Phenomenology

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TÉCNICO LISBOA

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

European Research Council
Established by the European Commission

LIP's Phenomenology group conducts research bridging theory and experiment in particle and astro-particle physics.

Its research, while independent, is centred around areas in which LIP has active experimental activities and aims to identify areas in which LIP's broader programme may evolve in the future.

Its purpose is to strengthen the impact of the overall LIP programme through the provision of excellent directed phenomenological research.

Phenomenology Group

- created in Jan 2018 as an aggregation of pheno activity within LIP (9.0 FTE)
  - group very involved in creation of 'Big Data and Simulation Competence Centre' at LIP
  - group very involved in the creation of the FCC group [identification of future areas of relevance]
  - developed important synergies with experimental groups
- by 2022 the group has more than doubled its workforce (20.3 FTE) across LIP's poles (Lisboa, Coimbra, Braga) with two main lines of work:
  - New Physics Searches [mostly in Braga]
  - Exploring QCD[mostly in Lisboa]

PEOPLE:: RESEARCHERS


Liliana Apolinário [Lisboa],
Exploring QCD


Nuno Castro [Minho],
New Physics Searches
:: also ATLAS


Grigorios Chachamis [Lisboa],
Exploring QCD


Ruben Conceição [Lisboa],
Exploring QCD
:: also Auger and SWGO

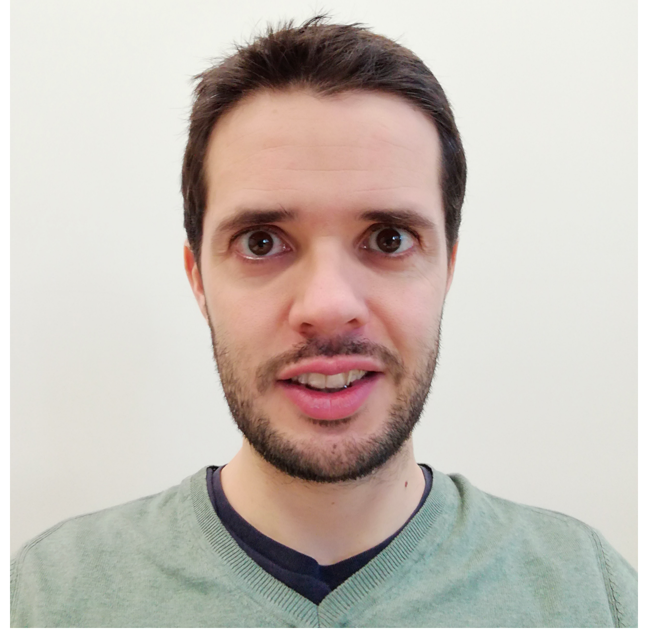

Pietro Faccioli [Lisboa],
Exploring QCD
:: also CMS and COMPASS/AMBER


Ricardo Gonçalo [Coimbra],
New Physics Searches
:: also ATLAS


Pablo Guerrero [Lisboa],
Exploring QCD


Guilherme Milhano [Lisboa],
Exploring QCD

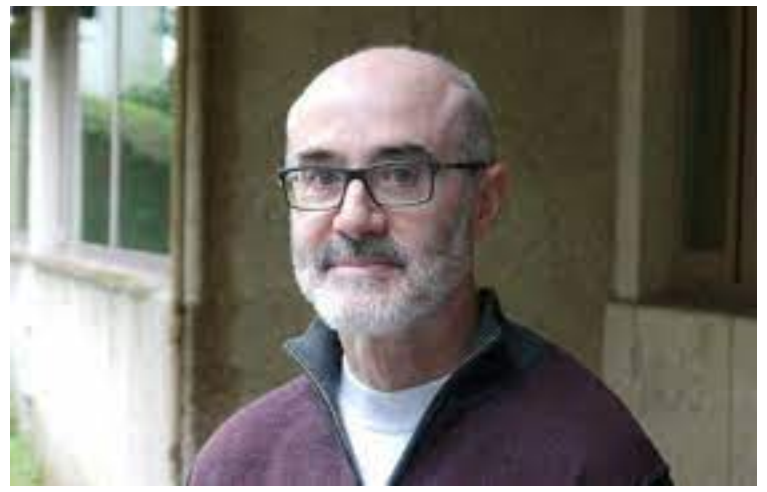

António Onofre [Minho],
New Physics Searches
:: also ATLAS


João Pires [Lisboa],
Exploring QCD


Miguel Romão [Minho],
New Physics Searches
:: also Private Sector

PEOPLE:: EXTERNAL COLLABORATORS [INVOLVED IN FUNDED PROJECTS]

Carlota Andrés, CPhT (France)
:: former LIP



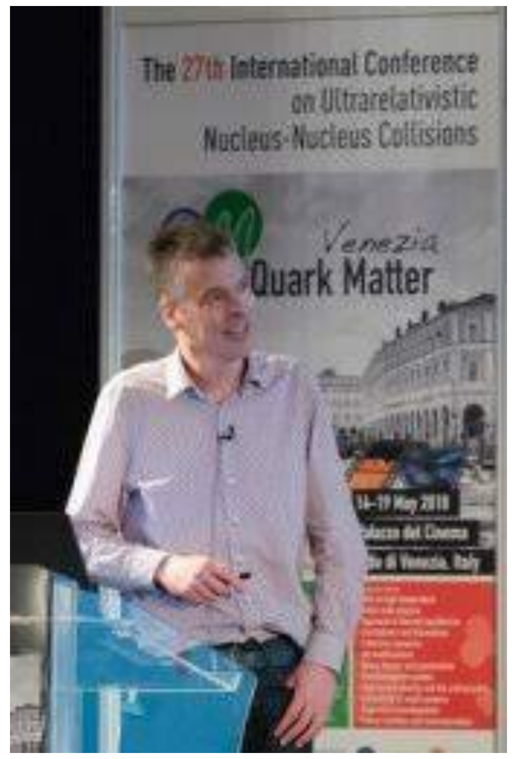
Néstor Armesto, IGFAE (Galicia)

Mikael Chala, U Granada (Spain)

Letícia Cunqueiro, U Roma (Italy)

Fabio Dominguez, IGFAE (Galicia)

Raghav Elayavalli , Yale U (USA)



Marco van Leeuwen, ,Nikhef (The Netherlands)

Carlos Lourenço, CERN

Werner Porod, Würzburg (Germany)

Carlos Salgado, IGFAE (Galicia)

José Santiago, U Granada (Spain)

