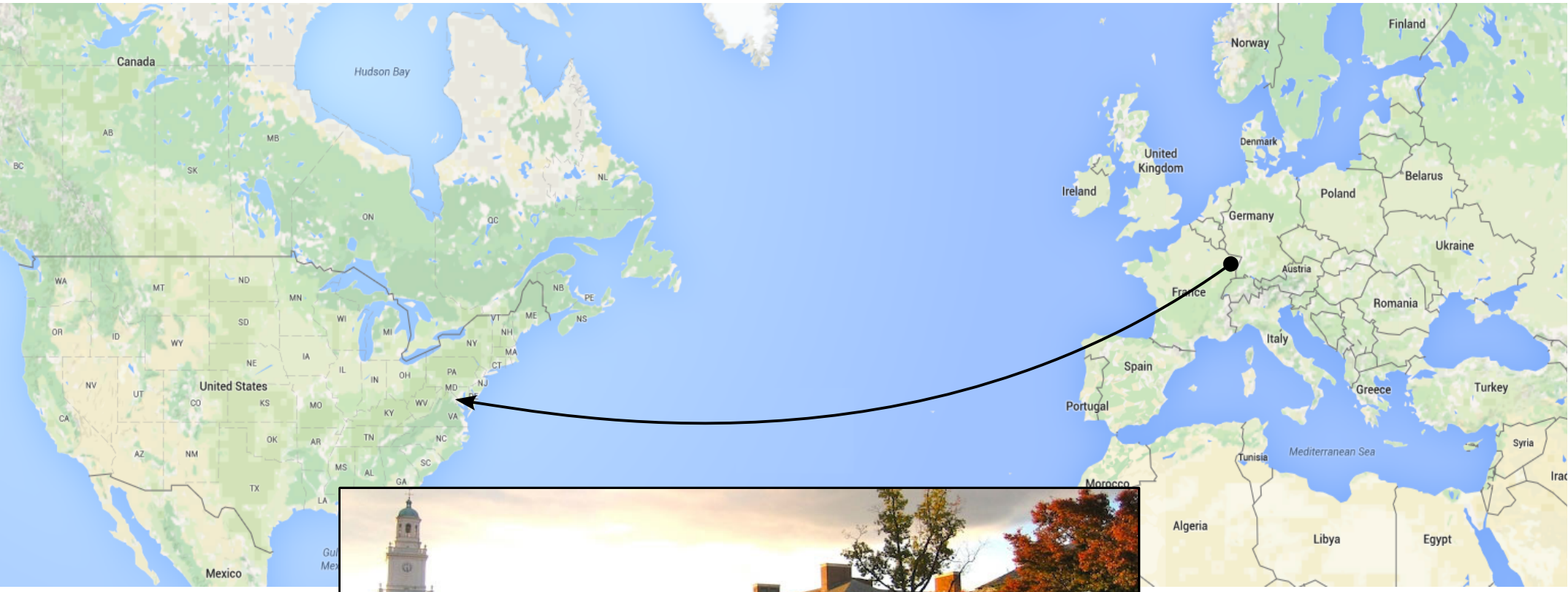
Les Houches 2015

CERN TH Retreat

Markus Schulze

Les Houches 2015

CERN TH Retreat



2008-2011: Johns Hopkins University, Baltimore

Les Houches 2015

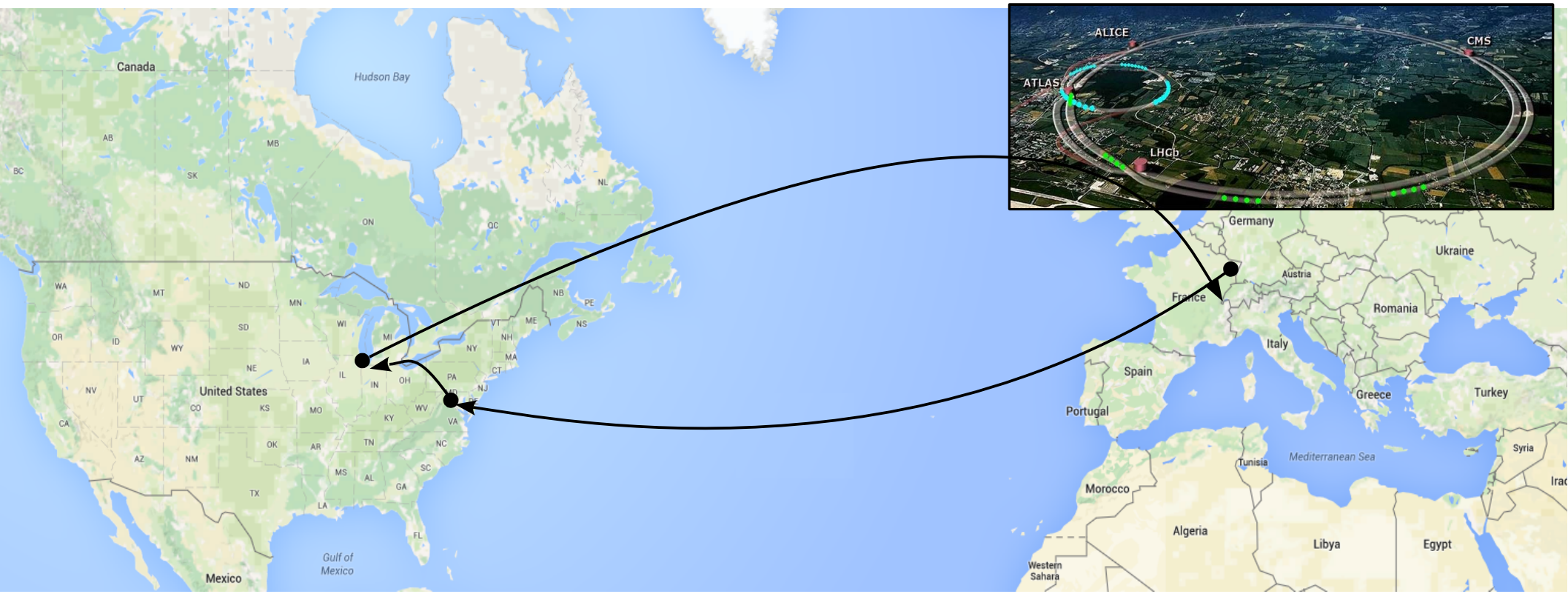
