**Shane Sweetman**

*Project update meeting*
*Week 5*

# A TMD-oriented analysis of $\pi^+\pi^-$ pairs in $e^+e^-$ collisions

# Outline (Week 5)

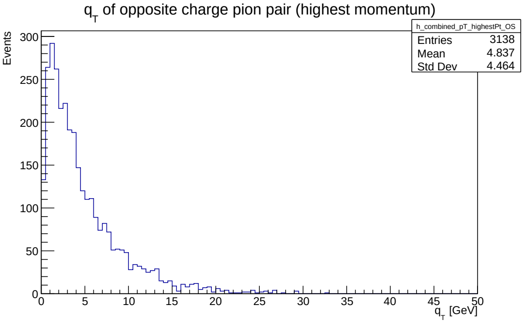
- **Quick recap:** thrust-axis $q_T^{\text{thrust}}$ gives the genuine small-$q_T$ region.
- Add an **OS/SS ratio panel** to highlight small shape differences and cancel common systematics.
- First tuning scan: `StringPT:sigma` (intrinsic transverse kicks at string breaking) and its impact on the low-$q_T^{\text{thrust}}$ peak.
- Next: vary **shower** $\alpha_s$ (radiation) and a simple **broadening dial** (primordial $k_T$) for comparison.

[2]

# Last week: beam-axis vs thrust-axis

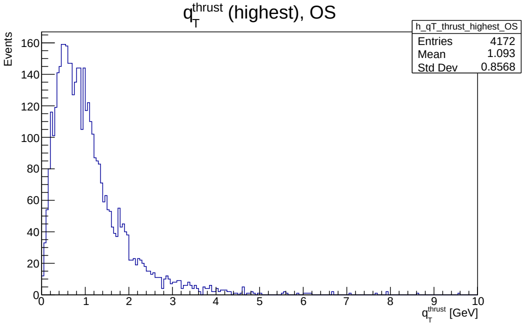
## Before (beam axis) — Week 2

Highest-$p_T$ OS using beam-axis $q_T$.




## After (thrust axis) — Week 4

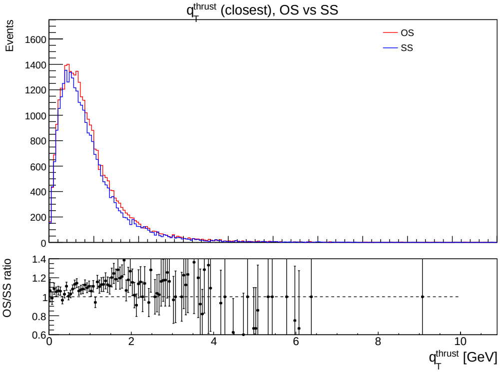
Highest-$p_T$ OS using $q_T^{\mathrm{thrust}}$ (zoomed to small-$q_T$).



# This week: overlays + OS/SS ratio panel

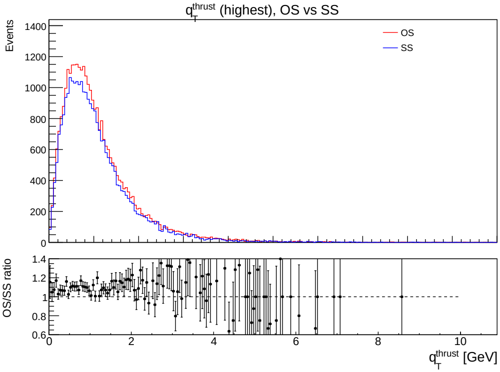
## Closest strategy

Overlay + OS/SS ratio vs $q_T^{\mathrm{thrust}}$.




## Highest-$p_T$ strategy

Overlay + OS/SS ratio vs $q_T^{\mathrm{thrust}}$.



# OS/SS ratio panel: what it is and what the errors mean

## What it is

Bottom panel is a **bin-by-bin** ratio in $q_T^{\mathrm{thrust}}$:

$$R(q_T^{\mathrm{thrust}}) \equiv \frac{N_{\mathrm{OS}}(q_T^{\mathrm{thrust}})}{N_{\mathrm{SS}}(q_T^{\mathrm{thrust}})}.$$

It highlights where OS and SS differ, after applying the same event/jet/pion cuts.

## What the error bars mean (counting statistics)

Each bin is a count ($N_{\mathrm{OS}}$, $N_{\mathrm{SS}}$), so the uncertainty is dominated by Poisson statistics:

$$\delta R \simeq R\sqrt{\frac{1}{N_{\mathrm{OS}}} + \frac{1}{N_{\mathrm{SS}}}}.$$

Low-stat bins (especially where SS is small) naturally give large error bars.

