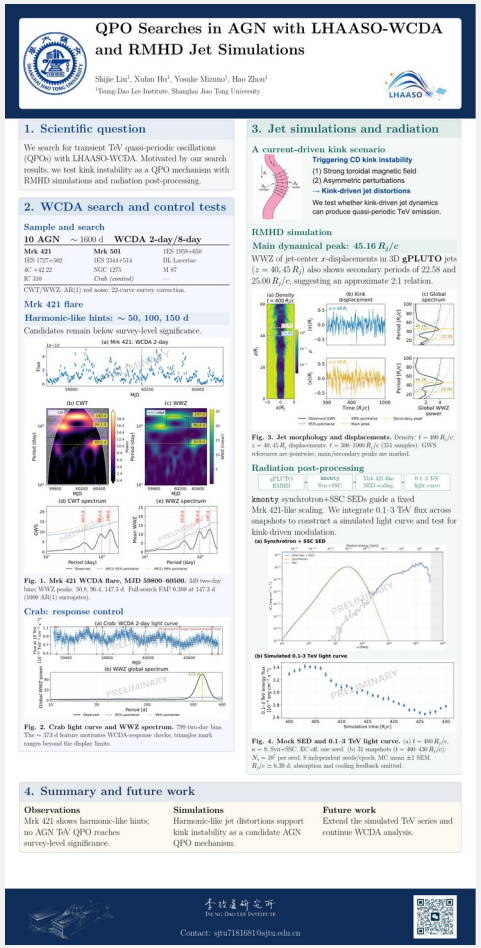
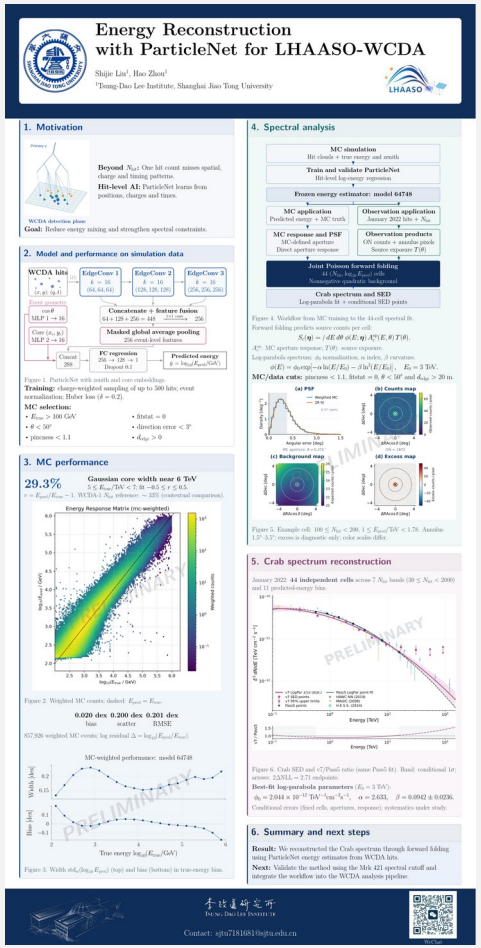
#49



QPO Searches in AGN with LHAASO-WCDA and RMHD Jet Simulations

with Xufan Hu, Yosuke Mizuno & Hao Zhou

#50



Energy Reconstruction with ParticleNet for LHAASO-WCDA

with Hao Zhou

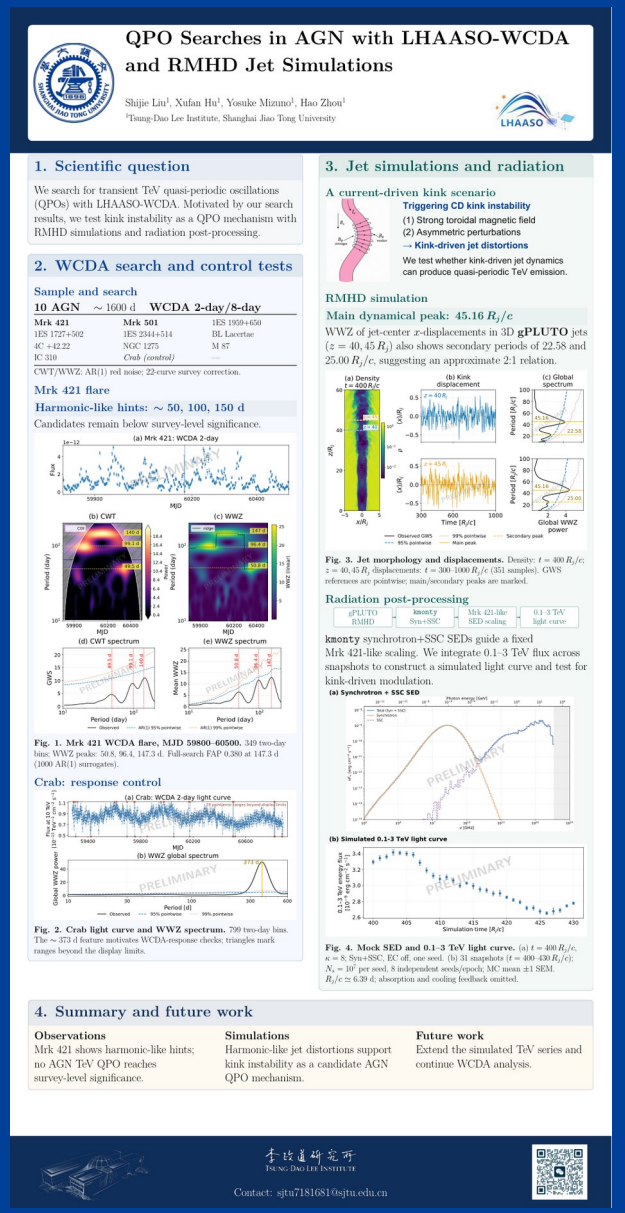
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POSTER #49

QPO Searches in AGN with LHAASO-WCDA and RMHD Jet Simulations

Shijie Liu, Xufan Hu
Yosuke Mizuno, Hao Zhou

Tsung-Dao Lee Institute
Shanghai Jiao Tong University



WCDA QPO search: AGN sample

10 AGN · ~1600 days · 2-day / 8-day bins

AGN sample

Mrk 421	BL Lacertae
Mrk 501	4C +42.22
1ES 1959+650	NGC 1275
1ES 1727+502	M 87
1ES 2344+514	IC 310

Search method

CWT / WWZ

AR(1) red noise

Control

Crab

WCDA response check

After AR(1) red-noise tests and survey correction,

no AGN shows a significant periodic signal.

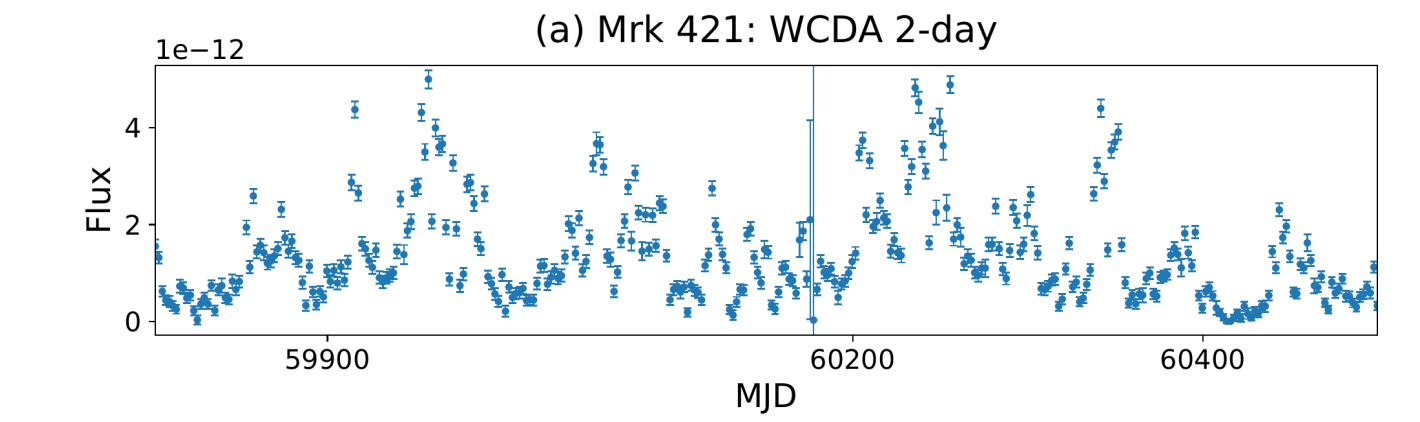
Mrk 421 shows interesting harmonic-like features.