CERN TH Retreat

2011-2013: Argonne National Lab, Chicago

Les Houches 2015

CERN TH Retreat

2013-2016: CERN, Geneva



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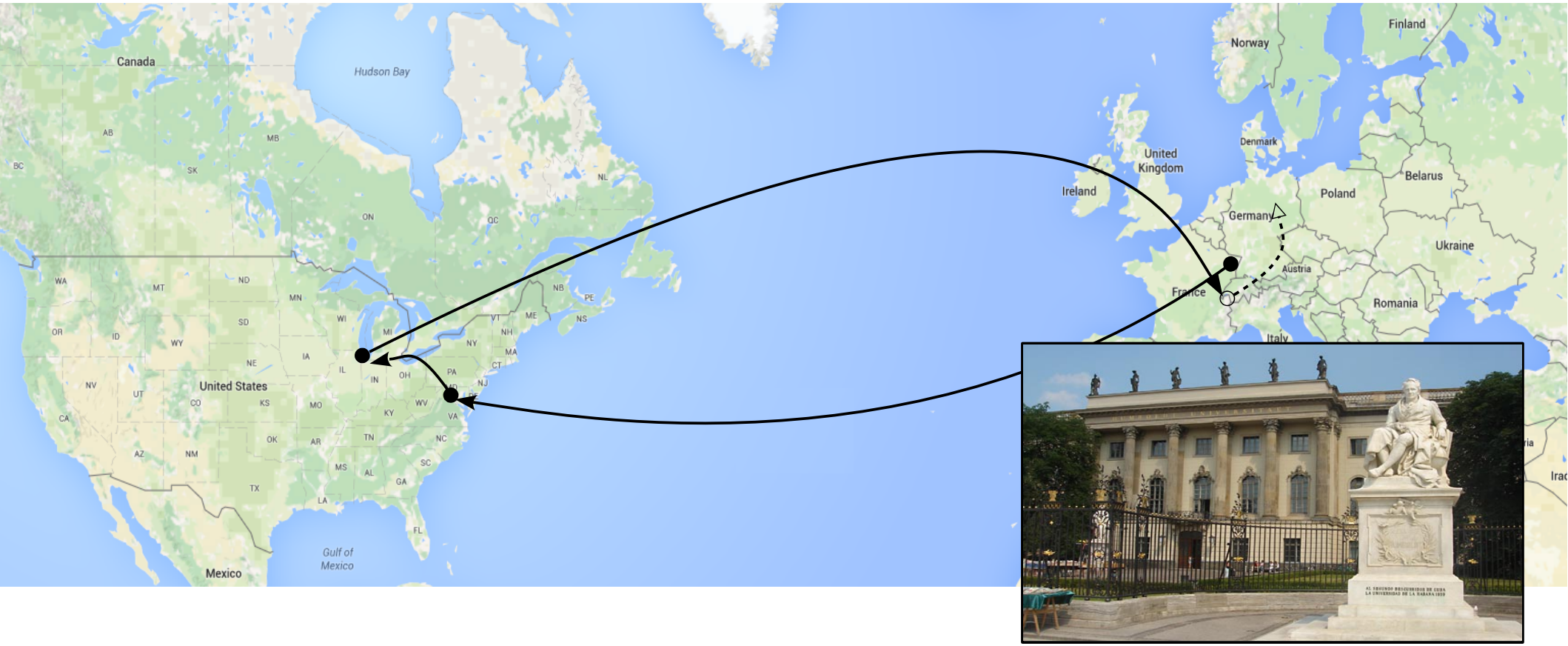


