SEARCH FOR EXCLUSIVE TOP QUARK PAIR PRODUCTION
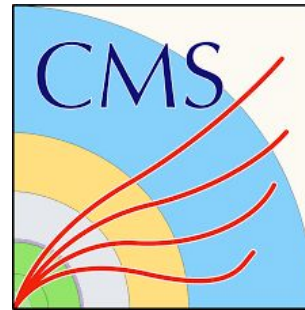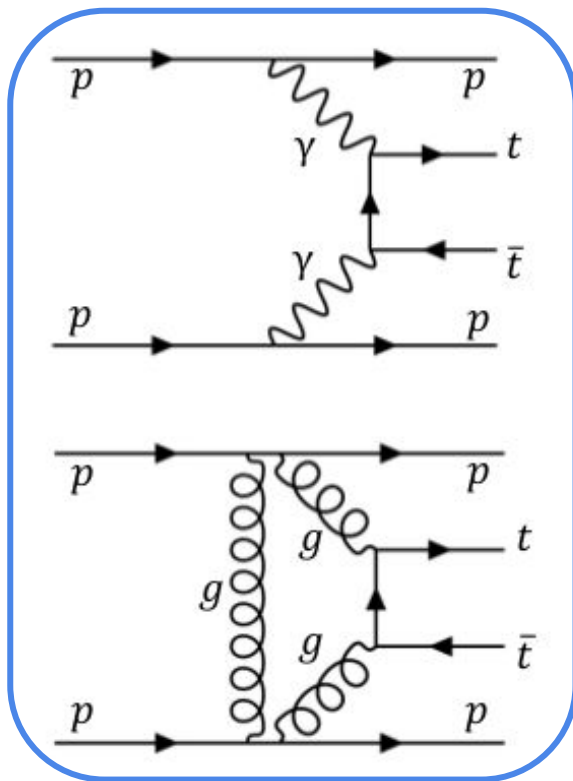
06/09/2018

BEATRIZ RIBEIRO LOPES

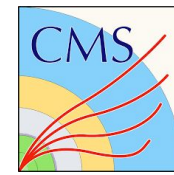PEDRO SILVA, MICHELE GALLINARO, JONATHAN HOLLAR

- When reconstructing a $t\bar{t}$ event, one has trouble reconstructing the full system (due to neutrinos etc)
- Exclusive production would allow the full reconstruction using the kinematics of the escaping protons

Independent measure of the mass
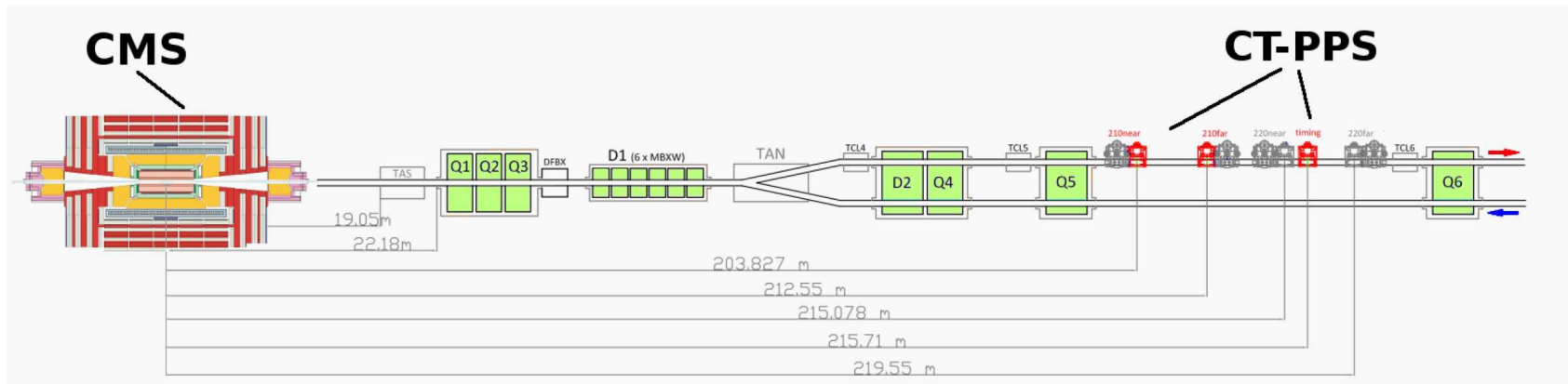Great resolution
Can be used to look for new physics

- **SM cross section predictions are very small (< 1fb^{-1}), no previous searches**
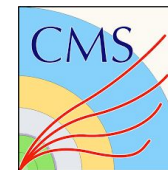
THE PPS DETECTOR

(PRECISION PROTON SPECTROMETER)

- LHC magnets bend scattered protons outside of the beam envelope
- Roman Pots placed a few mm from the beamline
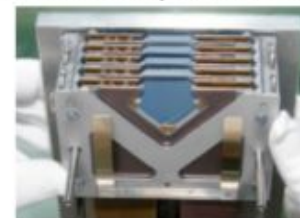- Detect protons at about ± 200 m from IP5

THE PPS DETECTOR

- Silicon strips and 3D pixel detectors
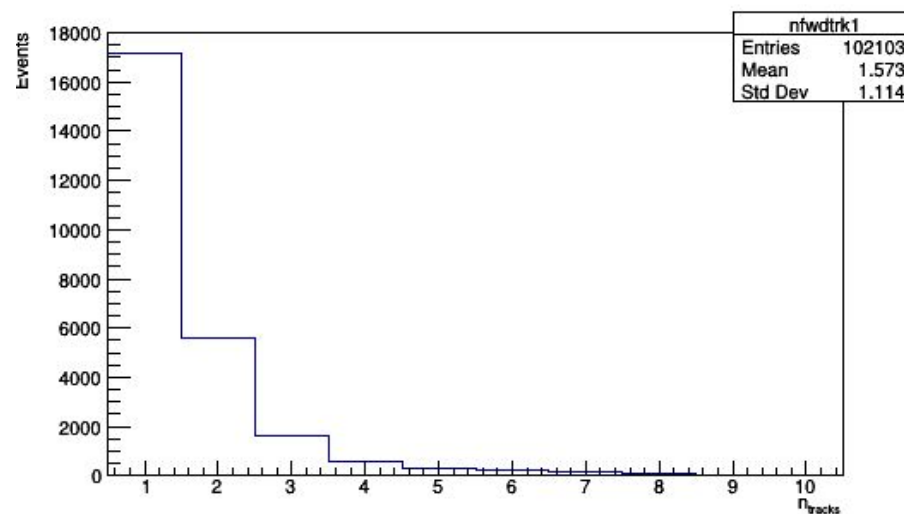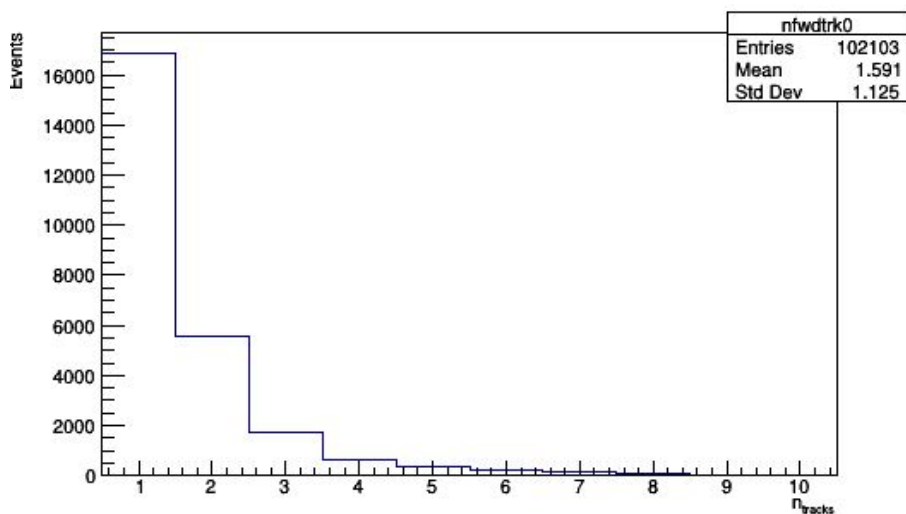- Used one strip and one pixel from each arm