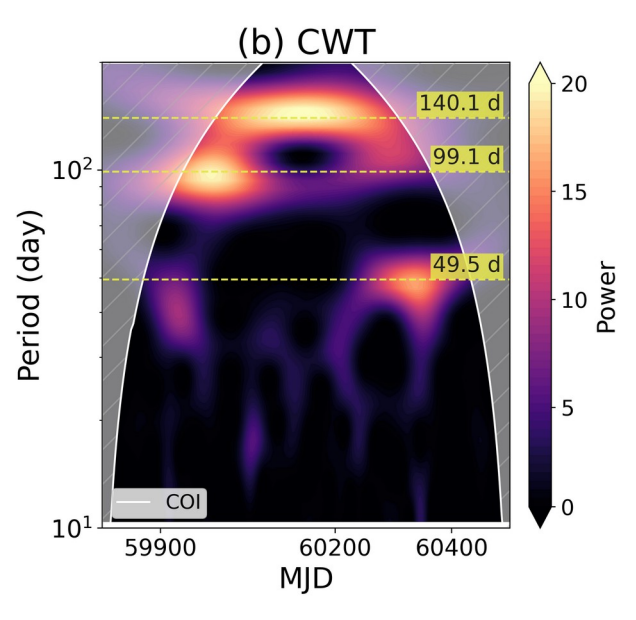
Mrk 421: harmonic-like hints

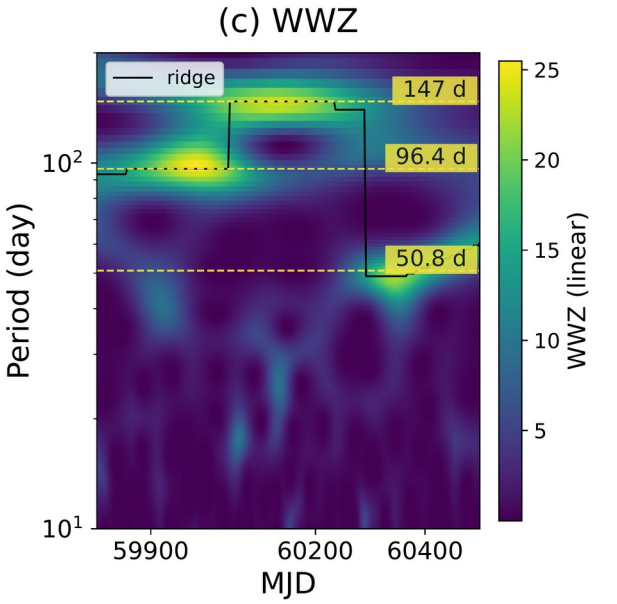
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PRELIMINARY

WCDA 2-day light curve · MJD 59800–60500





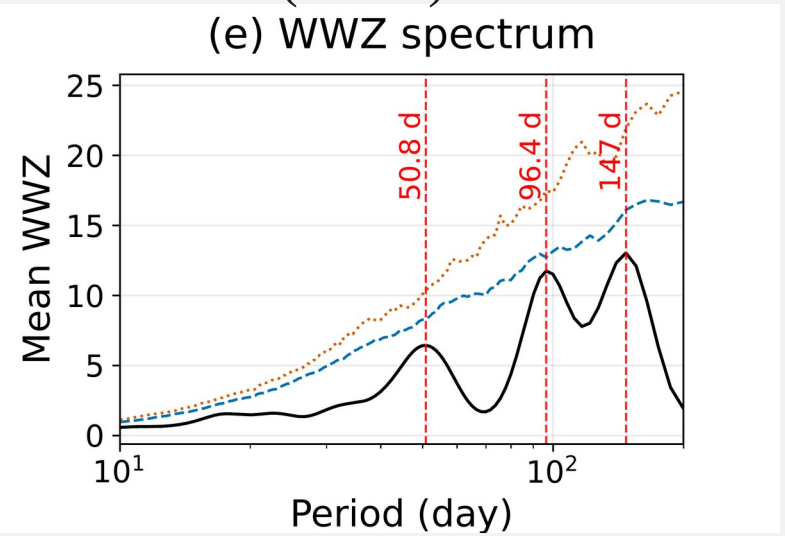


WWZ candidate timescales

50.8, 96.4, 147.3 d

Harmonic-like hints, with an evolving timescale.

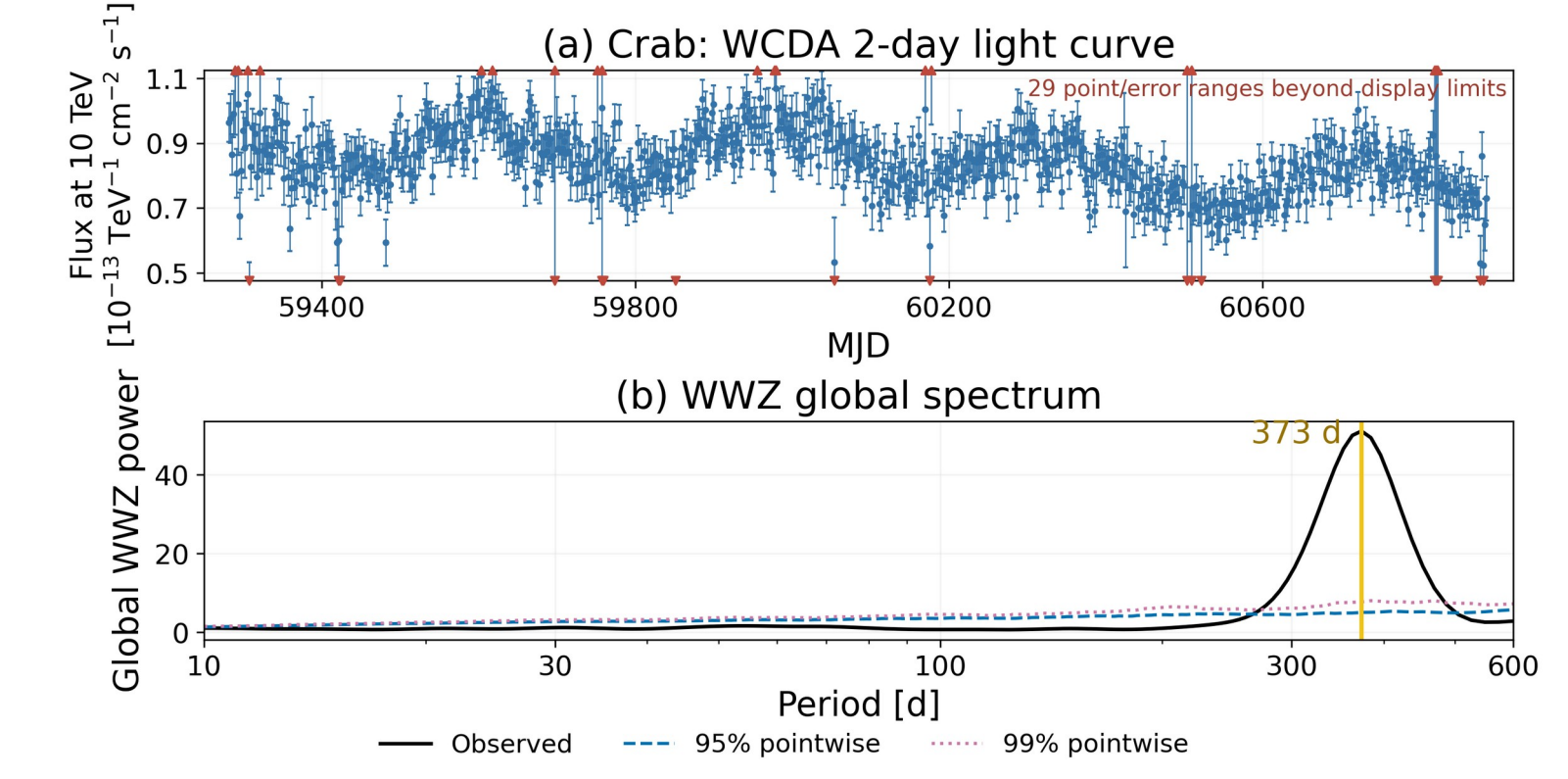
Full-search FAP = 0.380 at 147.3 d (WWZ)



