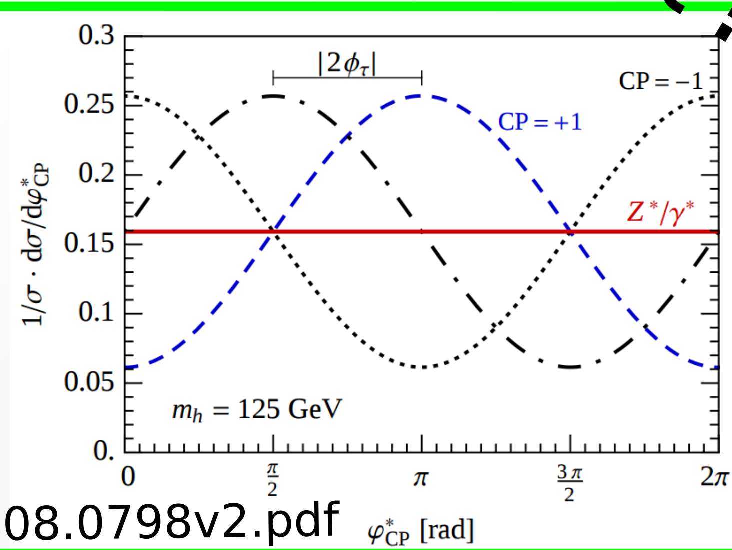
Why H→ττ?



