FCC Physics meeting

Michele Selvaggi

CERN

FCC Physics Hadron Detector Meeting - 05/04/2017 - CERN

Agenda

14:00 → 14:15 **Introduction** 15m

Speakers: Filip Moortgat (CERN) , Heather Gray (LBNL)

hgray_FCC_intro.pdf

14:15 → 14:20 **Plans for MC production** ¶ 5m

Speaker: Michele Selvaggi (CERN)

sampleprod_270320...

14:25 → 14:45 **Ideas for Higgs Analyses from the Physics Report** 20m

Speaker: Michelangelo Mangano (CERN)

Mangano-Higgs.pdf

14:50 → 15:10 **Update on charged Higgs boson and top FCNC studies** 20m

Speaker: Orhan Cakir (Ankara University (TR))

Study_cH_tFCNC_27...

15:10 → 15:30 **FCC prospects of s-channel single top, W'->tb and FCNC with top-quark** 20m

Speaker: Maksim Perfilov (M.V. Lomonosov Moscow State University (RU))

2017_03_27_FCC.pdf

15:35 → 15:55 **Top mass measurement at the FCC using Mellin's moments of leptonic observables in top pair production in the dilepton channel** 20m

Speaker: Dr. Giancarlo Panizzo (INFN Gruppo collegato di Udine)

Higgs properties

MLM

NEED VOLUNTEERS !!!

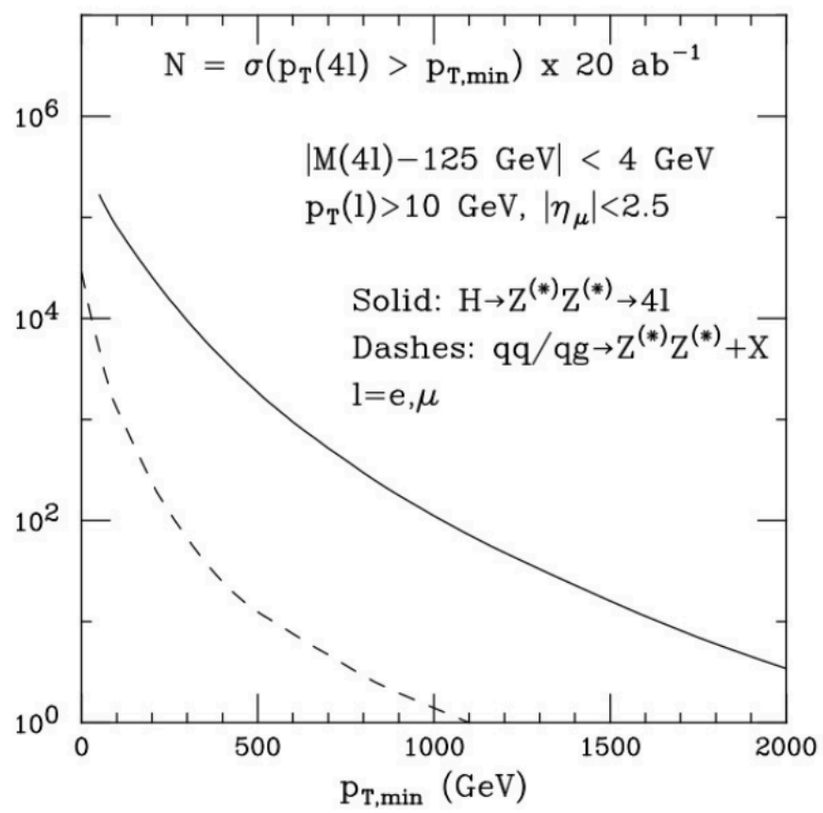
g_{HXY}	FCC-ee	FCC-hh
ZZ	0.16%	
WW	0.85%	
γ γ	1.7%	<1% ?
Zγ	?	1% ?
tt		1% ?
bb	0.42%	
τ τ	0.94%	
cc	1.0%	
ss	H→Vγ, in progr.	
μμ	6.4%	2% ?
uu,dd	H→Vγ, in progr.	
ee	e^+e^-→H, in progr.	
HH		5% ?
BR_{exo}	0.48%	< 10^{-6} ?

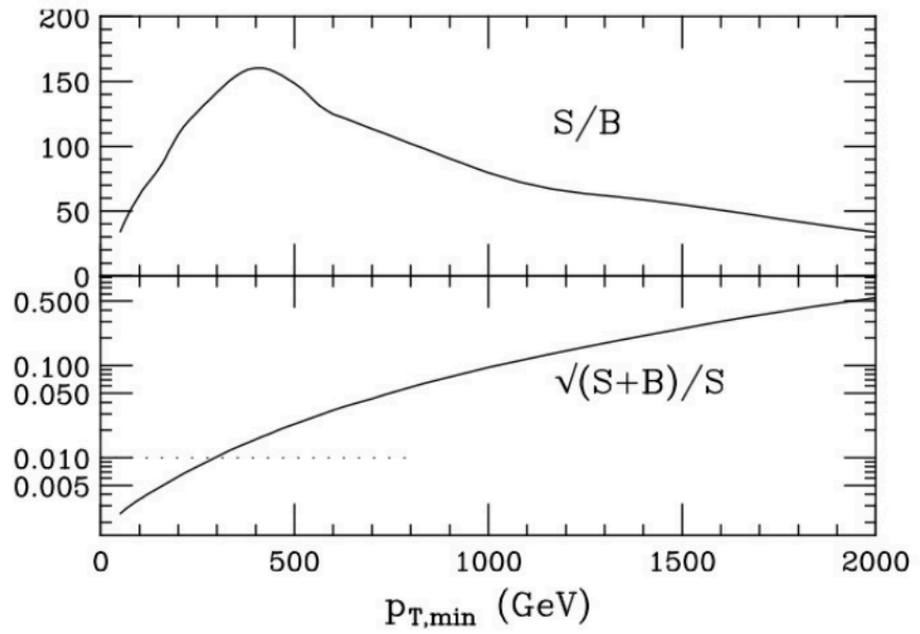
Goals

- Setup a "task force", to work coherently on defining target precision benchmarks
- Define meas'nt strategies based on
  - precise info from FCC-ee
  - selfcontained FCC-hh inputs
- Define precision for both
  - absolute BR or BR ratio meas's
  - $d\sigma/dp_T$, (both absolute and shape) to probe BSM sensitivity
- Start by identifying ideal regions of $S/\sqrt{B}$ (B=irreducible bgs), and allow for optimal det performance
- Identify regions of optimal separation between production channels
- Identify leading exptl syst, to be tested via concrete Delphes sim's, setting performance targets