2016: Humboldt University, Berlin

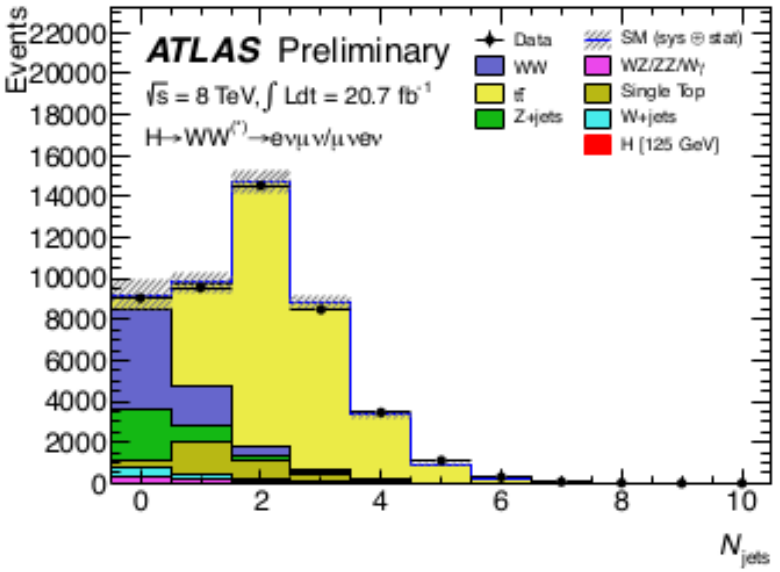
Research interests

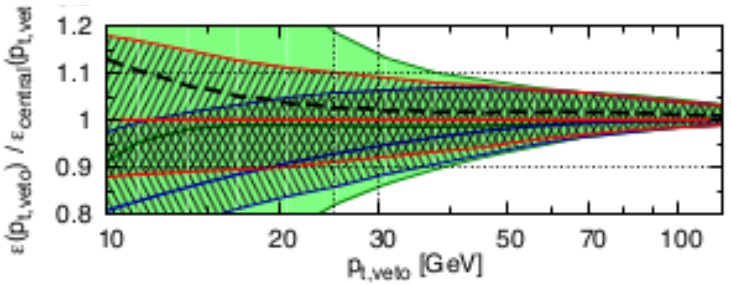
- Precision SM Phenomenology
- Perturbative QCD
- Higher order technology
- Top Quark Physics
- Higgs Boson Characterization
- Beyond the SM Physics