Silicon strip detector   3D pixel detector
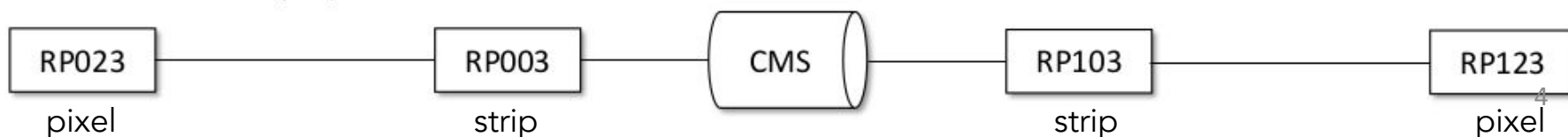
There is often more than one track in each detector!

nfwdtrk0	
Entries	102103
Mean	1.591
Std Dev	1.125

nfwdtrk1	
Entries	102103
Mean	1.573
Std Dev	1.114

(example requiring at least one proton track on each side)

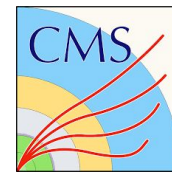| RP023	RP003	CMS	RP103	RP123
pixel	strip		strip	pixel

- From each track we get the momentum loss of the proton
- We can reconstruct the mass and rapidity of the system

$$\xi = \frac{p_i - p_f}{p_i}$$

for every possible combination

$$m_{RP} = \sqrt{s\xi_1\xi_2}$$

$$y_{RP} = \frac{1}{2}\ln\left(\frac{\xi_1}{\xi_2}\right)$$

1 per track in the RP

check which mass and rapidity values are compatible with what we are looking for!
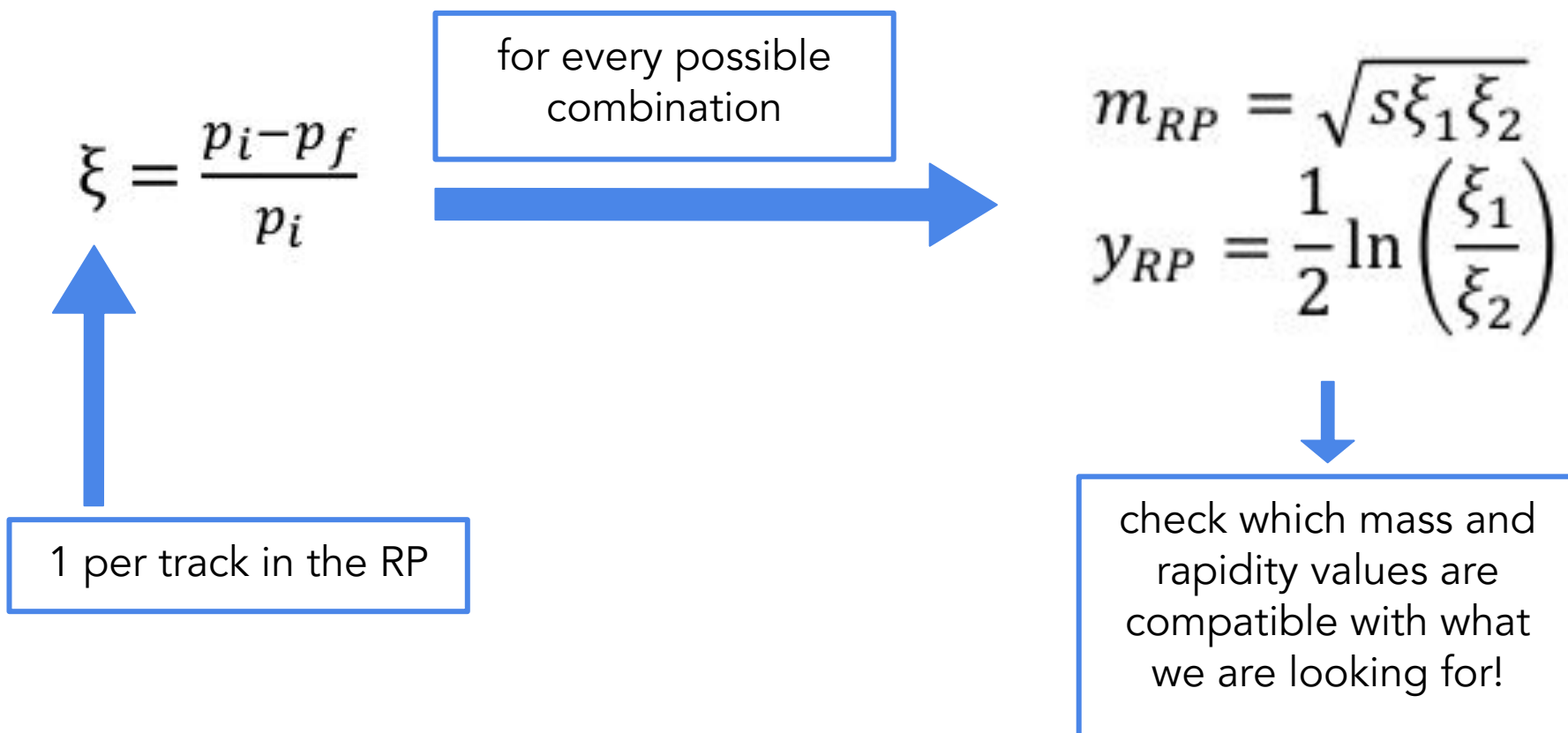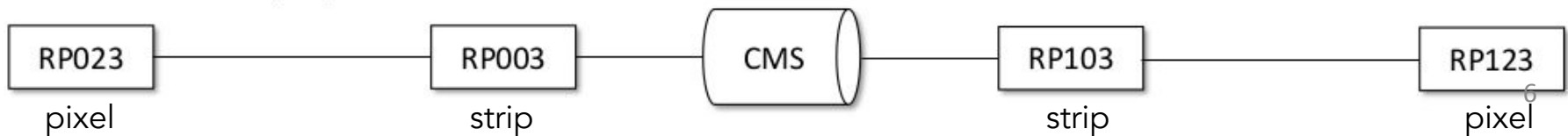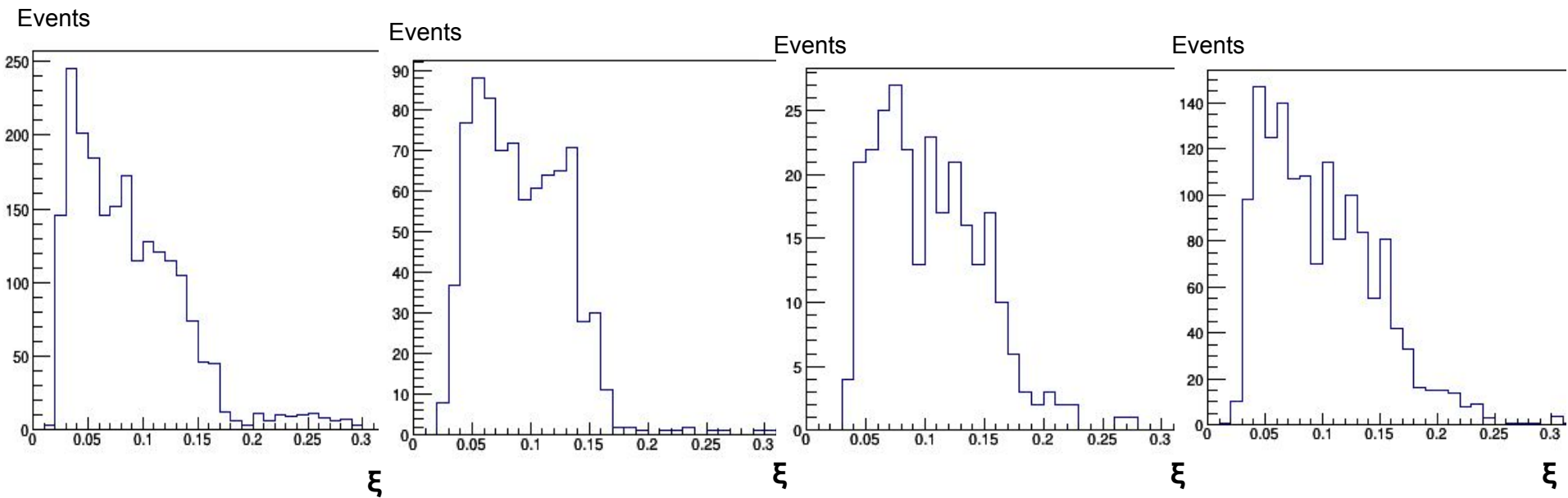
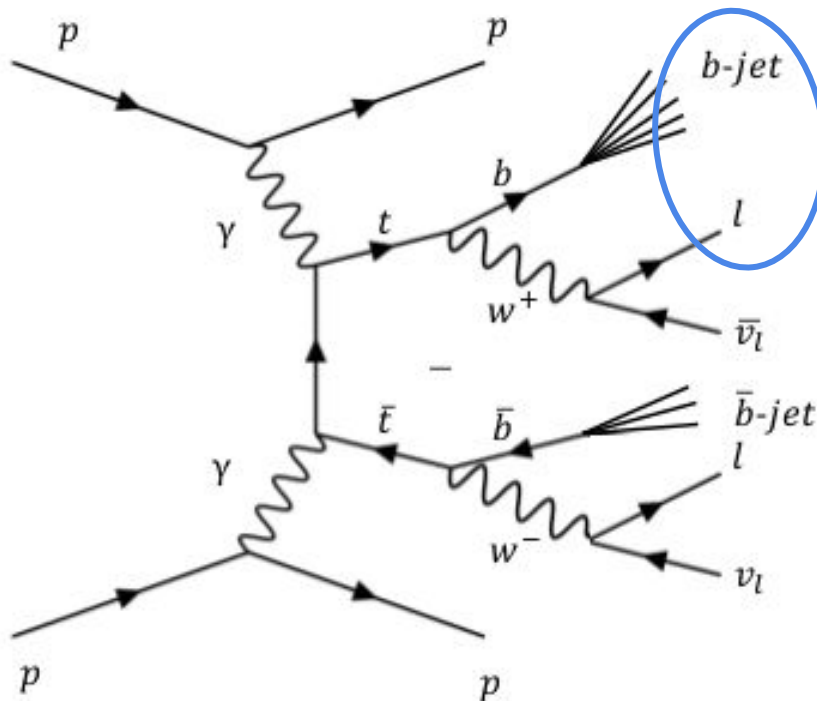# ξ DISTRIBUTIONS