AR(1): dashed / dotted = 95% / 99% pointwise

Crab control: check on the WCDA

PRELIMINARY



~373 days

Also tested:
J1952, IC443, ...

They all have near-year features

Likely seasonal detector response, possibly linked to weather.

Mrk 421: intrinsic activity dominates.

Annual modulation appears to have little impact on this flare search.

From WCDA search to RMHD simulations

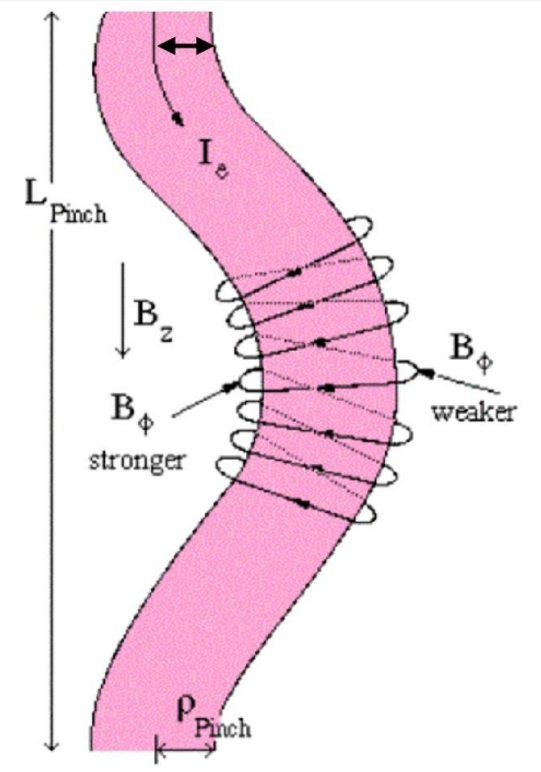
We focus on GeV–TeV γ-ray QPOs.
Blazars have relativistic jets
close to our line of sight.

The jet's toroidal magnetic field can drive
spontaneous helical distortions of the jet:
the current-driven kink instability.

Previous work: ~13 h QPOs in BL Lac

Optical/GeV QPOs, polarization and VLBA images
support a kink interpretation.

Can kink-driven jets produce transient GeV–TeV QPOs?

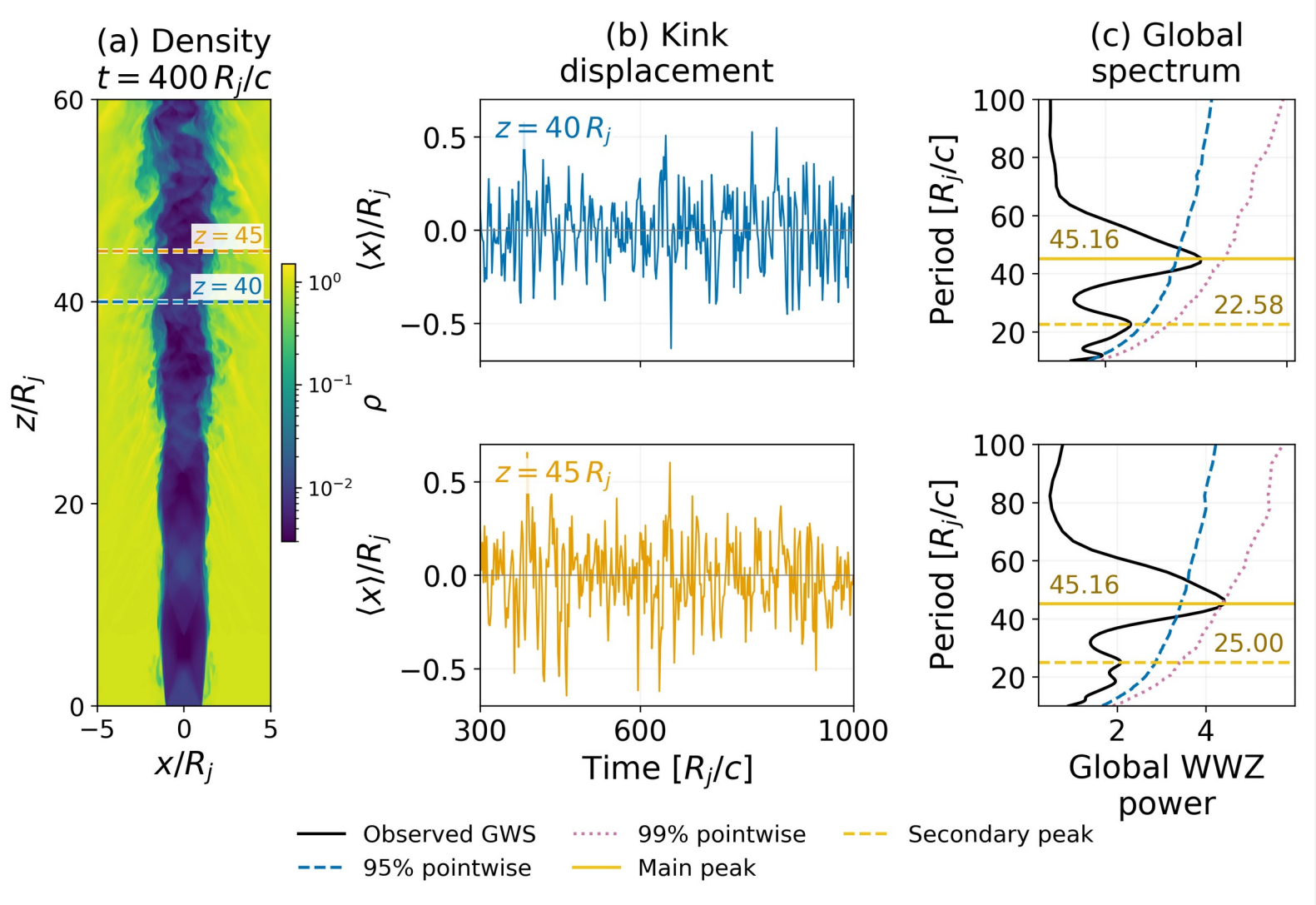


Strong toroidal field
and asymmetric perturbations

Jorstad et al. 2022,
Nature 609, 265–268

Kink-driven jet dynamics

PRELIMINARY



3D gPLUTO RMHD

We track sideways motion at z = 40 and 45 R_j.