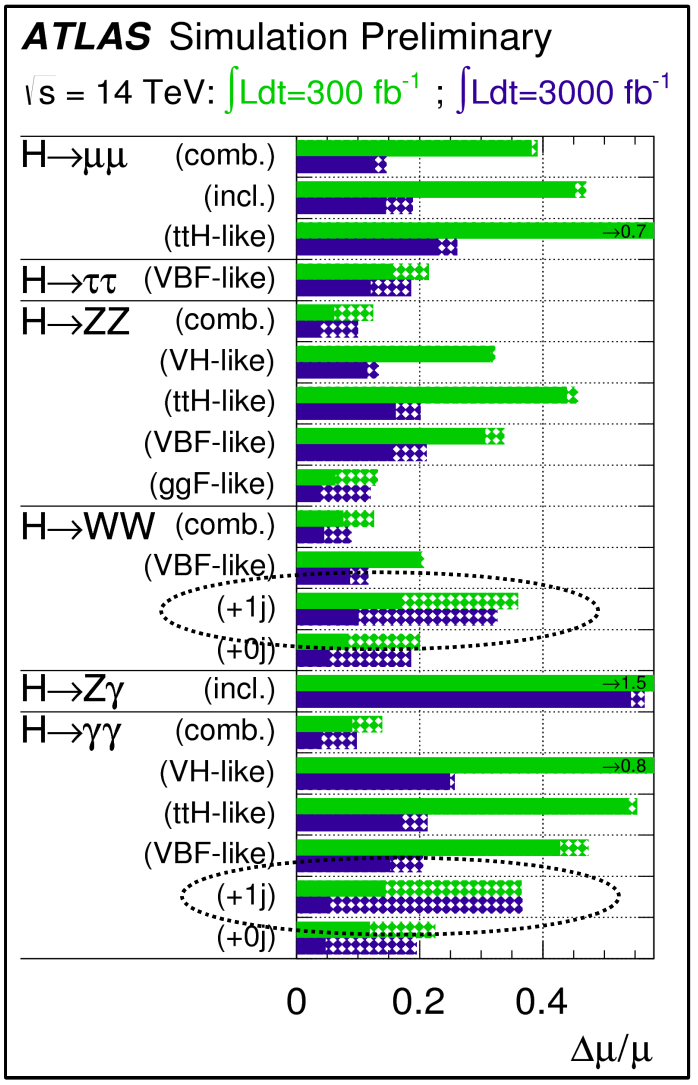
Higgs boson physics

NNLO QCD predictions for

$pp \to H$ + jet



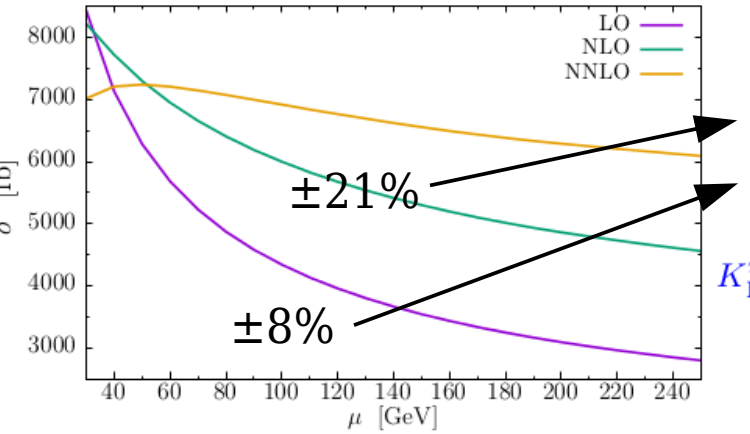




Higgs boson physics

NNLO QCD predictions for

$pp \to H$ + jet



$\sigma_{\rm LO} = 3.9^{+1.7}_{-1.1}$ pb

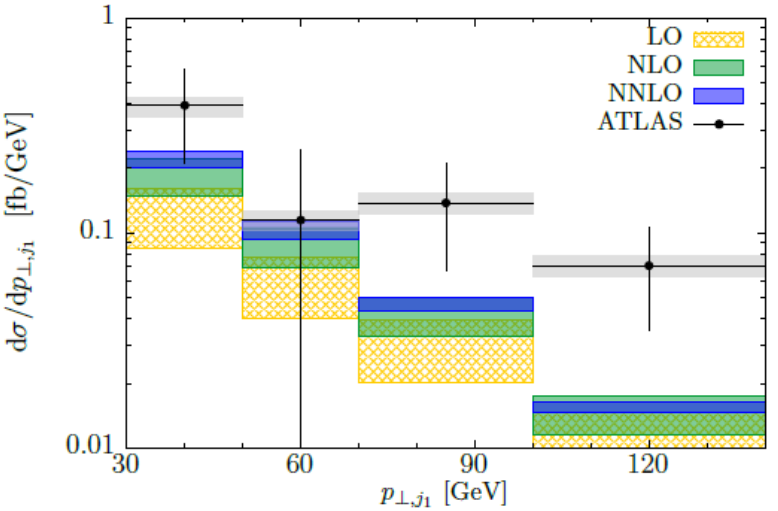
$\sigma_{\rm NLO} = 5.6^{+1.3}_{-1.1}$ pb

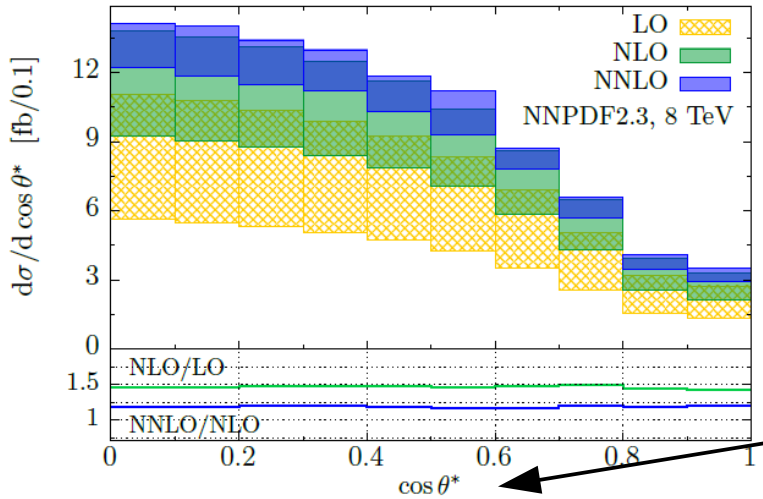
$\sigma_{\rm NNLO} = 6.7^{+0.5}_{-0.6}$ pb

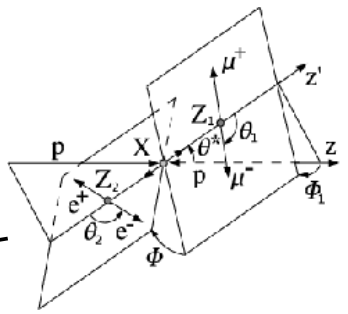
$K^{m_H}_{\rm NNLO} \sim 20\%,\ K^{m_H/2}_{\rm NNLO} \sim 4\%$

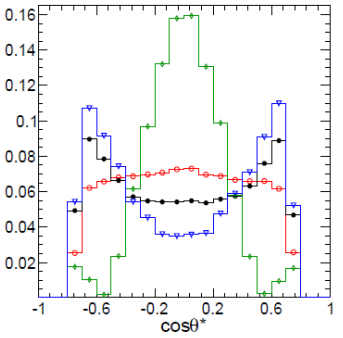
$\delta^{\rm PDF4LHC}_{\rm PDF} \sim 5\%$

$pp \to H{+}j \to \gamma\gamma + j$









Higgs boson physics

Higgs Boson Characterization
JHU Generator framework

[Anderson,Bolognesi,Caola,Gao,Gritsan,Martin,
Melnikov,Tran,Whitbeck,Zhou,M.S.]