Korinna Zapp, Lund U (Sweden)
:: former LIP

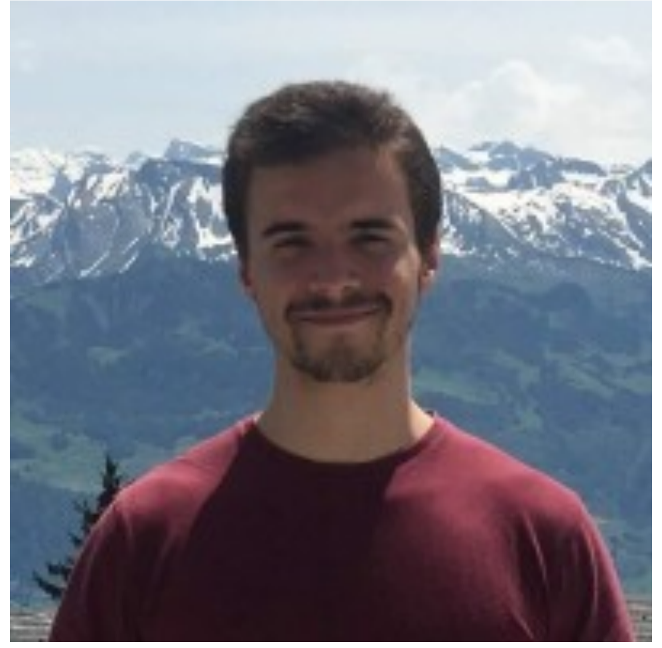
PEOPLE:: DOCTORAL STUDENTS

Mariana Araújo [2019-]
Exploring QCD
:: also CMS

André Cordeiro [2022-]
Exploring QCD
:: with IGFAE

João Gonçalvest [2021-]
Exploring QCD

Guilherme Guedes [2018-]
New Physics Searches
:: with U Granada



João Silva [2021-]
Exploring QCD
:: with IGFAE

Fernando Souza [2022-]
New Physics Searches

Dario Vaccaro [starting Sep 2022]
Exploring QCD

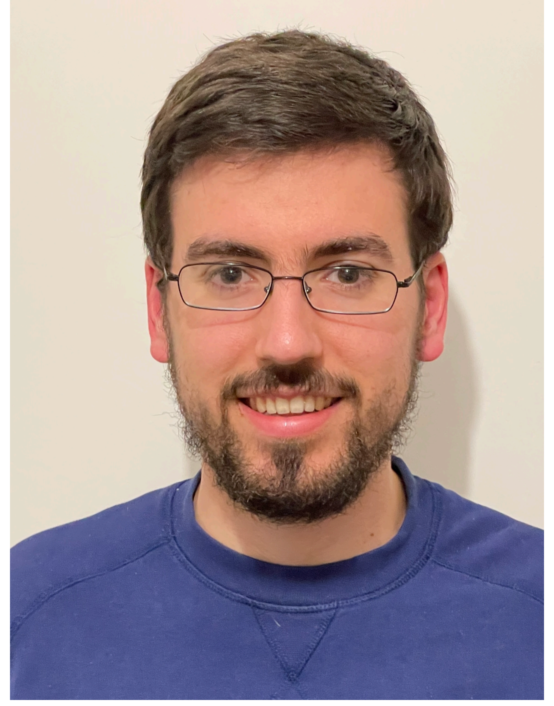
PEOPLE:: MASTER STUDENTS

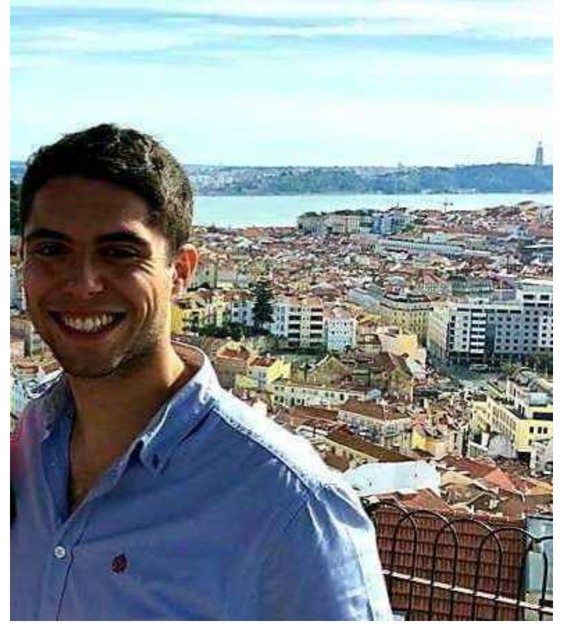

Francisco Barreiro


Tomás Cabrito


João Gomes


Lénea Luís


Manuel Mariano


João Mesquita
:: with Rome


Nuno Olavo
:: with Yale

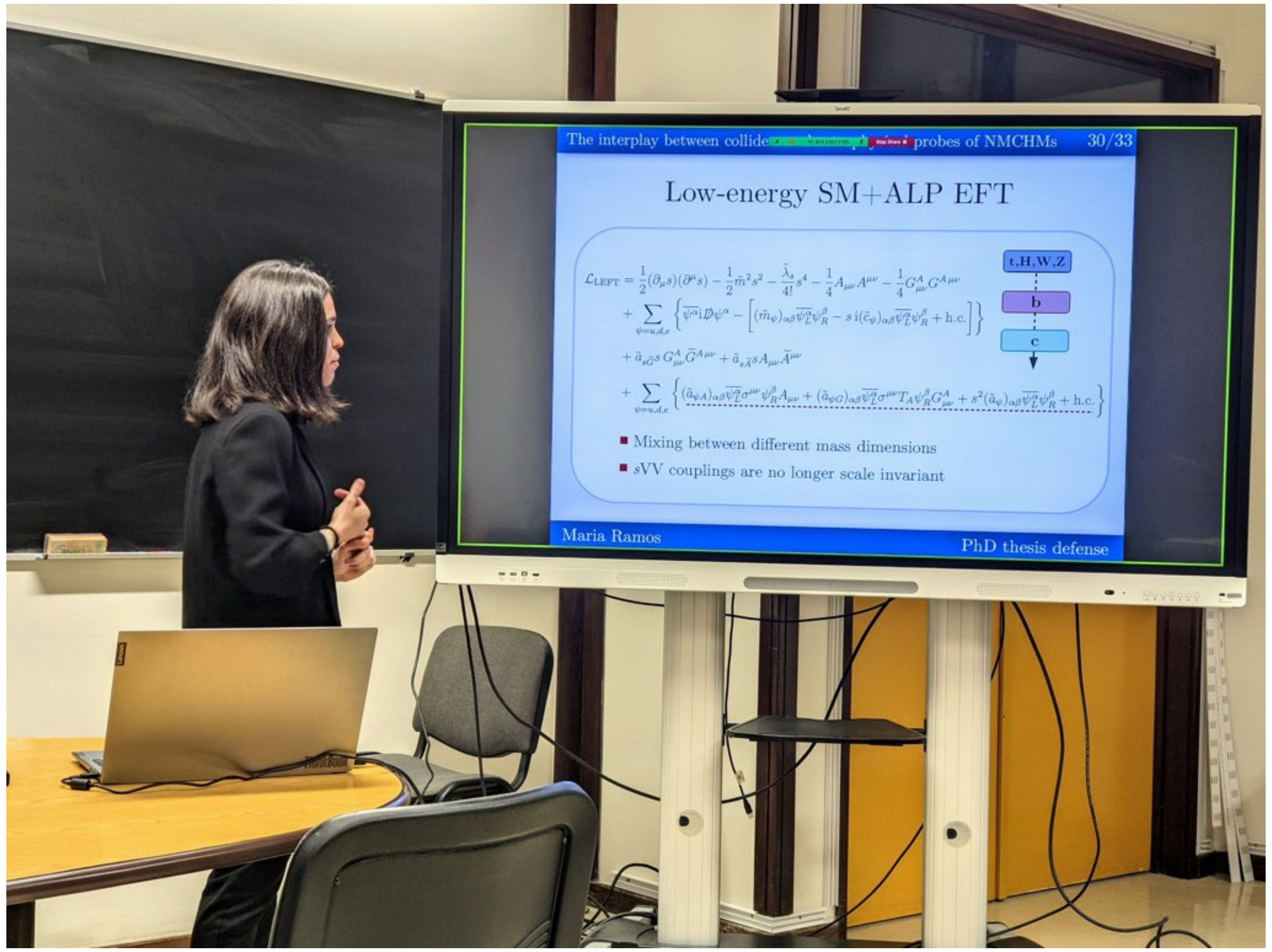
Service to the Scientific Community

- Member of Governing Board of Strong2020 and co-spokesperson of the NA3-JET-QGP WP [G. Milhano]
- Member of International Advisory Committee of the Initial Stages Conference [G. Milhano]
- Theory convener for the LHC Heavy Ion working group at the LPCC (2021-…) [L. Apolinário]
- Experimental convenor (Top contact) for the LHC EFT working group at the LPCC (2020-…) [N. Castro]
- Member of the Scientific Program Committee of PANIC 2021 [G. Milhano]
- Member of the Local Organising Committee of PANIC 2021 [L. Apolinário]
- Member of Local and Program Committee of DIS 2022 [G. Milhano]
- Short Term Scientific Mission Coordinator of COST Action 17137 [L. Apolinário (2018 - 2021); M. Romão (2021 - 2022)]
- National Delegate of COST Action 16201 [J. Pires (2018 -2021)]
- Convener of the 2021 INT program on Probing QCD at high energy and density with jets (2021) [L. Apolinário]
- Convener of Heavy-Ions Parallel Session of EPS-HEP 2021 [L. Apolinário]
- Convener of the 12th International workshop on MPI@LHC (2021) [L. Apolinário (Heavy-Ions) and G. Chachamis (High Multiplicities)]
- Member of International Advisory Committee of 13th International workshop on MPI@LHC (2022) [G. Chachamis]
- Portuguese representative in the ECFA Early-Career Researchers Panel (2021-2022) [L. Apolinário]

Funding

- diversified funding portfolio
  - national and EU
  - different PIs
- national funding [on-going]
  - THbridgeEXP-II [CERN/FIS-PAR/0032/2021] [until 2024] [G.Milhano]
  - TopHiggsPheno [CERN/FIS-PAR/0037/2021] [until 2023] [A. Onofre]
  - Quarkonia [CERN/FIS-PAR/0010/2019] [until 2022] [P. Faccioli]
  - QCDridge [EXPL/FIS-PAR/1195/2021] [until 2023] [G. Chachamis]
  - TimeJet [EXPL/FIS-PAR/0905/2021] [until 2023] [L. Apolinário]
- EU funding [on-going]
  - YoctoLHC ERC Advanced Grant (beneficiary) [until 2024] [C.Salgado (IGFAE); G. Milhano]
  - STRONG-2020 (NA3-JET-QGP WP coordination) [until 2023] [G. Milhano]

A MAJOR GROUP MILESTONE



First PhD thesis started and concluded in the group

Maria Ramos (Jan 2022)

The interplay between collider and astrophysical probes of non-minimal composite Higgs snapshots

A GLOBAL APPROACH TO PHYSICS BSM

G. Guedes, J. Santiago :: 2107.03429 [hep-ph]; M. Chala, GG., M. Ramos, JS :: 2012.09017 [hep-ph]; MC, GG, MR, JS :: 2106.05291 [hep-ph]; MC, A. Carmona, GG :: 2112.12724 [hep-ph]; S. Bakshi, MC, AC, GG :: 2205.03301 [hep-ph]

- Model-driven approach to search for specific signatures
  - dedicated search for Vector Like Leptons with an exotic decay channel
  - explores complementarity between collider and direct DM probes
- Model-independent approach – extending the SMEFT

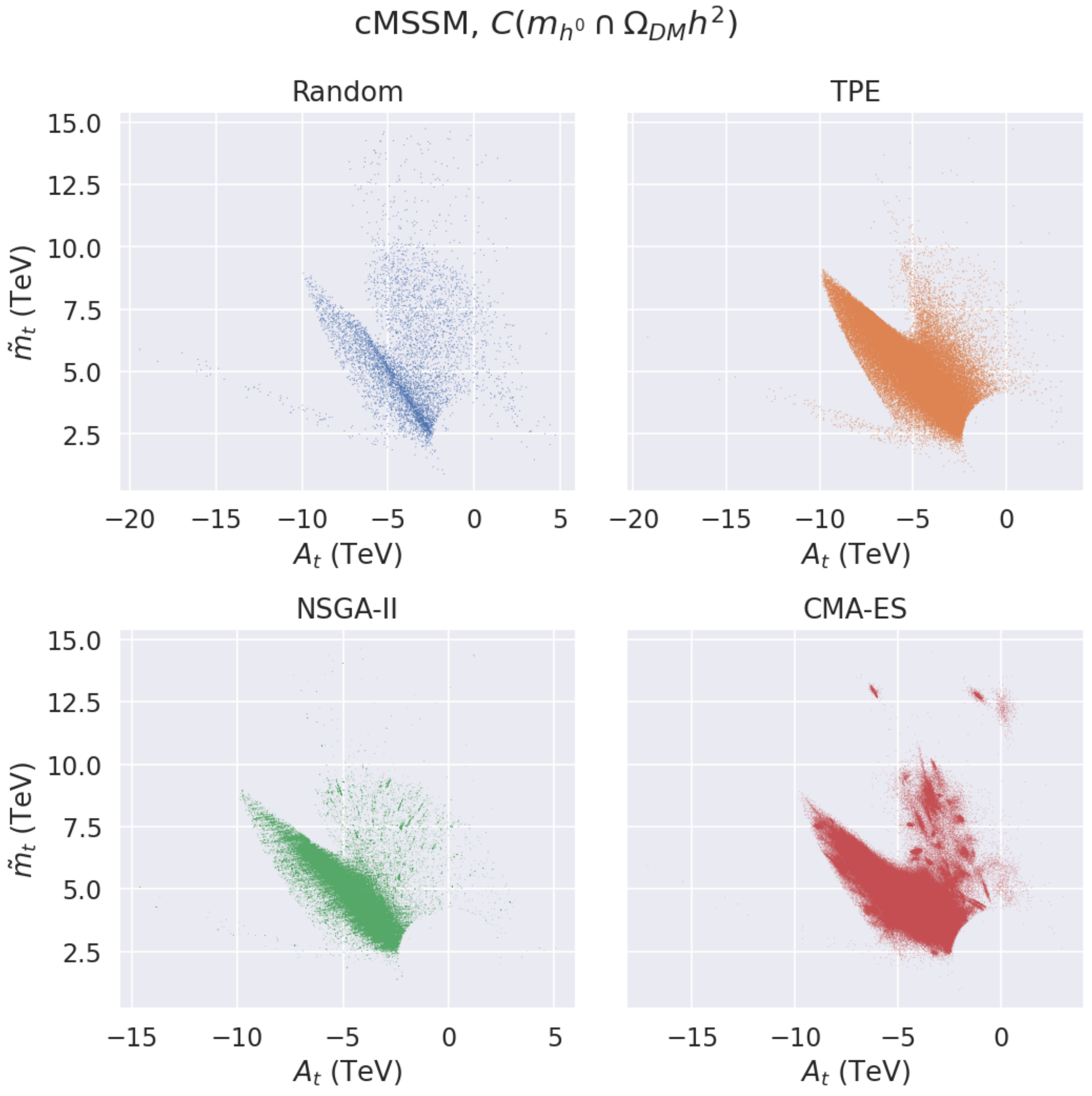
$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \frac{\mathcal{L}_{5+s}}{\Lambda} + \frac{\mathcal{L}_6}{\Lambda^2} + \frac{\mathcal{L}_8}{\Lambda^4} + \cdots$$

  - At dimension-5: extend the SMEFT with an axion-like particle, s.
  - At dimension-6: classification of UV extensions which can explain (g-2) of the muon at one-loop
  - At dimension-8: construction of Green’s basis and calculation of RGEs

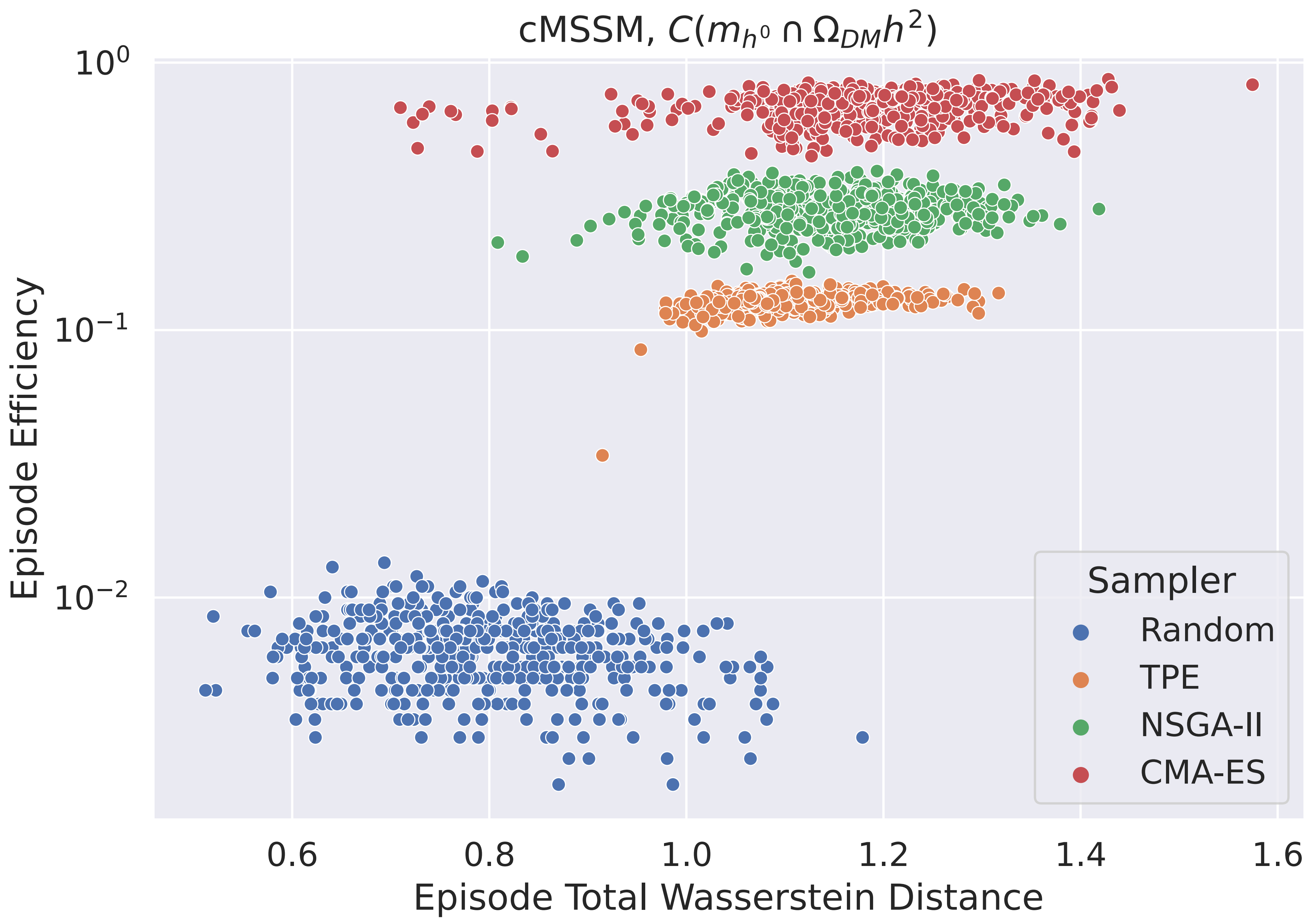
Efficient exploration of parameter spaces of BSM models