MLM

gg→H→ZZ*→4l at large p_T



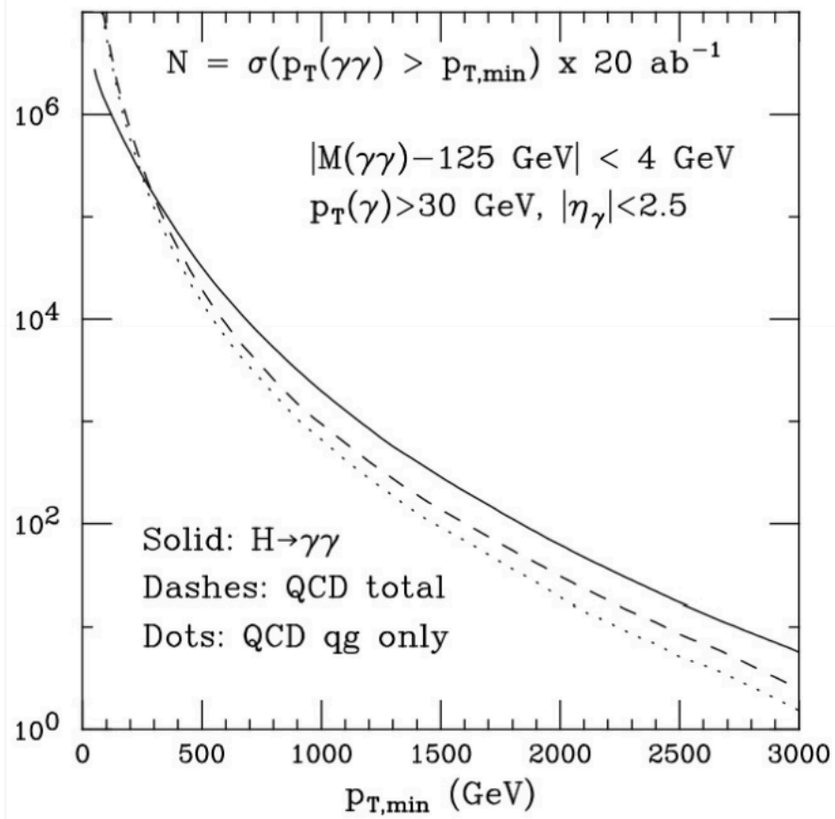


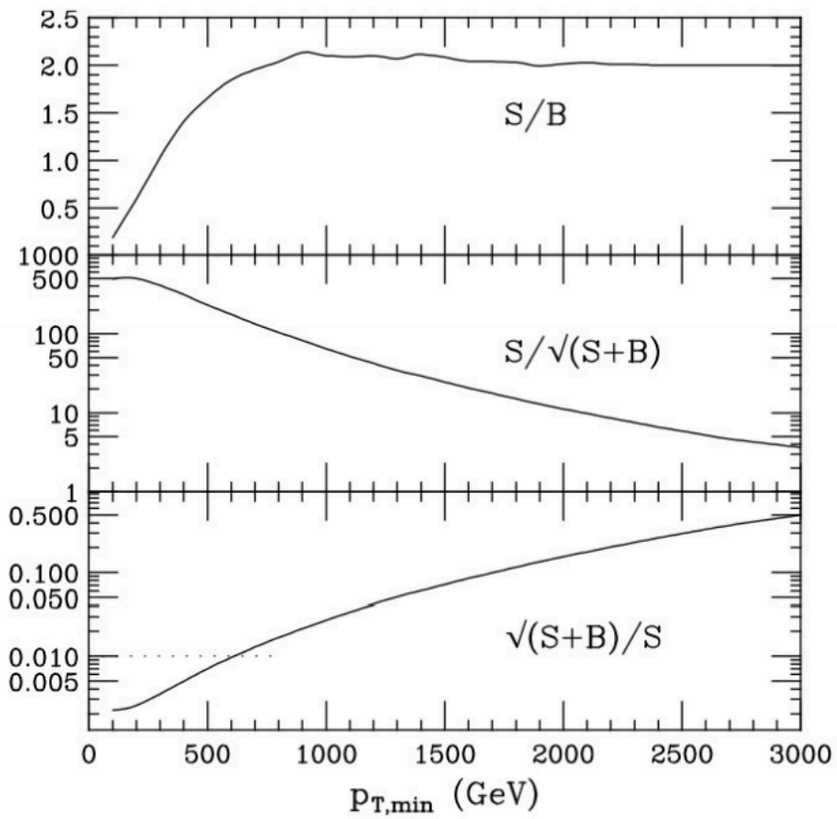
- S/B ~ 1 for inclusive production at LHC
- Practically bg-free at large p_T at 100 TeV, maintaining large rates