$$A(HVV)\sim\left[a_1-e^{i\phi_{\Lambda Q}}\frac{(q_{V1}+q_{V2})^2}{\Lambda_Q^2}-e^{i\phi_{\Lambda 1}}\frac{(q_{V1}^2+q_{V2}^2)}{\Lambda_1^2}\right]m_V^2\epsilon_{V1}^*\epsilon_{V2}^*+a_2 f_{\mu\nu}^{*(1)}f^{*(2),\mu\nu}+a_3 f_{\mu\nu}^{*(1)}\tilde{f}^{*(2),\mu\nu}$$

JHUGen → event generation

MELA → re-weighting

MELA → optimal discriminants for anomalous coupling fits & background suppression

AnalyticMELA → optimal discriminants for anomalous coupling fits & background suppression

AnalyticMELA → validation

Higgs Boson Characterization
JHU Generator framework

$$pp \longrightarrow \begin{cases} \text{spin-0} \\ \text{spin-1} \\ \text{spin-2} \end{cases} \longrightarrow \begin{cases} ZZ^* + Z\gamma^* + \gamma^*\gamma^* \rightarrow \text{leptons/ jets} \\ W^+W^- \rightarrow \text{leptons/ jets} \\ \gamma\gamma \text{ and } Z\gamma \end{cases}$$

$$pp \longrightarrow \text{spin-0} + \text{jet}$$

$$pp \longrightarrow \text{spin-0} + 2\text{jets} \quad (\text{'QCD'})$$

$$pp \longrightarrow \text{spin-0} + 2\text{jets} \quad (\text{VBF})$$

$$pp/e^+e^- \longrightarrow V^* \longrightarrow V + \text{spin-0}$$

$$pp \longrightarrow t\bar{t} + \text{spin-0} \longrightarrow (b\ell\nu/bjj)(\bar{b}\bar{\ell}\bar{\nu}/\bar{b}jj) + \text{spin-0}$$

$$pp \longrightarrow tq + \text{spin-0} \longrightarrow (b\ell\nu/bjj)j + \text{spin-0}$$

$$pp \longrightarrow Z/\gamma^* \, Z/\gamma^* \rightarrow 4f$$

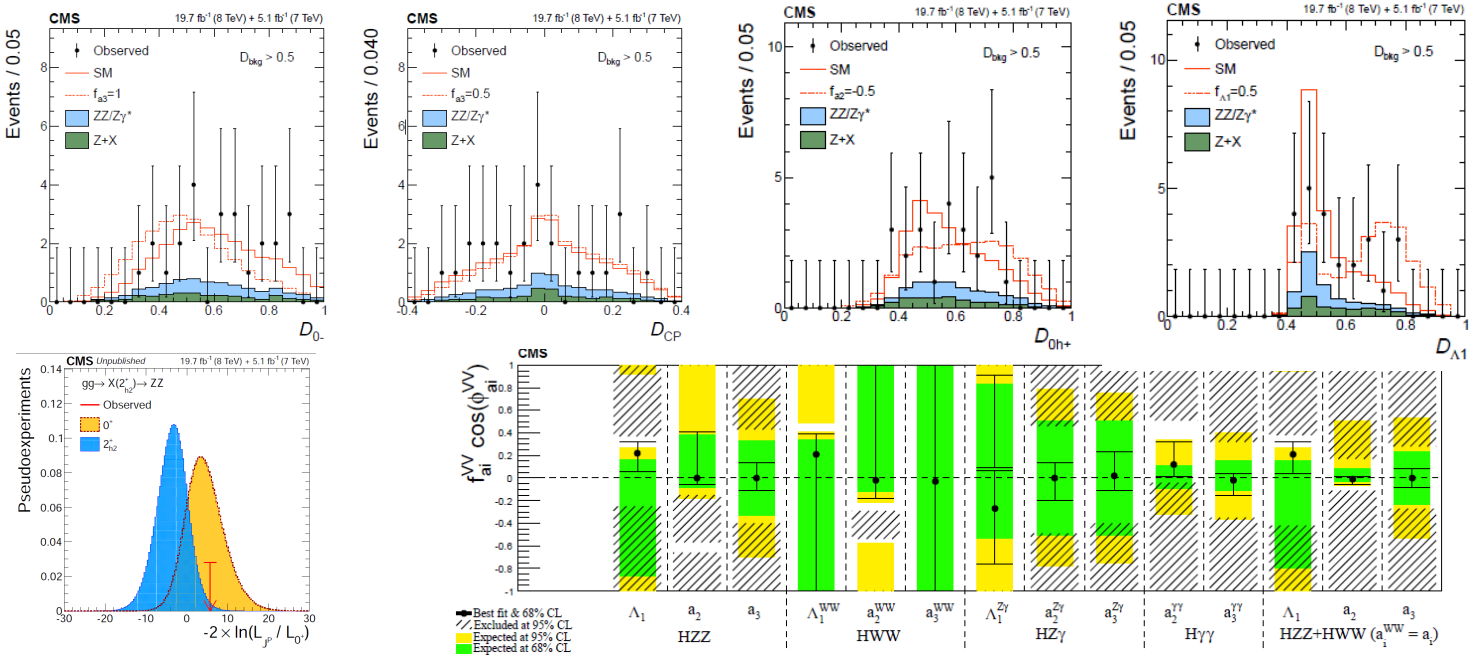
$$pp \longrightarrow H + qq \, (\text{VBF}) \longrightarrow 4\ell + qq$$