F. Souza, M. Romão, N. Castro, M.Nikjoo, W. Porod :: 2206.09223 [hep-ph]

- use AI/ML to efficiently explore parameter space of cMSSM e pMSSM without any prior knowledge [no training data]



different density artefacts produced by different samplers which can be understood [see paper for details]

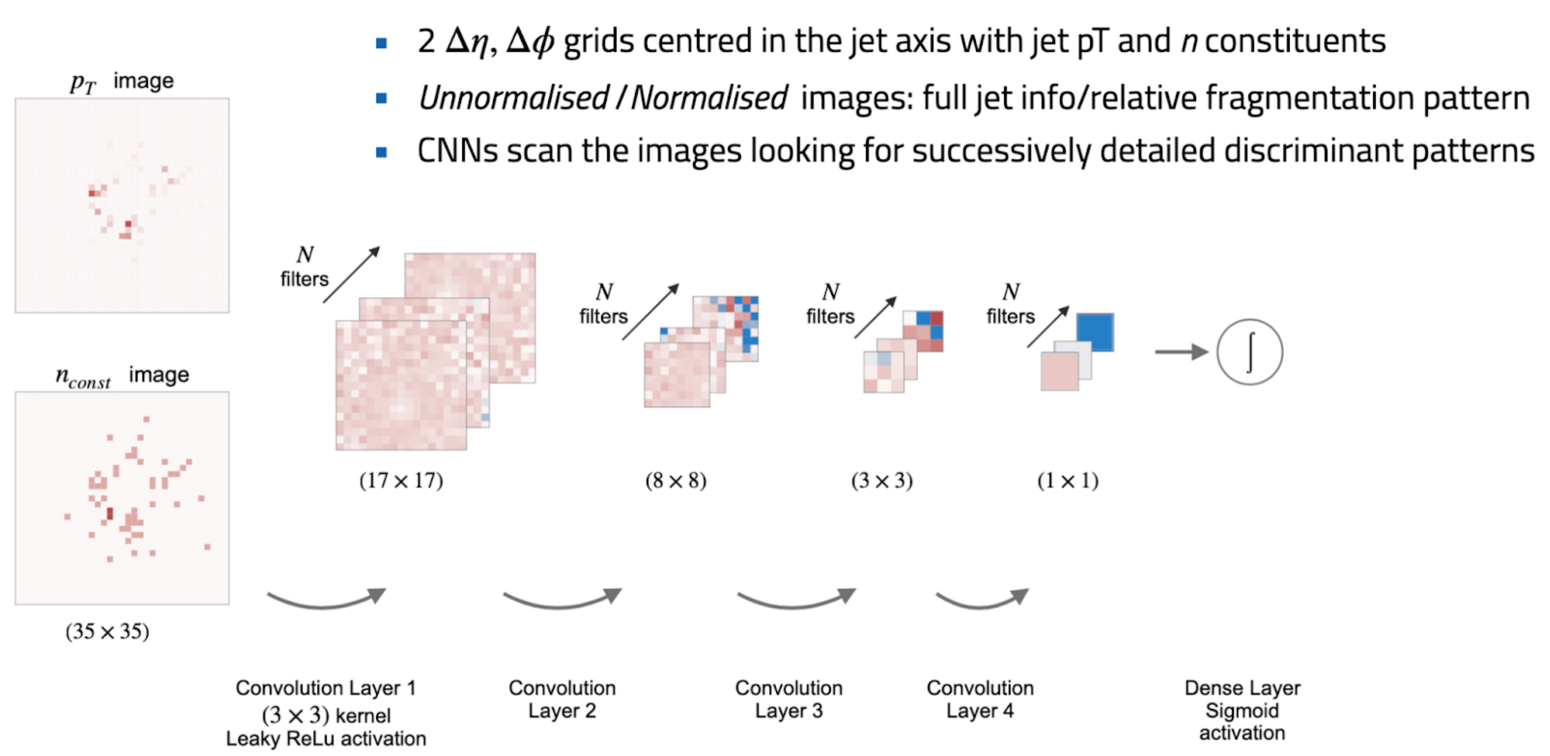


two-order of magnitude improvement in sampling efficiency with appropriate coverage of parameter space

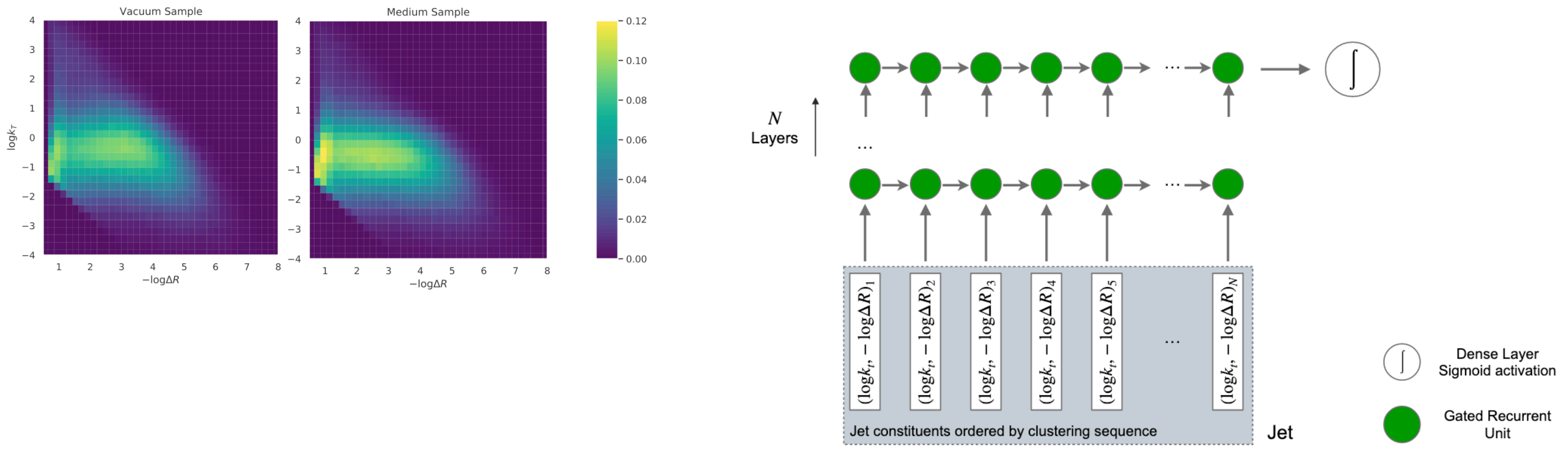
CLASSIFICATION OF QUENCHED JETS

L. Apolinário, N. Castro, M. Romão, G. Milhano, R. Pedro, F. Peres, :: 2106.08869 [hep-ph]

- distinguish in heavy ion collisions strongly modified jets from unmodified without second-party information
- explore jet representations with varying theoretical input for different ML/DL architectures
  - jet images :: Convolutional Neural Network (CNN)