Main period 45.16 R_j/c

Secondary periods 22.58 and 25.00 R_j/c

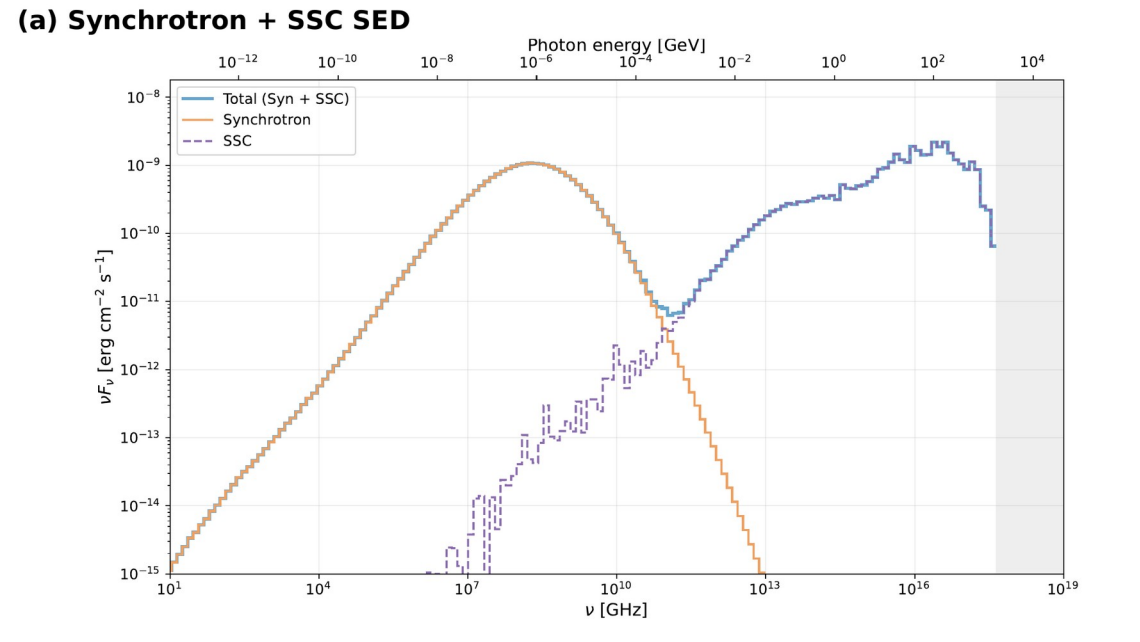
An approximate 2:1 pattern appears in the jet motion.

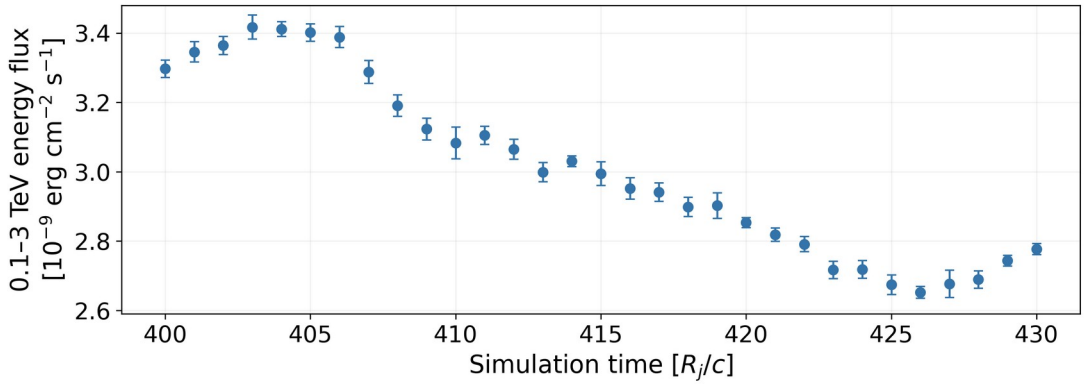
Radiation post-processing

Can the simulated light curve reproduce the candidate periodic timescales seen in Mrk 421 after physical calibration?

PRELIMINARY

kmonty: synchrotron + SSC from RMHD snapshots





We compare simulated and observed SEDs to calibrate dimensionless model parameters. Integrating 0.1–3 TeV gives the light curve.

Absorption and cooling feedback omitted

31 snapshots cover 30 R_j/c (t = 400–430 R_j/c)

8 seeds per epoch, mean ± 1 SEM

More simulation runs are needed.

Poster #49: Summary

Observations

No significant AGN periodicity after red-noise tests.
Harmonic-like features remain in Mrk 421.

Simulation interpretation: RMHD + radiation

Kink-driven jet motion shows an approximate 2:1 pattern.
This may correspond to the observed harmonic-like features.

Next steps

Extend the TeV light curve and continue the WCDA search.