ττ channel - the most sensitive to MSSM Higgs bosons at large tanβ

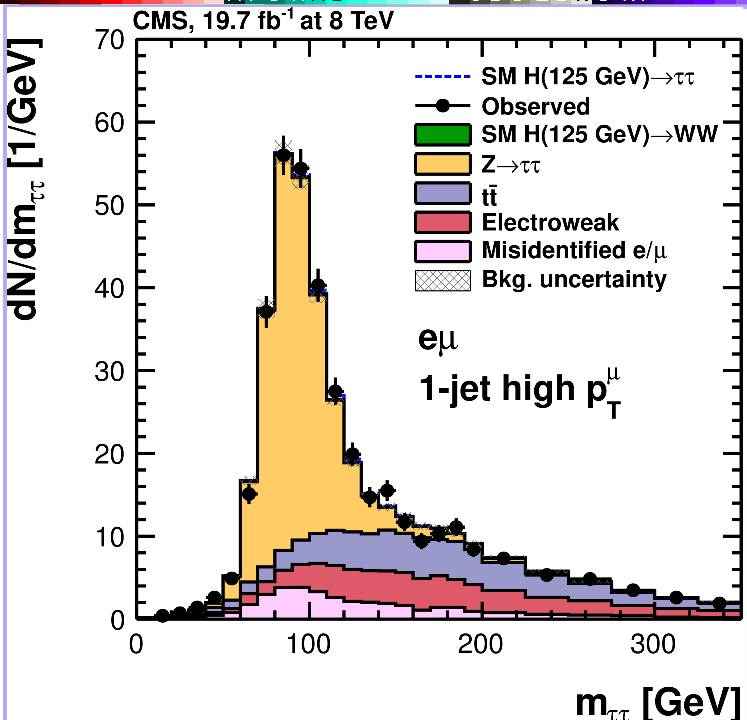
important channel in some BSM scenarios

CP-odd sensitive

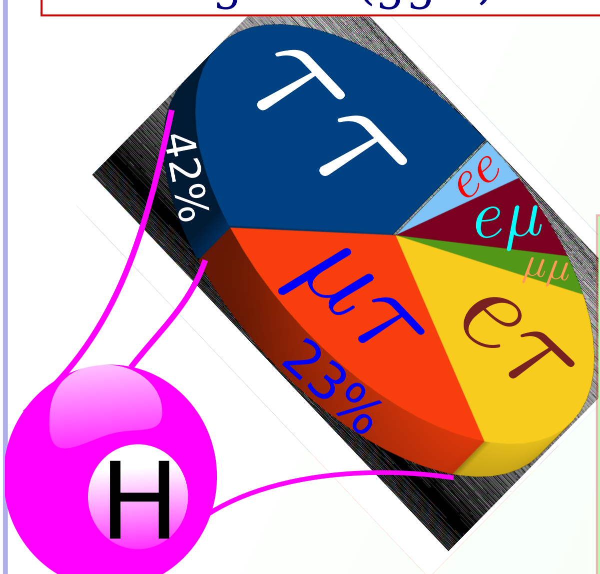


arxiv.org/pdf/1408.0798v2.pdf

Analysis



Background processes grow generally slower with E then signals (ggH, VBF)

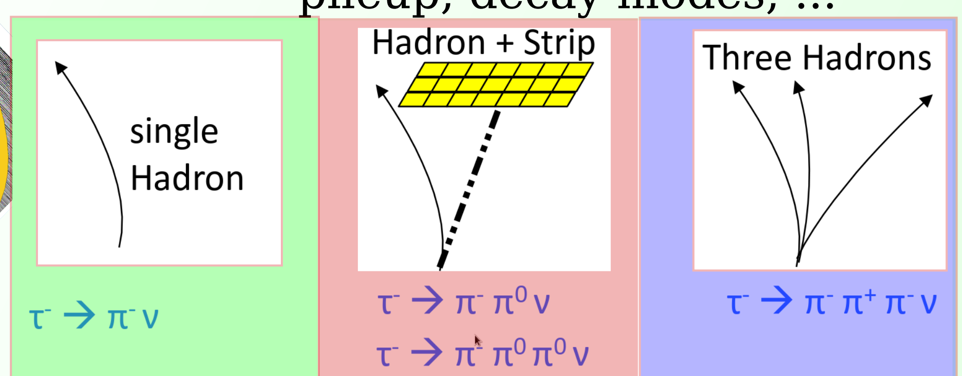


Large background:

- need to distinguish Z↦ττ and H↦ττ mass peak
  - likelihood method to estimate full $m_{\tau\tau}$
- data-driven bkg. estimates where possible
  - embedding for Z (see: tomorrow A. Kowalewska's talk)