+ signal interference with spin-0
(off-shell kinematics)

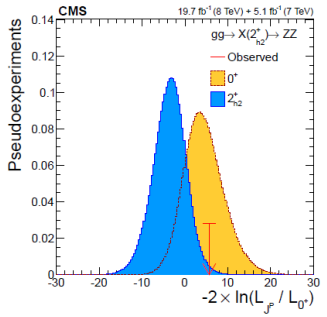
Higgs boson physics

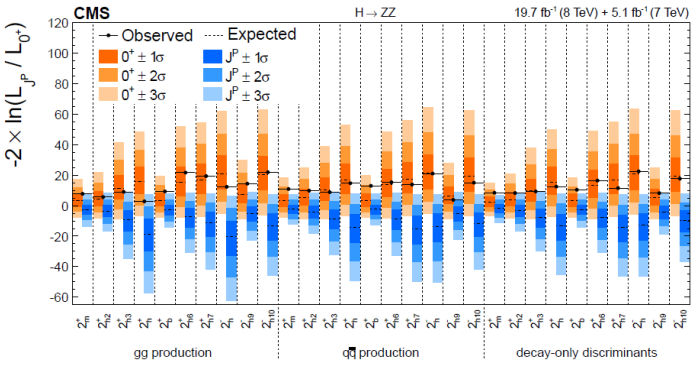
Higgs Boson Characterization JHU Generator framework

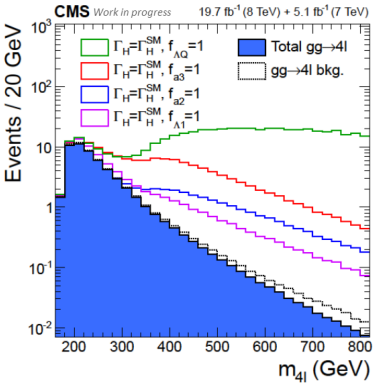
Application in experimental analysis:



[CMS-HIG-14-018]
arXiv:1411.3441







Top quark physics

Top quark mass determination from kinematic distributions

- Investigation of off-shell effects, NLO QCD top decay & Parton Shower on m_{top} extraction

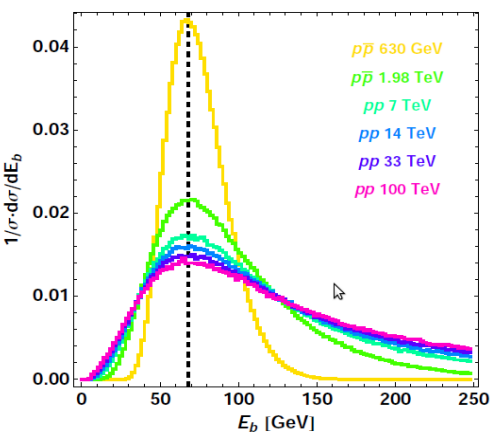
  [G.Heinrich,J.Schlenk,J.Winter,MS]

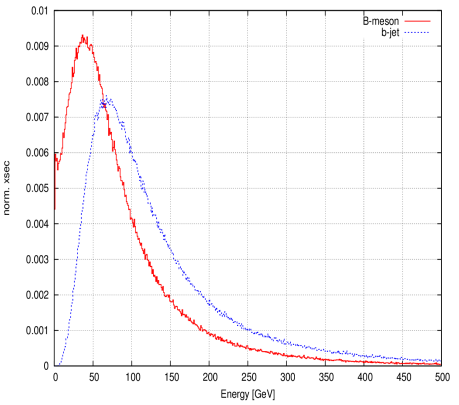
- Using energy distribution of the B-meson in top decay

  [K.Agashe,D.Kim,R.Franceschini,M.S.]

Comparison:
- WWbbar vs. ttbar (narrow-width)
- NLO decay vs. parton shower decay

Observables:
- m_{lb}
- approx. of m_{lb} without E_{b}
- m_{T2}





Top quark physics

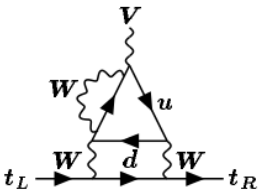
Probing top quark electroweak couplings at the LHC