jet images :: CNN

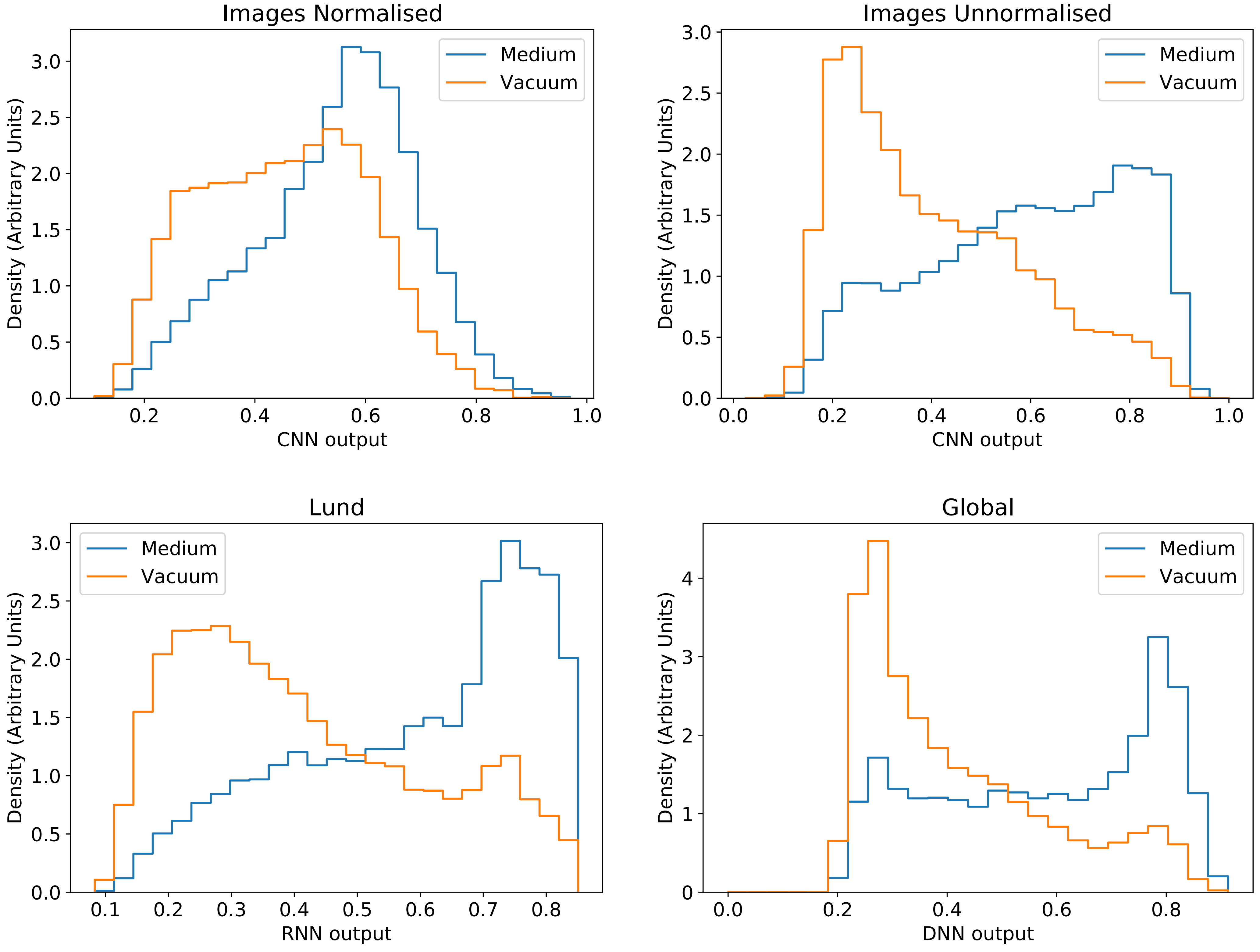


Lund plane coordinates [(kT,ΔR) of clustering steps] :: RNN

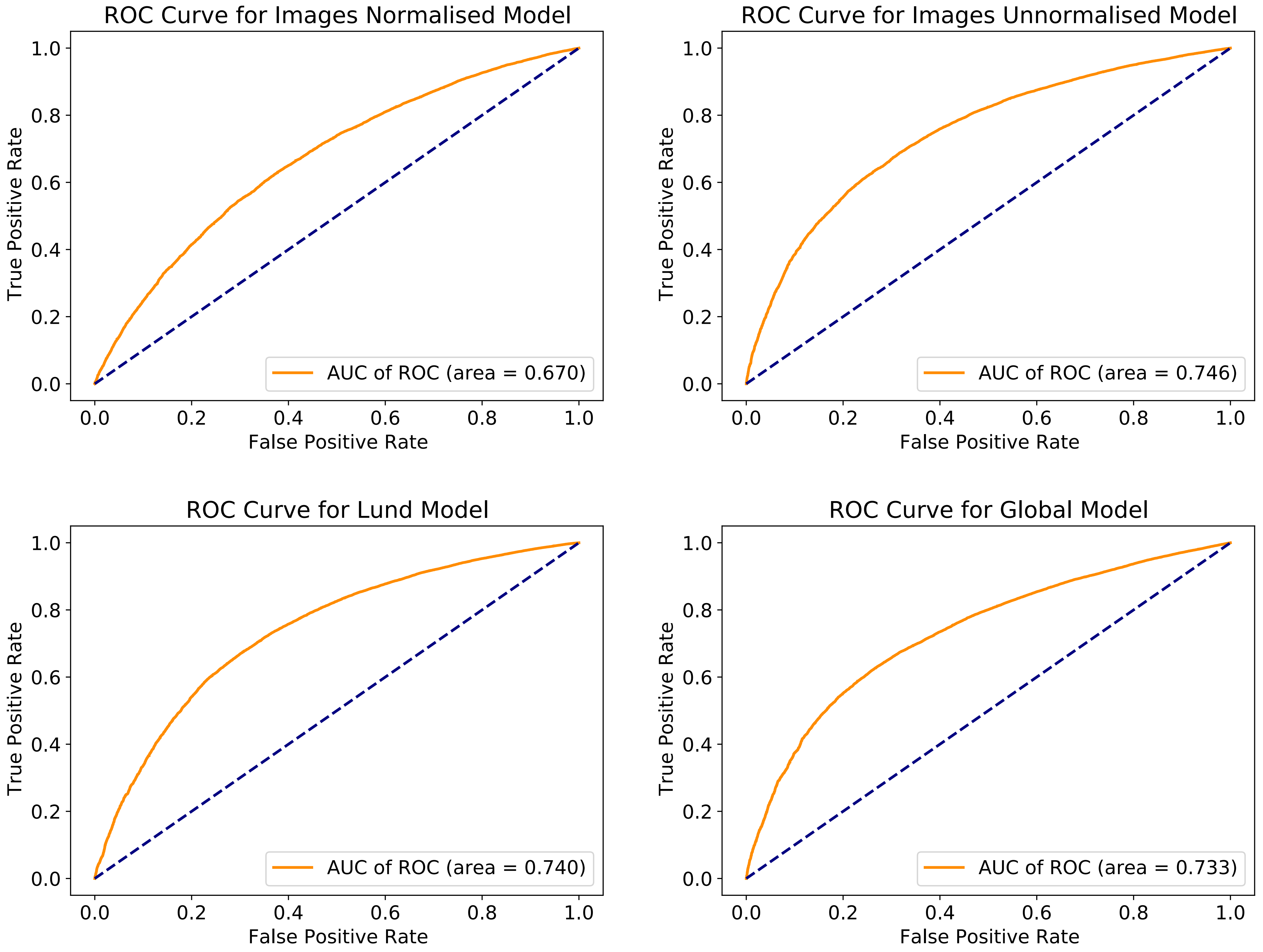
tabular data [p_T and multiplicity] :: DNN

CLASSIFICATION OF QUENCHED JETS

L. Apolinário, N. Castro, M. Romão, G. Milhano, R. Pedro, F. Peres, :: 2106.08869 [hep-ph]



network outputs [discriminant]



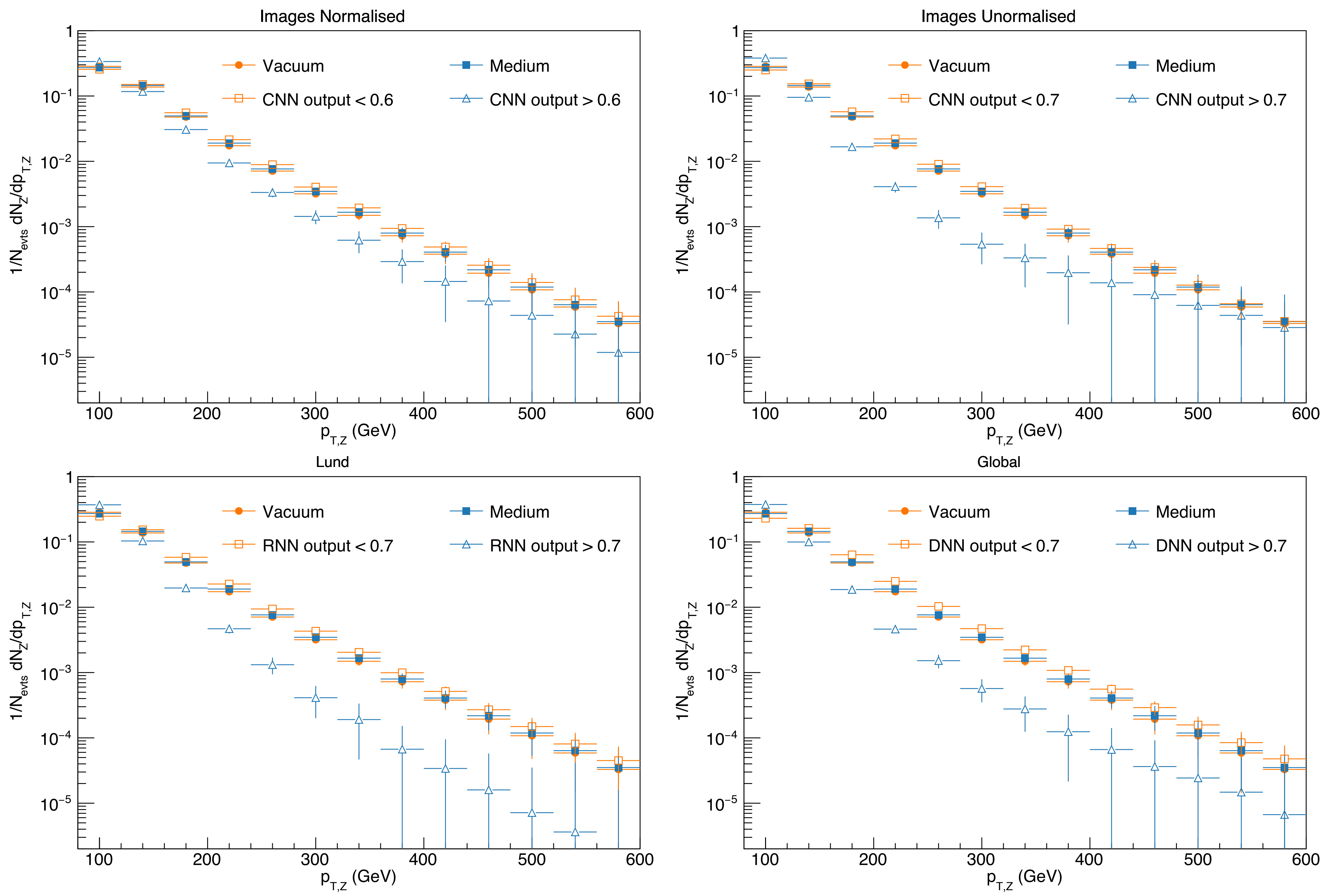
performance

worse performance but more robust

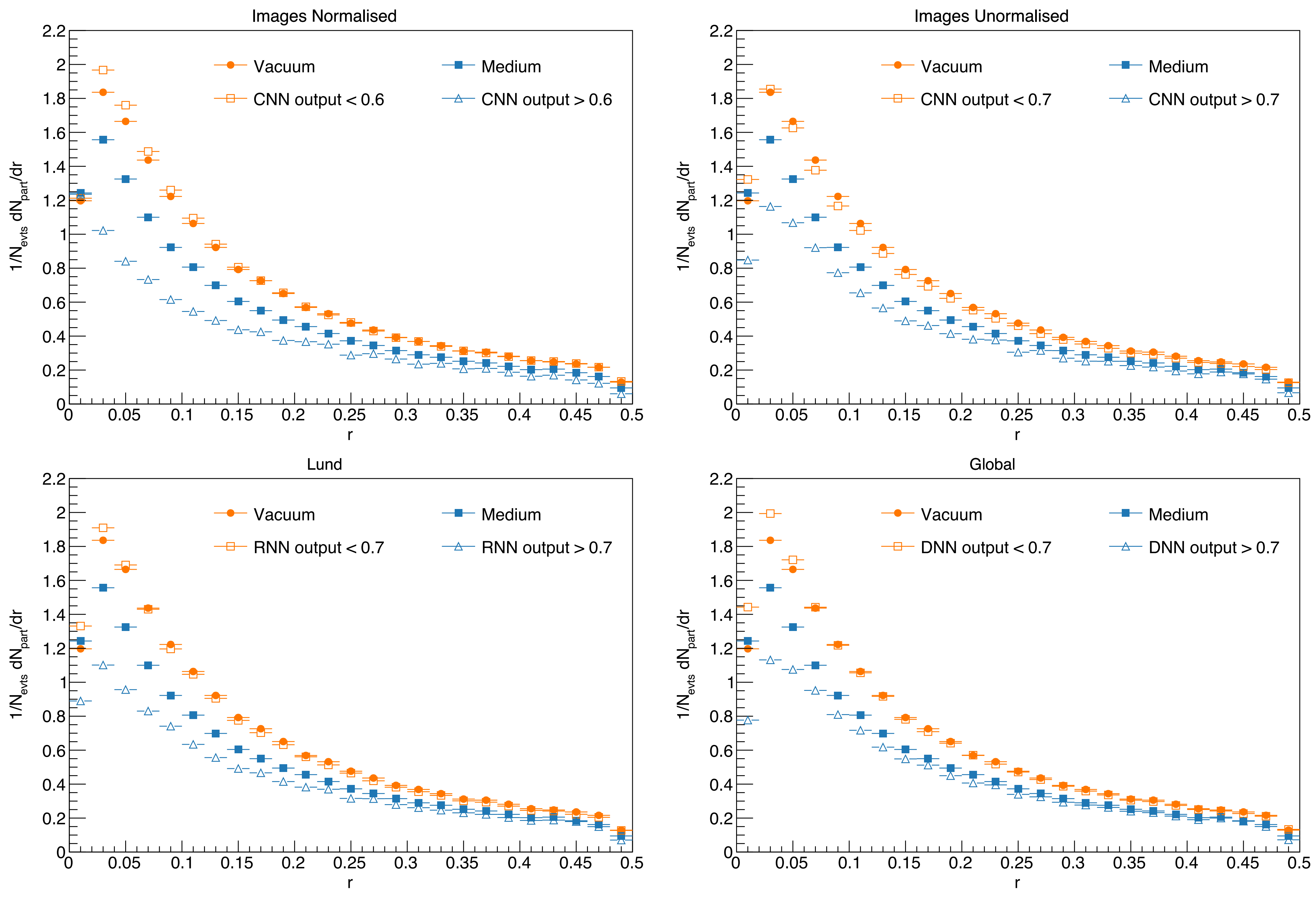
Model	$p_{T,jet}$ >30 GeV	$p_{T,jet}$ >125 GeV
Normalised jet images CNN	0.67	0.65
Unnormalised jet images CNN	0.75	0.68
Lund sequences RNN	0.74	0.69
Global DNN	0.73	0.64

