Measuring the Quenching of *b*-quark Jets via Muon-Tagging in PbPb Collisions with the CMS Detector

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UIC Physics Thesis Preliminary Defense

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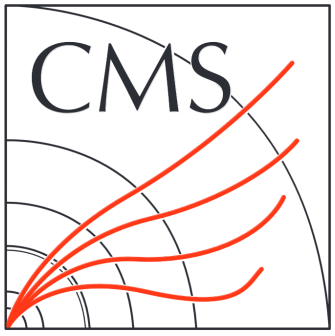
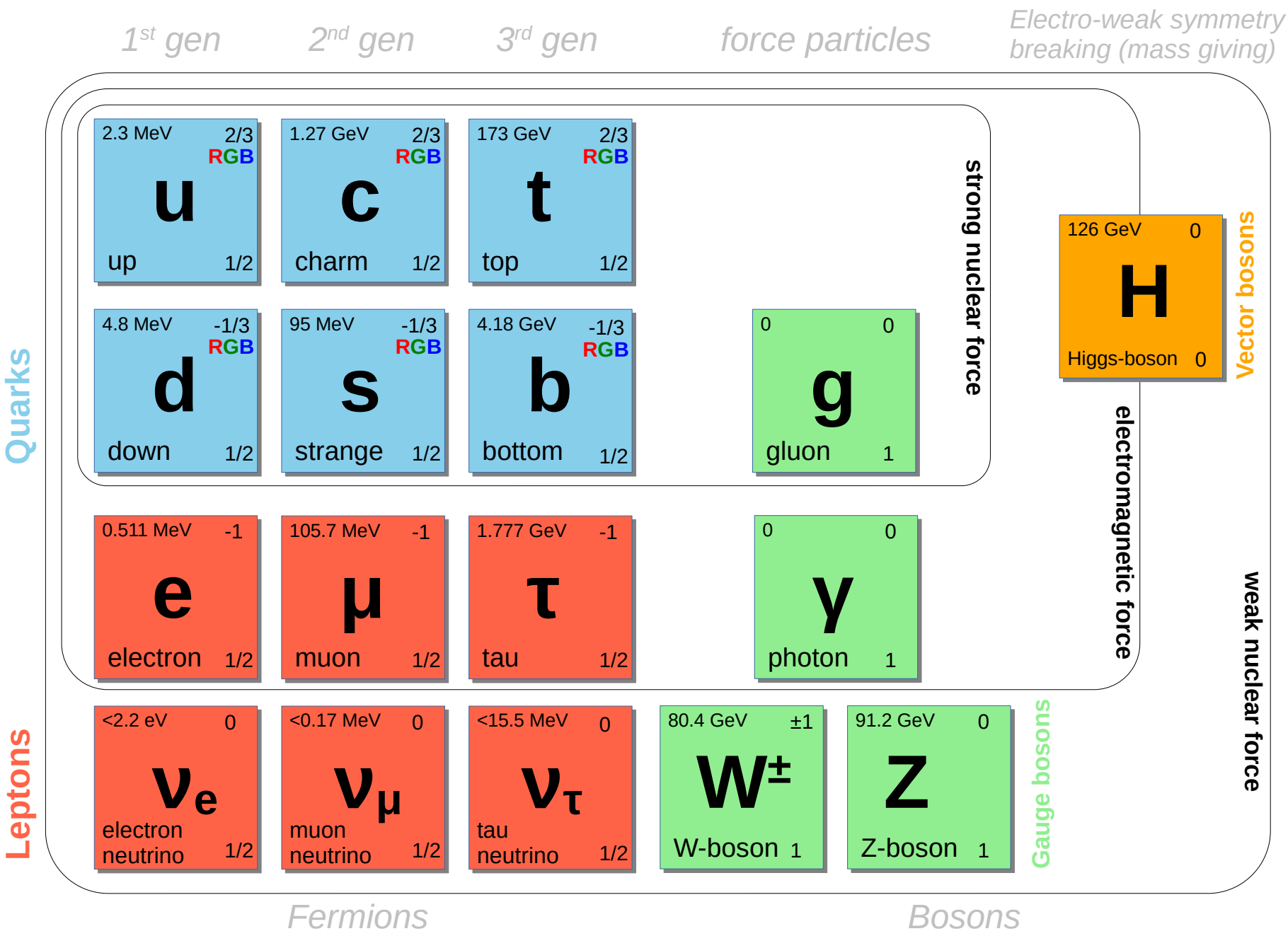
Day November 2023



The Standard Model of Particle Physics



Jets (in theory)

Jet: a collimated set of hadronic decay products from a parent parton

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Hard processes in pp collisions

- **hard processes** → **Short-distance** physics of **partons** ⊗ **Long-distance** physics of **hadrons**

Cross-section factorization

$$d\sigma^{p+p\to h+X} = \sum_f d\sigma^{p+p\to f+X} \bigotimes D_{f\to h}(z,\mu_F^2)$$

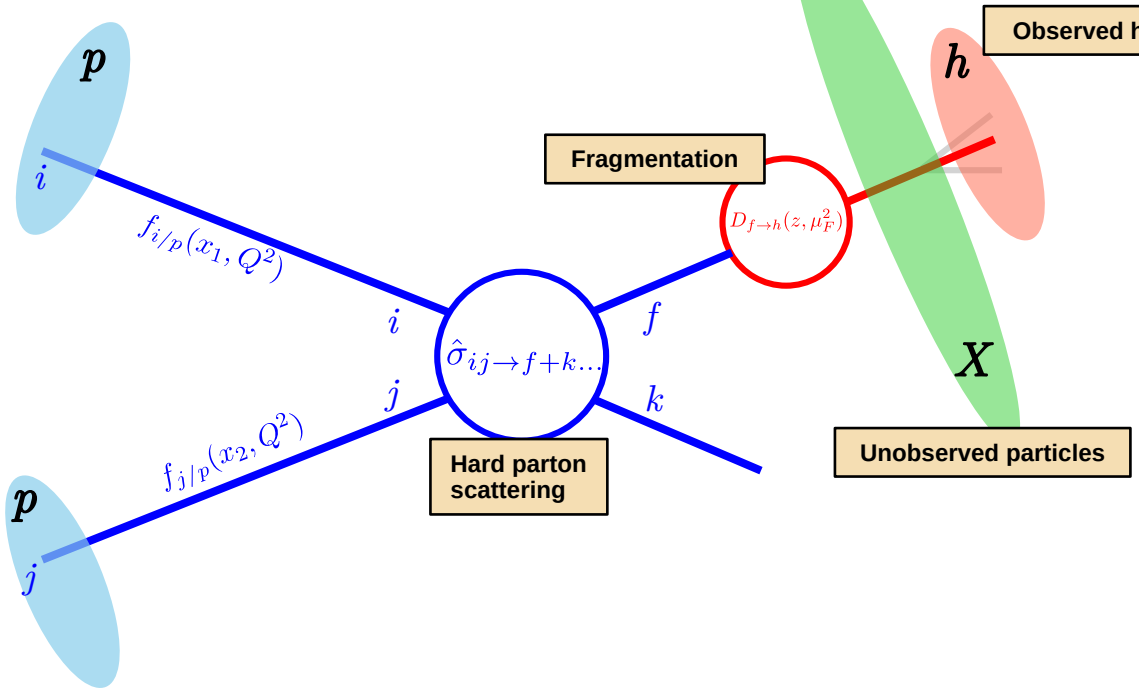
$$d\sigma^{p+p\to f+X} = \sum_{i,j,k\ldots} f_{i/p}(x_1,Q^2) \bigotimes f_{j/p}(x_2,Q^2) \bigotimes \hat{\sigma}_{ij\to f+k\ldots}$$

$D_{f\to h}(z,\mu_F^2)$: fragmentation function for a parton f fragmenting into a hadron h

Parton distribution function for parton i of incoming proton p

Hard partonic cross-section

- We use **hard processes** in pp collisions as a **reference** when we study QGP medium effects



- Partonic cross-section in vacuum is **perturbatively calculable**!
- Fragmentation is non-perturbative → must rely on **QCD-inspired models!**

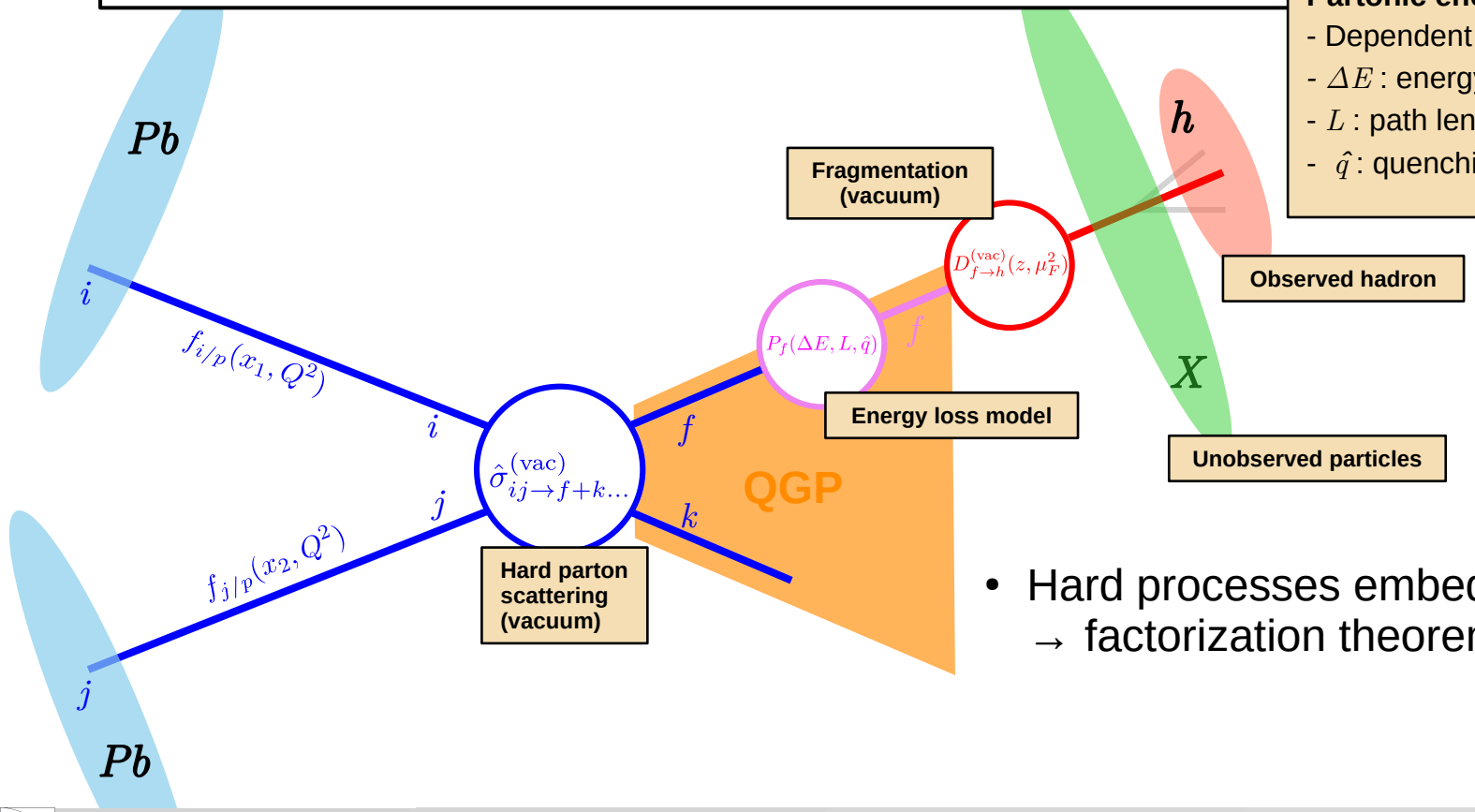
Hard processes in PbPb collisions

- **hard processes** → **Short-distance** physics of **partons in vacuum** ⊗ **Model-dependent energy loss** of **partons in QGP** ⊗ **Long-distance** physics of **hadrons in vacuum**

Cross-section factorization

$$d\sigma^{A+A\to h+X}_{(\mathrm{med})} = \sum_f d\sigma^{A+A\to f+X}_{(\mathrm{vac})} \otimes P_f(\Delta E, L, \hat{q}) \otimes D^{(\mathrm{vac})}_{f\to h}(z, \mu_F^2)$$