$p_{T,min}$ (GeV)	δ_{stat}
100	**0.3%**
300	**1%**
1000	10%

gg→H→γγ at large p_T

MLM



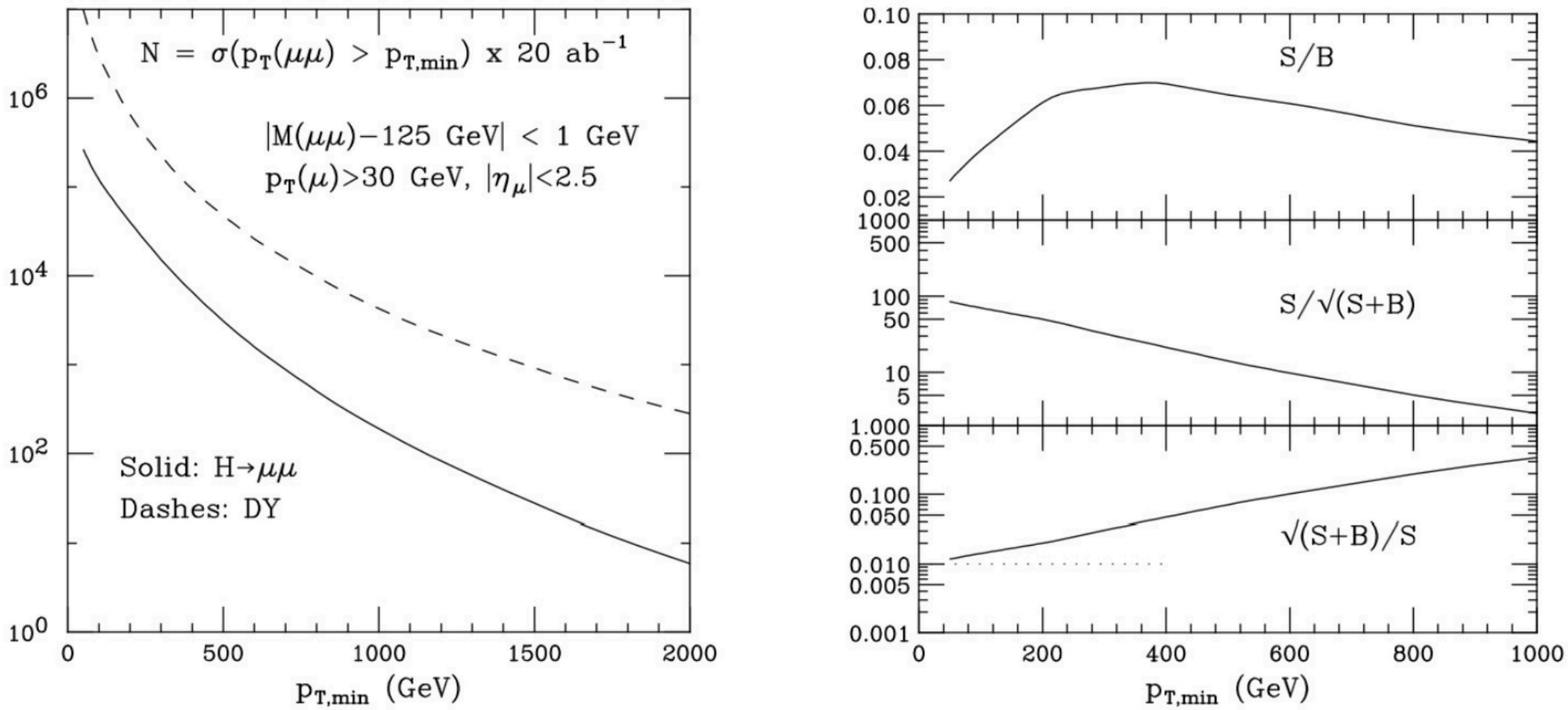


- At LHC, S/B in the H→γγ channel is O(few %)
- At FCC, for p_T(H)>300 GeV, S/B~1
- Exptl systematics on BR(μμ)/BR(γγ)? (use same fiducial selection to remove H modeling syst's)
- Exptl mass resolution at large pt(H)?
- Potentially accurate probe of the H pt spectrum up to large pt

$p_{T,min}$ (GeV)	δ_{stat}
100	**0.2%**
400	**0.5%**
600	**1%**
1600	10%

gg→H→μμ at large p_T

MLM



- Stat reach ~1% at p_T~100 GeV
- Exptl systematics on BR(μμ)/BR(γγ)? (use same fiducial selection to remove H modeling syst's)

$p_{T,min}$ (GeV)	δ_{stat}
100	**1%**
500	10%

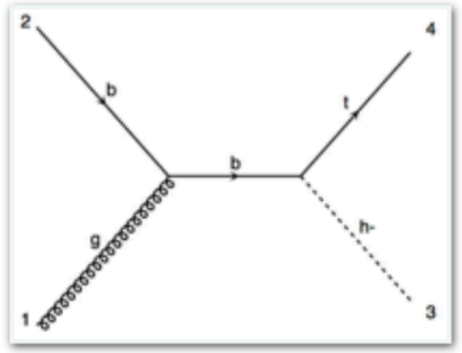
Charged Higgs

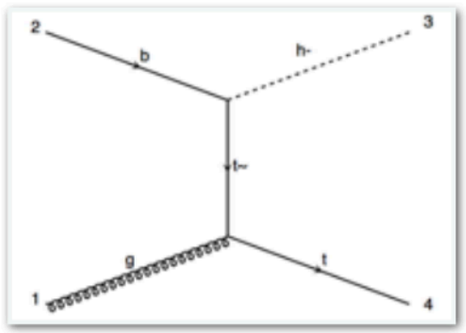
O. Cakir

Signal and Background

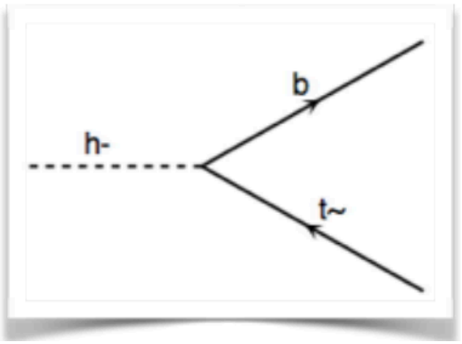
The cross sections for the signal process pp -> tH^- +X ->tbt~ +X

- 2.022 pb at m_H=500 GeV
- 0.281 pb at m_H=1000 GeV
- 0.0273 pb at m_H=2000 GeV





Production



Decay

+ similar diagrams for d,s

Signal:
-> tH^- ->tbt~
-> W^+W^-bbb~

then three channels
-> 3 bjets+4 jets (full had)
-> 3 bjets+2 jets+1l+MET (single lepton)
-> 3 bjets+2l+MET(dilepton)

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Top FCNC

O. Cakir

Signal

Signal:

-> W b **γ** (off-shell top)

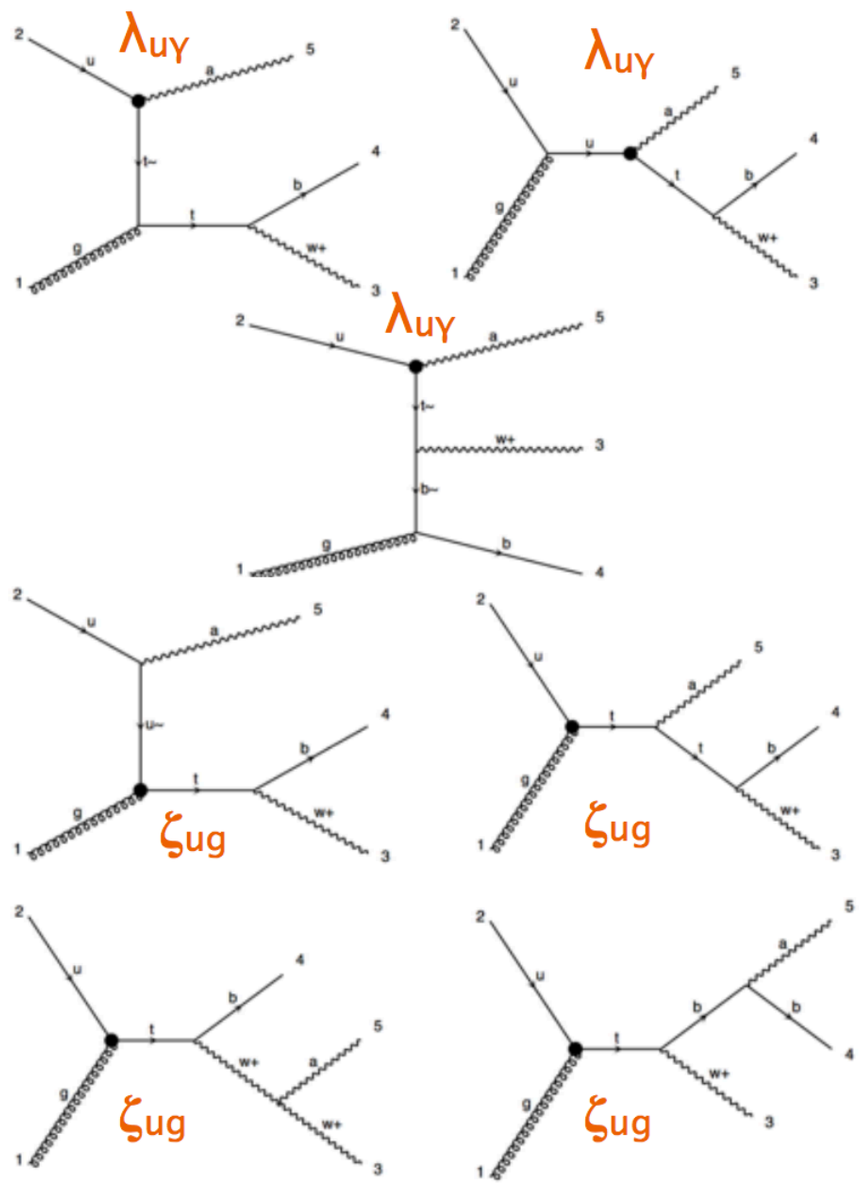
-> **t γ** then W b **γ** (on-shell top)