CLASSIFICATION OF QUENCHED JETS

L. Apolinário, N. Castro, M. Romão, G. Milhano, R. Pedro, F. Peres, :: 2106.08869 [hep-ph]



transverse momentum spectrum



jet profile

pp jets reliably identified as unmodified
purified sample of modified jets in AA

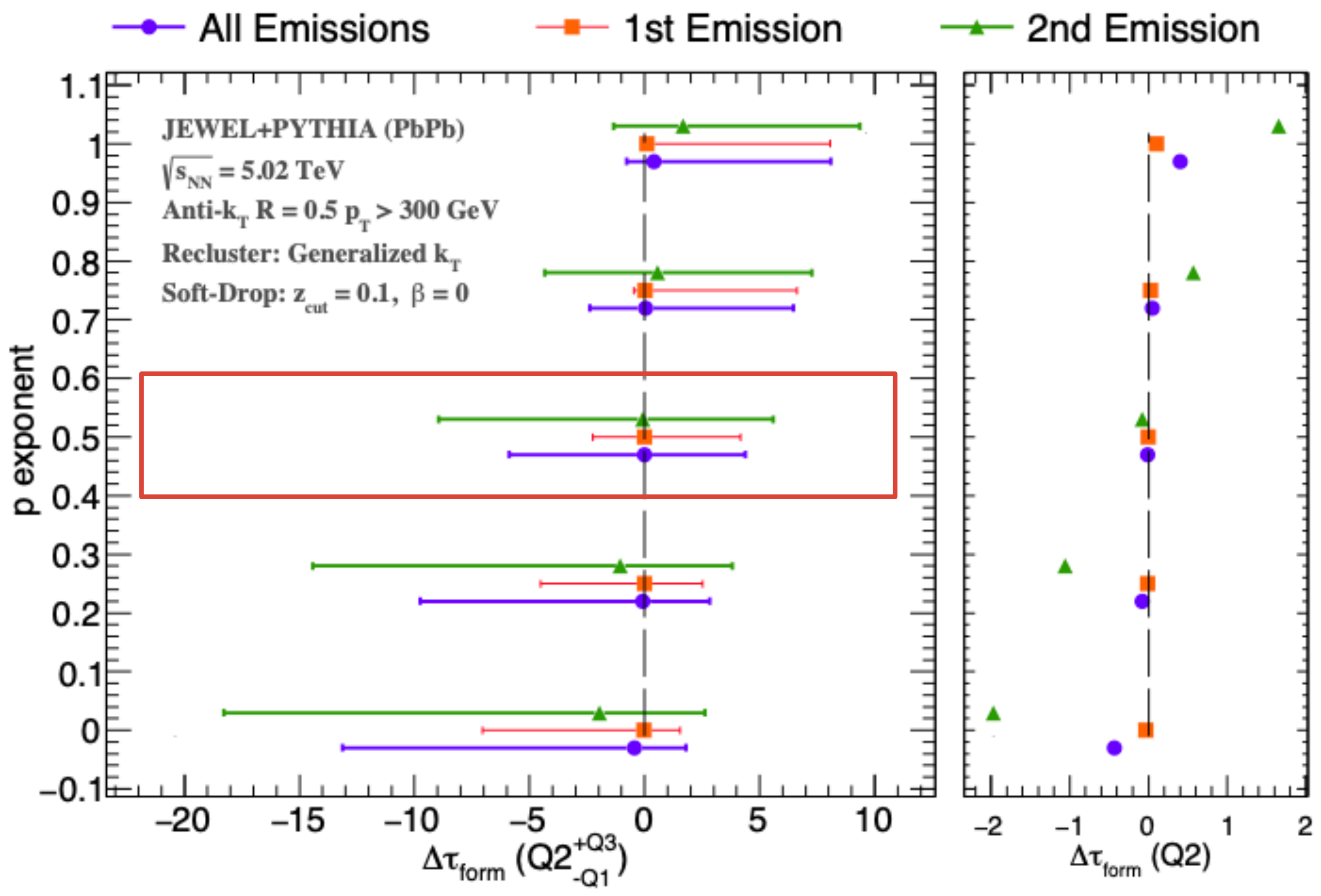
JET TIME RECLUSTERING

L. Apolinário, A. Cordeiro, K. Zapp :: 2012.02199 [hep-ph]

- recluster jets in formation time [p=0.5 in gen-kT measure]

$$d_{ij} \sim p_{t,i}\frac{\Delta R_{ij}^2}{R^2} \sim p_{t,i}\theta^2 \sim \frac{1}{\tau_{\rm form}}$$

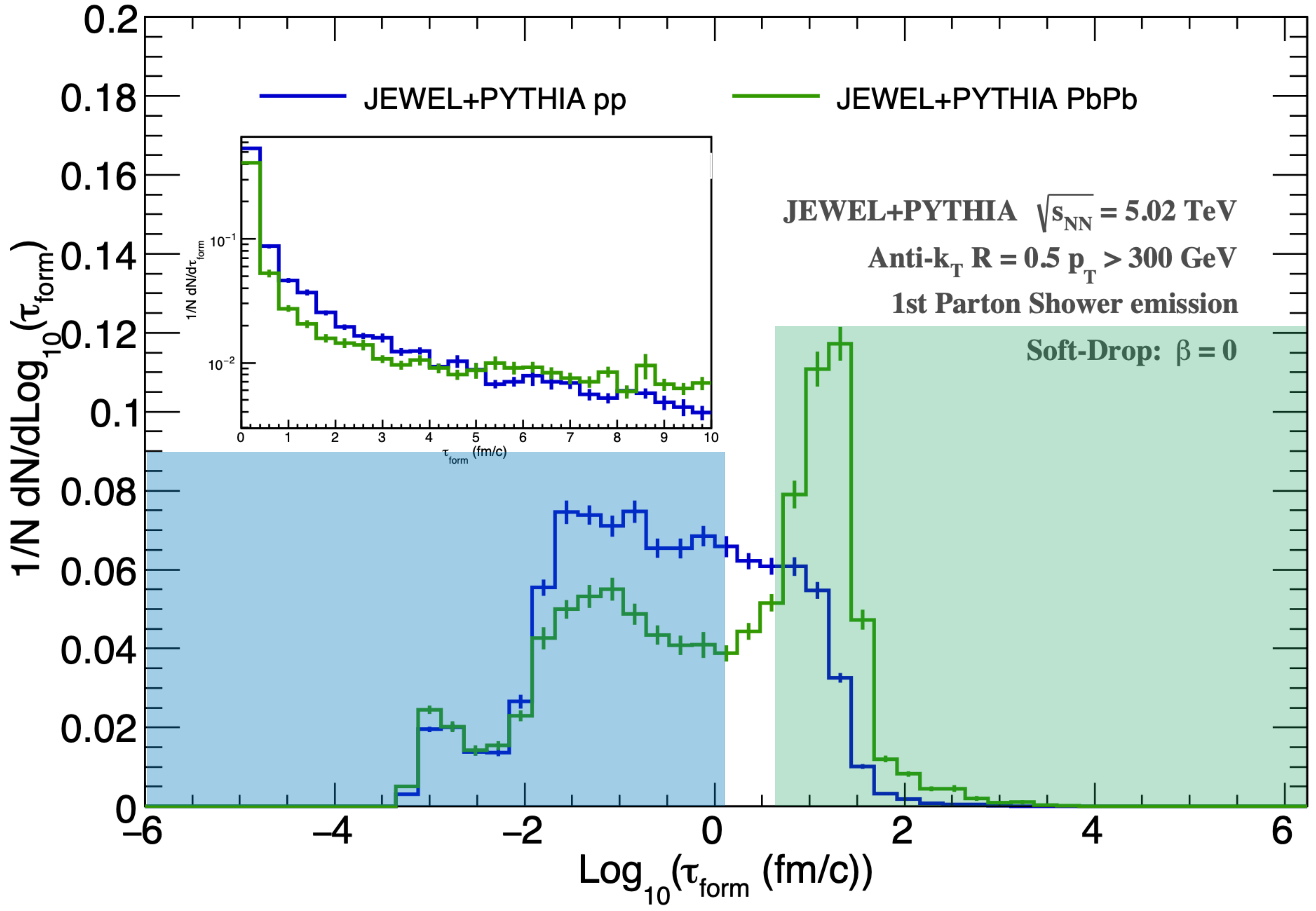
- maximizes correlation between MC parton shower and jet reclustering info



$$\Delta\tau_{\rm form} = \tau_{\rm form}^{\rm Parton\ Shower} - \tau_{\rm form}^{\rm Unclustering}$$

Allows selection of two populations

- "Early" jets: τ < 1 fm/c (strongly modified)
- "Late" jets: τ > 3 fm/c (weakly modified)



A jet quenching classifier:

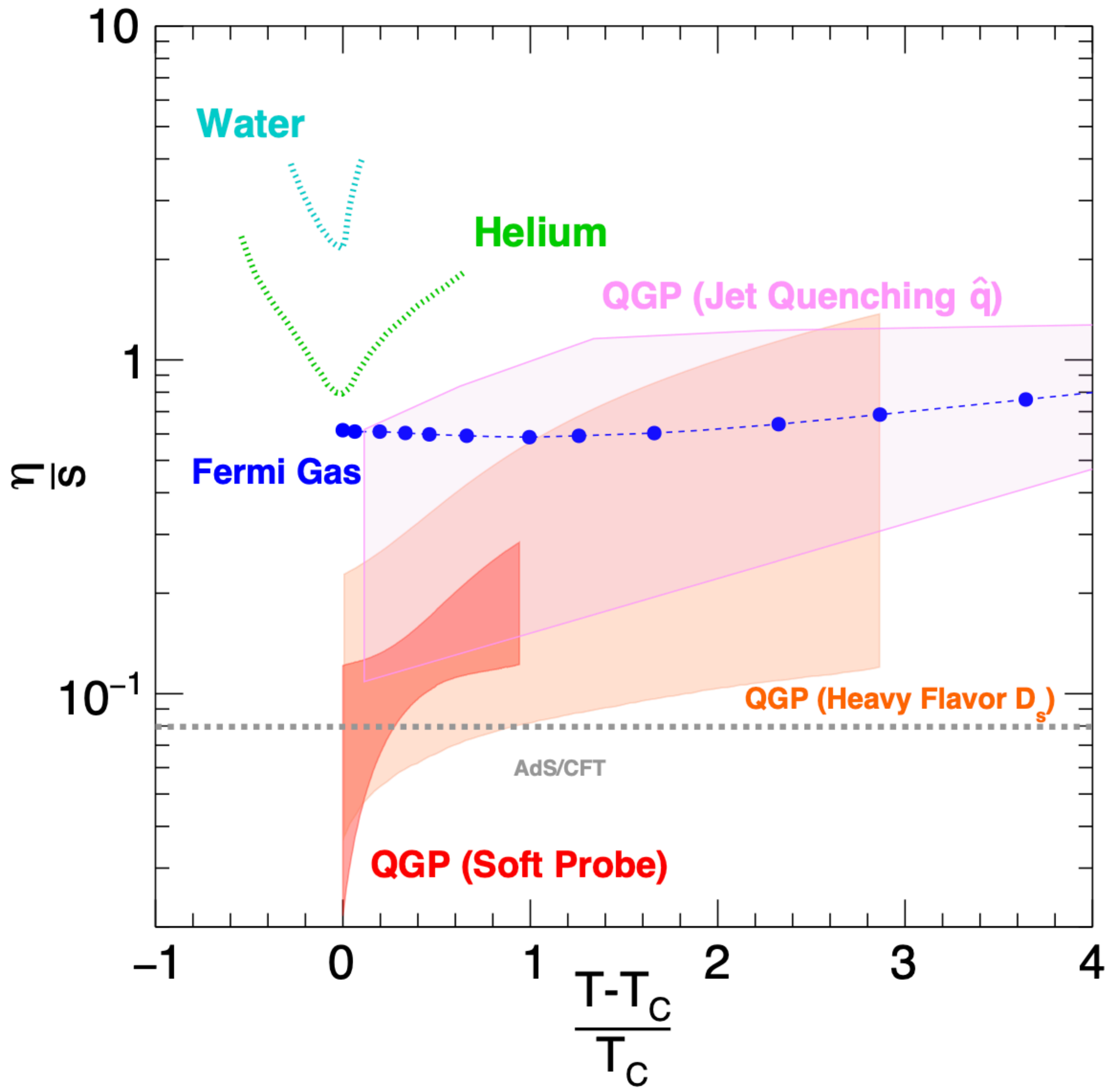
Important step towards a tomographic analysis of the QGP!

[REVIEW] HEAVY-QUARKS AND JETS AS PROBES OF THE QGP

L. Apolinário, M. Winn, Y-J. Lee :: 2203.16352 [hep-ph] to appear in Prog.Nucl.Part.Phys

Address in depth fundamental questions in heavy-ion collisions at RHIC and LHC

- How factorized are the initial-state from final-state effects (colliding nuclei)?
- How can we infer, from data-driven observations, the elementary QCD parton-medium interactions (jet quenching)?
- What are we learning about the Quark-Gluon Plasma?
- How is the Quark-Gluon Plasma formed and evolving?
- Are hadronization mechanisms changed by the presence of a Quark-Gluon Plasma?
- (....)