Partonic energy loss model.
- Dependent on parton f
- ΔE : energy lost to medium
- L : path length traversed by *f* through medium
- $\hat{q}$: quenching parameter



- Hard processes embedded in **QCD medium** → factorization theorems **unknown**

Jets

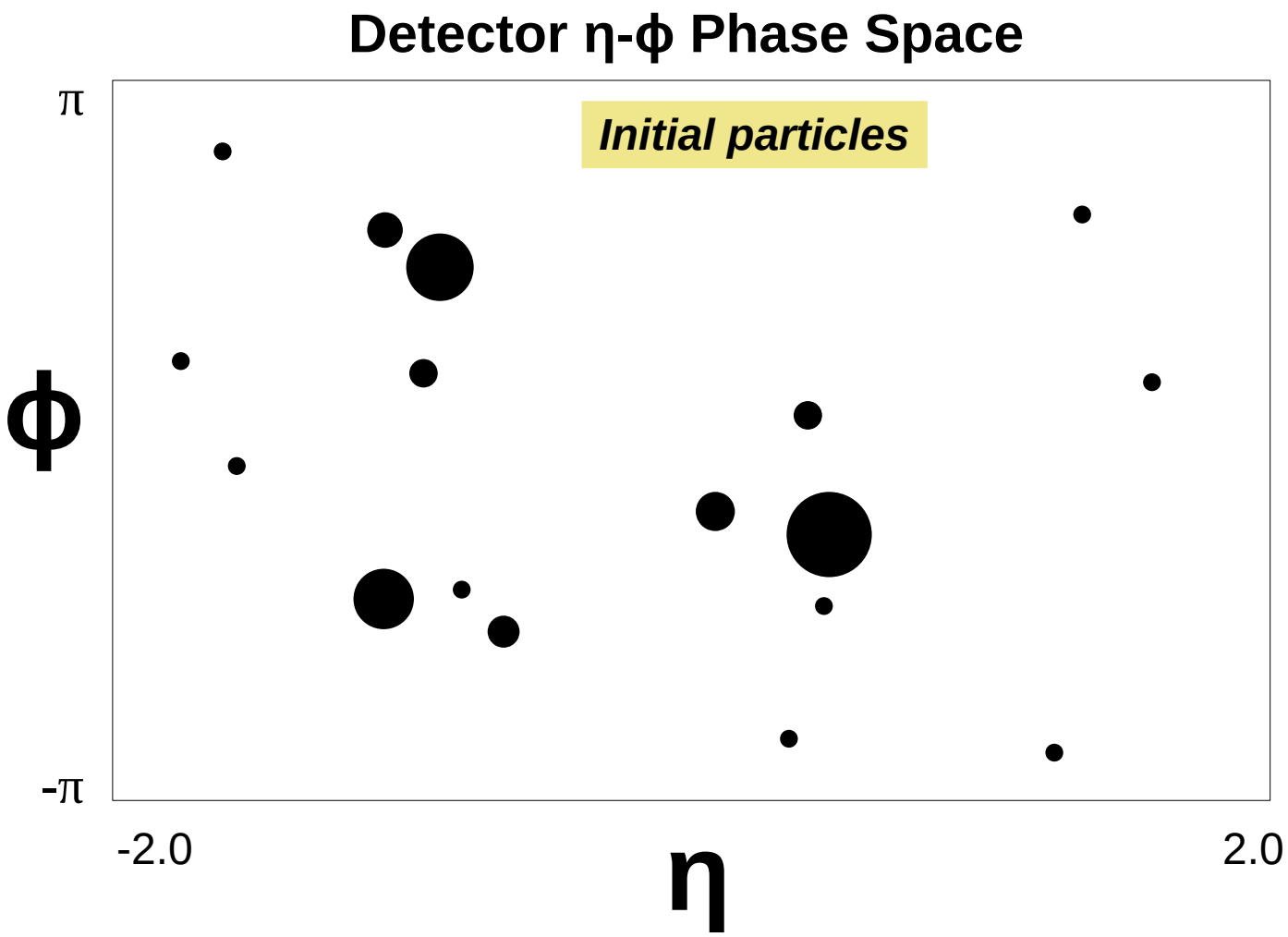
In reality, fragmentation results in a spray of particles!

Leading hadron factorization → 1^{st} order jet

Jet (theory)
- a collimated set of hadronic decay products from a parent parton
-

Jets – Clustering

$$d_{ij} = \min(p_{\mathrm{T,i}}^{2k}, p_{\mathrm{T,j}}^{2k}) \frac{\Delta R_{ij}^2}{R^2}$$



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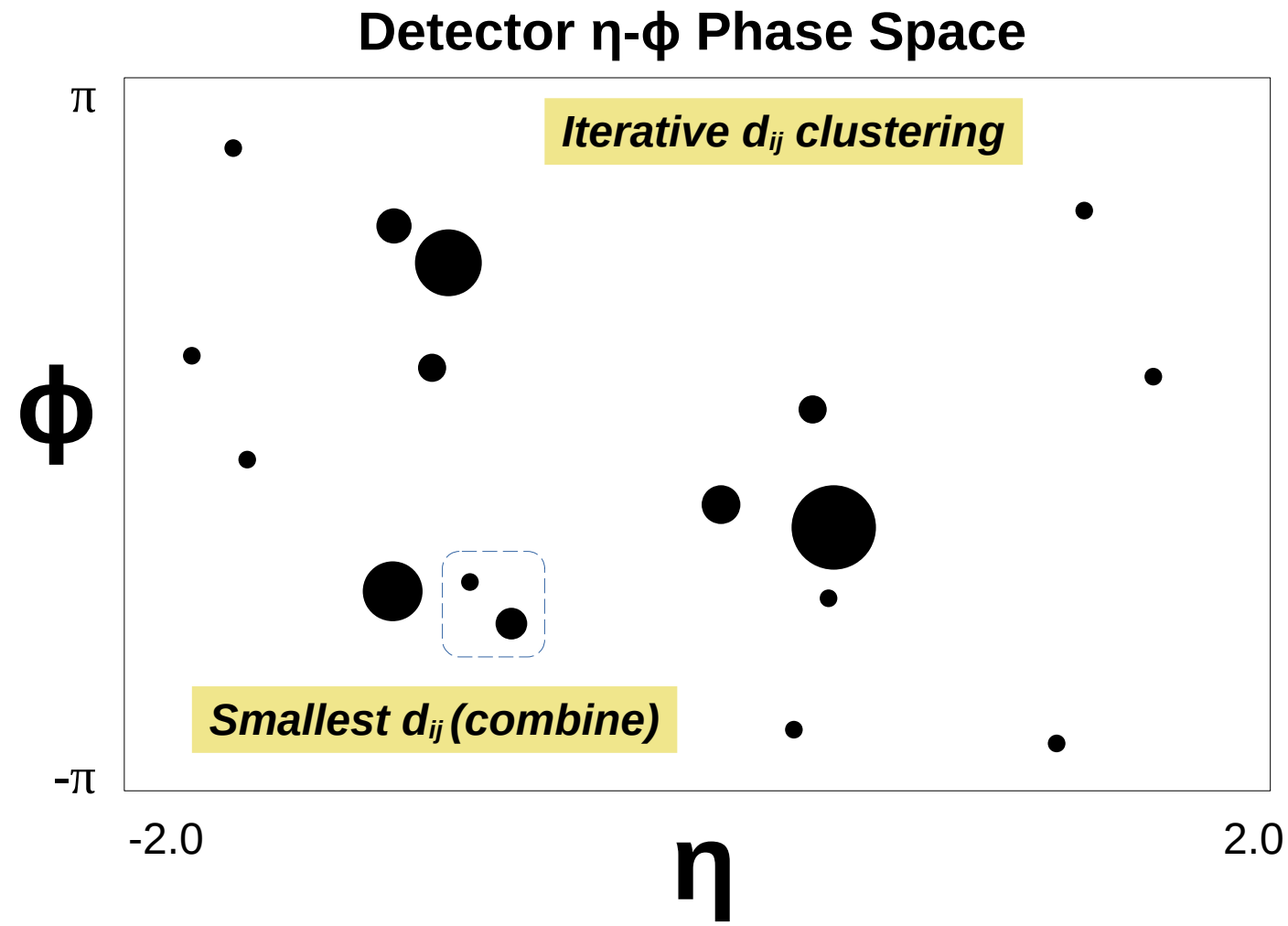

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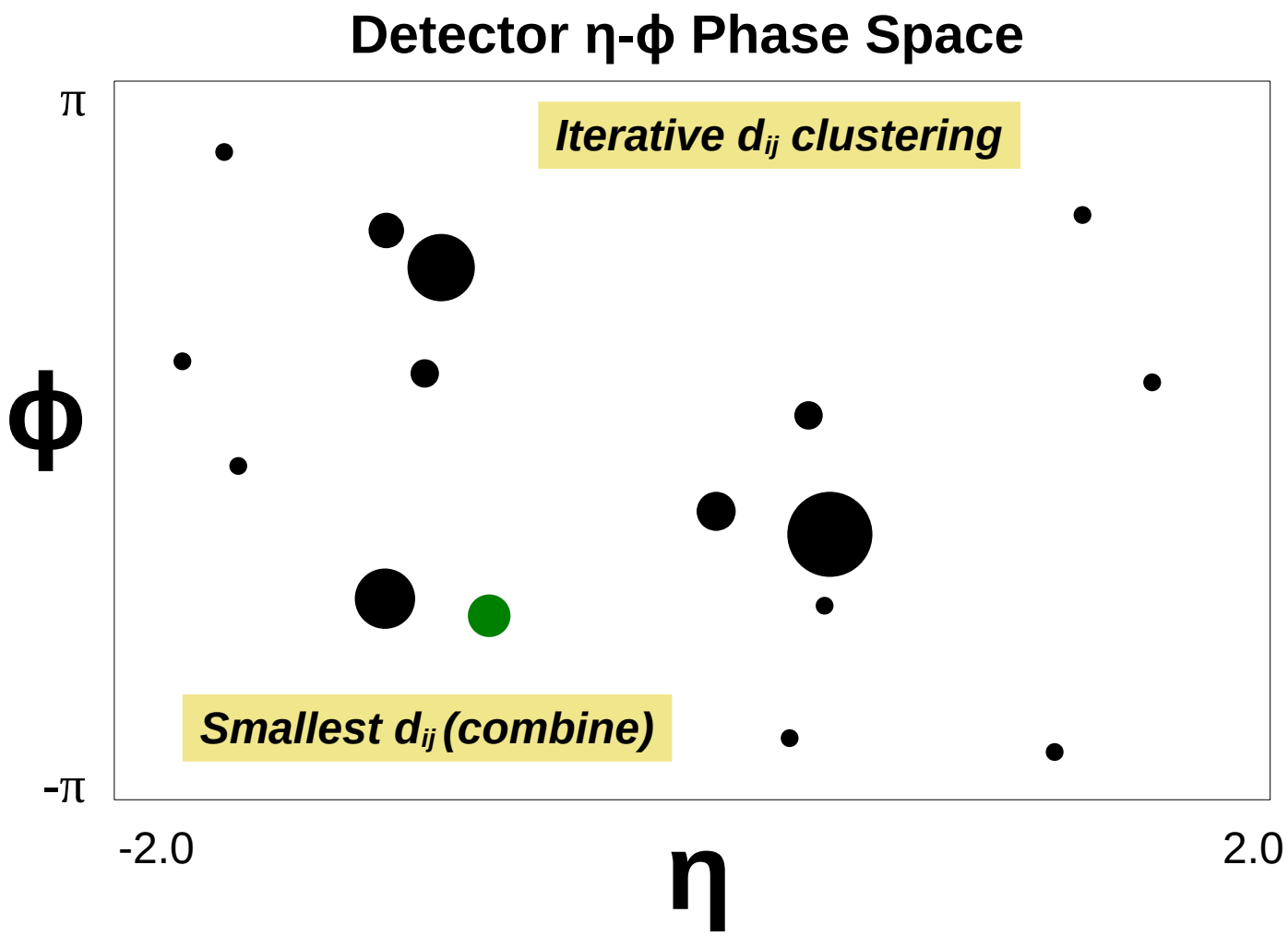