then two channels

-> photon+1 bjet+2 jets (hadronic)

-> photon+1 bjet+1l+MET (single lepton)

Diagrams for tuγ and tug vertices



+ similar diagrams for tcγ and tcg vertices

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Charged Higgs/FCNC

O. Cakir

Comments

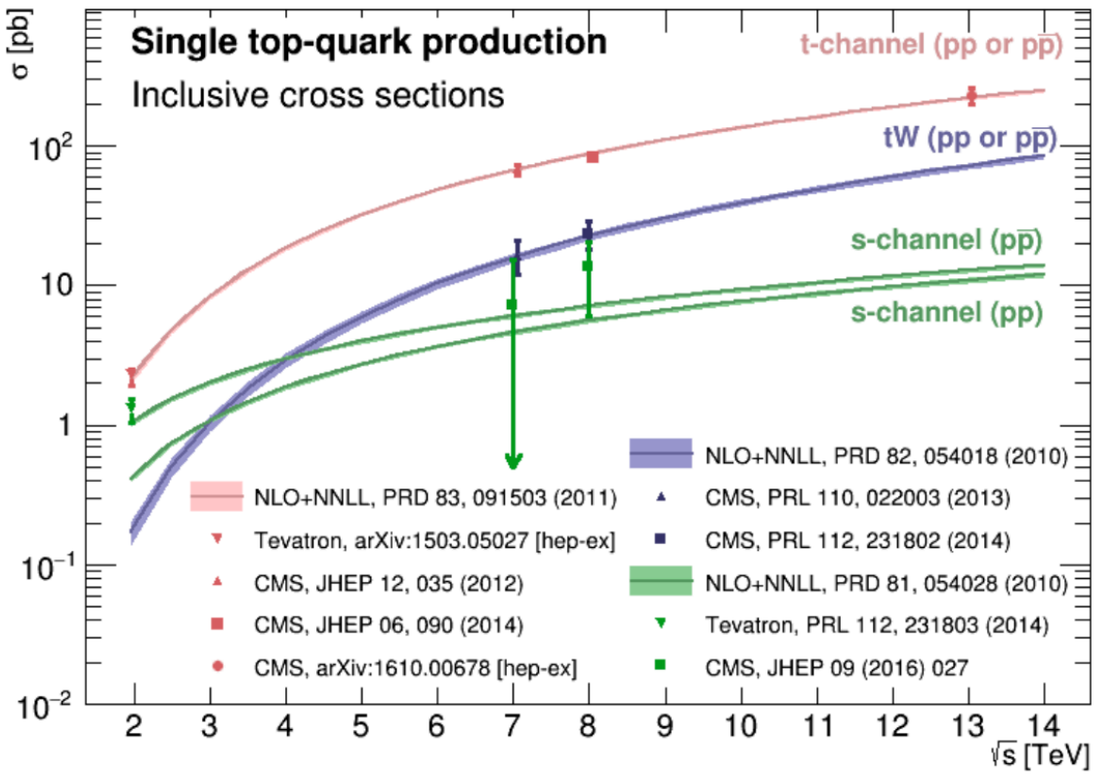
- We use FCCSW and other tools within SW. Pythia8 has internal subprocess b g->H- t, it is available in the 5FS.
  - *Main background is t tbar+1bjet. We have produced t tbar+1jet background events (200k). Background t tbar+012jets can be used in the analysis. The background WW+jets can also be discussed. Events may be categorised into separate regions (SR, CR) according to reco jets and b-tagged jets.*
- For process pp->tγ+X / pp->Wbγ+X, event generation with MadGraph5, hadronization and decays in Pythia8, fast simulation with Delphes 3.4. We have the cross sections and kinematical distributions of jets, electron, muon, met and photon.
  - *Main background is W+bjet+photon. We have produced W+bjet +photon background events (200k). The background W+jets +photon can be discussed. After event selection SR and CR can be designed.*