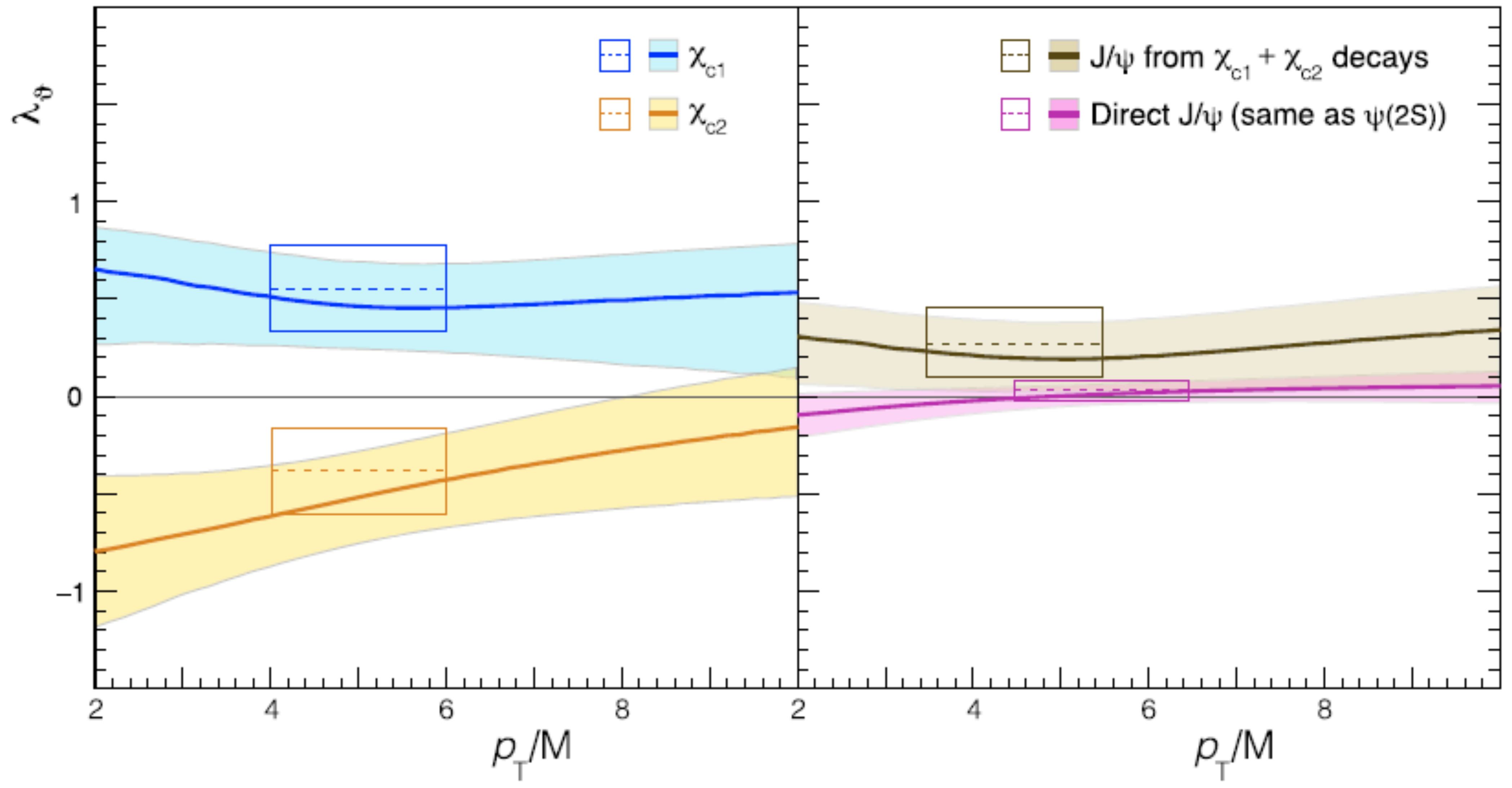
Towards a unified QCD description from soft to hard probes of the QGP

QUARKONIA

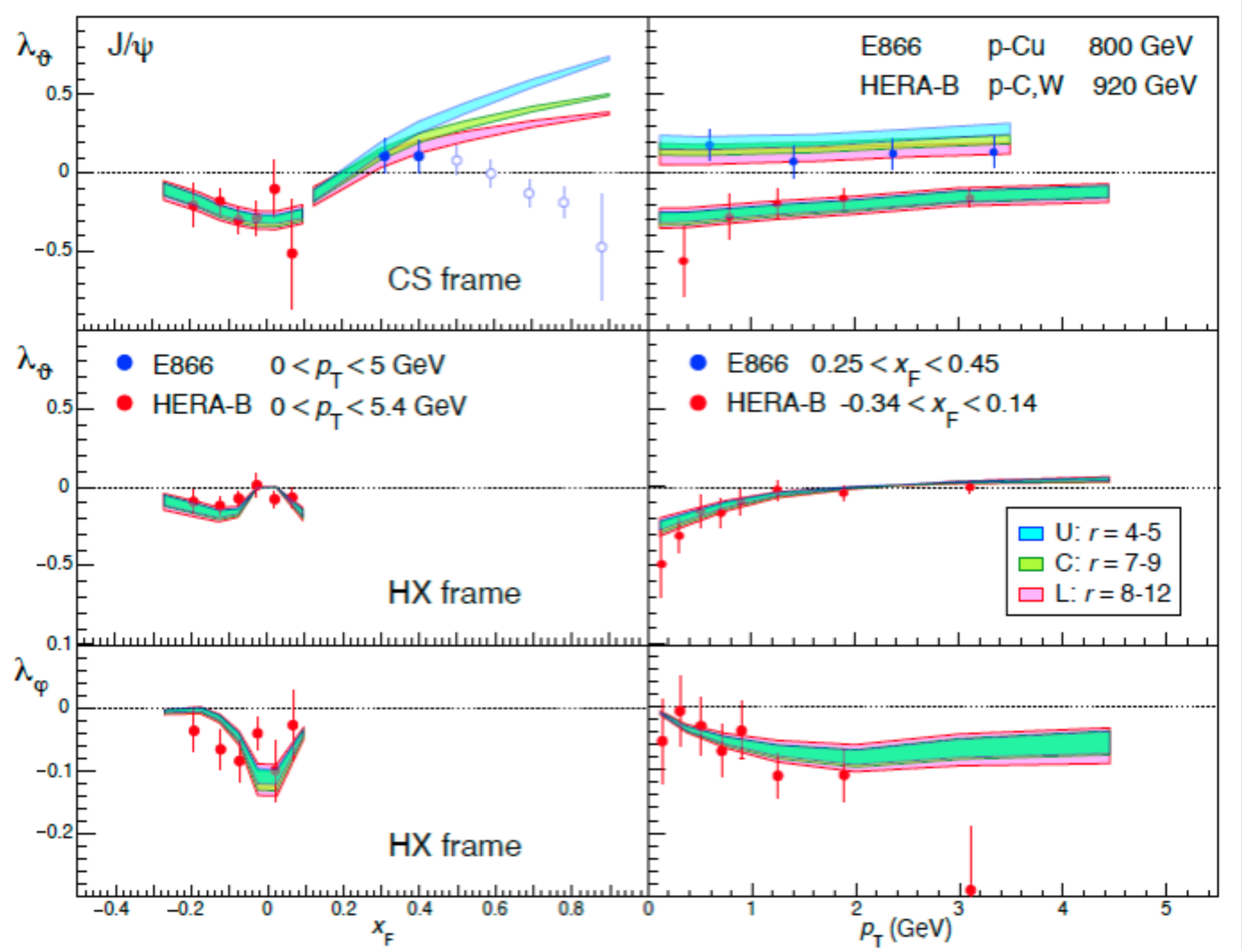
P. Faccioli, C. Lourenço, T. Madlener :: 2006.15446 [hep-ph]; M. Araújo,P. Faccioli, C. Lourenço :: to appear soon

Global studies of quarkonium production with:

LHC pp data

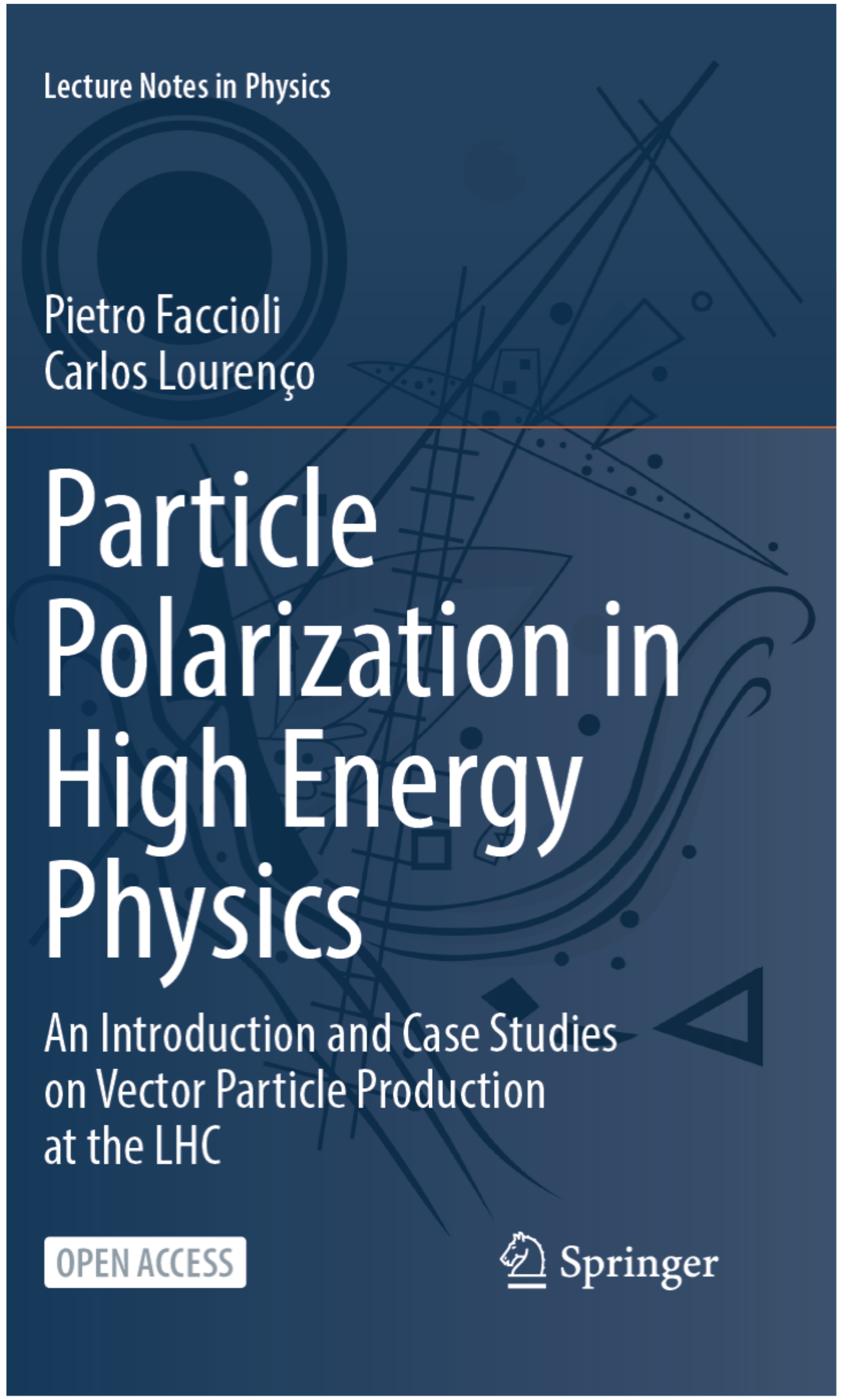


First data-driven determination of the χ_{c1}, χ_{c2} and *direct* J/ψ polarizations



low-p_T data (p-A and π-A) including predictions for AMBER

[LECTURE NOTES] QUARKONIA



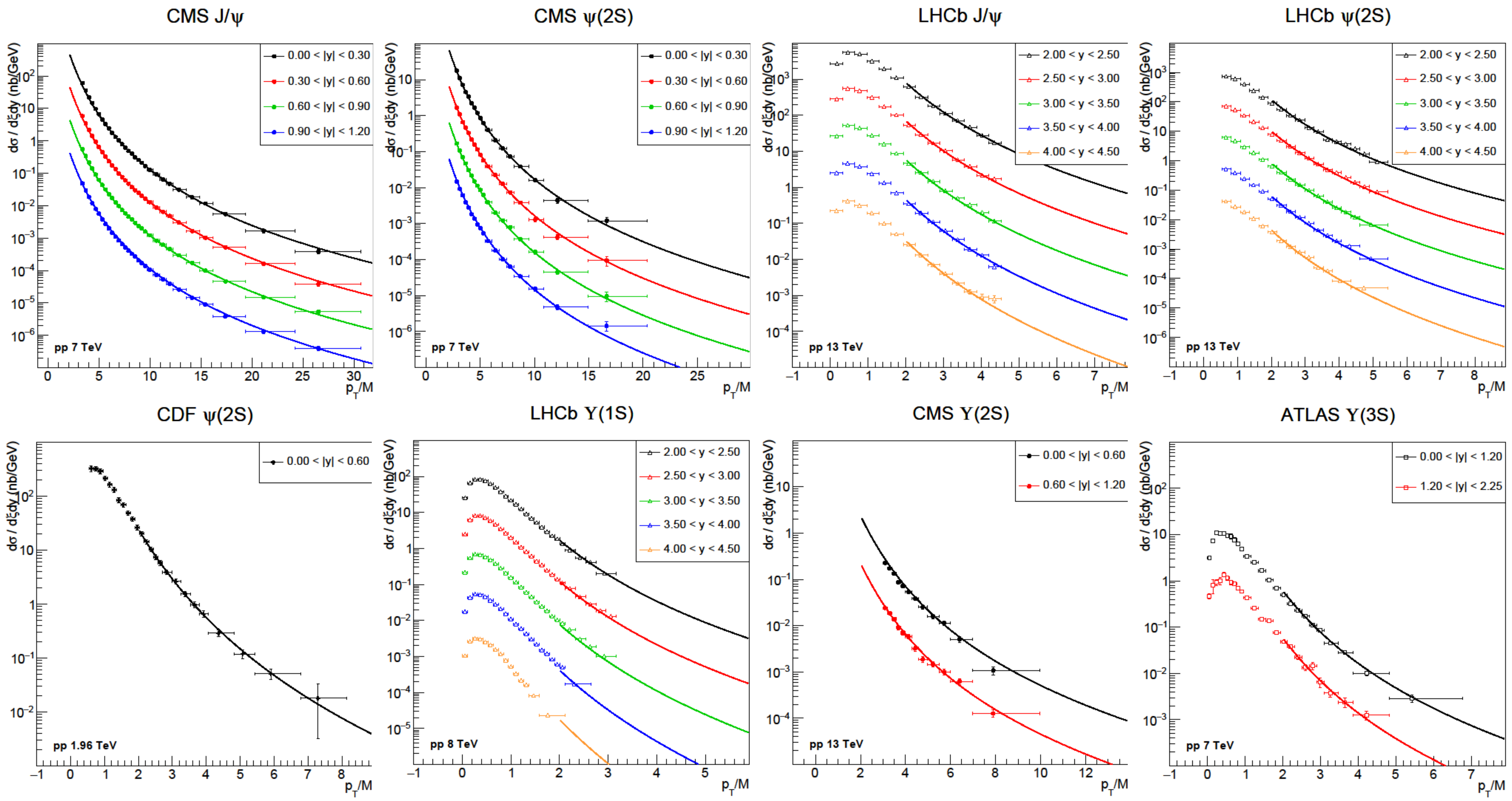
Polarization studies beyond quarkonium

Lecture Notes in Physics (vol. 1002)
to appear in August, OPEN ACCESS
https://link.springer.com/book/9783031088742