  - norm. factors for W+jets from control region
- increase S/B ratio by categorization
  - jet multiplicity and lepton pT driven
- need good τ ID and MET RECO performace
  - tau is the only lepton decaying hadronically
  - many factors to consider:
    jets RECO, energy scale, pileup, decay modes, ...

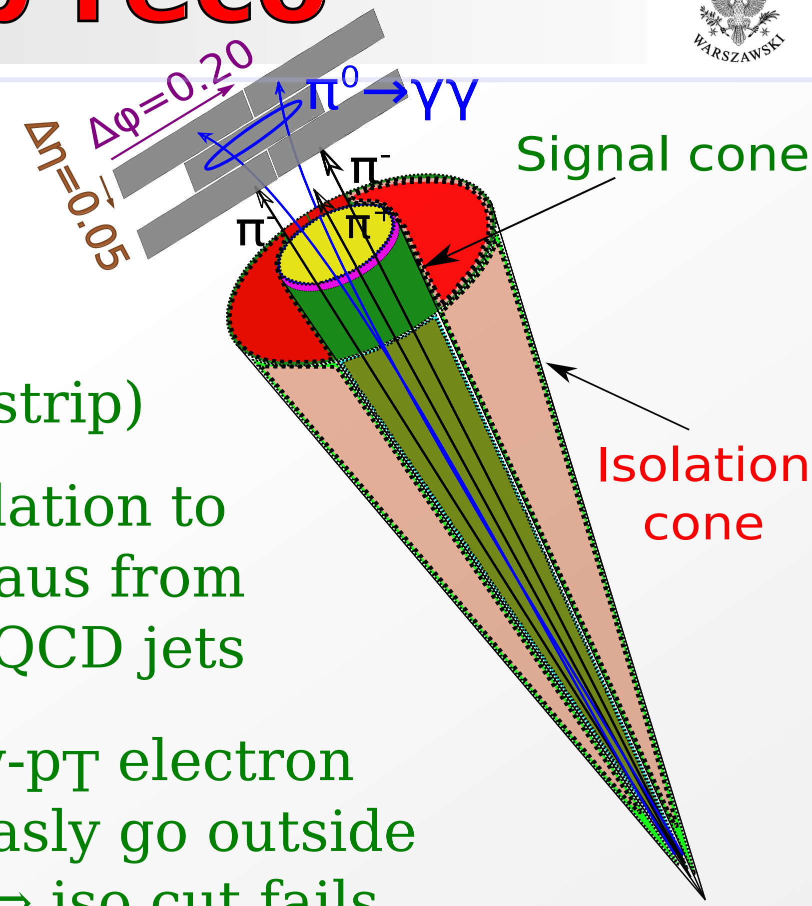
Decay channel	BR (%))
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	17.36
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	17.85
$\tau^- \to h^- \nu_\tau$	11.6
$\tau^- \to h^- \pi^0 \nu_\tau$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$	4.8
others	3.1