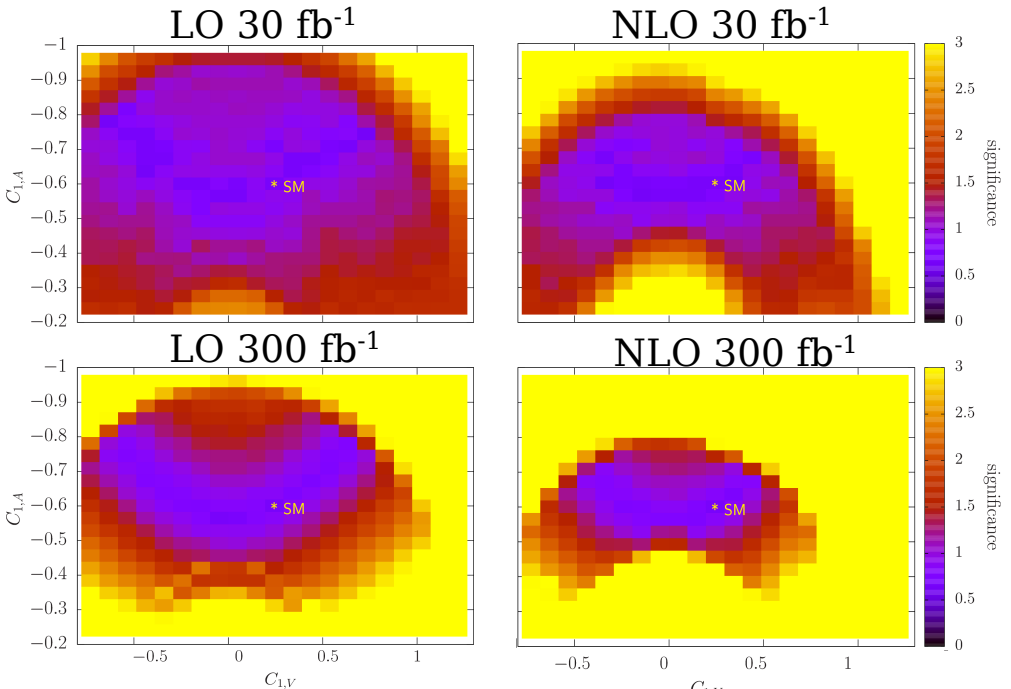
[R.Röntsch,MS]

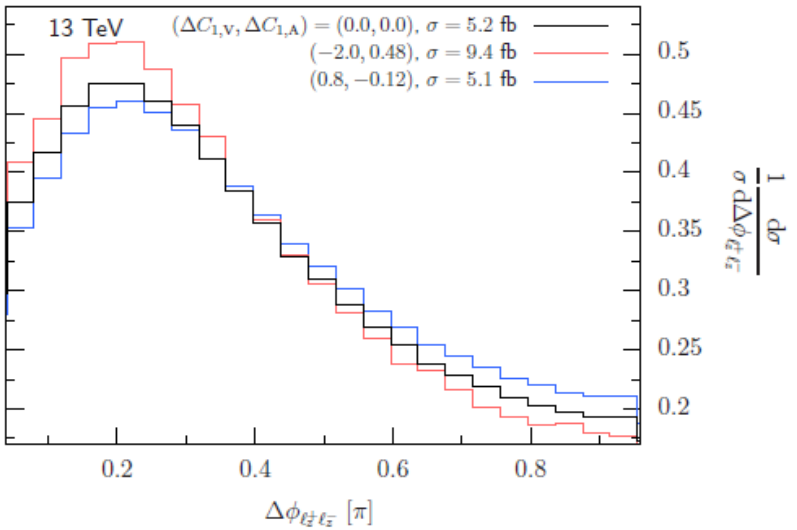
$$\mathcal{L}^{\mathrm{OS}}_{V f_i f_j} = \bar{f}_j \gamma^\mu (\mathcal{A}_L P_L + \mathcal{A}_R P_R) f_i V_\mu + \bar{f}_j i\sigma^{\mu\nu} q_\nu (\mathcal{B}_L P_L + \mathcal{B}_R P_R) f_i V_\mu + \mathrm{H.c.},$$

modifies strength of SM couplings

introduces anomalous weak *magn.* and *electric dipole moments*







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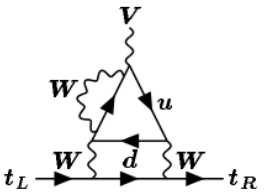