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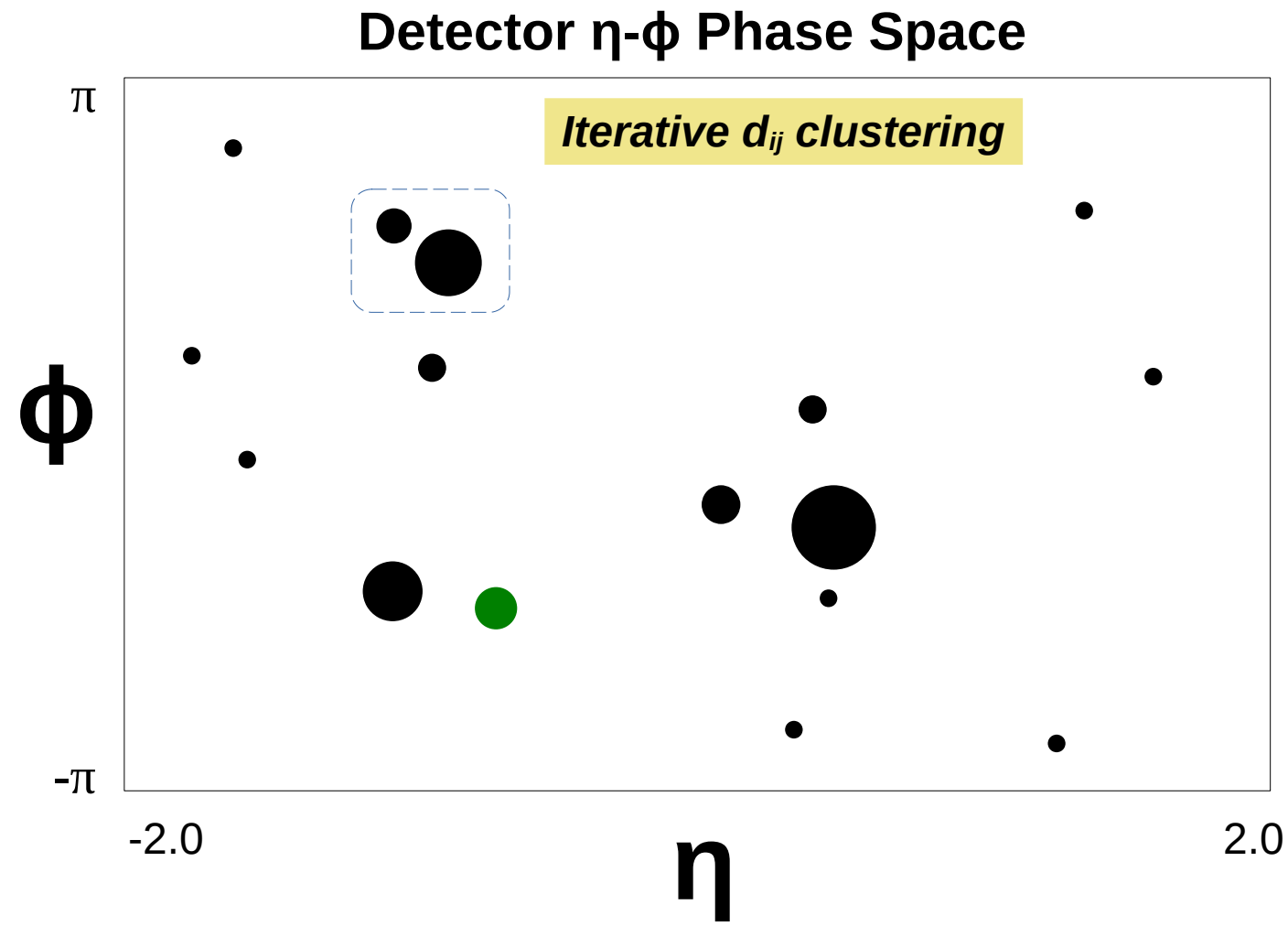

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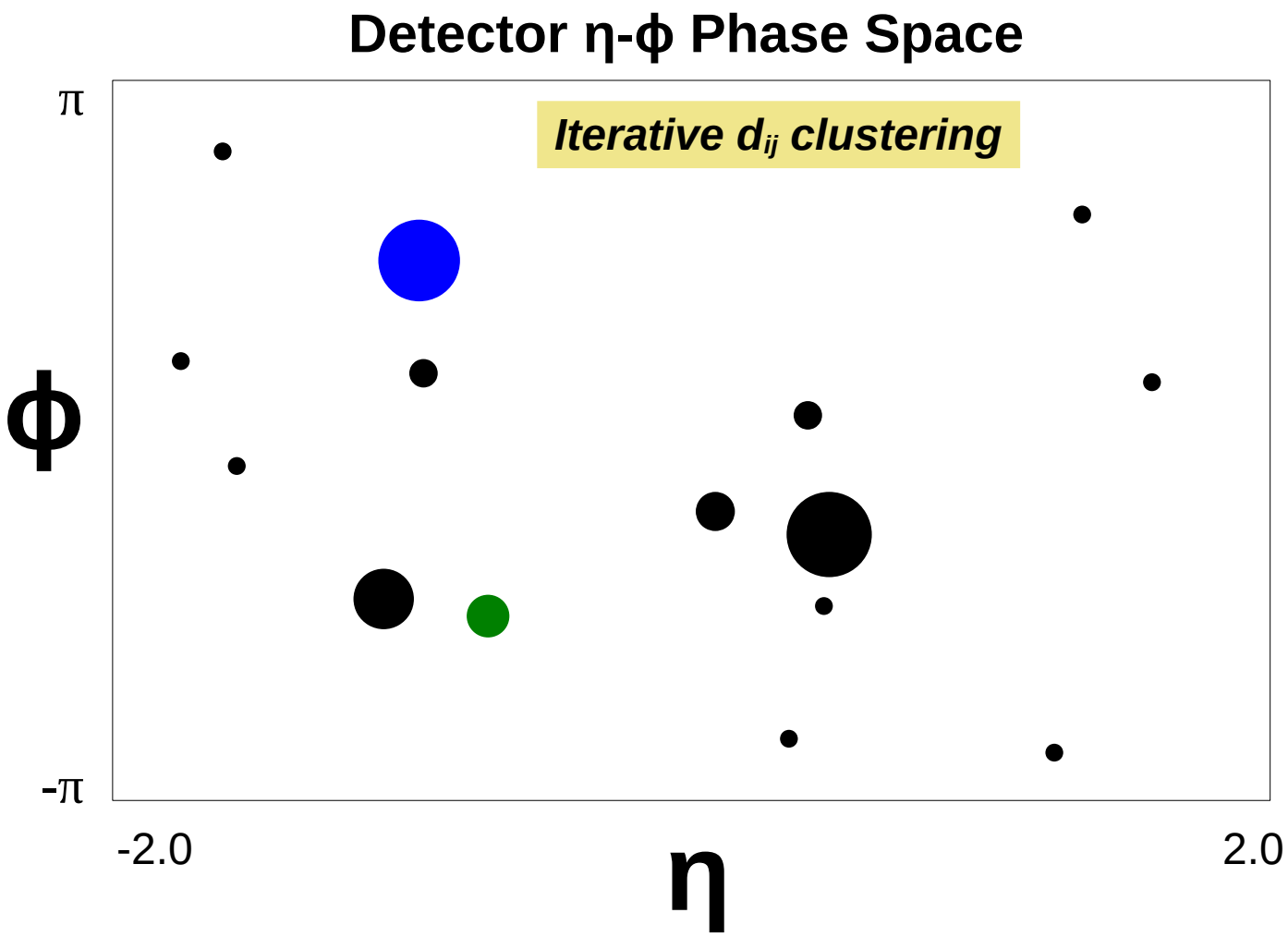

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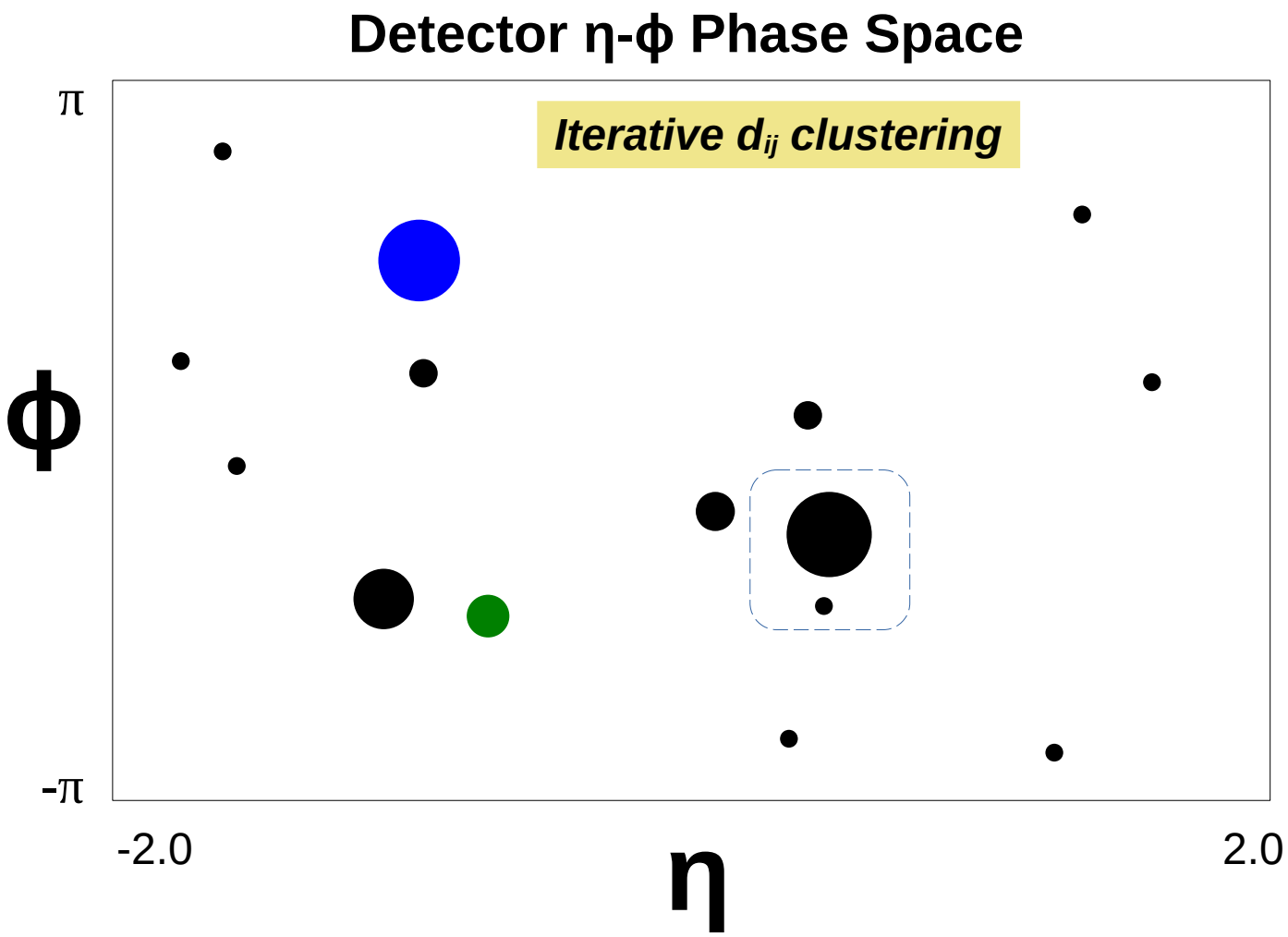