π^- or K^-



HPS → Dynamic strip reco

HPS - "Hadron Plus Strip"

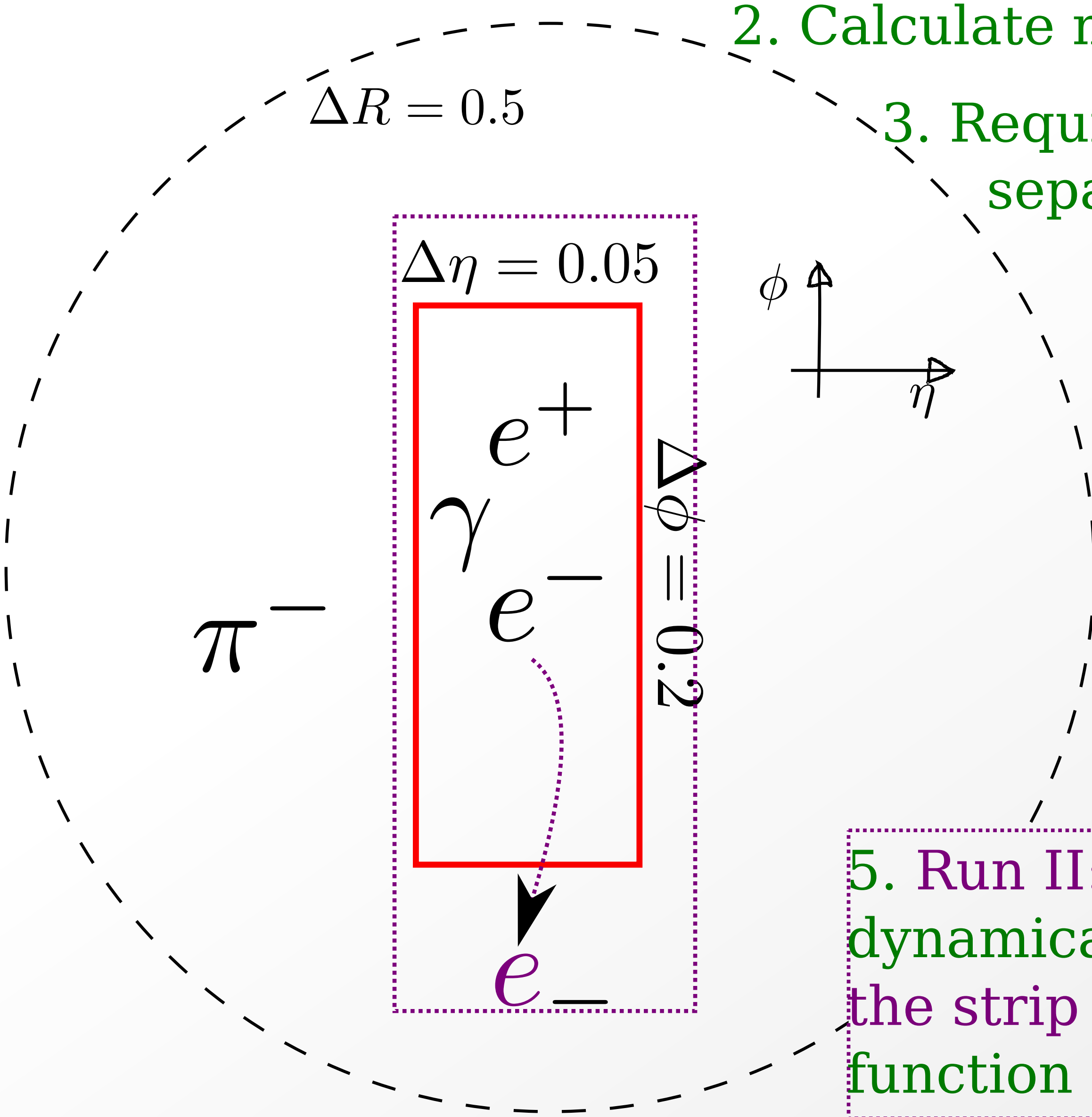


1. Reconstruct π^0 from observed $\gamma, e^{\pm}$ within a fixed-size (Run I) window

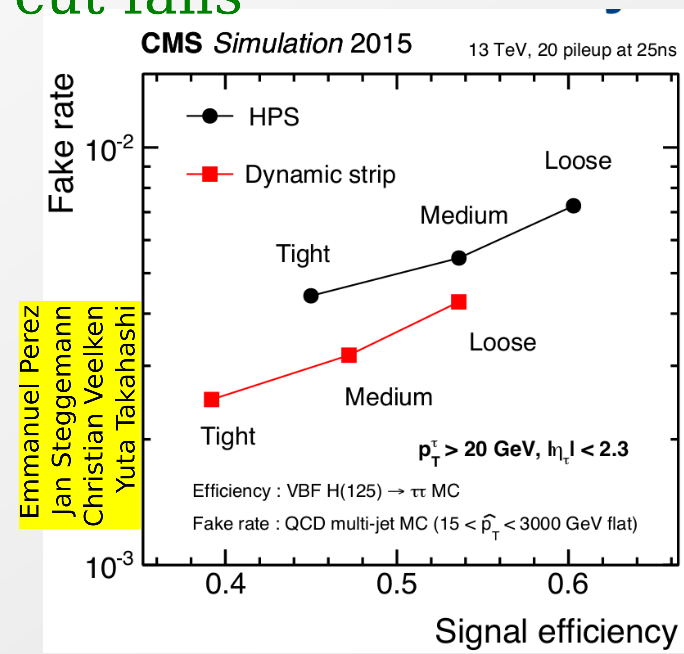
2. Calculate $m(\pi^- + \text{strip})$

3. Require isolation to separate taus from QCD jets

4. low-p_T electron can easily go outside strip ⇒ iso cut fails



5. Run II: dynamically change the strip size as a function of $p_T(e)$



Run II Tau ID

New decay mode finding:

DY 3-4% eff. gain

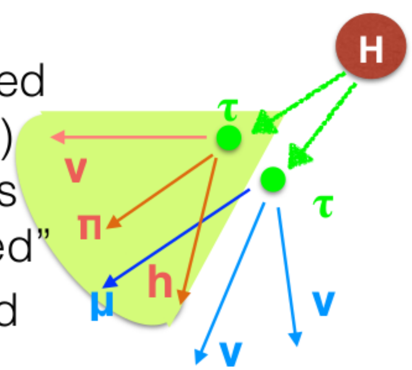
Decay channel	BR (%))
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	17.36
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	17.85
$\tau^- \to h^- \nu_\tau$	11.6
$\tau^- \to h^- \pi^0 \nu_\tau$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$	4.8
others	3.1

Run I, II: 1-prong; 1-prong + π⁰s; 3-prong

Run II only: 3-prong + π⁰s; 2-prong; 2-prong + π⁰s — recovery of tracking inefficiencies