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POSTER #50

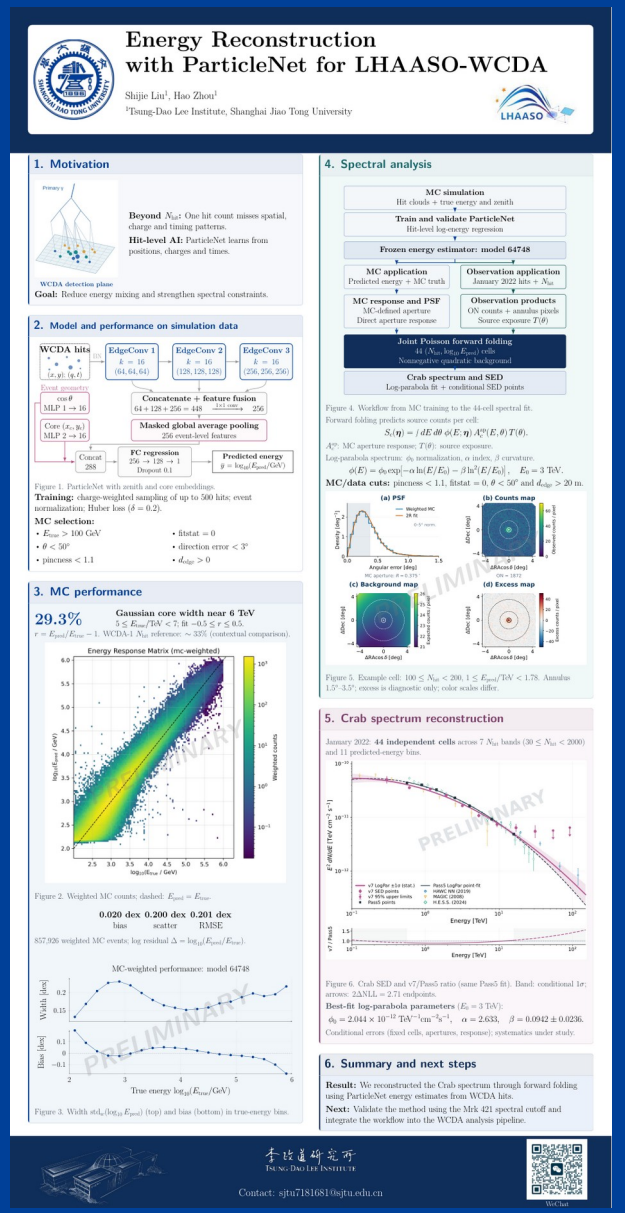
Energy Reconstruction

with ParticleNet for

LHAASO-WCDA

Shijie Liu · Hao Zhou

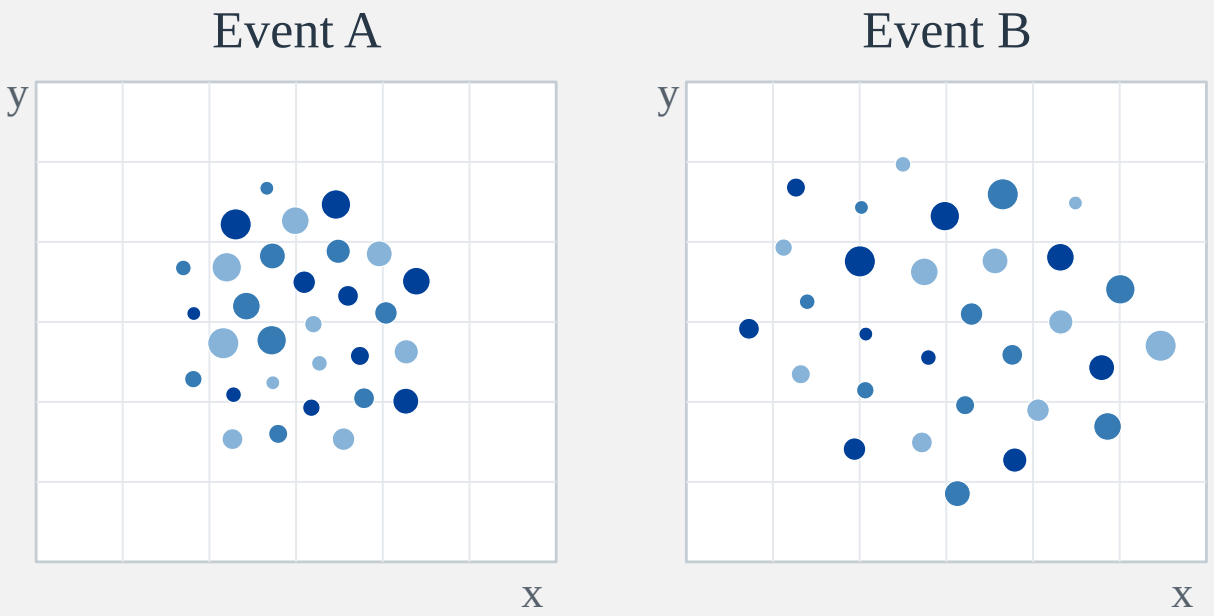
Tsung-Dao Lee Institute
Shanghai Jiao Tong University



Why go beyond Nhit?

Traditional analyses bin events by Nhit.

Two illustrative events, both with Nhit = 30



Size: charge · colour: relative arrival time

Schematic figure

Nhit is only a count.

Spatial, charge and timing patterns are lost.

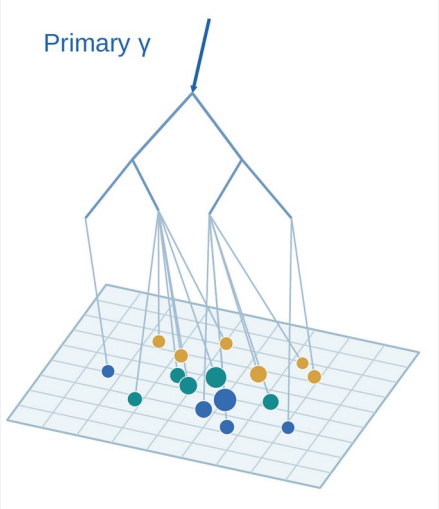
Estimate energy from hits

(x, y, q, t), plus
zenith and core position.

Goal: less energy mixing.

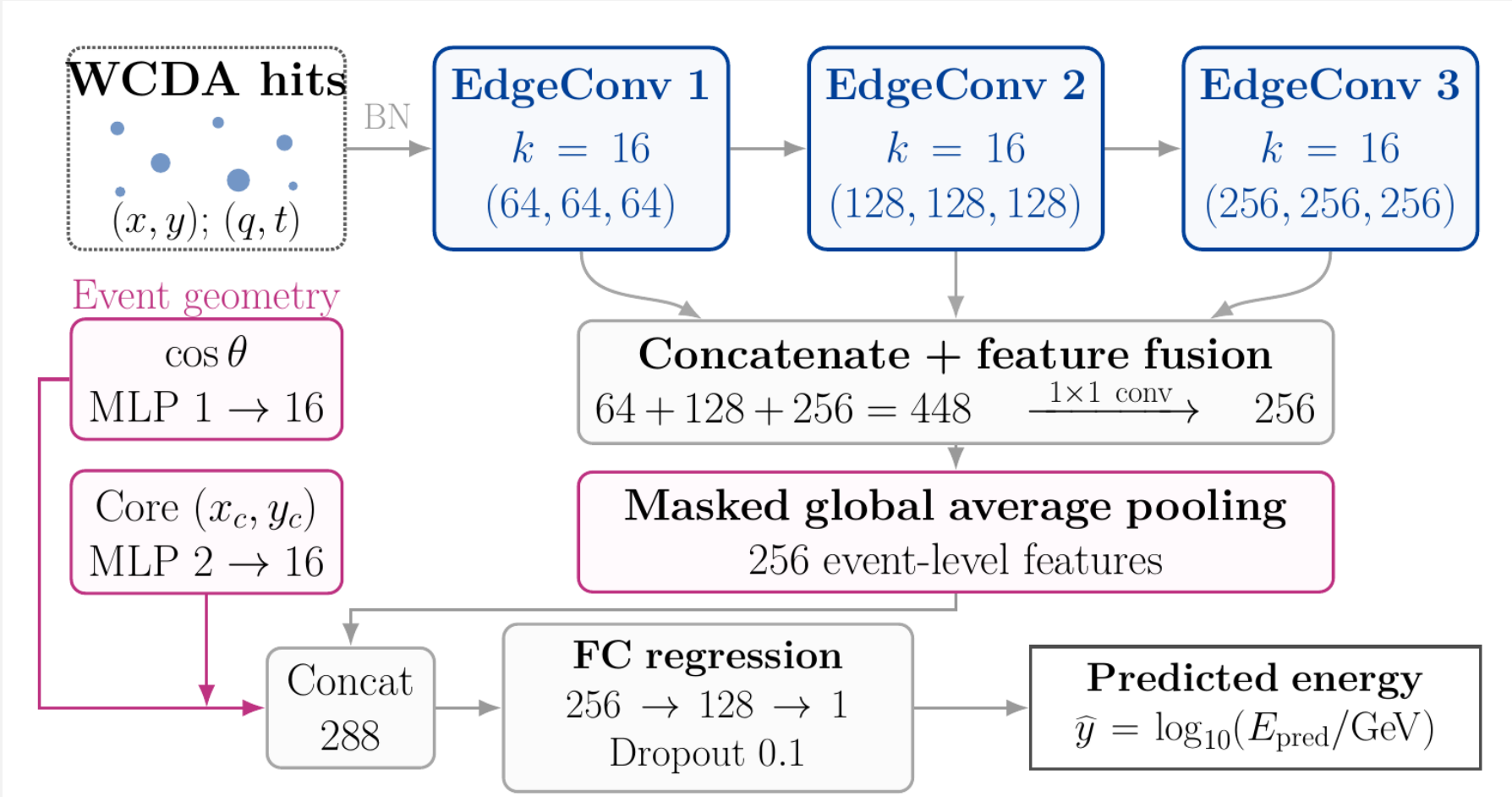
ParticleNet architecture

- **Local hit patterns + event geometry → predicted energy**



Hits: (x, y, q, t)