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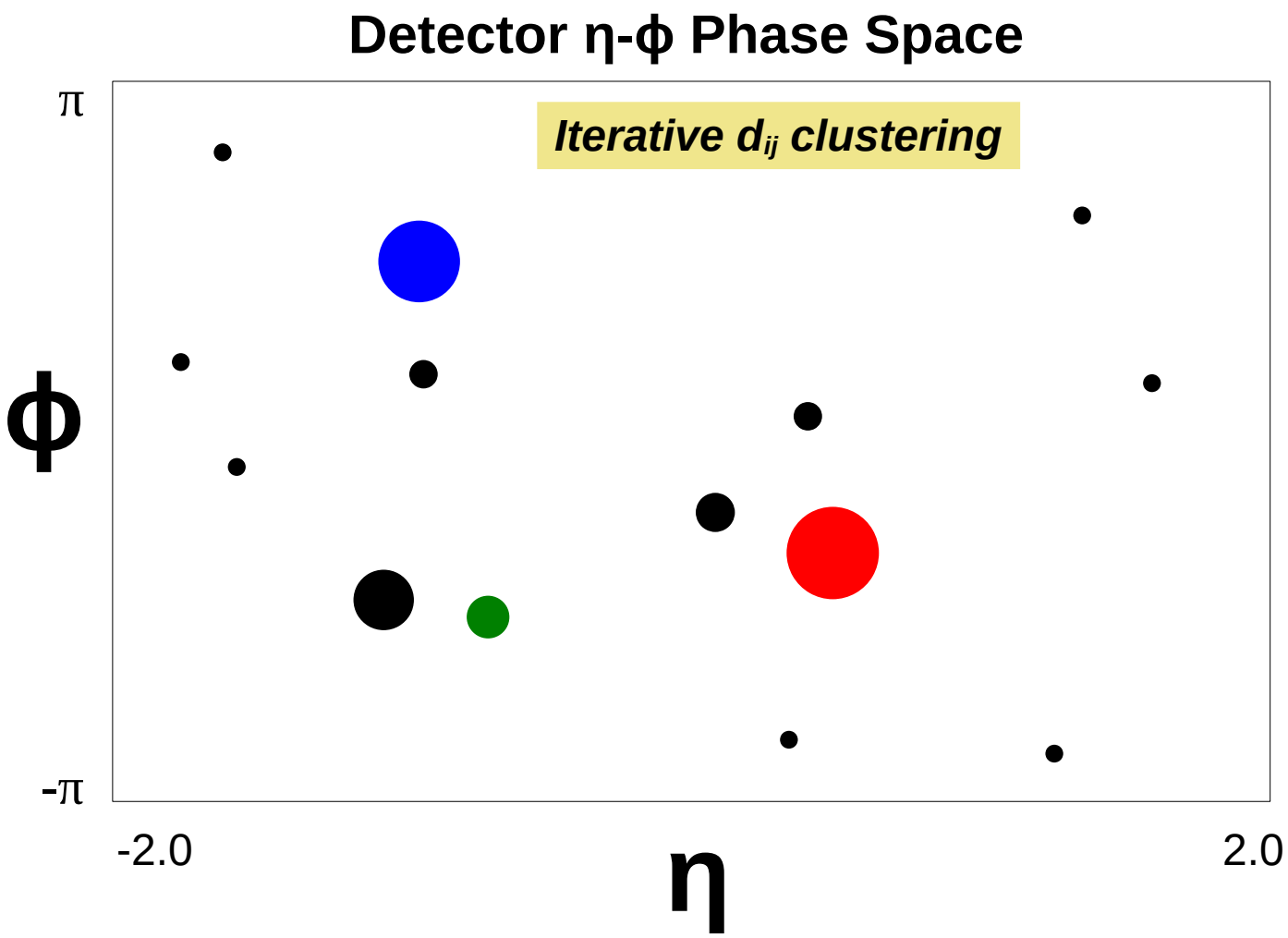

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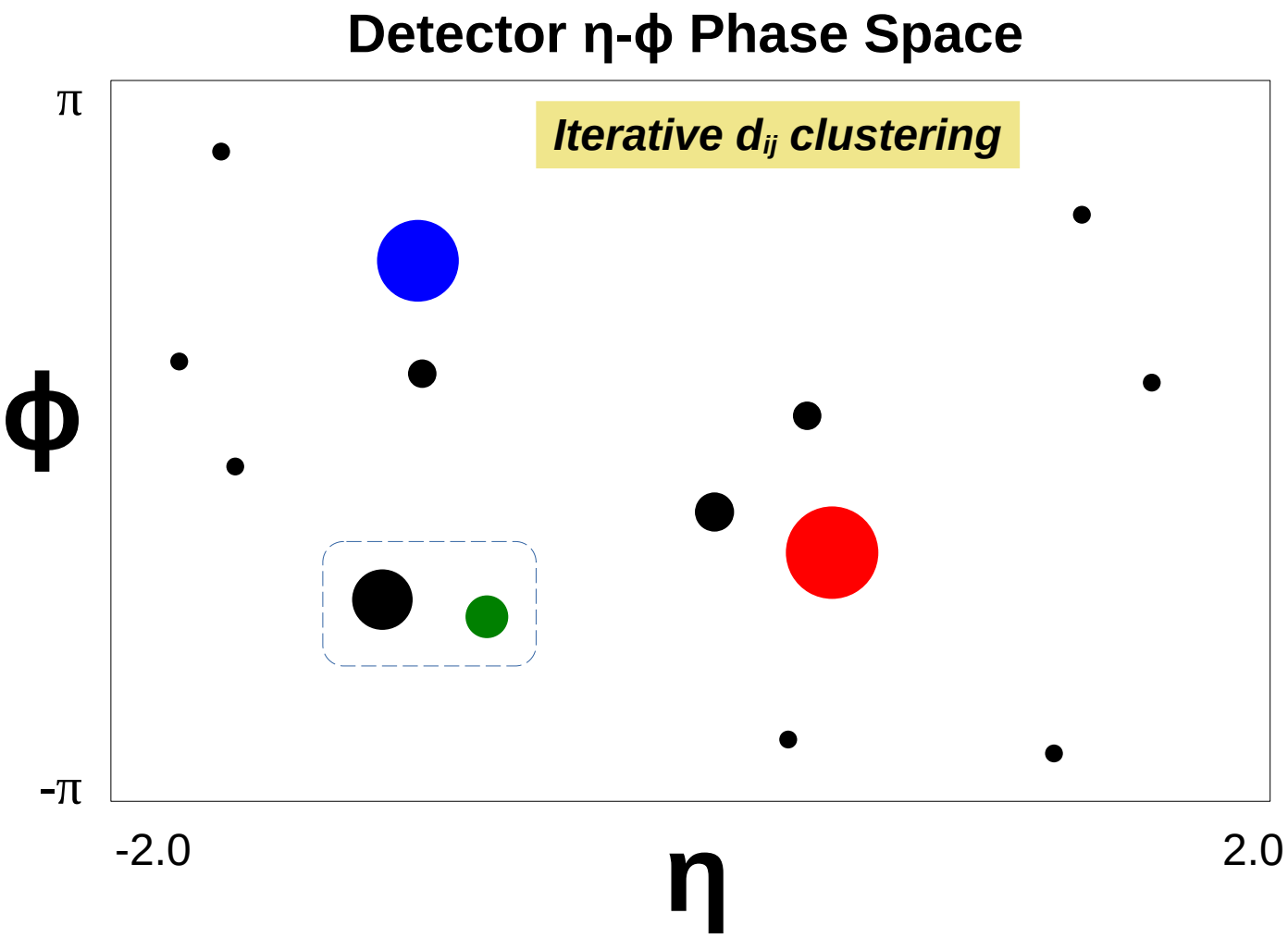

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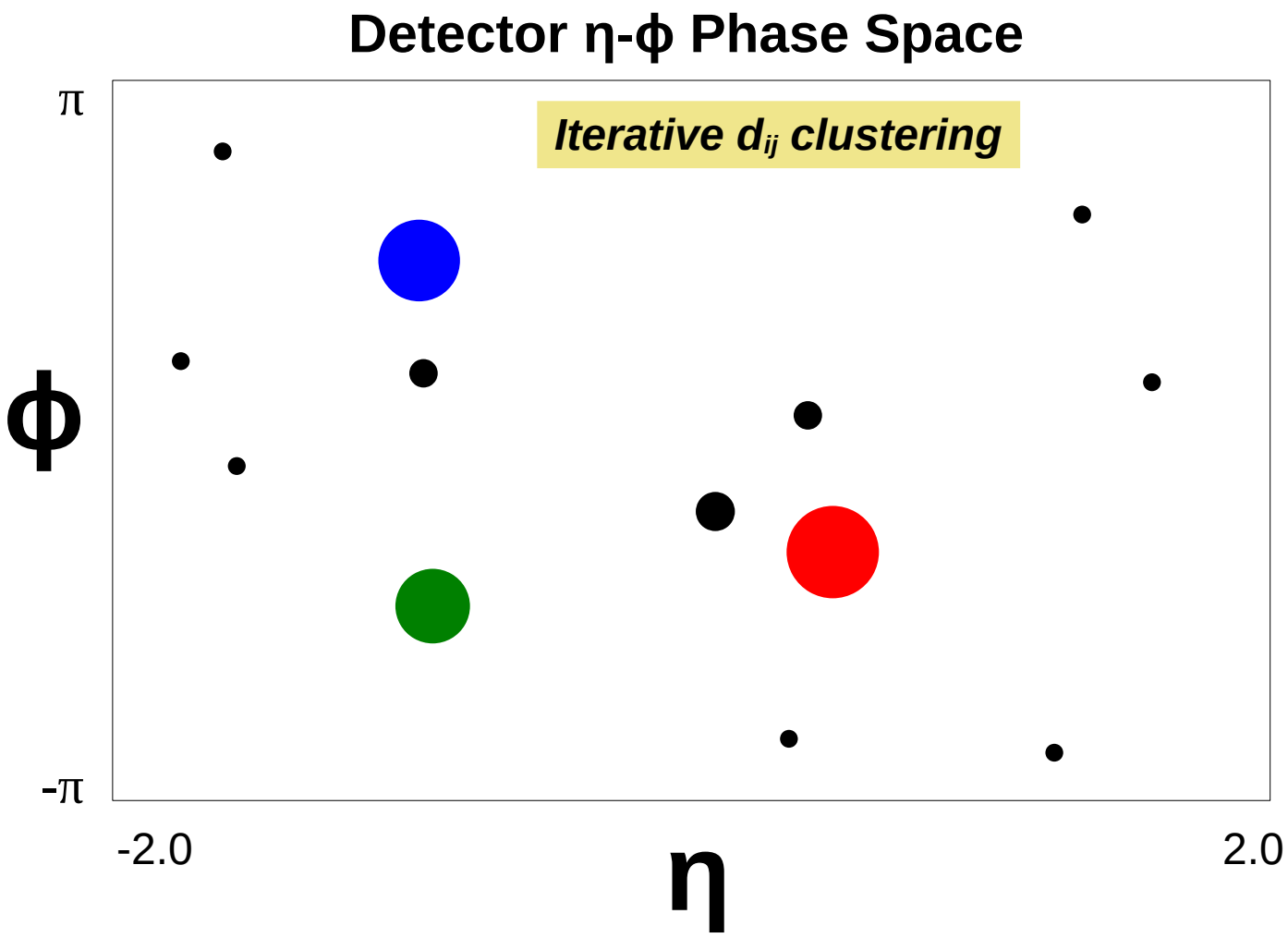