$$\xi = \frac{p_i - p_f}{p_i}$$

- Expected range: $0.02 \leq \xi \leq 0.2$
(but some events are observed above due to misresconstruction)

- Acceptance in both arms is asymmetric

$t\bar{t}$ Pre-selection

- Using data from 2017, sqrt(s)=13 TeV
  L = 41.4fb^{-1} (but only 18.7fb^{-1} with calibrated pixels)
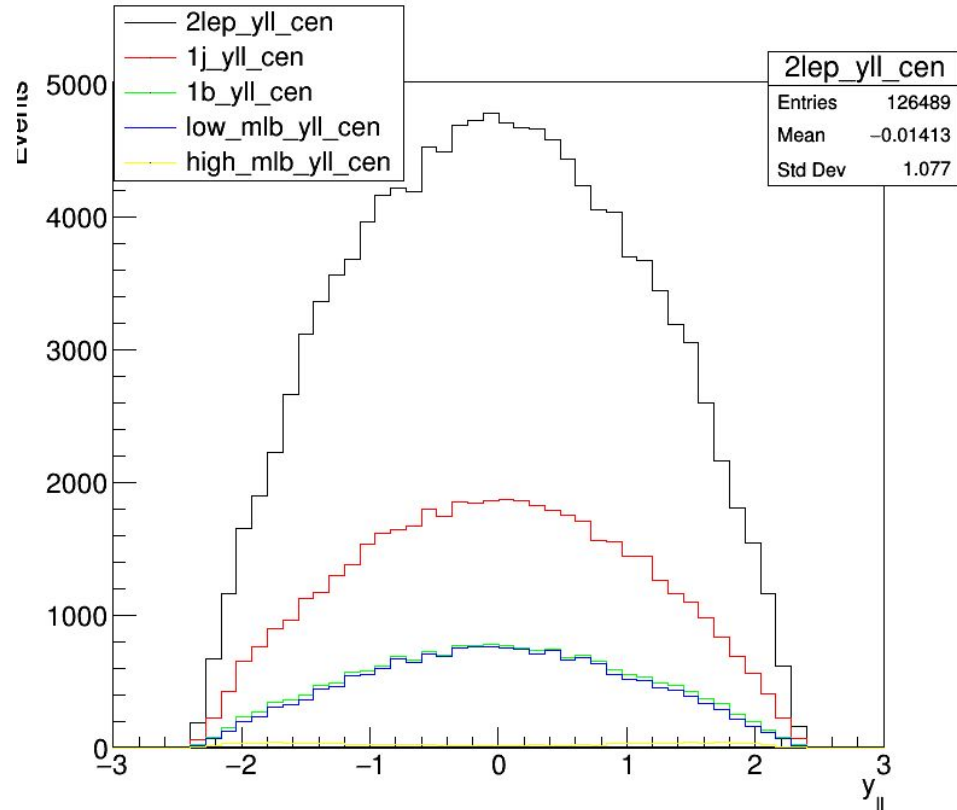
- Looking at dilepton events

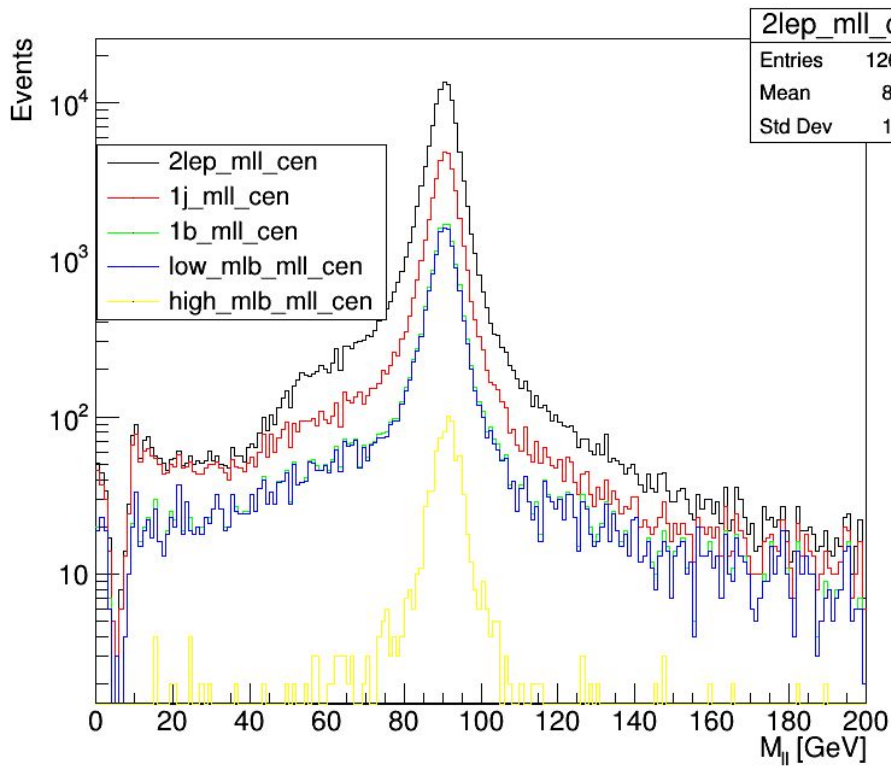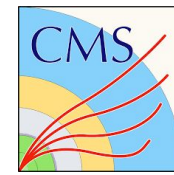- Require:

  ○ 2 leptons (not Z->ll)

  ○ M_{ll}> 20 GeV

  ○ ≥1 jet
    (p_T>20 GeV & $|\eta|$<4.7)

  ○ ≥1 b-jet
    (p_T>30 GeV & $|\eta|$<2.5)

  ○ M_{lb}<160 GeV

- Events failing cuts are categorized separately

$$M_{lb} < \sqrt{m_t^2 - m_W^2}$$

Z→ll dominates
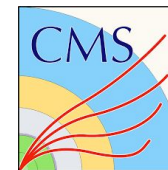
Central system
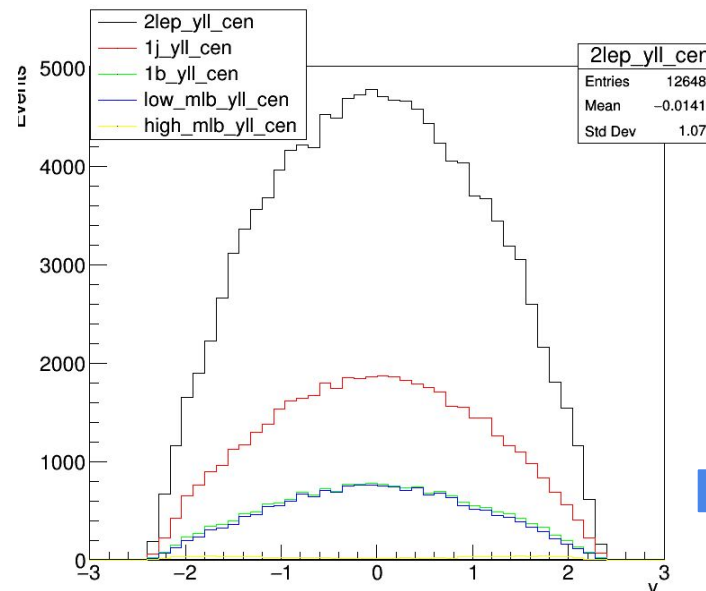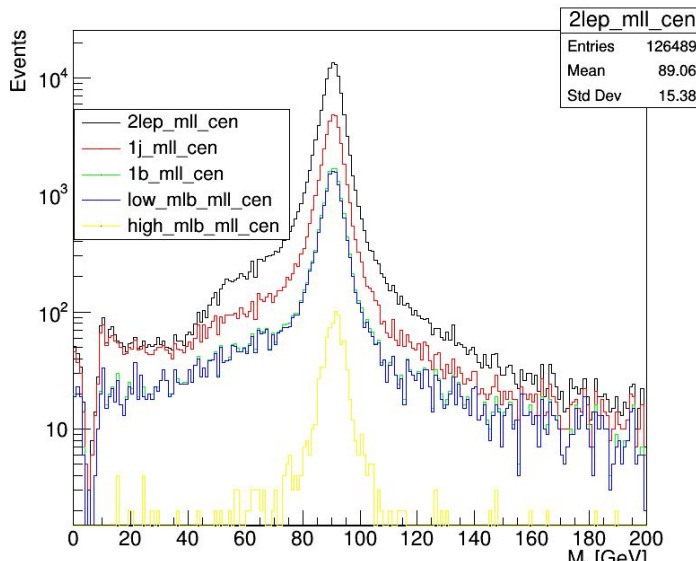
Roman Pots
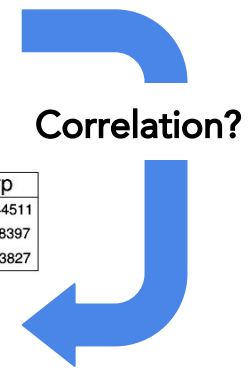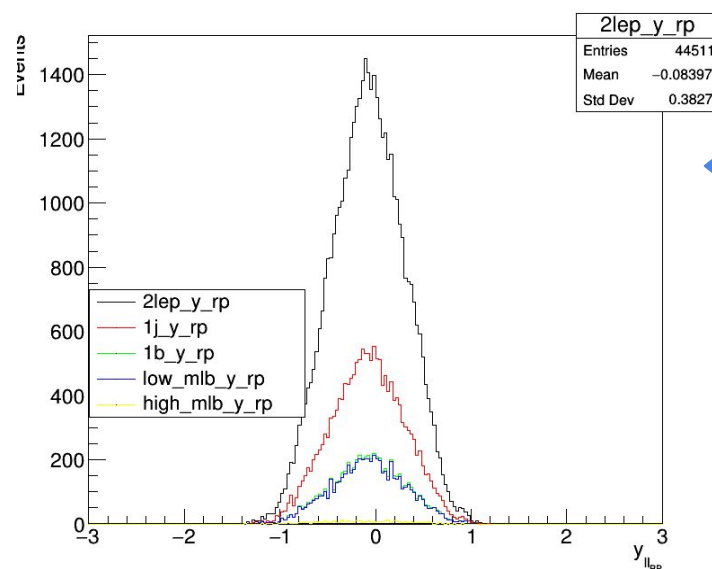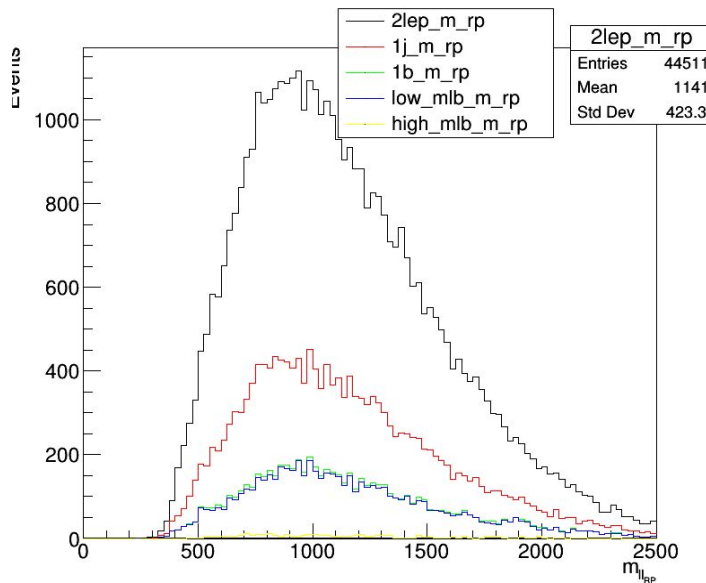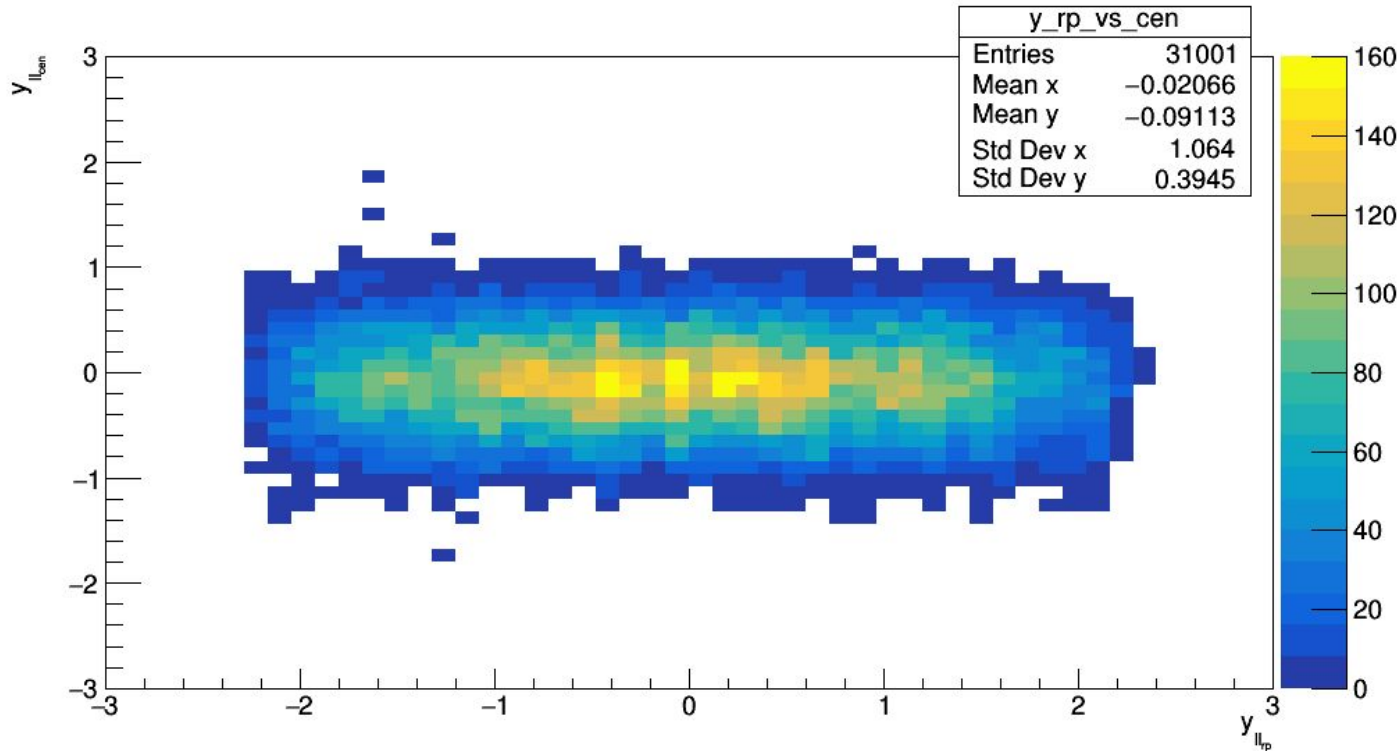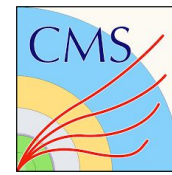
Correlation?