≤ 500 sampled hits
Sampled by charge
Huber loss: δ = 0.2

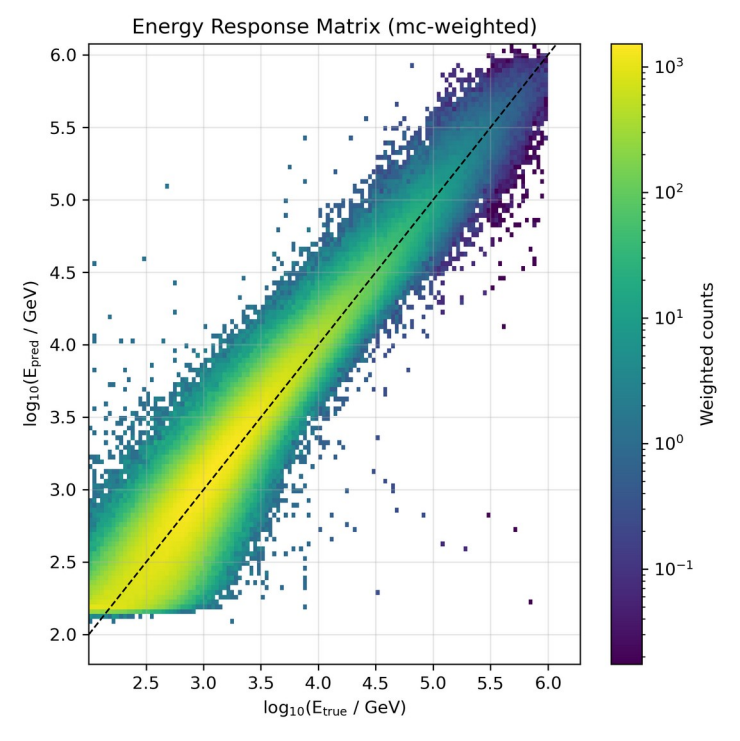


H. Qu and L. Gouskos, Jet tagging via particle clouds, Phys. Rev. D 101, 056019 (2020).

MC performance

- **MC-weighted evaluation · 20 true-energy bins · Preliminary**

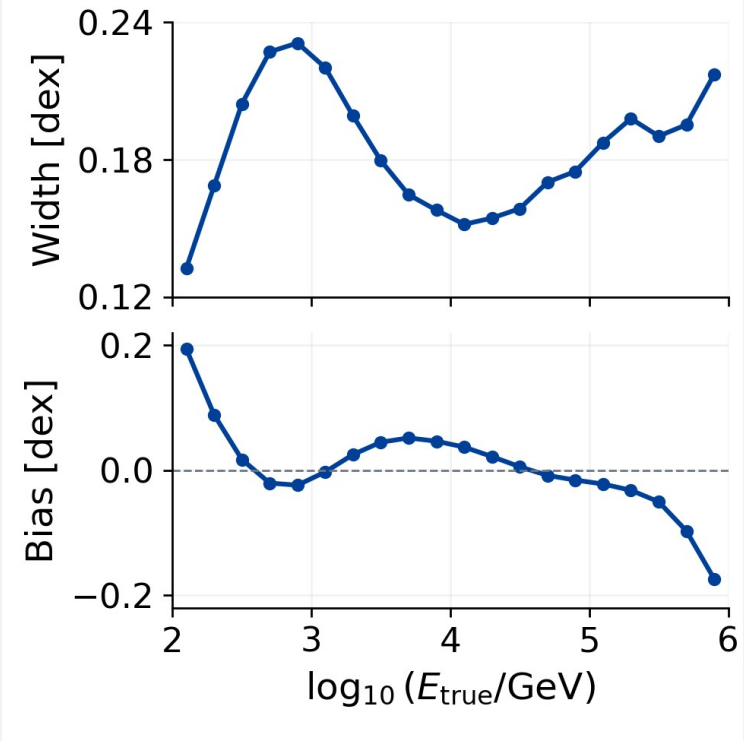
Energy response



857,926 MC events

Evaluation sample

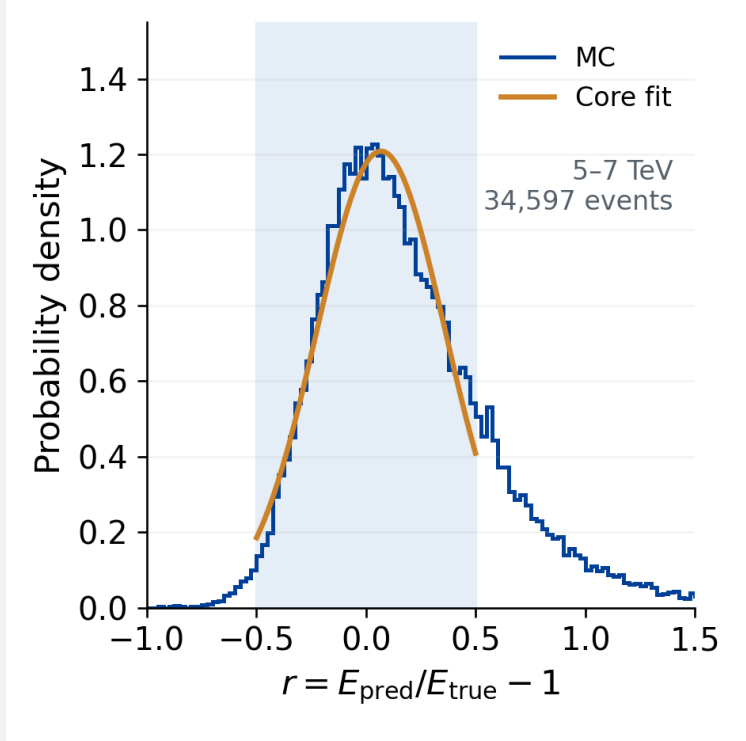
Width and bias



Width: stdw(log$_{10}$ Epred) in each bin

Bias: ⟨log$_{10}$(Epred / Etrue)⟩w

Residual at 5–7 TeV



29.3% Gaussian core

From 1D to 2D

- **Keep the Nhit bins; split each one by predicted energy.**

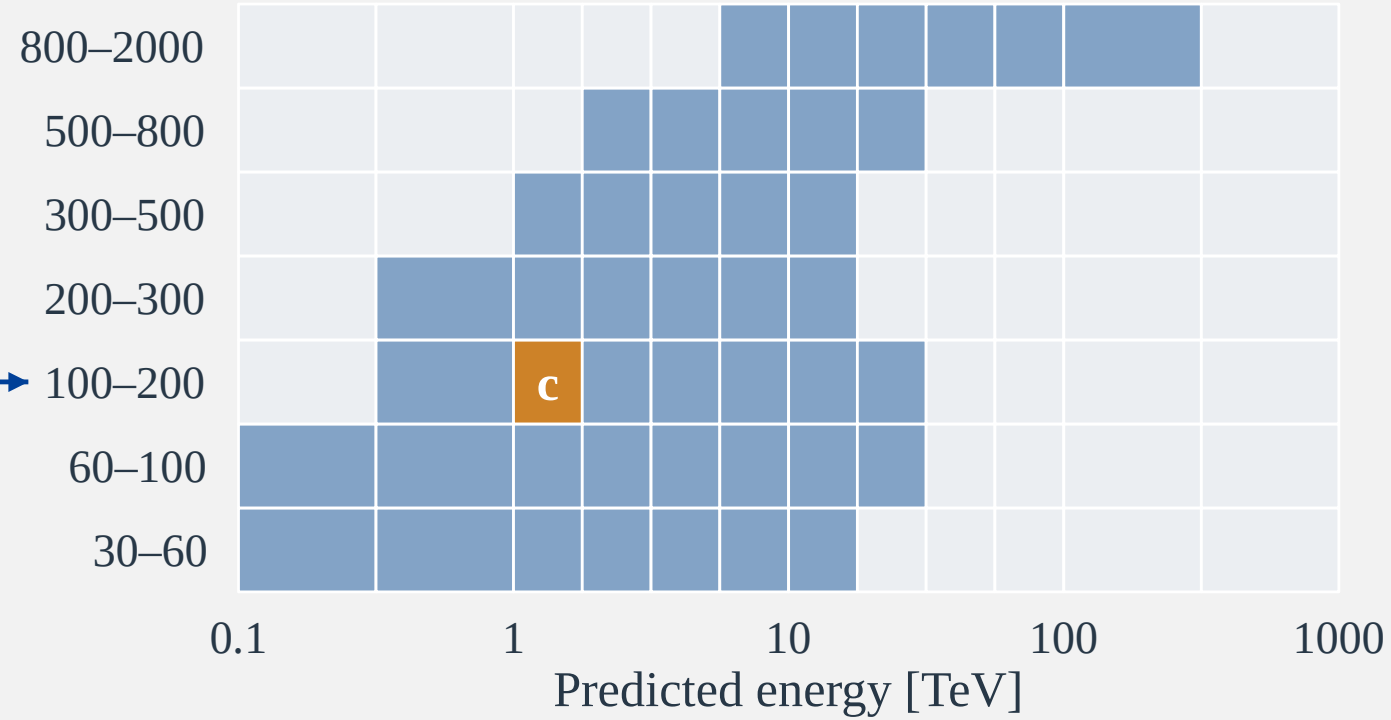
1D: Nhit

800–2000
500–800
300–500
200–300
100–200
60–100
30–60

One axis: Nhit

Split by Epred

2D: Nhit × Epred



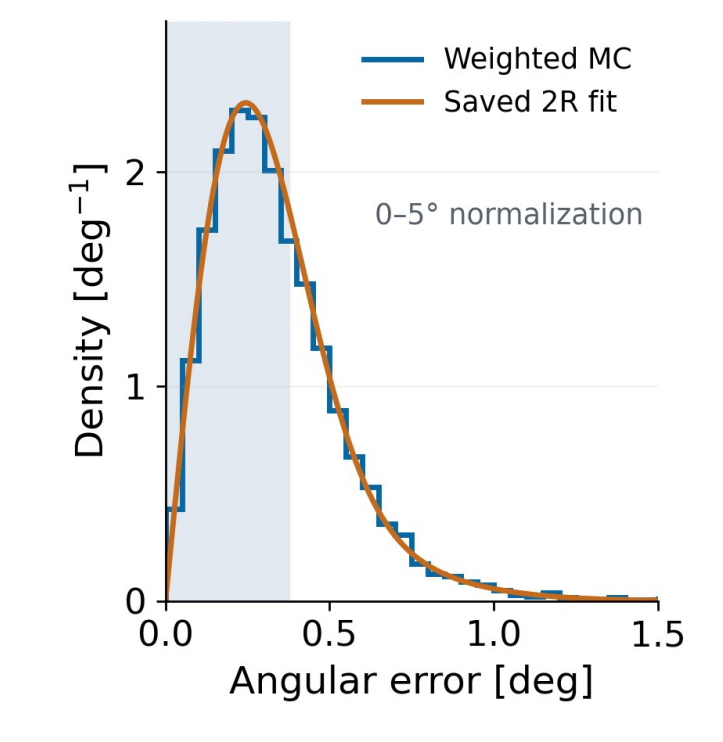
44 MC-selected cells Not selected Example c