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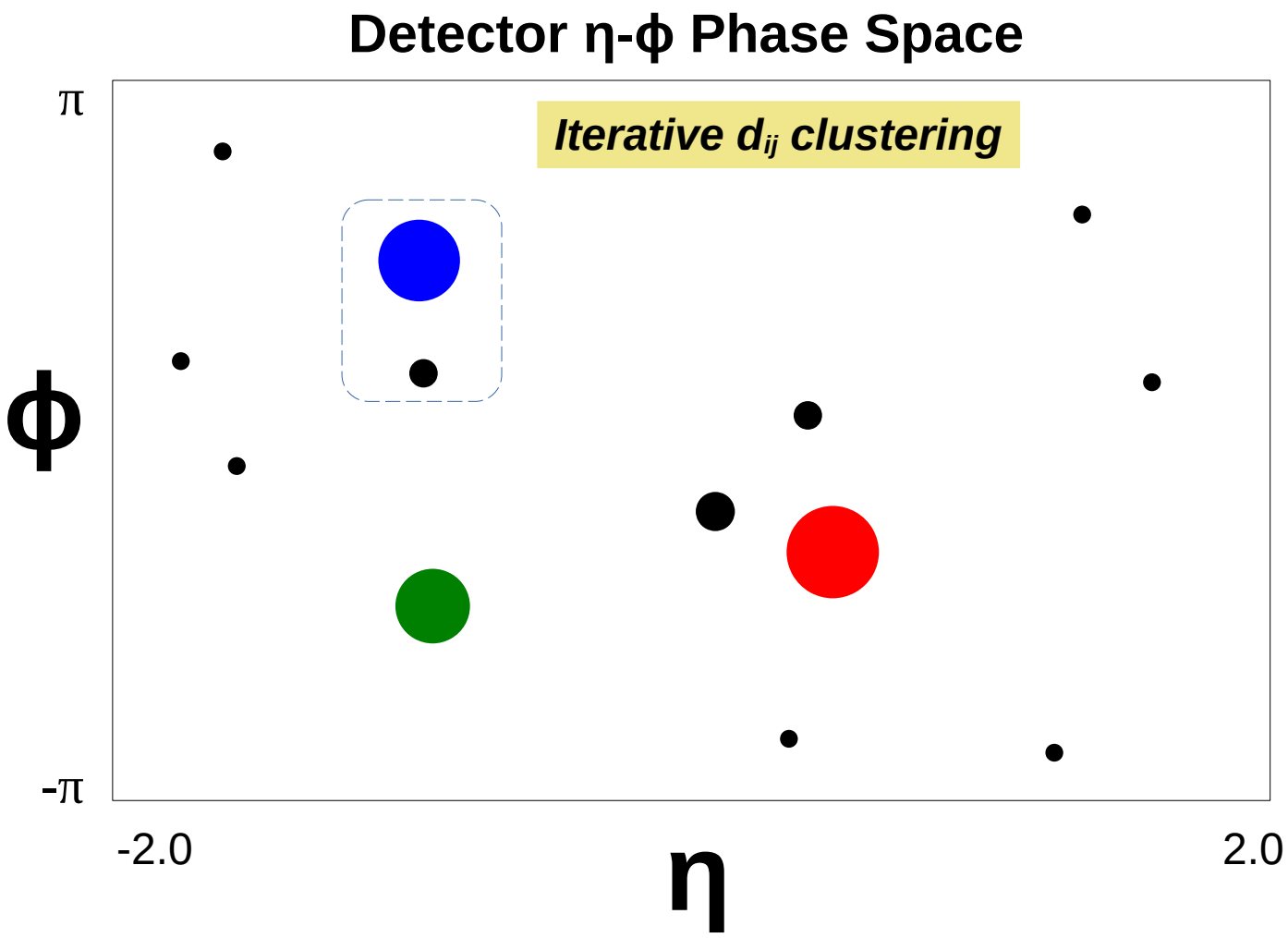

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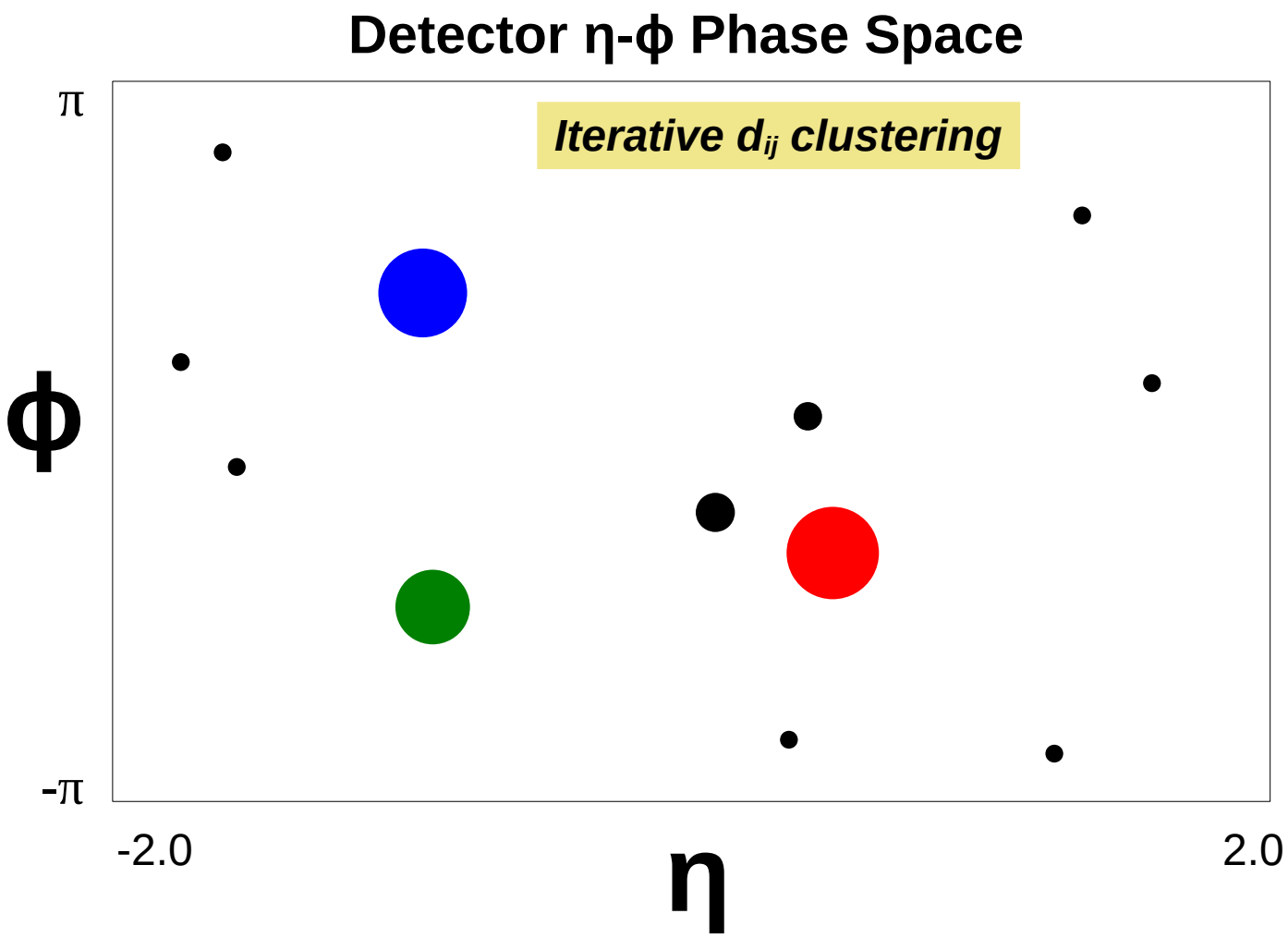

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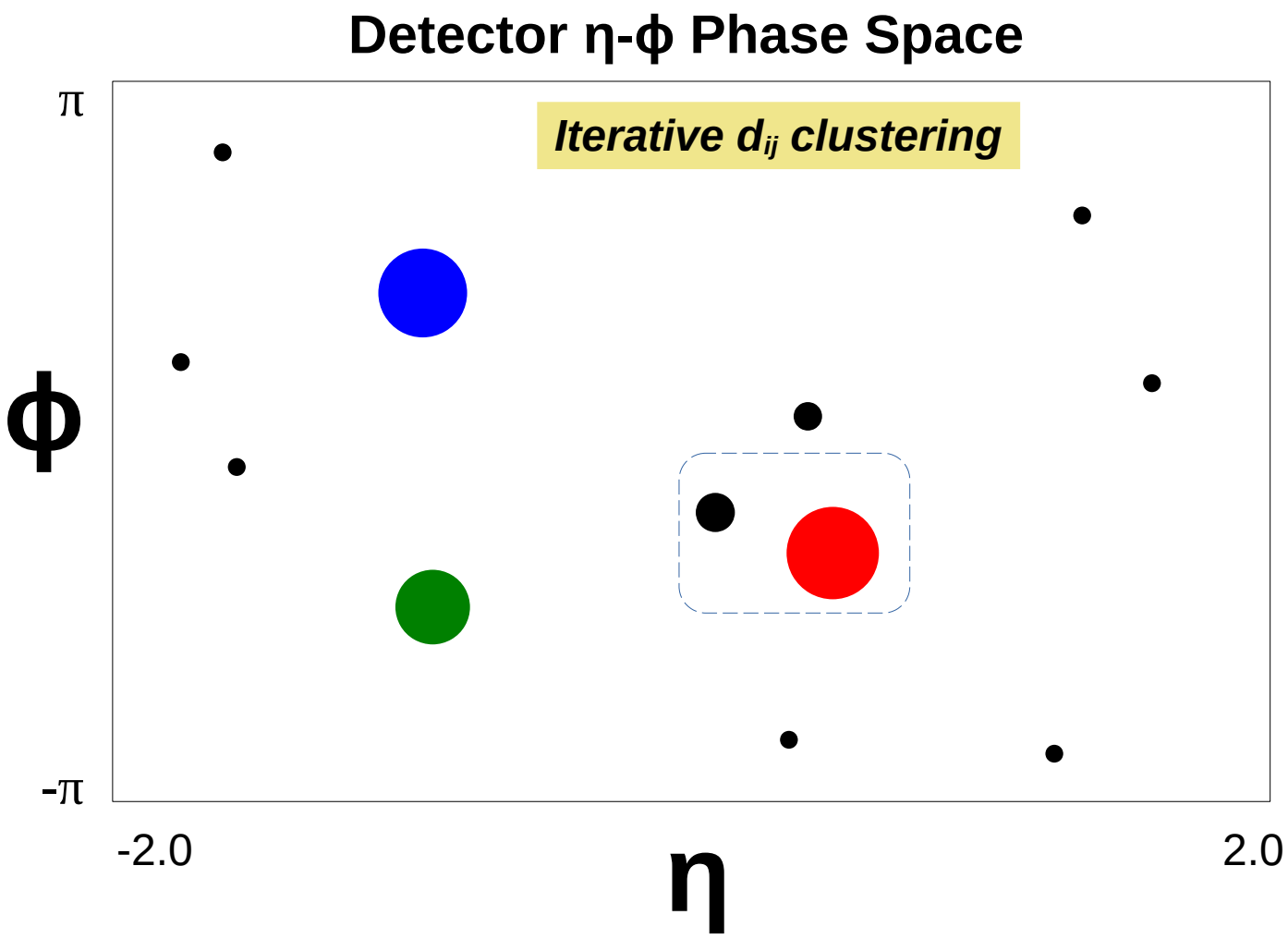

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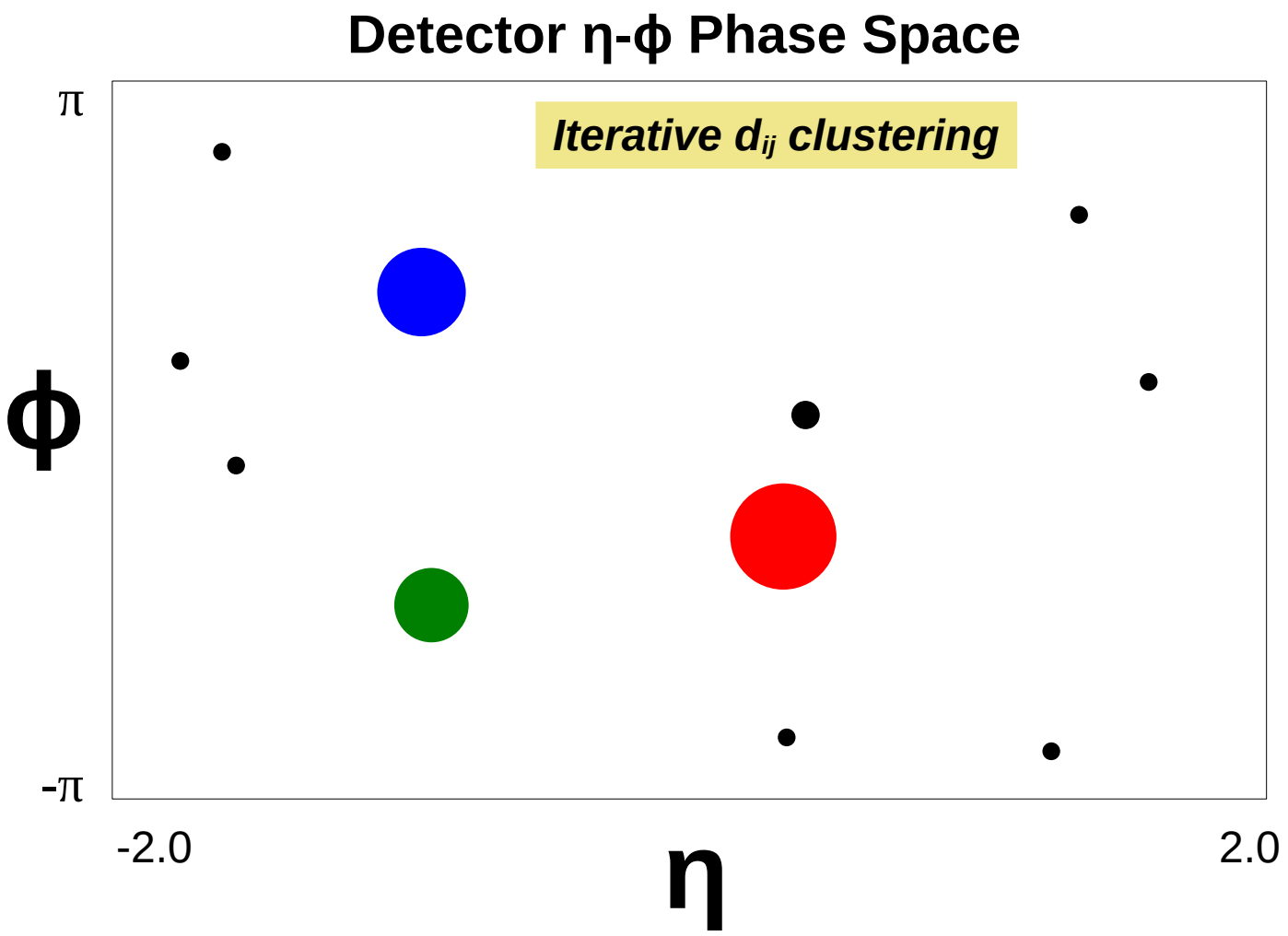