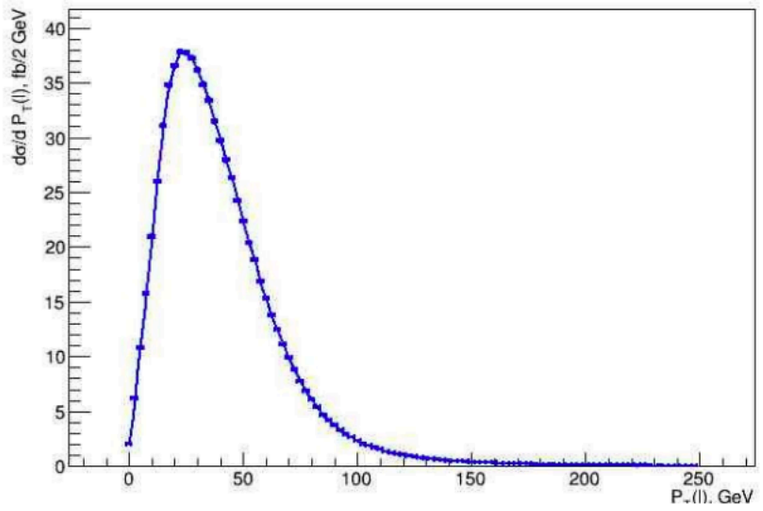
Single top s-channel

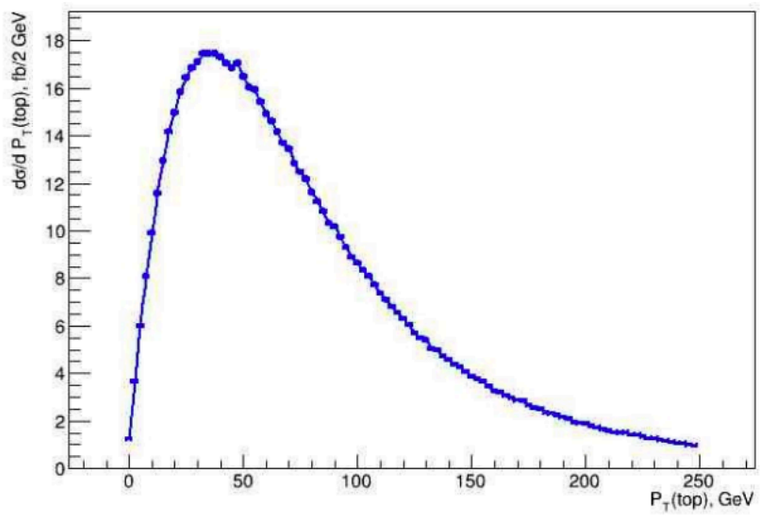
M. Perfilov

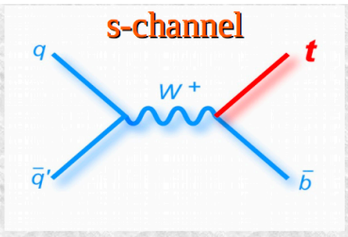
Single top features:

- Cross section proportional to $|V_{tb}|^2$ => allows direct measurement
- Wtb vertex enables tests of V–A structure
- Sensitive to new physics, e.g. anomalous couplings, 4th generation, W', H^+









	LO CS	*NLO CS*
	$pp \to t\bar{b}+\bar{t}b \to \nu_l, \bar{l}, b, \bar{b}+\bar{\nu}_l, l, b, \bar{b}$	
FCC @ 100 TeV	***80.79 (CompHEP)***	***121.2***

- One can directly apply the k-factor 1.5 for normalization to NLO
  - *the s-channel distribution shapes are the same for LO and NLO*

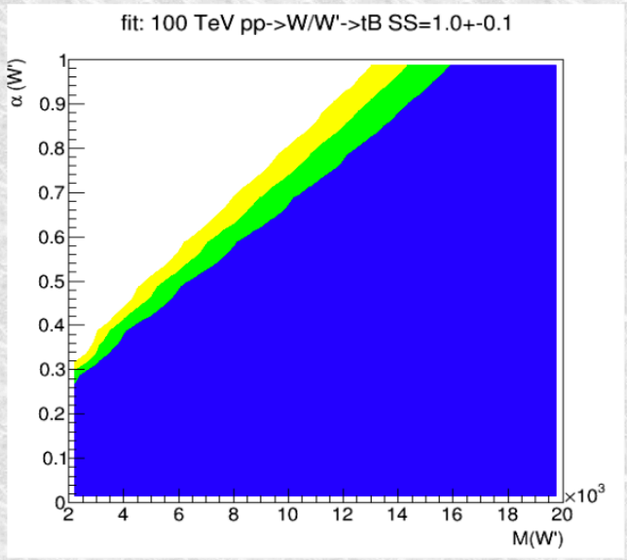
Phys.Rev. D70 (2004) 114012

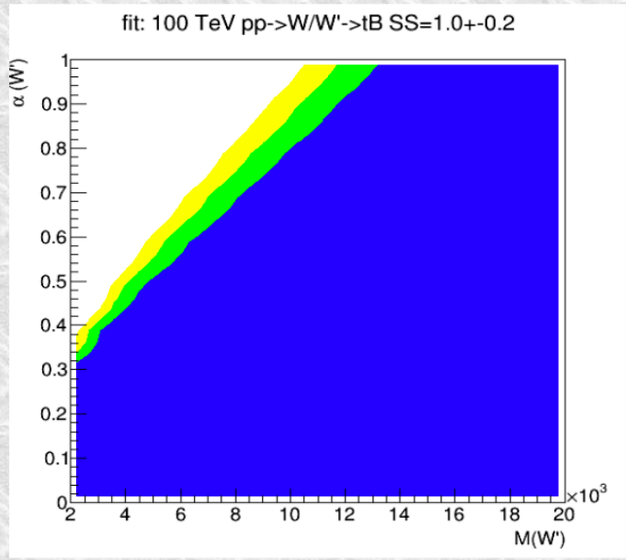
W’

M. Perfilov

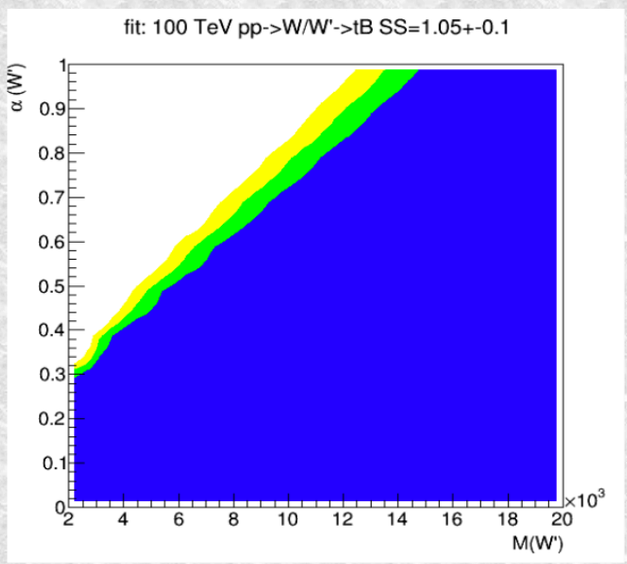
- FCC W' prospects:
  - *SM + left W'; variation of W' couplings to fermions and W' masses*
  - *Cut Mtb>1000 GeV*

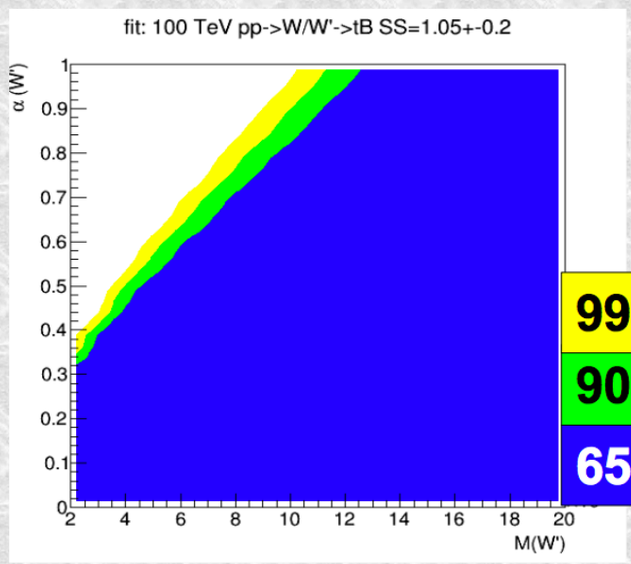
No signal:





Some signal:





99% CL of the fit

90% CL of the fit

65% CL of the fit

- **Estimated exclusion of W' masses up to 16 TeV with SM-like couplings**

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FCNC

M. Perfilov

- CompHEP-based generators:

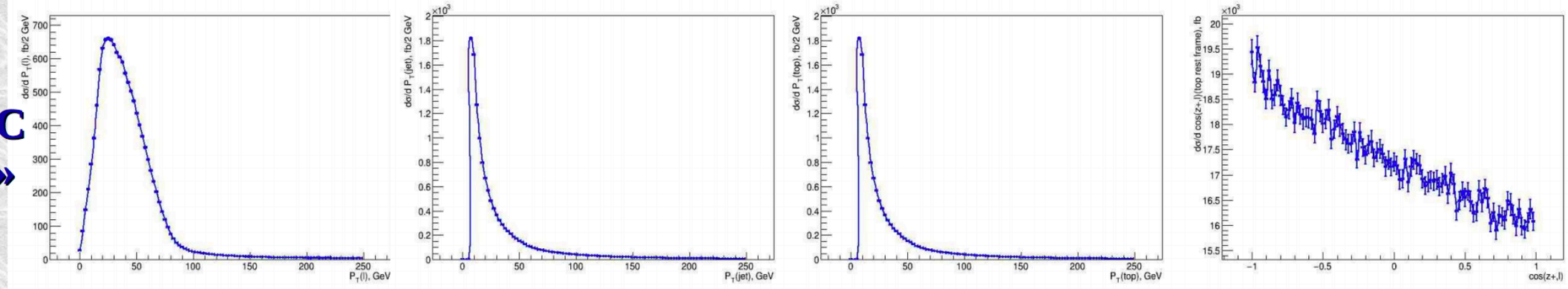
  - two event samples for values of FCNC parameters:

  - all necessary diagrams $\frac{k^c}{\Lambda} = 0.03\ TeV^{-1}$, $\frac{k^u}{\Lambda} = 0.03\ TeV^{-1}$

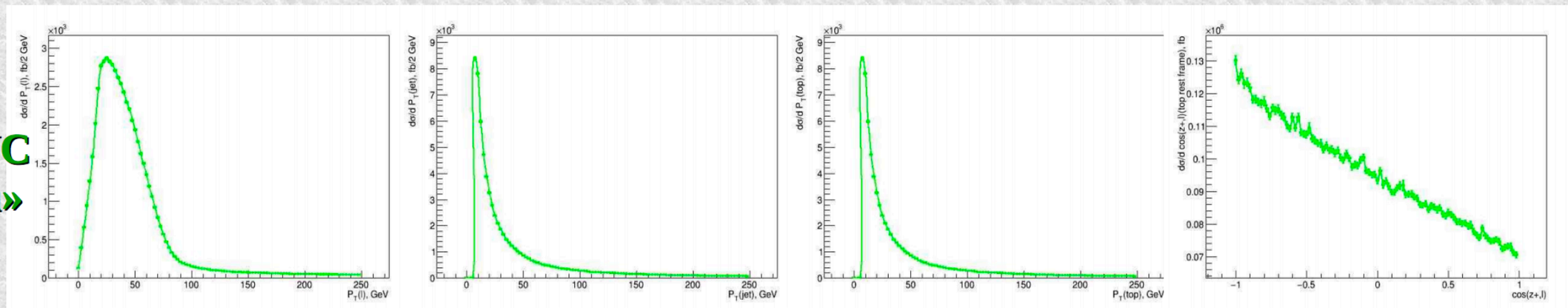
  - samples with other FCNC coupling values can be obtained with the quadratic renormalization of the existing samples to the new values

- Representative distributions

FCNC «tgc»



FCNC «tgu»



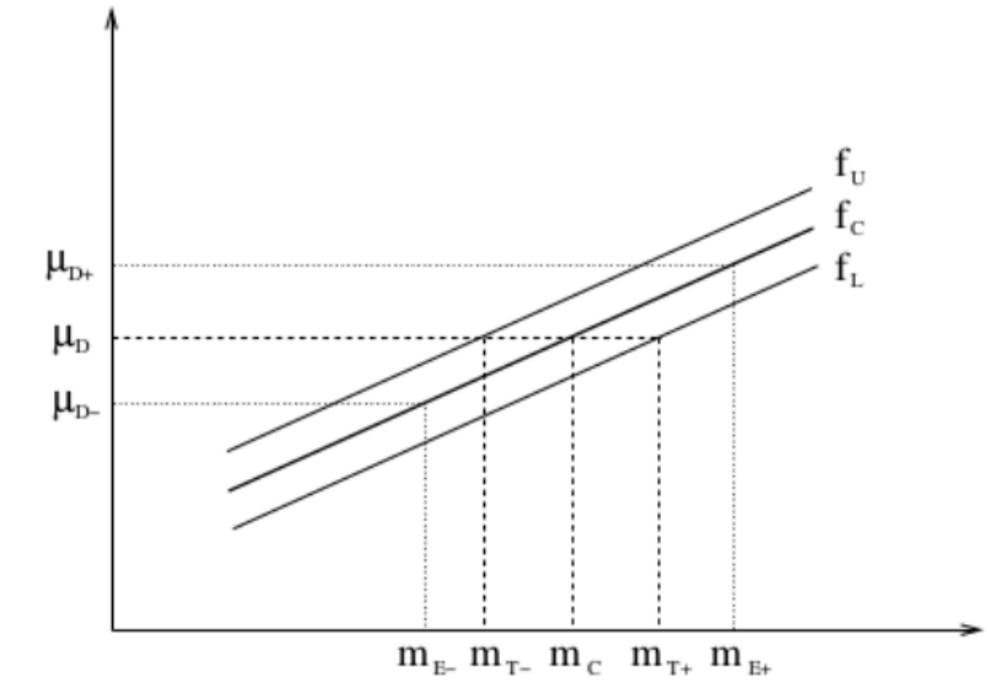
Top Mass

G. Panizzo

Interesting proposal: measuring top mass with leptonic varibles only

- See *Determination of the top quark mass from leptonic observables*
- This method is promising a *theoretical* error at 0.8 GeV