No correlation is observed...

As expected, because exclusive cross sections are very low and the selection is still very loose at this point...

ESTIMATE ACCEPTANCE OF RP

MC ttbar at generator level using FPMC+Herwig

- Expected range: $0.02 \leq \xi \leq 0.2$

	Surviving events
Initial number of simulated events	100%
Events with 2 leptons	3.70%
Events in RP acceptance	1.01%

~27%

The background comes mainly from real ttbar events combined with random pileup protons
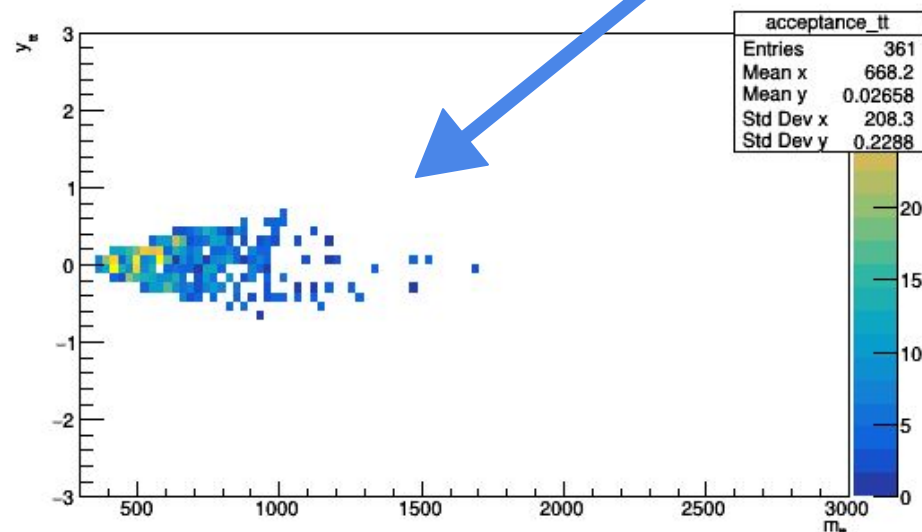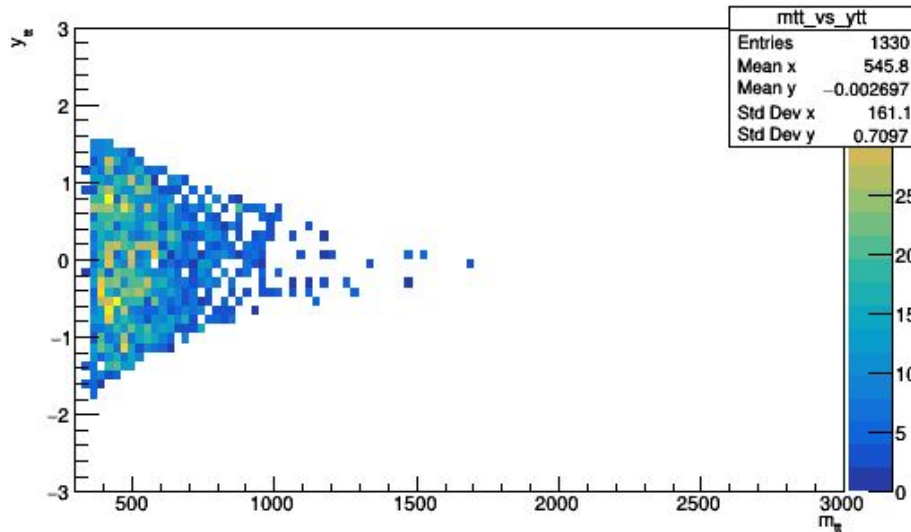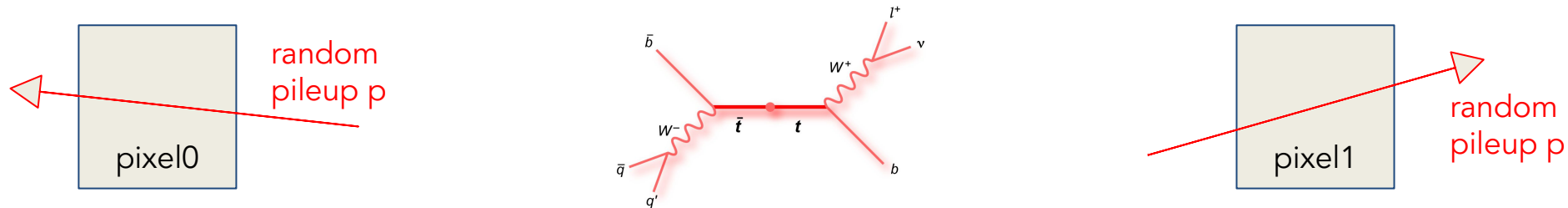

- Get the histograms of the number of forward tracks (pixel 0 and 1) and the **ξ** distribution

For each event:
- Generate a random number of tracks in each pixel
- For each track generate a random **ξ**
- For all combinations, compute a "fake" mass of the dilepton system
- If this "fake" mass is between 300 and 600 GeV (ttbar threshold region), count the event
- Divide by total number of events with $300 < M_{RP} < 600$