Semi leptonic: cleaning technique

- Remove ID'ed leptons (e/μ) from ak4 jets
- Use "cleaned" jet as a seed



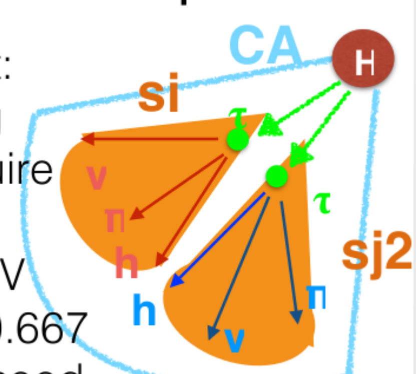
Run I: channel dependent RECO

New boosted τ_h-ID algorithm:

Run II: improved ID

Full hadronic: boosted technique

- Start from CA8 jet: Use sub-jet finding algorithm and require 2 subjects : pT(sj1,sj2) > 10GeV Max(m1,m2)/mj< 0.667
- Use sub-jet as a seed



CMS MVA Tau ID Performance

MICHAŁ OLSZEWSKI EPIPHANY 2016

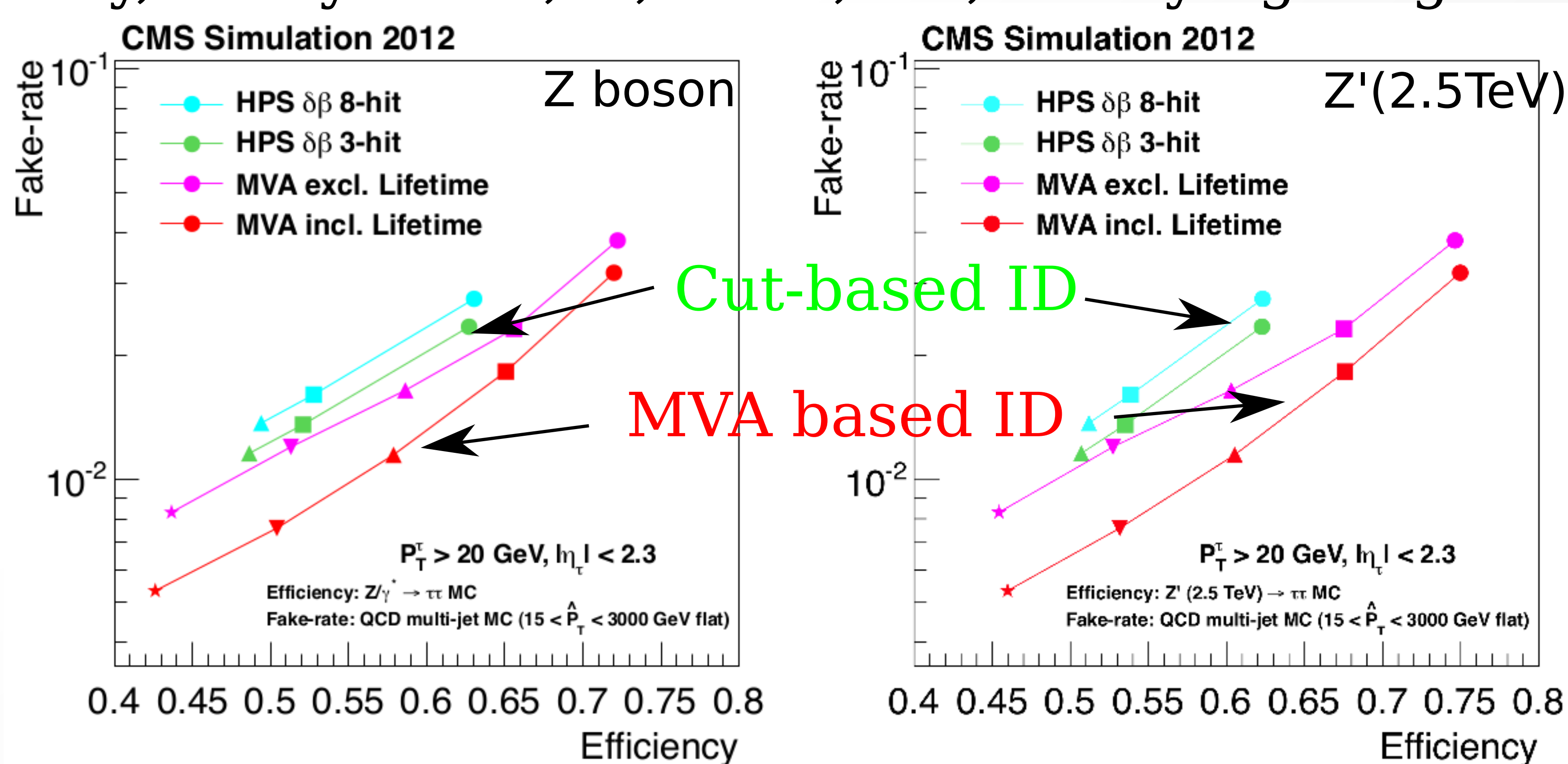
RUN I

Cut-based isolation: $I_\tau = \sum P_T^{charged}(d_Z < 0.2cm) + \max(P_T^\gamma - \Delta\beta, 0)$

- $\sum P_T^{charged}(d_Z < 0.2cm)$: particles inside cone from hard scattering
- P_T^γ: gammas inside cone
- $\Delta\beta$: corr. pileup energy deposits

RUN II

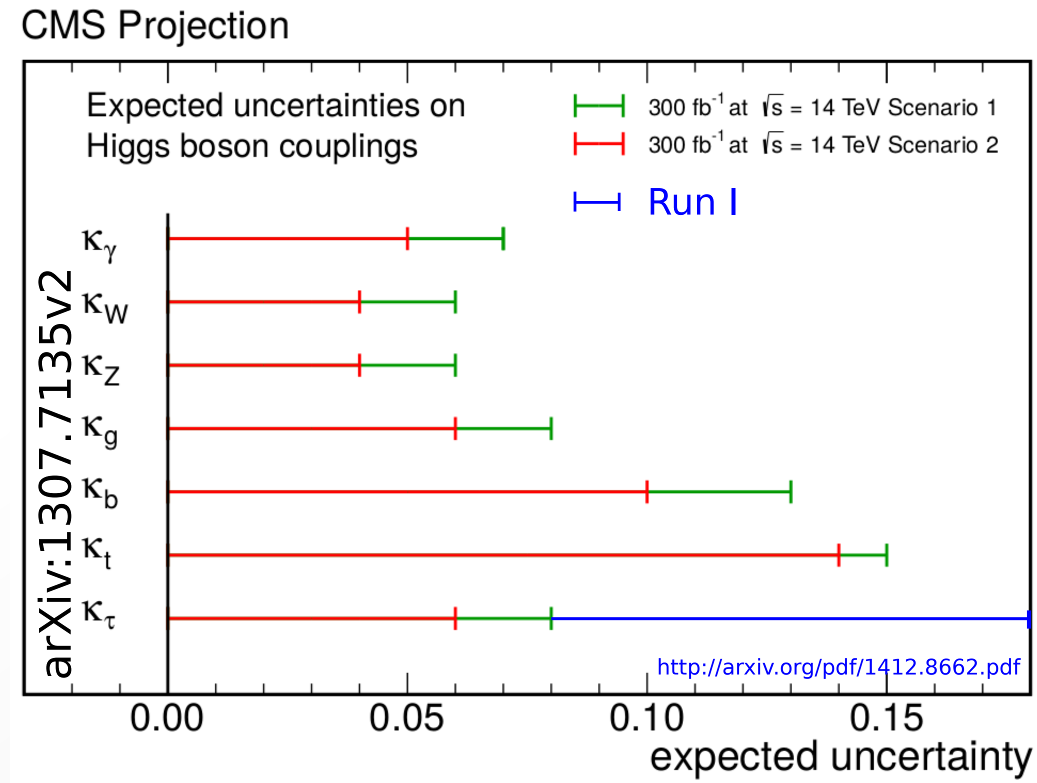
MVA isolation variables: PT and η of tau, cut-based variables separately, decay mode, IP, 3D IP, SIP, tau flying length.