Label	Observable
1	$p_T(\ell^+)$
2	$p_T(\ell^+\ell^-)$
3	$M(\ell^+\ell^-)$
4	$E(\ell^+) + E(\ell^-)$
5	$p_T(\ell^+) + p_T(\ell^-)$



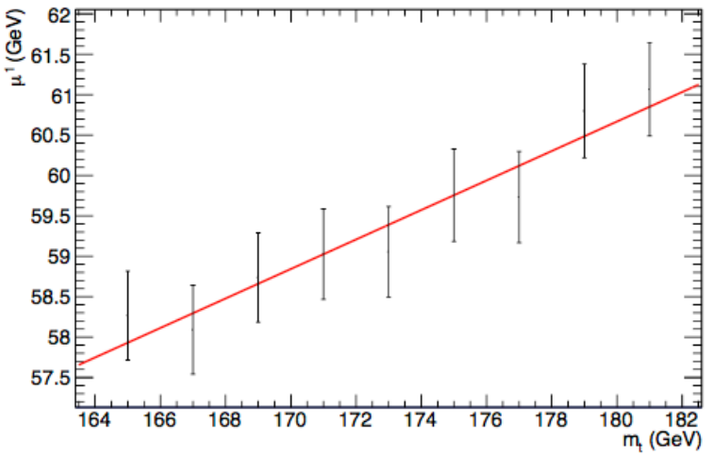
$$\mu^{O}_{(i)} = \frac{1}{\sigma}\int d\sigma O^{i}$$

Top Mass

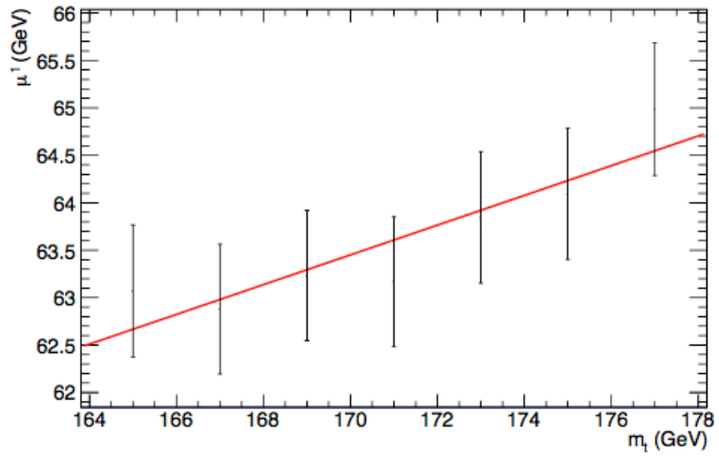
G. Panizzo

The study is really preliminary, we have just started to produce samples and obtaining μ_i predictions:

LHC



FCChh



SnowMass Strategy

- Detailed in (arXiv:1308.1636)
- Produce 2 → 4 **merged** samples, i.e:
  - pp → V + 0/1/2/3 jets
  - pp → VV + 0/1/2 jets
  - pp → VVV + 0/1 jets
- Binned in $H_T = \Sigma\ p_T$(final state)

Dataset Name	Main Processes	Final States	Order
Dominant Backgrounds			
B-4p, Bj-4p[a]	vector boson + jets	$V + nJ$	$\mathcal{O}(\alpha_s^n \alpha_w)$
BB-4p	divector + jets	$VV + nJ$	$\mathcal{O}(\alpha_s^n \alpha_w^2)$
TT-4p	top pair + jets	$TT + nJ$	$\mathcal{O}(\alpha_s^{2+n})$
TB-4p	top pair off-shell $T^* \to Wj$ + jets	$TV + nJ$	$\mathcal{O}(\alpha_s^{n+1} \alpha_w)$
TJ-4p	single top (s and t-channel) + jets	$T + nJ$	$\mathcal{O}(\alpha_s^{n-1} \alpha_w^2)$
LL-4p	off-shell $V^* \to LL$ + jets	$LL + nJ$ $[m_{ll} > 20$ GeV$]$	$\mathcal{O}(\alpha_s^n \alpha_w^2)$
Subdominant Backgrounds			
TTB-4p	top pair + boson	$(TTV + nJ), (TTH + nJ)$	$\mathcal{O}(\alpha_s^{2+n} \alpha_w)$
BLL-4p	off-shell divector $V^* \to LL$ + jets	$VLL + nJ$ $[m_{ll} > 20$ GeV$]$	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
BBB-4p	tri-vector + jets, Higgs associated + jets	$(VVV + nJ), (VH + nj)$	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
H-4p	gluon fusion + jets	$H + nJ$	$\mathcal{O}(\alpha_s^n \alpha_h)$
BJJ-vbf-4p	vector boson fusion + jets	$(V + nJ), (H + nJ)$ $[n \geq 2]$	$\mathcal{O}(\alpha_s^{n-2} \alpha_w^3)$

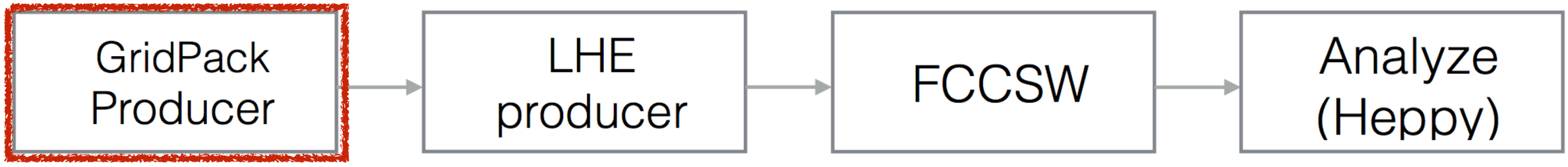
Our Strategy

- Cannot use SnowMass samples because of gen. level acc. cuts
- Produce separate V and H samples
- Adding:
  - ggH, VBF H, VH, ttH,
  - ggHH, VBF HH
- We plan on producing the following samples (work in progress):

Samples **H_T bins**

```
"pp_v0123j_5f":[0,1500,2900,5100,8500,100000],
"pp_vvv01j_5f":[0,1200,3000,6000,100000],
"pp_vv012j_5f":[0,300,1400,2900,5300,8800,100000],
"pp_vbf_v01j_5f":[0,2000,4000,7200,100000],
"pp_llv01j_5f":[0,800,2000,4000,100000],
"pp_ll012j_5f":[0,200,700,1500,2700,4200,100000],
"pp_tv012j_5f":[0,500,1500,2800,4700,7400,100000],
"pp_t123j_5f":[0,1900,3500,5900,100000],
"pp_ttv01j_5f":[0,1100,2700,4900,8100,100000],
"pp_tt012j_5f":[0,600,1200,2100,3400,5300,8100,100000],
"pp_h012j_5f":[0,100,1900,4400,8500,100000],
"pp_vh012j_5f":[0,300,1400,2900,5300,8800,100000],
"pp_hh01j_5f":[0,300,1400,2900,5300,8800,100000],
"pp_tth01j_5f":[0,1100,2700,4900,8100,100000],
"pp_vbf_h01j_5f":[0,2000,4000,7200,100000],
"pp_vbf_hh01j_5f":[0,2000,4000,7200,100000]
```