QUARKONIA

M. Araújo :: pheno PhD thesis work

Quarkonium production at LHC energies: understanding hadron formation by the strong force



Short- and long-distance scaling patterns indicate universal pT /M behavior

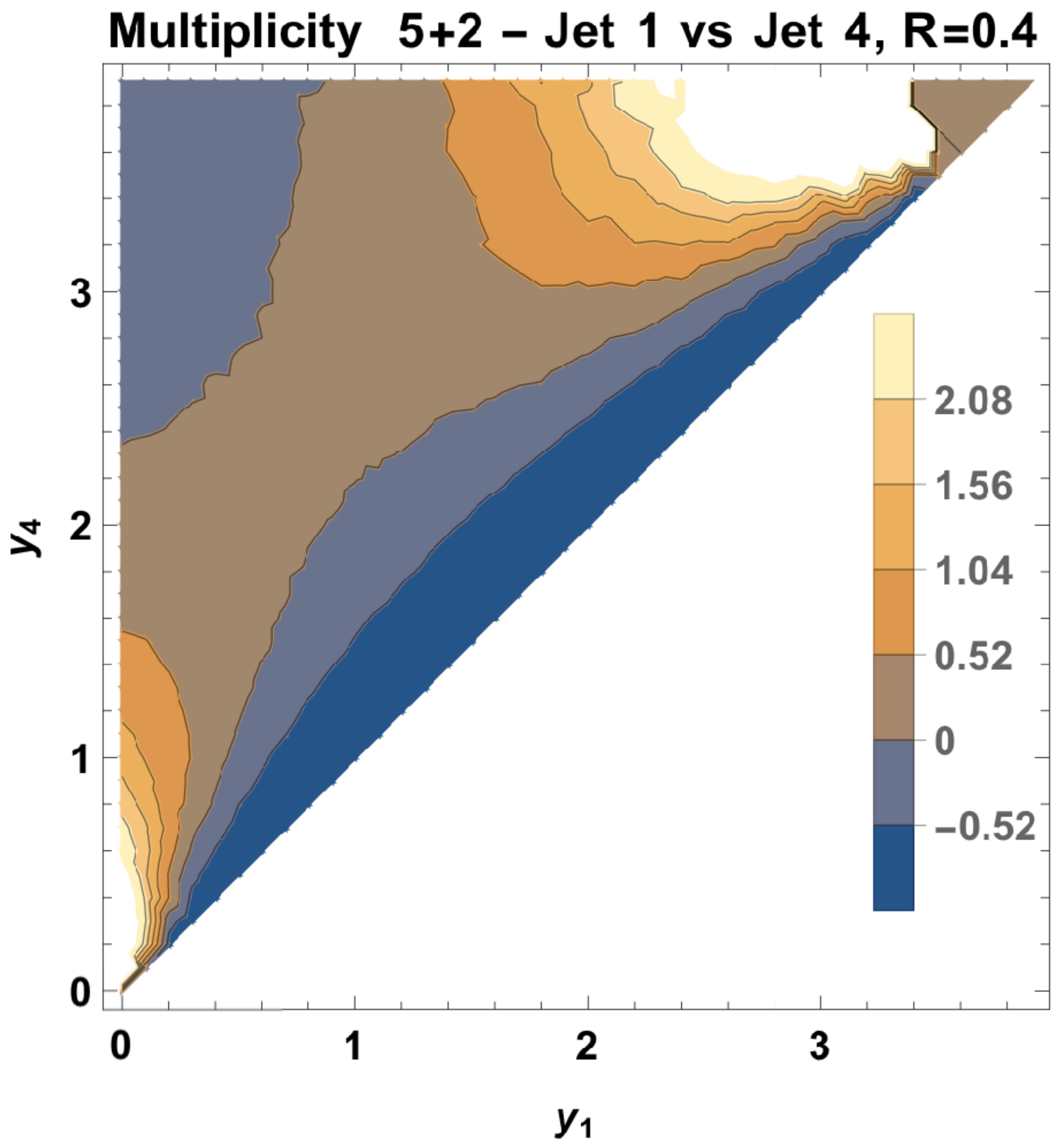
→ extend analysis in two dimensions not yet considered: rapidity (y) and √s

An empirical parametrization of the partonic cross section coupled with proton PDFs

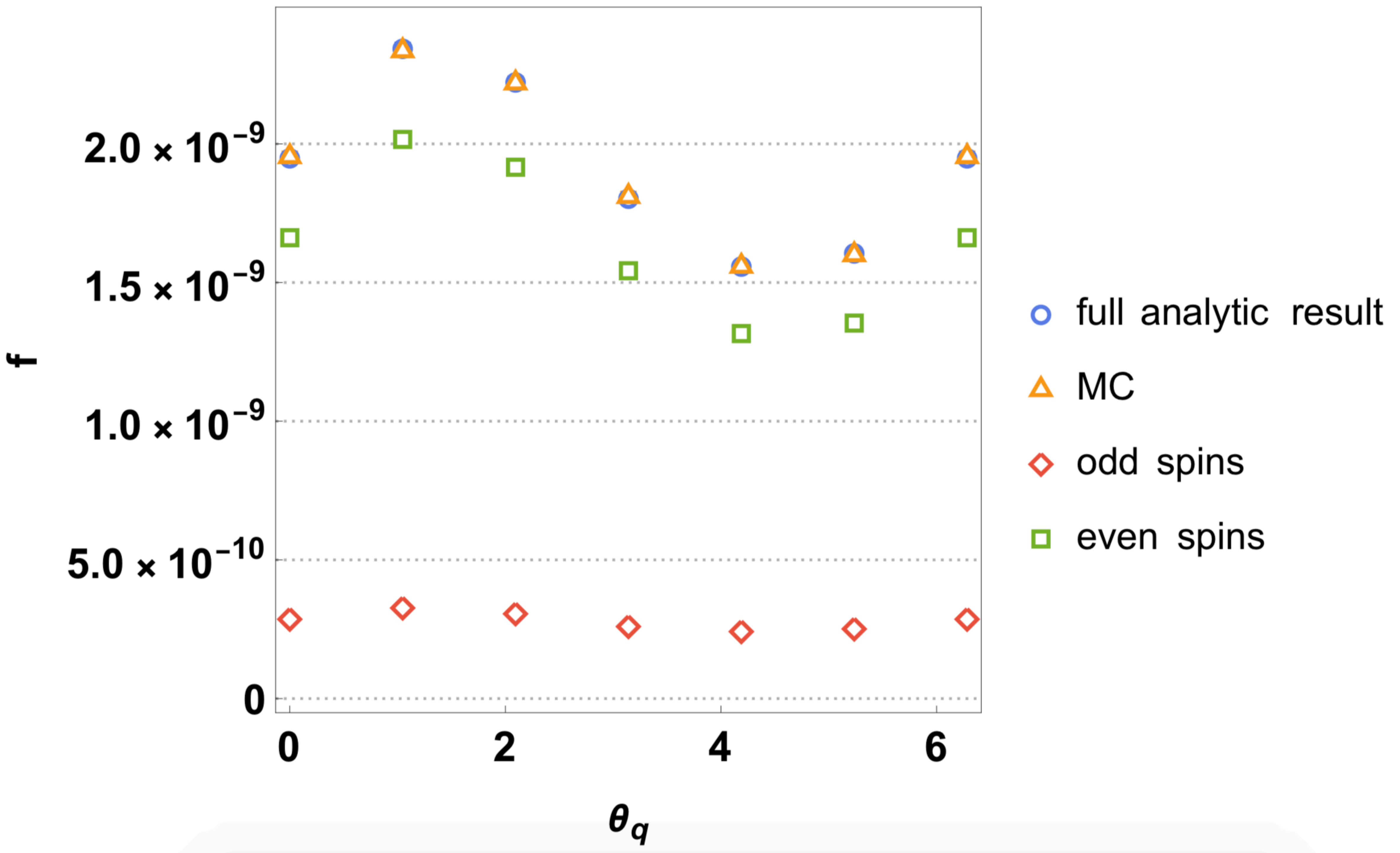
reproduces measurements from multiple states and experiments vs across pT /M, y and √s

Forward Physics and High Energy QCD

G. Chachamis et al.:: 2203.07462 [hep-ph]; N. León, GC, A. Sabio Vera:: 2106.11255 [hep-ph]; GC, AS-V:: 2203.12418 [hep-th]; AL, GC, AS-V:: 2012.09664 [hep-ph];GC et al.:: 2203.12852 [hep-ex]



Rapidity-rapidity correlations between jets in multijet final states with BFKLex MC



The formal approach to study diffractive processes with MC techniques

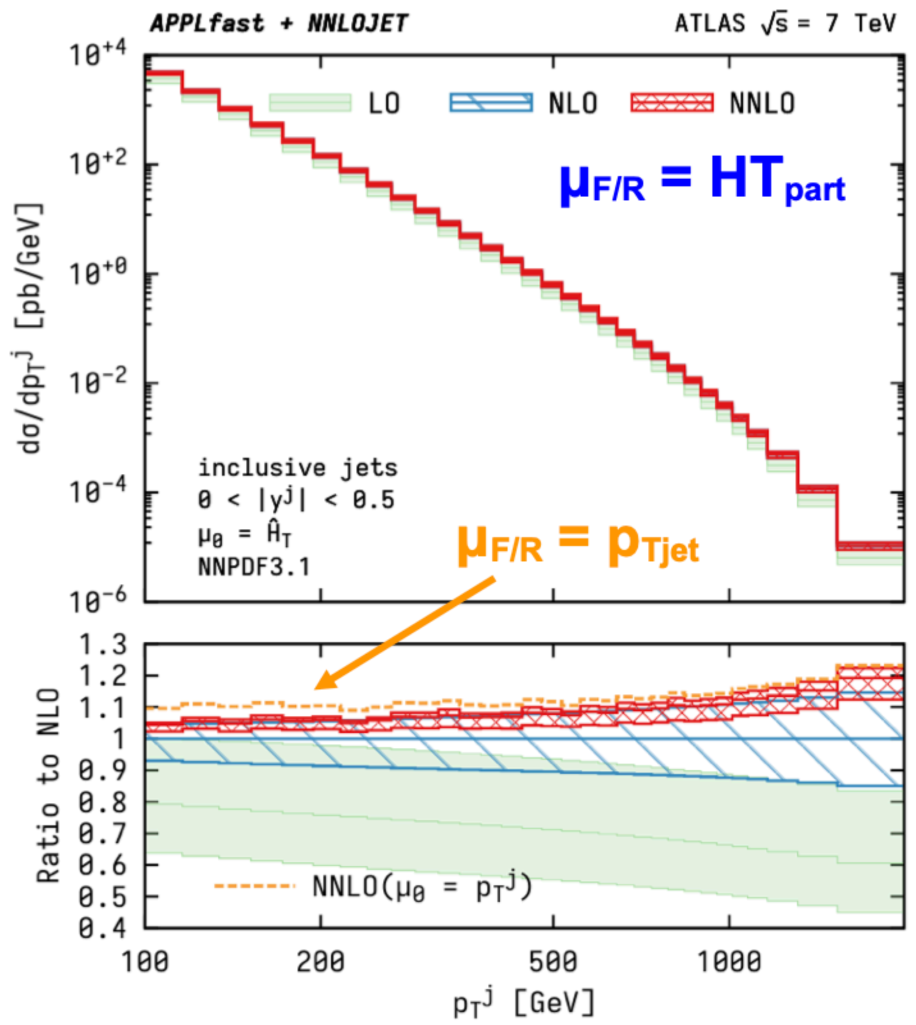
NNLO GRIDS FOR JET PRODUCTION AT THE LHC

J.Pires et al., NNLO interpolation grids for jet production at the LHC:: 2207.XXXX [hep-ph]