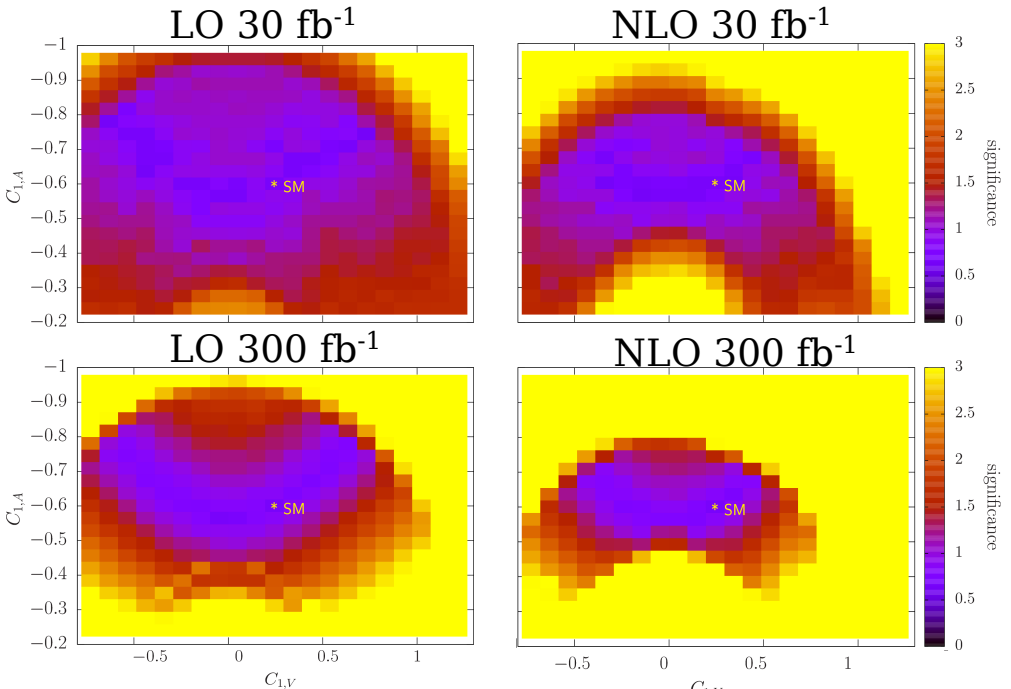

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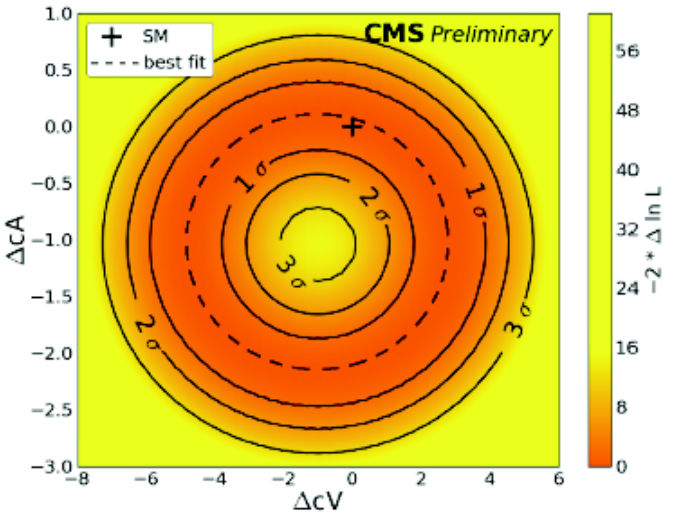
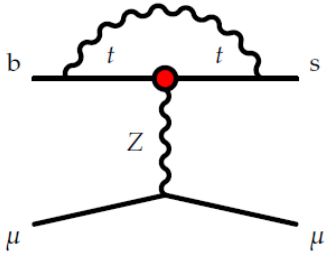


Difference between SM C_V and $C_{1,V}$

Top quark physics

- Current developments:
  - ttbar + photon (NLO production and decay)
  - global constraints: *ttbar, ttbar+W,Z,*photon
  - cross talk with *B*-physics



[Brod,Greljo,Stamou,Uttayarat]

Process	O_{tG}	O_{tB}	O_{tW}	$O_{\varphi Q}^{(3)}$	$O_{\varphi Q}^{(1)}$	$O_{\varphi t}$	$O_{t\varphi}$	O_{4f}	O_G	$O_{\varphi G}$
$t \to bW \to bl^+\nu$	N		L	L				L		
$pp \to t\bar{q}$	N		L	L				L		
$pp \to tW$	L		L	L				N	N	N
$pp \to t\bar{t}$	L						N	L	L	L
$pp \to t\bar{t}\gamma$	L	L	L				N	L	L	L
$pp \to t\bar{t}Z$	L	L	L	L	L	L	N	L	L	L
$pp \to t\bar{t}h$	L						L	L	L	L
$gg \to H,\ H \to \gamma\gamma$	N						N			L

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^\mu\left(V_L P_L + V_R P_R\right) t\, W_\mu^- - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_\nu}{M_W}\left(g_L P_L + g_R P_R\right) t\, W_\mu^- + \text{H.c.}\,.$$

$$\mathcal{L}_{Ztt} = -\frac{g}{2c_W}\bar{t}\gamma^\mu\left(X_{tt}^L P_L + X_{tt}^R P_R - 2s_W^2 Q_t\right) t\, Z_\mu - \frac{g}{2c_W}\bar{t}\frac{i\sigma^{\mu\nu}q_\nu}{M_Z}\left(d_V^Z + id_A^Z\gamma_5\right) t\, Z_\mu\,,$$

$$\mathcal{L}_{\gamma tt} = -eQ_t\bar{t}\gamma^\mu t\, A_\mu - e\bar{t}\frac{i\sigma^{\mu\nu}q_\nu}{m_t}\left(d_V^\gamma + id_A^\gamma\gamma_5\right) t\, A_\mu\,.$$

$$\mathcal{L}_{Htt} = -\frac{1}{\sqrt{2}}\bar{t}\left(Y_t^V + iY_t^A\gamma_5\right) t\, H$$

- matrix element-based discrimination of anomalous models in *ttbar+H* (at NLO QCD) and single *top+H*

$$D_{cp} = \frac{|M_{cp}|^2}{|M_{SM}|^2 + |M_{PS}|^2}$$