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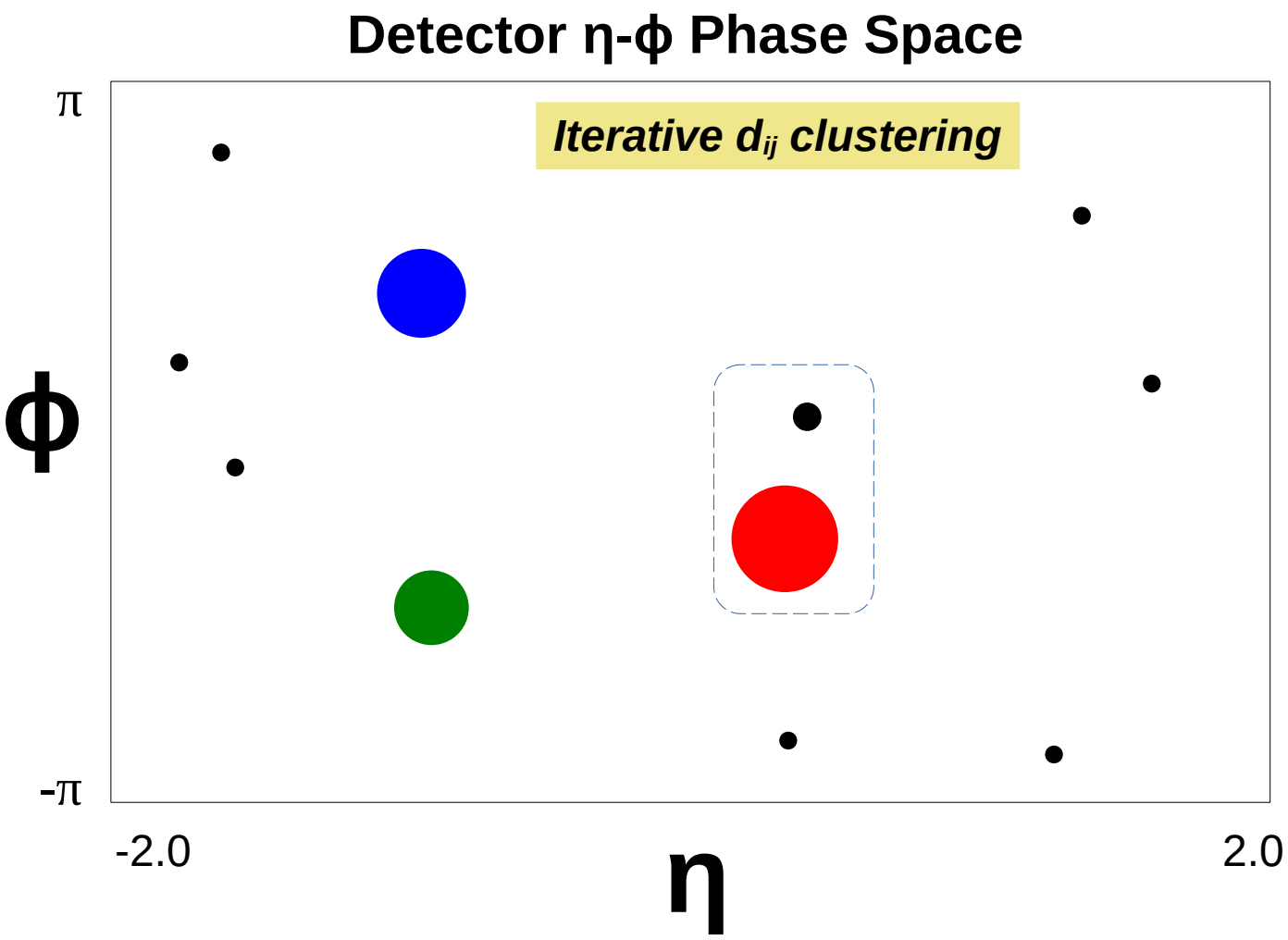

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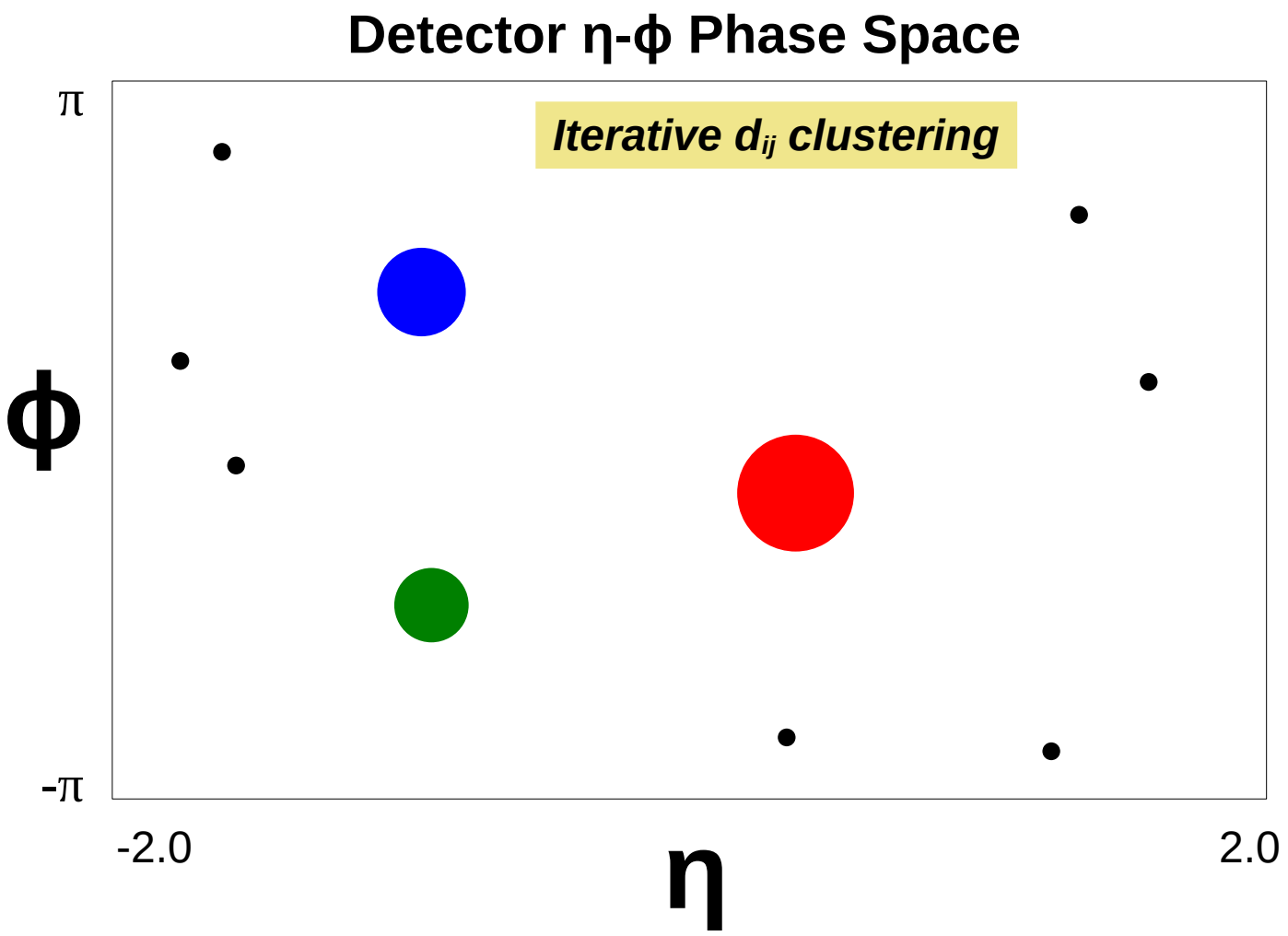

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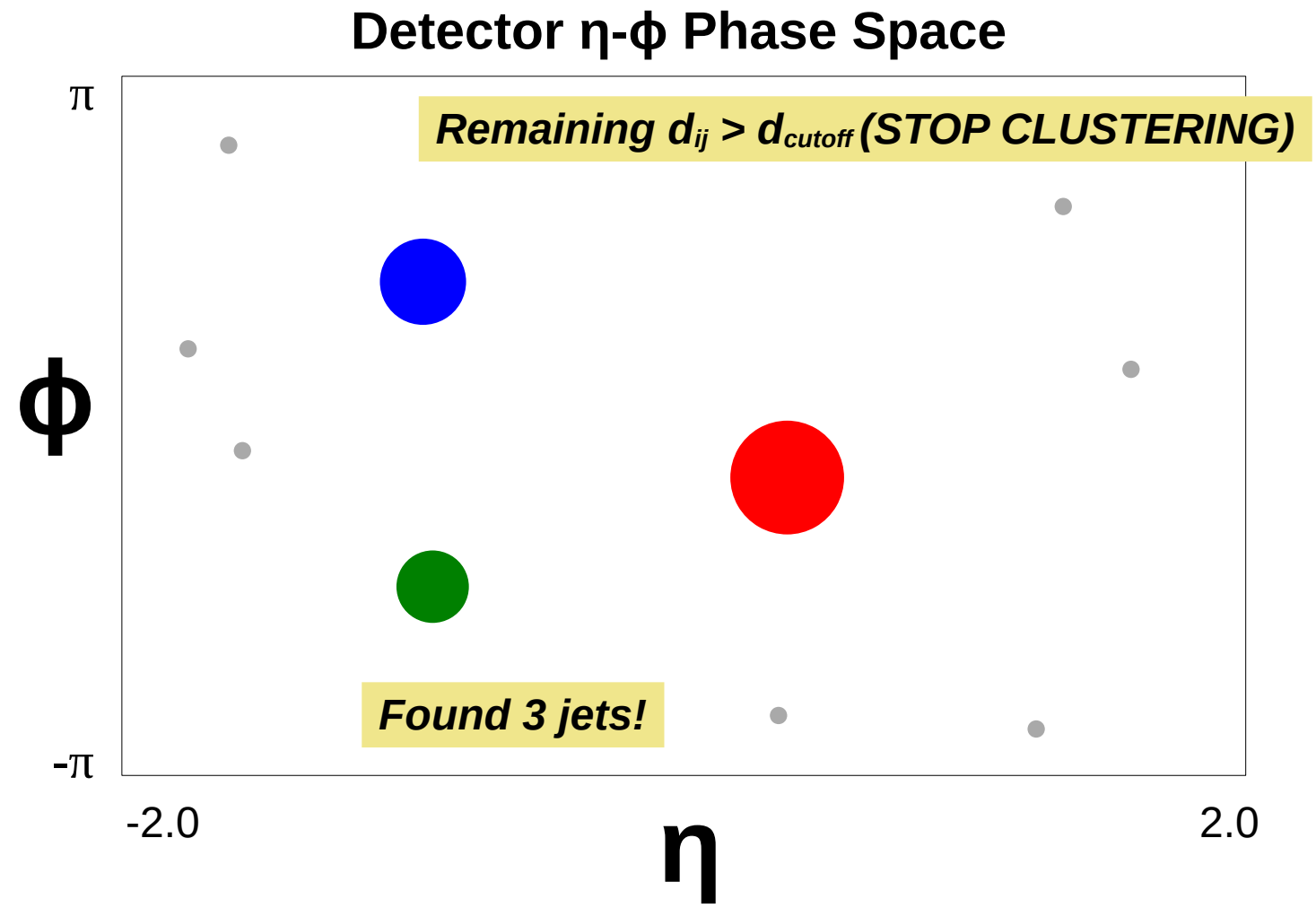