Example c: 100 ≤ Nhit < 200 · 1 ≤ Epred / TeV < 1.78

Responses for one cell

- **Example c: 100 ≤ Nhit < 200 · 1 ≤ Epred / TeV < 1.78**

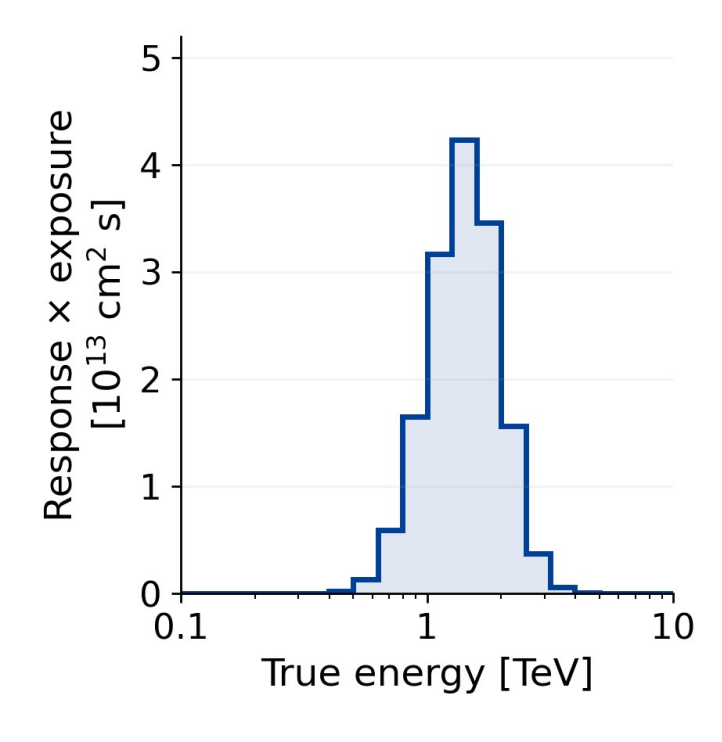
Angular response



Aperture R = 0.375°

Direct MC aperture

Energy response

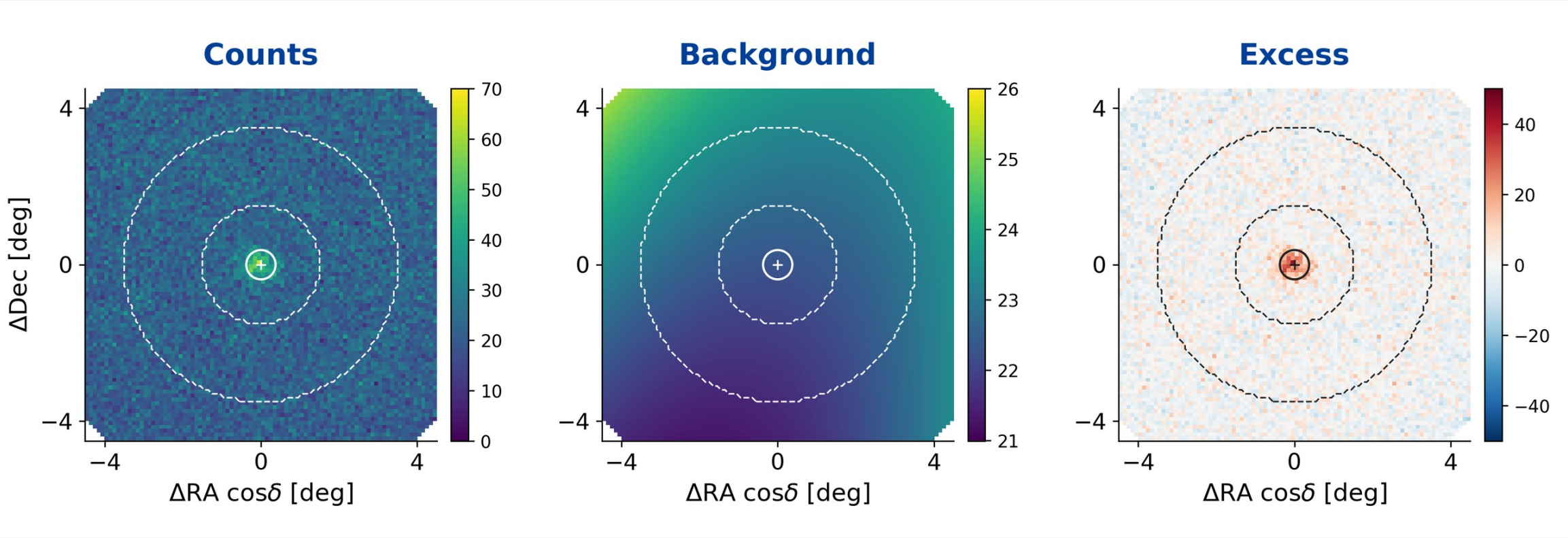


Fold with source spectrum

→ expected source counts

Crab counts in one cell

- **100 ≤ Nhit < 200 · 1 ≤ Epred/TeV < 1.78 · January 2022**



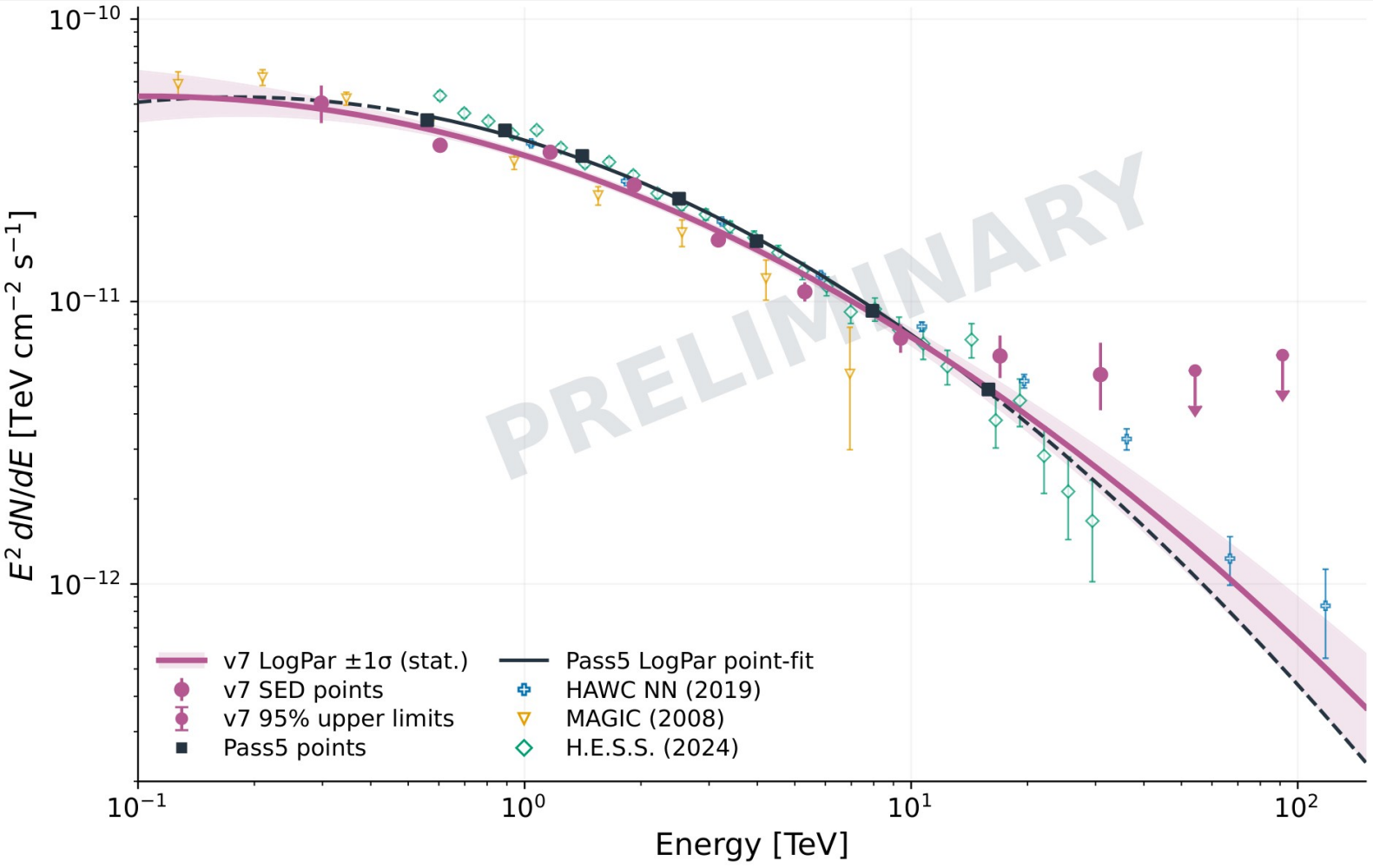
ON = 1872 **Background ≈ 986** **Excess ≈ 886**

ON + annulus counts → joint Poisson fit of source spectrum and background

0.1° pixels; 1.5–3.5° ring; separate color scales. Unsmoothed excess is diagnostic.