# Counts vs shape: interpreting OS/SS “sensitivity” in a sigma scan

## Why raw-count ratios can mislead

Changing `StringPT:sigma` can change **event yield after cuts** (thrust, 2 jets, pion finding) as well as the $q_T^{\mathrm{thrust}}$ **shape**. So a raw ratio can move even if only the **overall yield** changed.

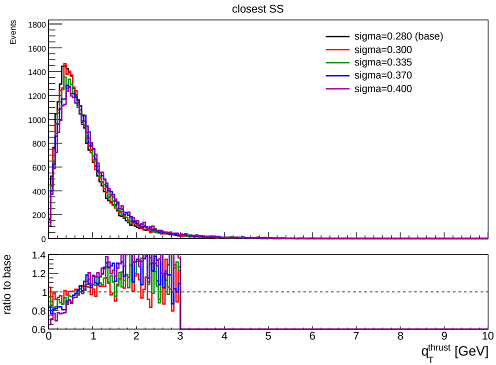
## Use shape (density) to isolate redistribution in $q_T$

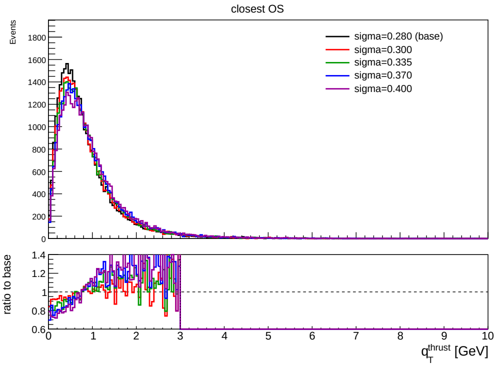
Shape-normalise each histogram **including bin width** so the area is 1:

$$\frac{1}{N}\frac{dN}{dq_T} \quad [1/\mathrm{GeV}], \qquad \int_0^{q_T^{\max}} \frac{1}{N}\frac{dN}{dq_T}\, dq_T = 1.$$

This matches the common paper convention for shape comparisons, $\frac{1}{\sigma_{\mathrm{fid}}}\frac{d\sigma}{dq_T}$, so the ratio panel highlights **shape changes**, not yield. [1]

# Scan 1: `StringPT:sigma` (closest selection)

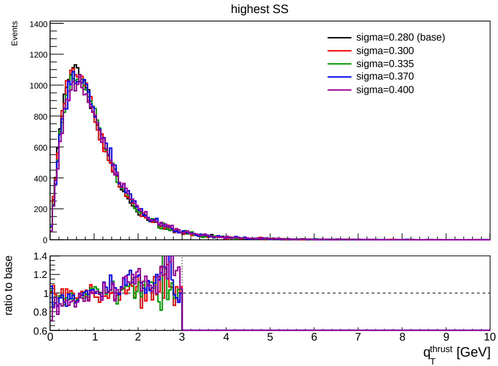


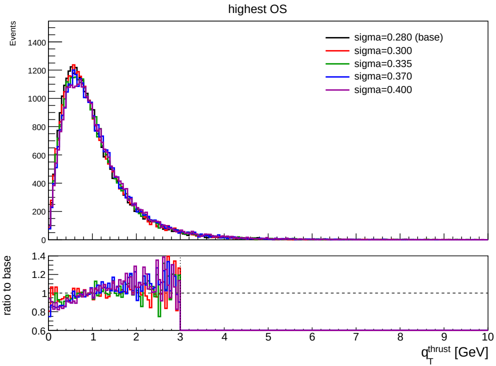




## What `StringPT:sigma` controls

String breaking gives each new $q\bar{q}$ pair equal-and-opposite transverse kicks. Larger `sigma` $\Rightarrow$ more intrinsic fragmentation smearing $\Rightarrow$ broader low-$q_T^{\mathrm{thrust}}$. [1,2]

# Scan 1: `StringPT:sigma` (highest-$p_T$ selection)




## What I'm checking

Does changing `sigma` broaden OS and SS the same way? Does the OS/SS ratio shape move beyond uncertainties? [1,2]

# Next tuning knobs: shower $\alpha_s$ and “primordial” $k_T$

## Timelike shower strength ($\alpha_s$)

Increasing the final-state shower coupling typically produces more radiation and recoil, which can broaden $q_T^{\text{thrust}}$ in the 0–10 GeV window and also change selection acceptance (thrust / 2-jet cuts).

## Primordial $k_T$ (broadening knob)

Pythia also includes a “primordial” transverse momentum smearing knob (mainly relevant in hadron-collision contexts). We will treat it as a secondary broadening dial (and keep it simple: check whether it can mimic our observed widening).

[1]

# Questions?

# References


[1] P. Skands, S. Carrazza, J. Rojo, *Tuning PYTHIA 8.1: the Monash 2013 Tune*, `https://arxiv.org/pdf/1404.5630`.

[2] PYTHIA 8 Online Manual, *Tunes*: `https://pythia.org/latest-manual/Tunes.html`