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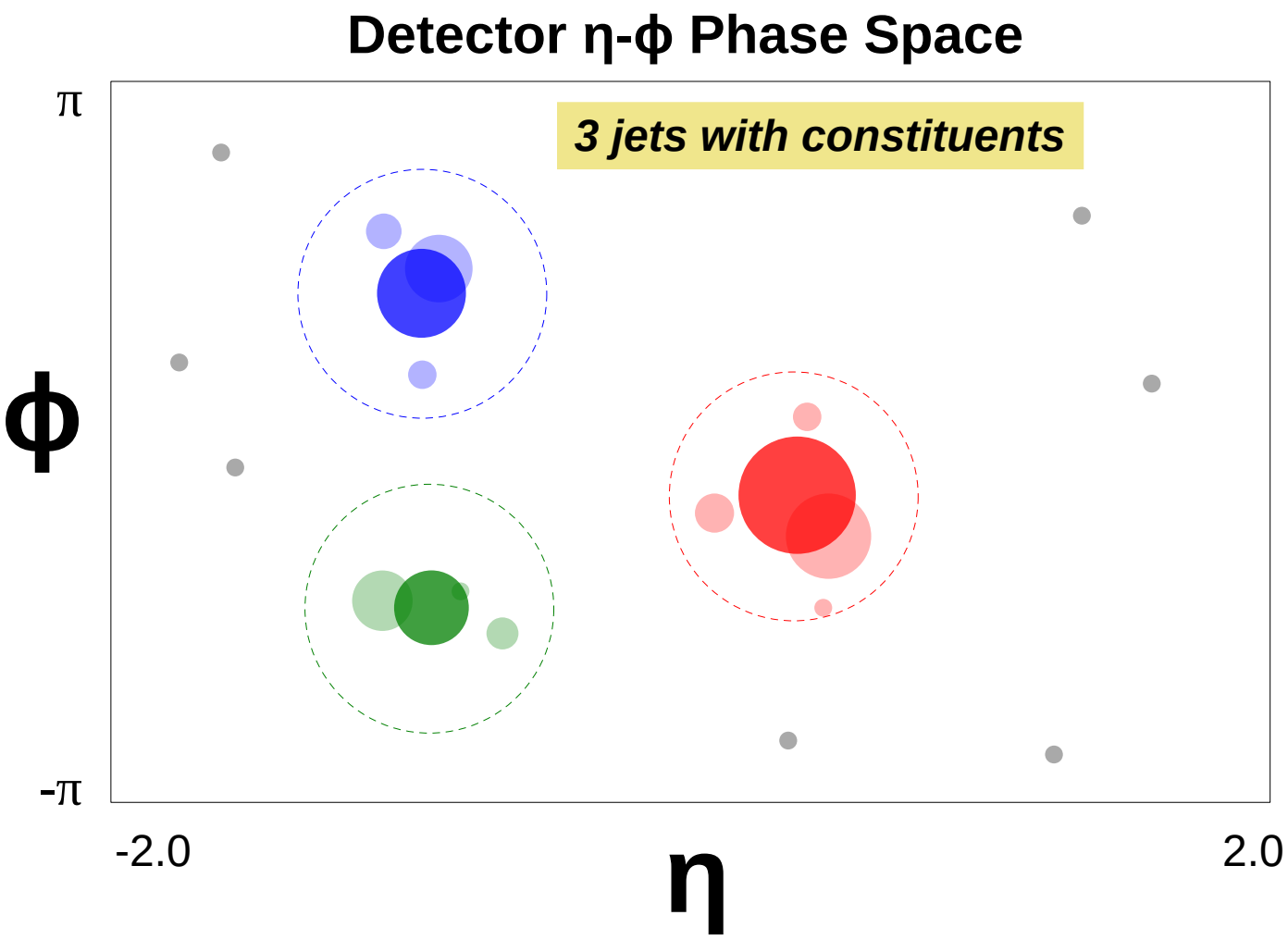
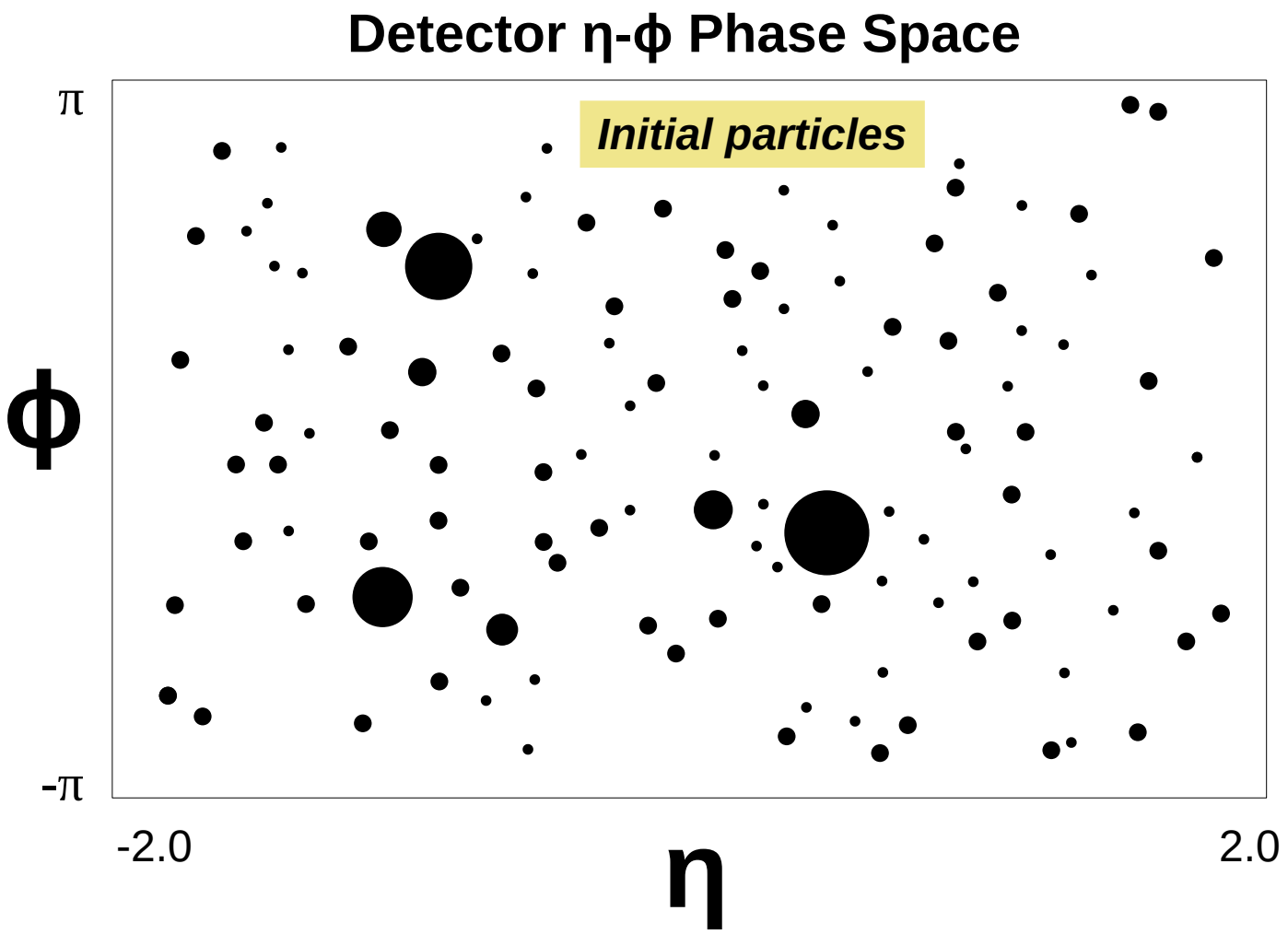


Jets – Clustering

$$\Delta_{ik} = p_{\mathrm{T,i}}^{\alpha} \sqrt{(\eta_i - \eta_k^g)^2 + (\phi_i - \phi_k^g)^2}$$



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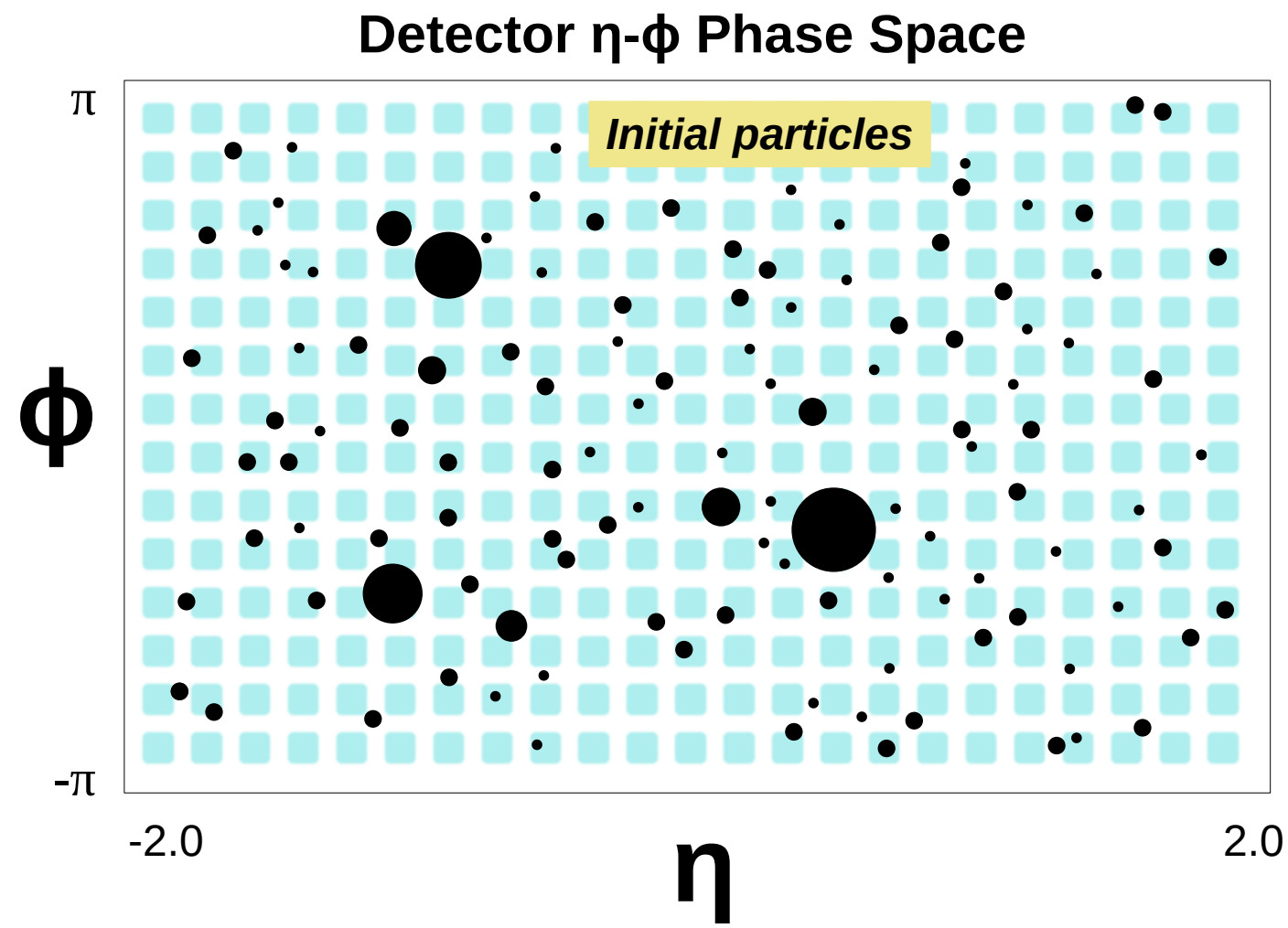