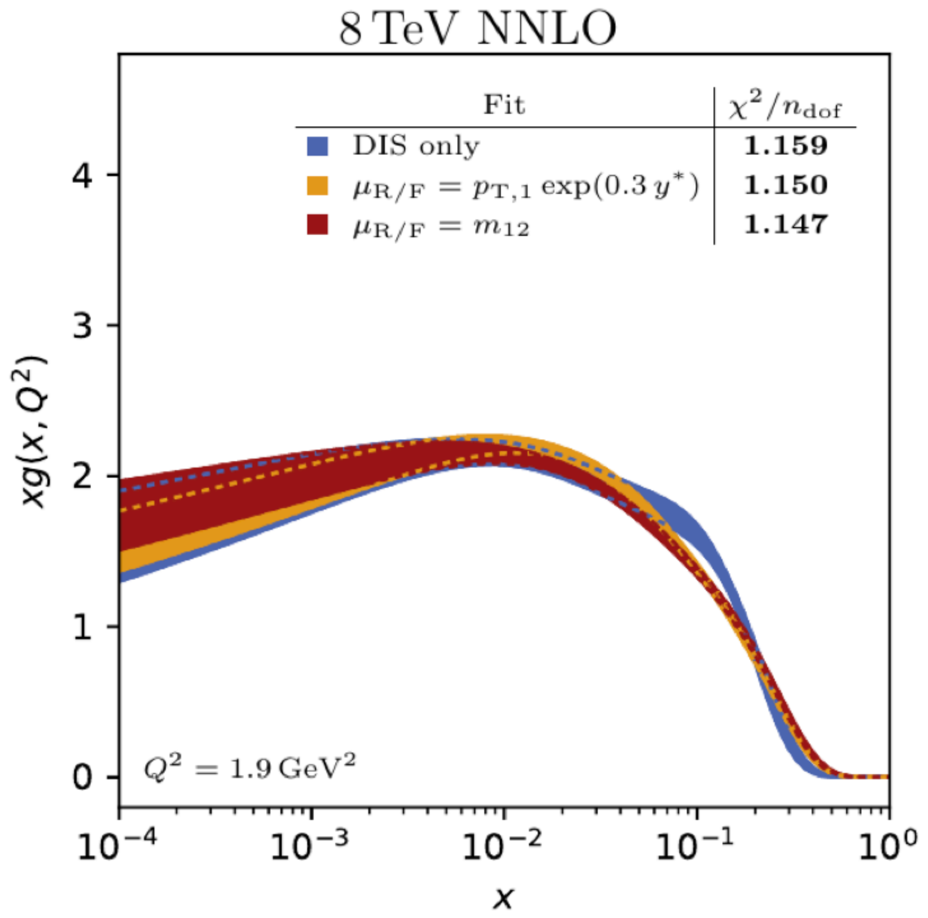
- New interpolation grids for numerous jet datasets at the LHC computed for ATLAS&CMS
- ingredients: → theory predictions from MC NNLOJET
- output → pQCD cross sections projected on grids in FASTnlo and APPLGRID formats
- Interpolation of the MC cross section on a (x_1,x_2,Q^2) grid allow fast recalculations of the cross section for several PDF and α_s values. Ex: CMS 8 TeV 3D dijet cross section:

```
$fnlo-tk-cppread 2jet.NNLO.fnl3832_yb0_ys0_ptavgj12.tab.gz NNPDF31_nnlo_as_0118 _ LHAPDF
```

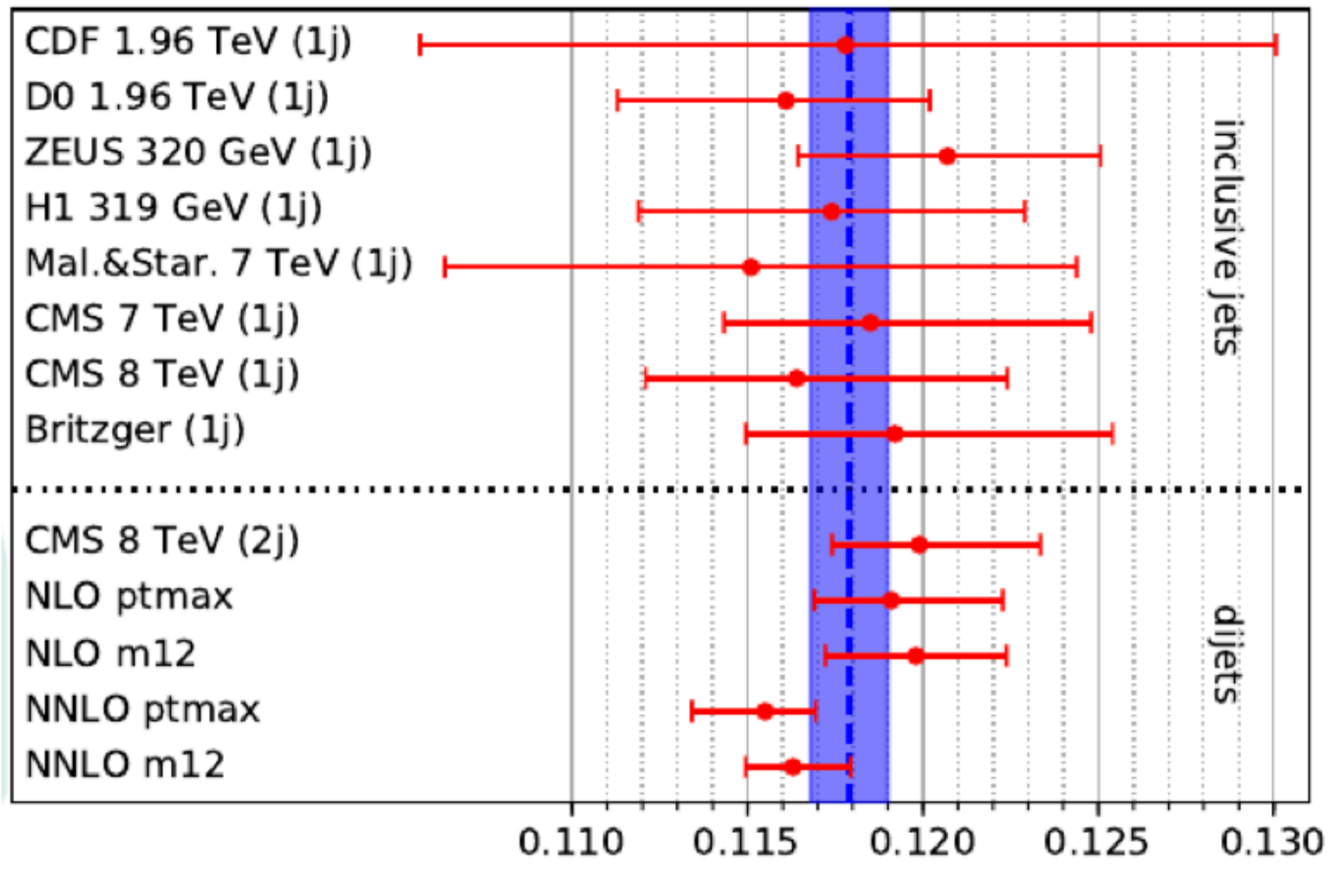
- Grid size: few GB ; NNLO cross section evaluation time: few minutes
- Proofs of principle: → gluon PDF fit with HERA DIS+CMS 8 TeV dijet data with xfitter
  → gluon PDF+α_s fit at NNLO (for two renormalisation and factorization scale choices)



Scale uncertainty bands: LO, NLO, NNLO



Gluon PDF fit: HERA DIS+CMS 8 TeV 3D dijet data

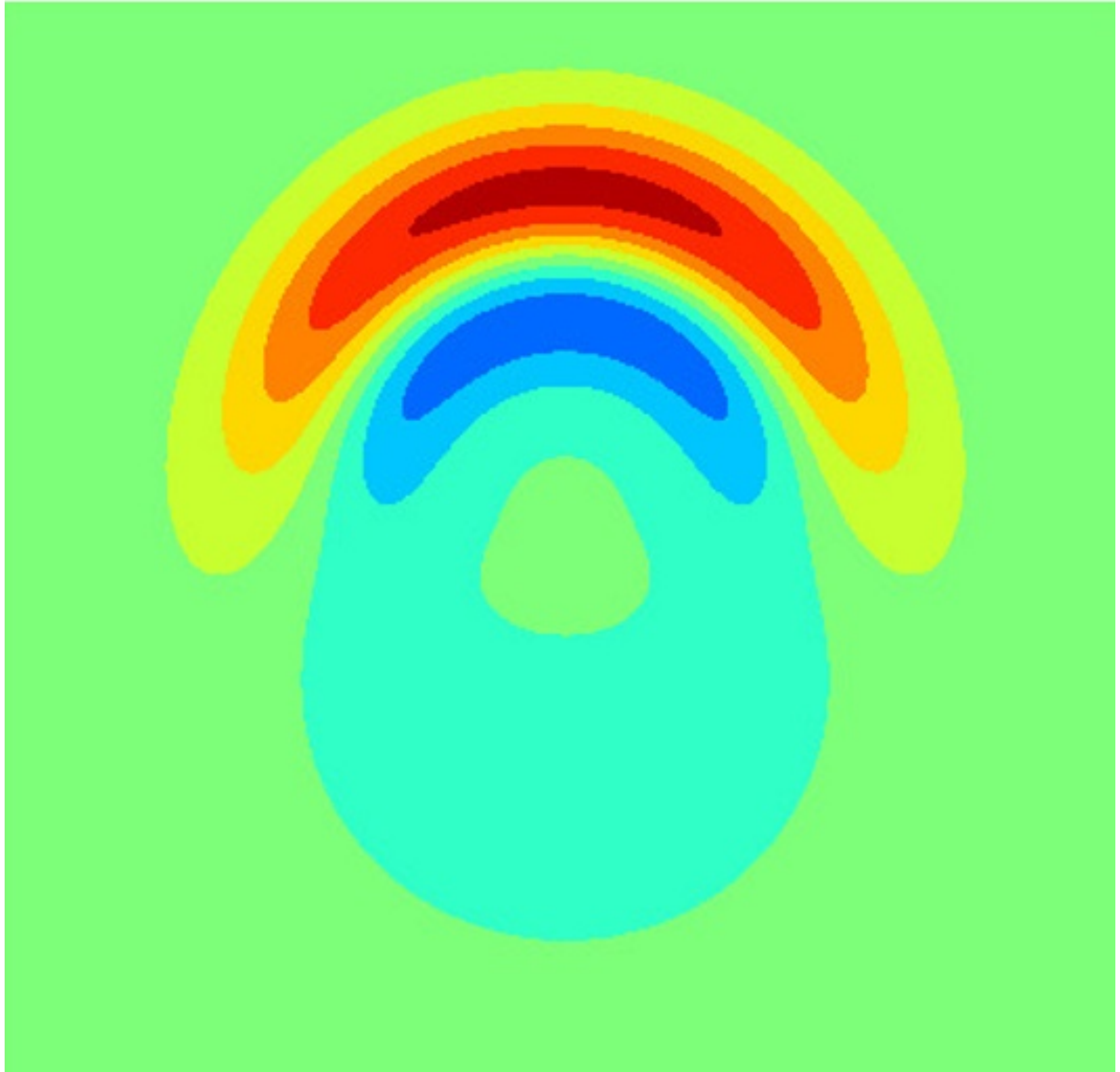


α_s scale uncertainties smaller at NNLO and smaller α_s values (CMS 3D dijet data)

Fitted $\alpha_S(M_Z)$ values

NLO	$\mu = p_{T,1} e^{0.3 y^*}$	$0.1191 \pm 0.0015(\text{exp})^{+0.0028}_{-0.0016}(\text{scale})$
	$\mu = m_{12}$	$0.1198 \pm 0.0015(\text{exp})^{+0.0021}_{-0.0021}(\text{scale})$
NNLO	$\mu = p_{T,1} e^{0.3 y^*}$	$0.1155 \pm 0.0012(\text{exp})^{+0.0008}_{-0.0017}(\text{scale})$
	$\mu = m_{12}$	$0.1163 \pm 0.0013(\text{exp})^{+0.0010}_{-0.0004}(\text{scale})$

Fitted α_s values obtained with the CMS dijet data and other jet cross sections



J. Casalderrey-Solana, G. Milhano, D. Pablos, K. Rajagopal, X. Yao :: 2010.01140 [hep-ph]

thank you !