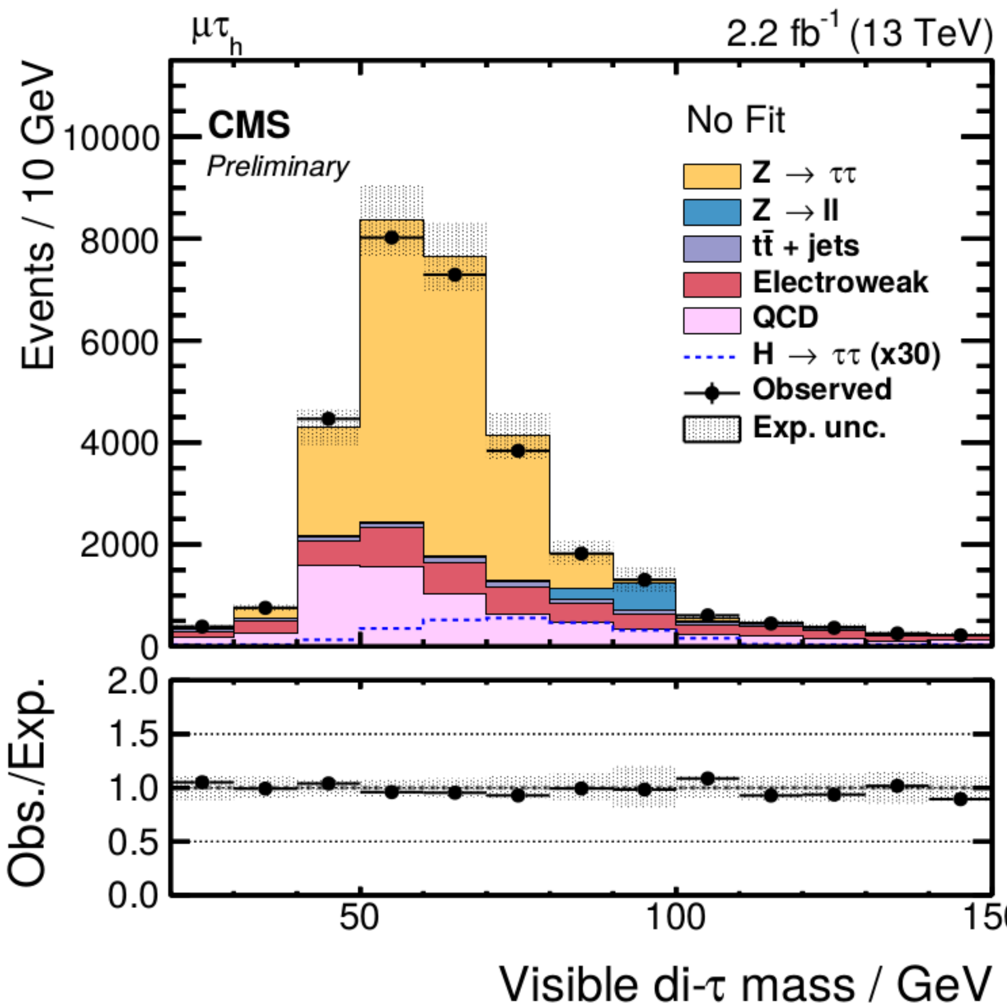


40-50% jet→τ fake rate reduction wrt. cut-based isolation and preserving eff.

Conclusions: From Run I to Run II

- The CMS H → ττ search performed greatly during Run I





- Run II brings a beneficial increase in the cross sections for the signal processes, which rise faster than the backgrounds

- Preparatory work for reaching the 5σ "goal" with the first fb^{-1} of Run II data is ongoing