Result: fraction of fake coincidences = 0.03

FINAL SELECTION
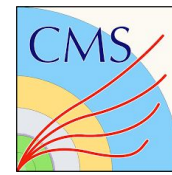
Require: 2 leptons & M_ll > 20 GeV, just pixels

Separate categories:

- ≥1 jet
- ≥1 b-jet
- M_{lb} < 160 GeV (low M_{lb})
- 300 GeV < M_{RP} < 600 GeV (M_{RP} cut)
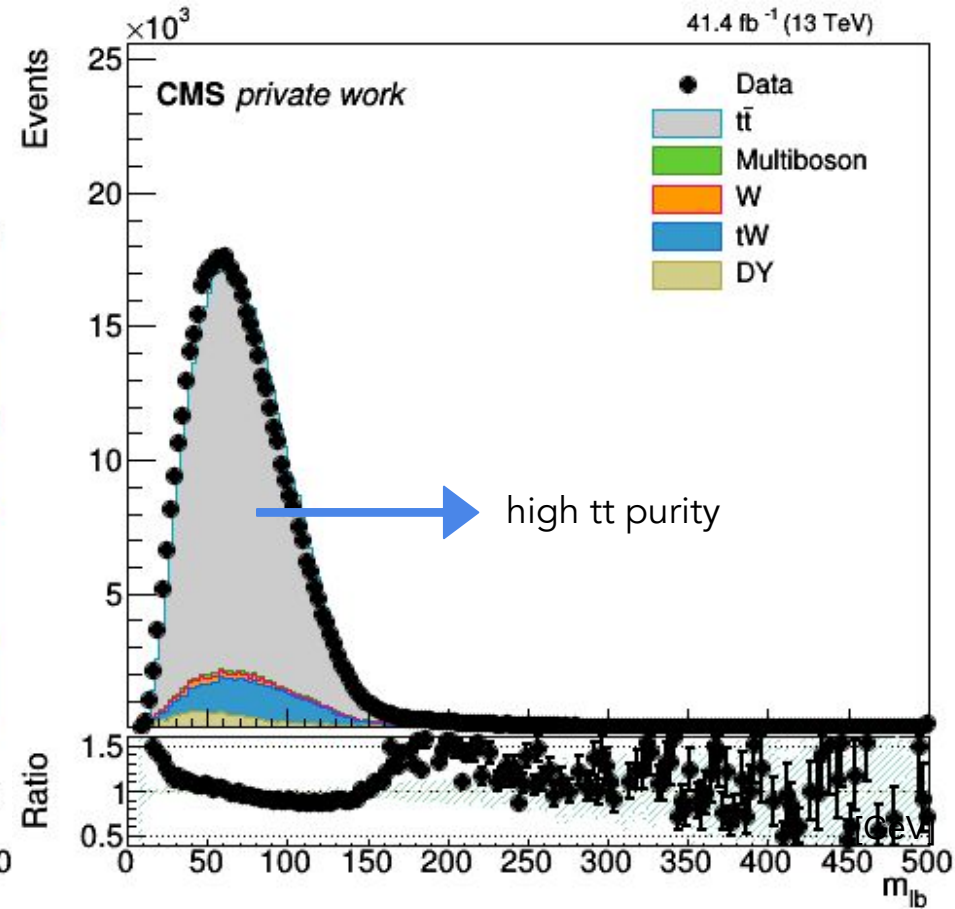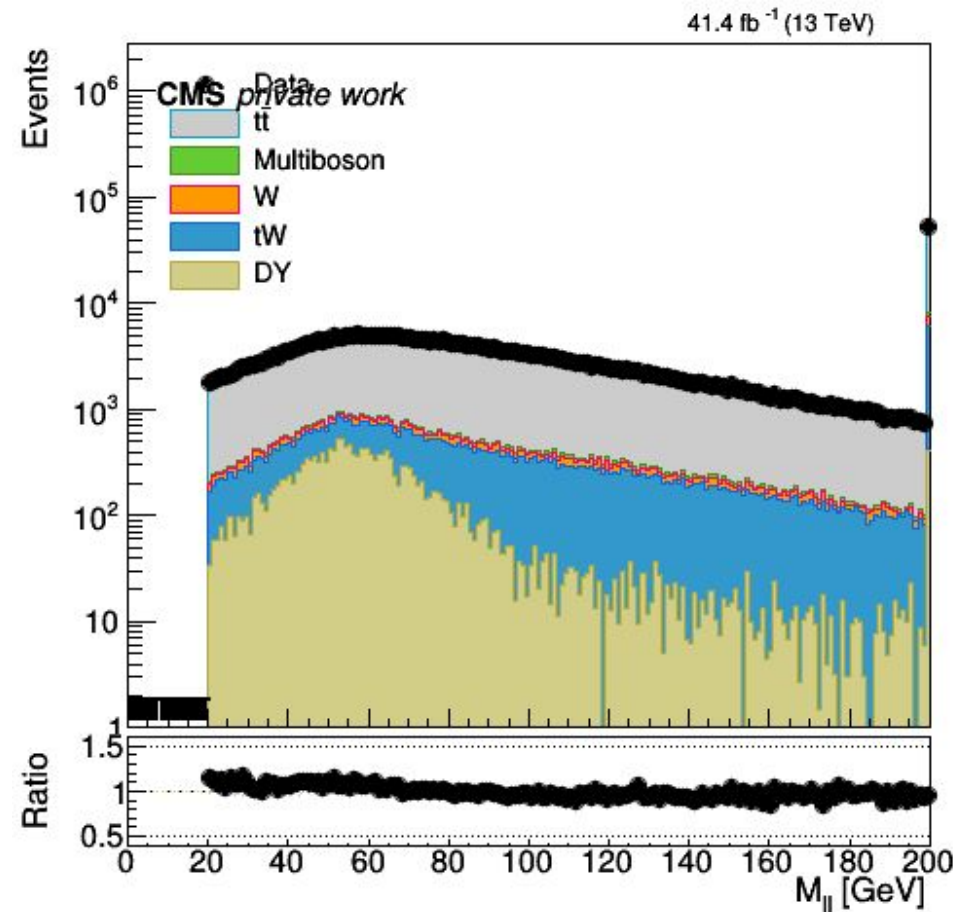- Pass "fake M_{RP}" generator (fake M_{RP})

- Same flavour leptons (ee or μμ)
- Opposite flavour (eμ)
- Z-peak (same flavour and mass of the dilepton around the Z mass)
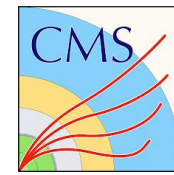
- Category: ≥1 b-jet, Opposite flavour