Crab spectrum

- **January 2022 data only · 44 cells · Preliminary results**



Log-parabola fit

$E_0 = 3$ TeV

$\alpha = 2.633$

$\beta = 0.094 \pm 0.024$

Conditional stat. errors

Takeaways

- We estimate event energy from individual WCDA hits.
- We built the response and forward-folded the Crab spectrum for January 2022.
- **Next: assess systematics and study the Mrk 421 spectral cutoff.**

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Thanks!

Come say hi at the poster :)

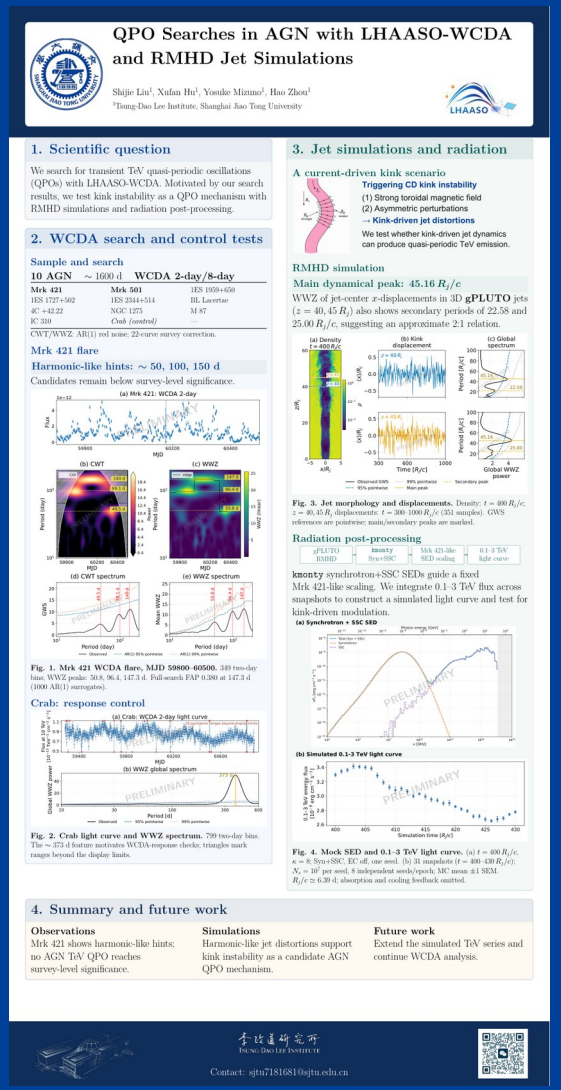
#49 QPO · #50 Energy

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WeChat

#49



#50