If $p_{\mathrm{T,i}} > p_{\mathrm{T,k}}{}^{\mathrm{g}}$

Then $p_{\mathrm{T,i}}$ -= $p_{\mathrm{T,k}}{}^{\mathrm{g}}$ & $p_{\mathrm{T,k}}{}^{\mathrm{g}} \to 0$

Else if $p_{\mathrm{T,i}} < p_{\mathrm{T,k}}{}^{\mathrm{g}}$

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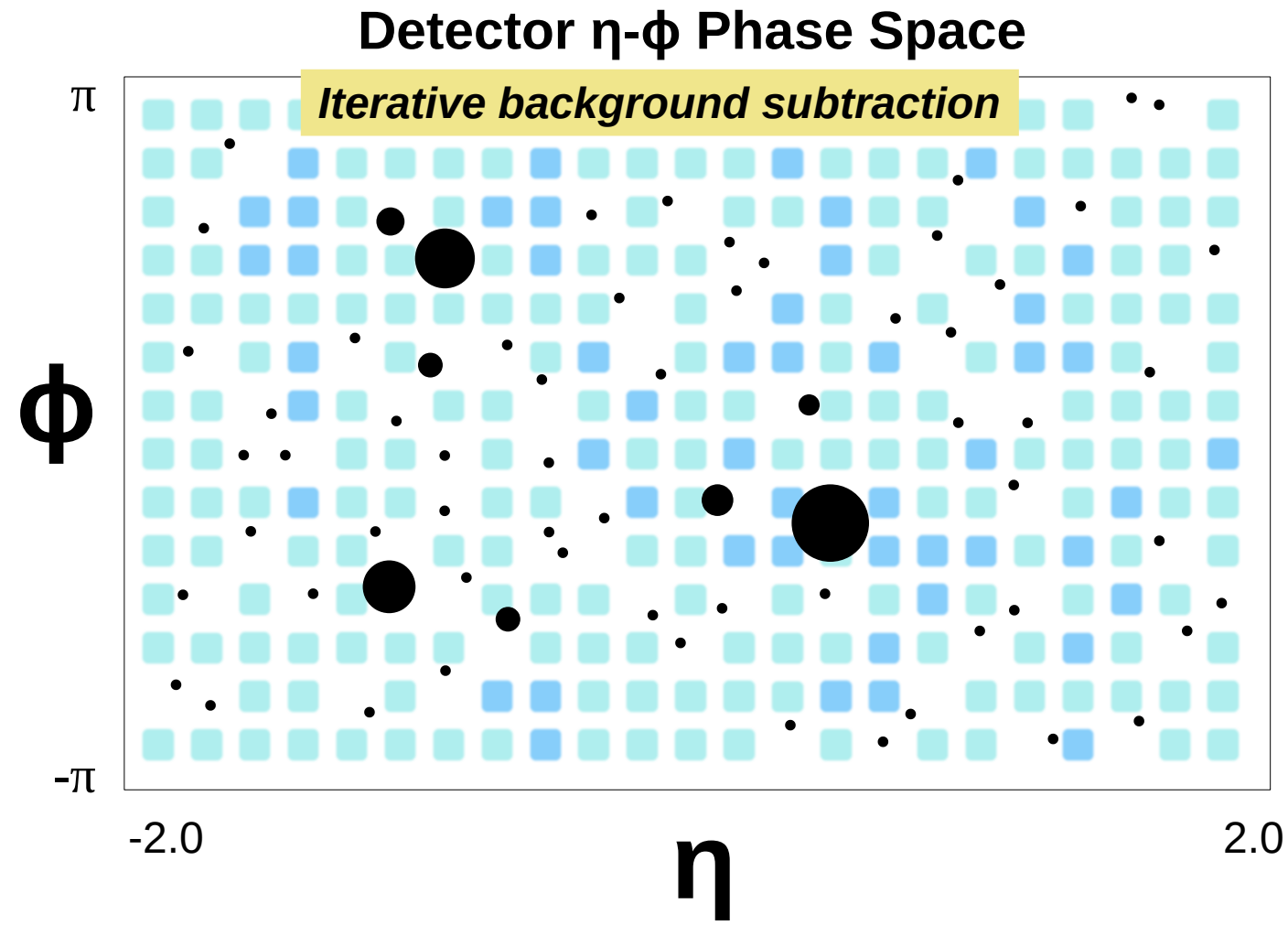

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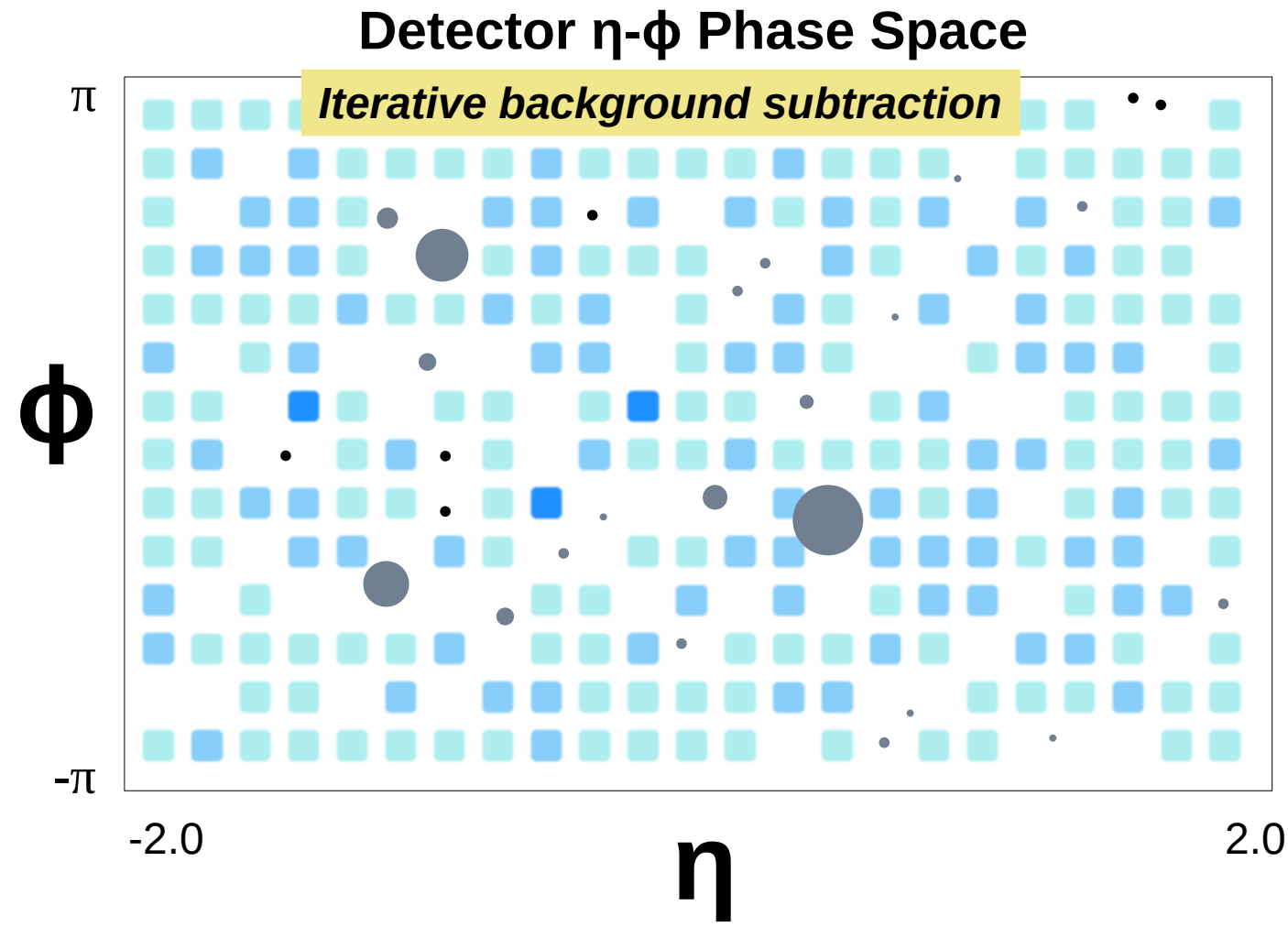

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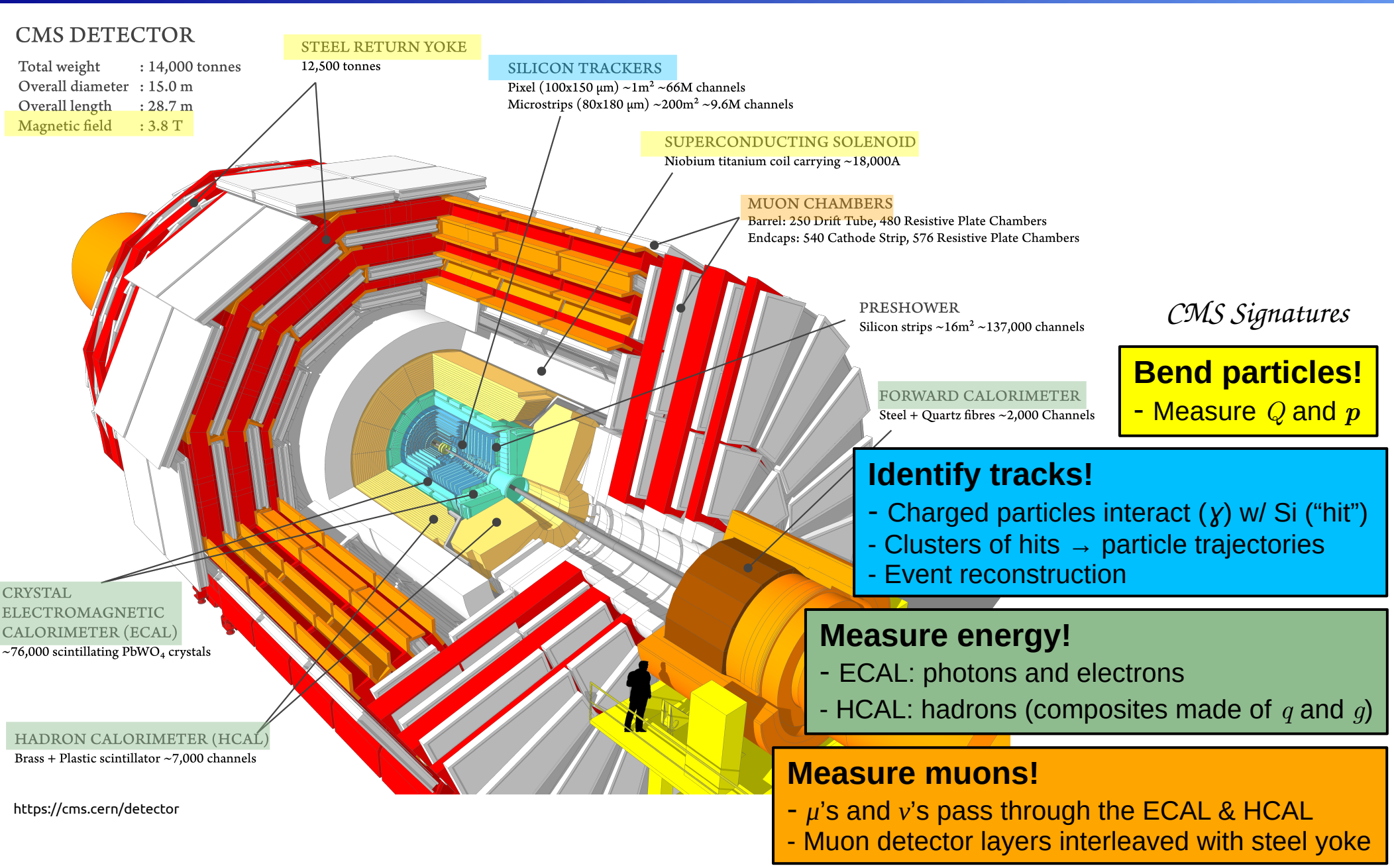
The Compact Muon Solenoid (CMS)



CMS Signatures

Bend particles!
- Measure Q and p

Identify tracks!
- Charged particles interact (γ) w/ Si ("hit")
- Clusters of hits → particle trajectories
- Event reconstruction

Measure energy!
- ECAL: photons and electrons
- HCAL: hadrons (composites made of q and g)

Measure muons!
- μ's and ν's pass through the ECAL & HCAL
- Muon detector layers interleaved with steel yoke

The Compact Muon Solenoid (CMS)

Monte carlo event generators

Title