high tt purity

- Category: low M_{lb}, Opposite flavour
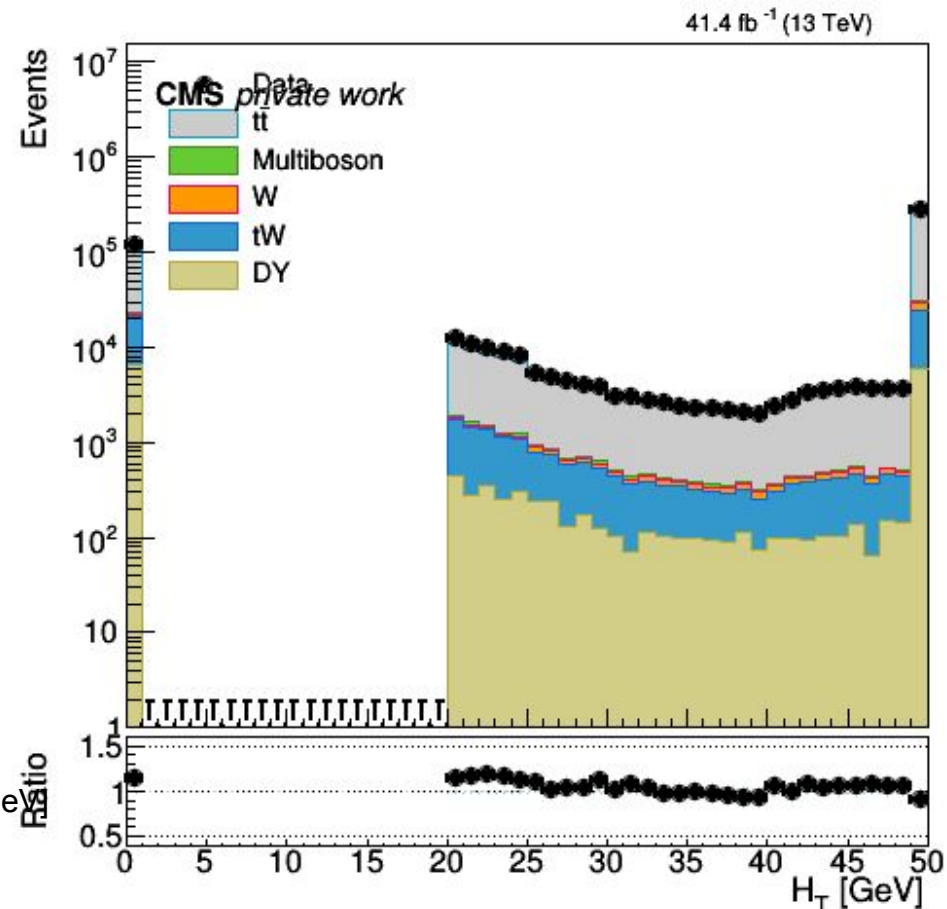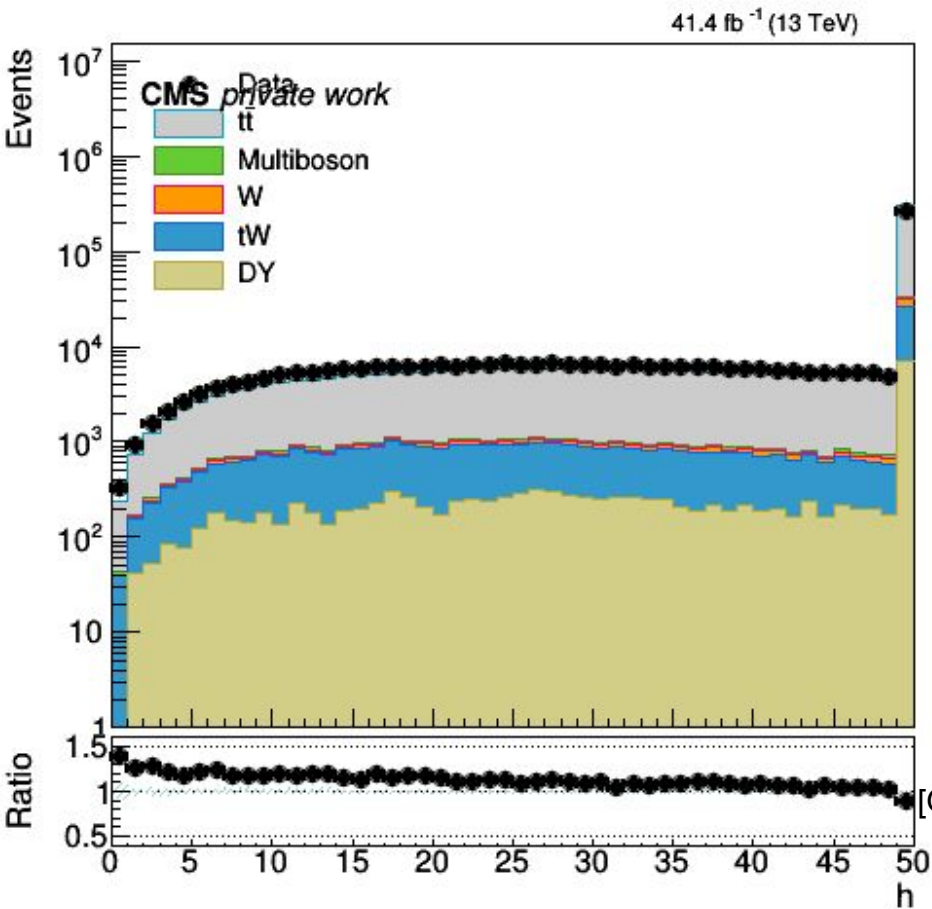
Reconstruct kinematics

- Used the algorithm in https://arxiv.org/abs/1305.1878 to try to reconstruct the kinematics of the central system for the selected events

- No correlation is observed... (region still dominated by QCD ttbar)
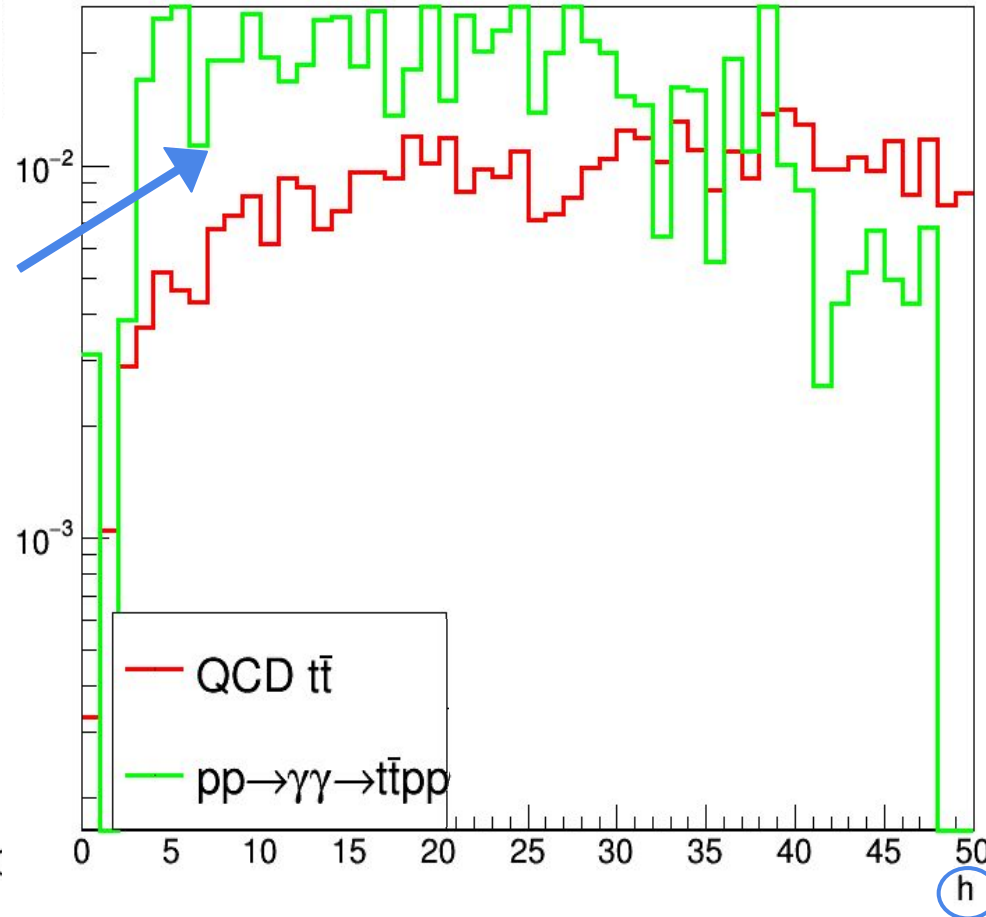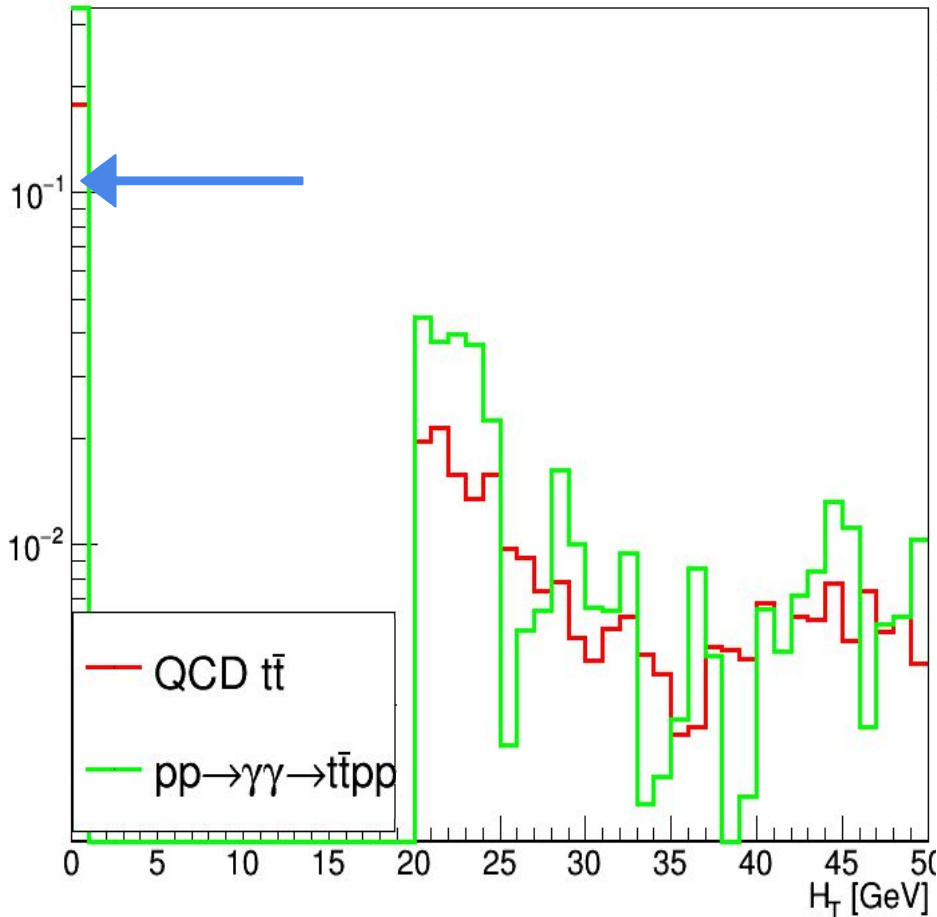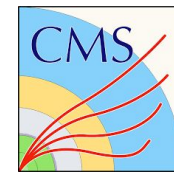
Significantly different behaviours… Signal events mostly at $H_T = 0$ and low h