Workflow: GridPacks



- GridPack Producer[1]
  - makes MG5_aMC@NLO GridPacks (i.e standalone script that produces LHE files)
  - Can be used either locally or on lxbatch/condor queues

```
./run.sh [nevents] [seed]
```

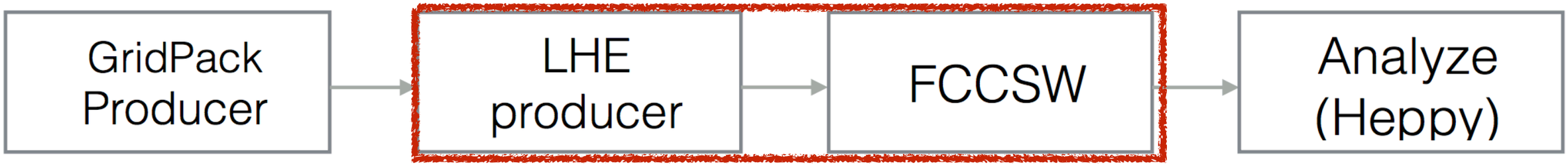
- For simplicity, GP that are of common interest will be produced centrally (WIP) and stored here **(most are produced already):**

/eos/fcc/hh/generation/mg5_amcatnlo/gridpacks

[1] https://github.com/selvaggi/GridPackProducer

Workflow: LHE/FCCSW

C. Helsens



- LHE Producer[1]
  - Produces Les Houches Event (LHE) files using GridPacks using lxbatch queues (working on extending to HTCondor)
  - This part should be carried out by the user

- FCCSW file producer (work in progress):
  - Produces FCCSW files using LHE files
  - This part should be carried out by the user

[1] https://github.com/clementhelsens/LHEventProducer

Workflow: LHEs

C. Helsens

List of produced LHE files can be found here:

http://fcc-physics-events.web.cern.ch/fcc-physics-events/LHEevents.php

	name	nevents	nfiles	outputdir	mainprocess	finalstates	cross section (pb)
1	pp_bbaa01j_4f	9,950,000	995	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_bbaa01j_4f/	bbaa + 0,1 jets 4 flavor scheme		5.899
2	pp_bbh	9,930,000	993	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_bbh/	bbar plus higgs	inclusive	0.916
3	pp_bbja_4f	10,000,000	1000	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_bbja_4f/	bbja 4 flavor scheme		4679
4	pp_bjaa01j_4f	9,990,000	999	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_bjaa01j_4f/	bjaa + 0,1 jets 4 flavor scheme		16.9
5	pp_h012j_5f_HT_0_100	10,010,000	1001	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_h012j_5f_HT_0_100/	gluon fusion higgs (finite mt) + 0/1/2 jets	0 < HT < 100	313.4
6	pp_h012j_5f_HT_100_400	0	0		gluon fusion higgs (finite mt) + 0/1/2 jets	100 < HT < 400	220.7
7	pp_h012j_5f_HT_1900_4400	0	0		gluon fusion higgs (finite mt) + 0/1/2 jets	1900 < HT < 4400	0.2767
8	pp_h012j_5f_HT_400_1000	0	0		gluon fusion higgs (finite mt) + 0/1/2 jets	400 < HT < 1000	47.27
9	pp_h012j_5f_HT_4400_8500	0	0		gluon fusion higgs (finite mt) + 0/1/2 jets	4400 < HT < 8500	0.003932
10	pp_hh	10,000,000	1000	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_hh/	gluon gluon fusion di-higgs	inclusive	0.65
11	pp_hh01j_5f_HT_0_300	10,000	1	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_hh01j_5f_HT_0_300/	gluon fusion di-higgs + 0/1 jets	0 < HT < 300	0.3501
12	pp_hh01j_5f_HT_1400_2900	10,000	1	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_hh01j_5f_HT_1400_2900/	gluon fusion di-higgs + 0/1 jets	1400 < HT < 2900	0.01262
13	pp_hh01j_5f_HT_2900_5300	10,000	1	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_hh01j_5f_HT_2900_5300/	gluon fusion di-higgs + 0/1 jets	2900 < HT < 5300	0.0007101
14	pp_hh01j_5f_HT_300_1400	10,000	1	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_hh01j_5f_HT_300_1400/	gluon fusion di-higgs + 0/1 jets	300 < HT < 1400	0.7453
15	pp_hh01j_5f_HT_8800_100000	0	0		gluon fusion di-higgs + 0/1 jets	8800 < HT < 100000	2.703e-06
16	pp_jjaa01j_5f	8,485,000	340	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_jjaa01j_5f/	dijet diphoton + 0,1 jets 5 flavor scheme		55.72
17	pp_jjaa_4f	9,990,000	999	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_jjaa_4f/	dijet diphoton 4 flavor scheme		431.2
18	pp_jjaa_5f	9,890,000	989	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_jjaa_5f/	dijet diphoton		17.97
19	pp_jjja01j_5f	12,965,000	1061	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_jjja01j_5f/	photon +jets + 0,1 jets 5 flavor scheme		4.133e+05
20	pp_jjja_5f	9,950,000	995	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_jjja_5f/	photon +jets		1.023e05
21	pp_ll012j_5f_HT_0_200	0	0		V -> ll (l=e,mu,ve,vm,vt) +	0 < HT < 200	0
22	pp_ll012j_5f_HT_1500_2700	10,000	1	/eos/fcc/hh/generation/mg5_amcatnlo/lhe/pp_ll012j_5f_HT_1500_2700/	V -> ll (l=e,mu,ve,vm,vt) +	1500 < HT < 2700	1.03

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Future plans

- Delphes/FCCSW

  - New release 3.4.1 coming very soon:
    - include latest **Tracker** configuration
    - include latest **Calorimeters**
    - add Jet **Substructure** variables (requires FCCSW release)

- MC production

  - update framework for **FCCSW** job submission (together with C. Helsens)
    - factorized LHE/FCCSW production
    - **automatise** jet **merging** procedure
    - upgrade to **HTCondor**
  - will announce a **tutorial** shortly (although instructions are already available)