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Conclusion of the 2 weeks work at CERN:

- Outlined the start of a hunt for exclusive ttbar production
- Dileptons chosen as starting point due to its purity
- Defined selection categories for signal and control regions
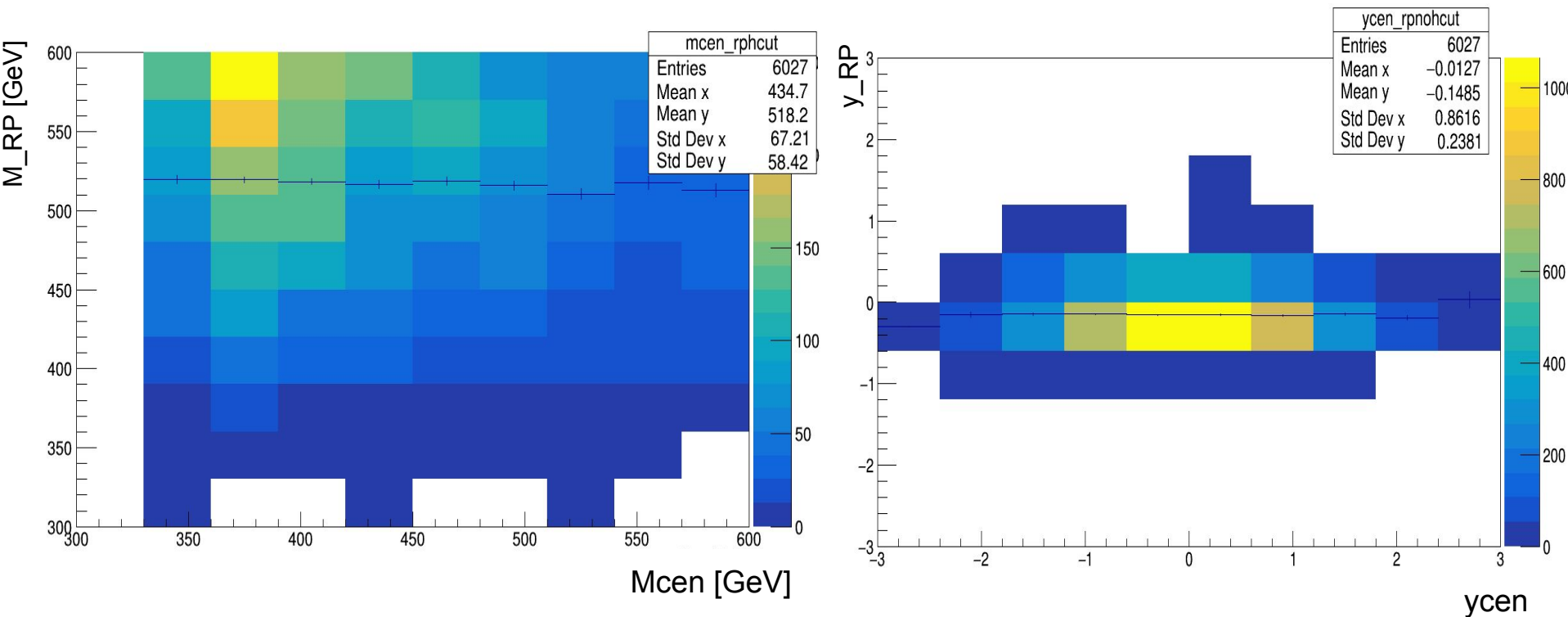- Established method to determine combinatorial background
- Signal acceptance estimated with MC
- Reconstructed kinematics in the central and forward regions

Next steps (to be implemented in the next days):

- Implement statistical analysis
  (sneak preview in the backup for the more curious)
- Derive an upper limit on the cross section

THANK YOU FOR YOUR ATTENTION

BACKUP

Yields

```
Signal
acceptance is 0.0101
low mlb selection eff is 0.344965204441 (SF) 0.427912491696 (OF)
lumi x Acc x eff = 65.0547920985 (SF) 80.6972930175 (OF)
Background
Roman pot fake rate is determined to be: 0.0333633630167
```
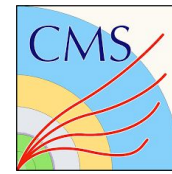
	SR_SF	SR_OF	ttCR_SF	ttCR_OF	dyCR
qcdTT	1171.4	1457.0	402792.0	502913.1	111034.4
DY	1766.0	95.2	266350.2	16775.3	2806112.3
others	29.6	34.6	9549.8	11777.4	11360.7
total	2967.0	1586.8	678692.0	531465.8	2928507.4
data_obs	9012.0	4048.0	866717.0	528106.0	3609025.0

- (data_observed in the signal regions is arbitrary)

- We perform a fit to the absolute cross section of pp->ttpp with 5 categories
  - 2 signal regions ($M_{RP} \in [300,600]$, $H_T = 0$)
  - 3 control regions (no cut in M_{RP})
- Main systematic uncertainties included
- $\sigma < 900$ fb

Contour of the likelihood for the scale factor for qcdTT and DY processes which are fit using the dedicated control regions. The point marks the fitted values.	Likelihood scan results for the signal at expectation level for a xsec=900fb scenario. The line intersects the likelihood at the boundaries of the 68% CI.