

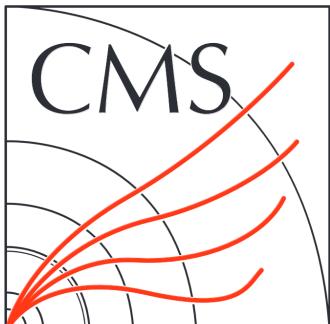
Measuring the Quenching of *b*-quark Jets via Muon- Tagging in PbPb Collisions with the CMS Detector

Clayton Bennett

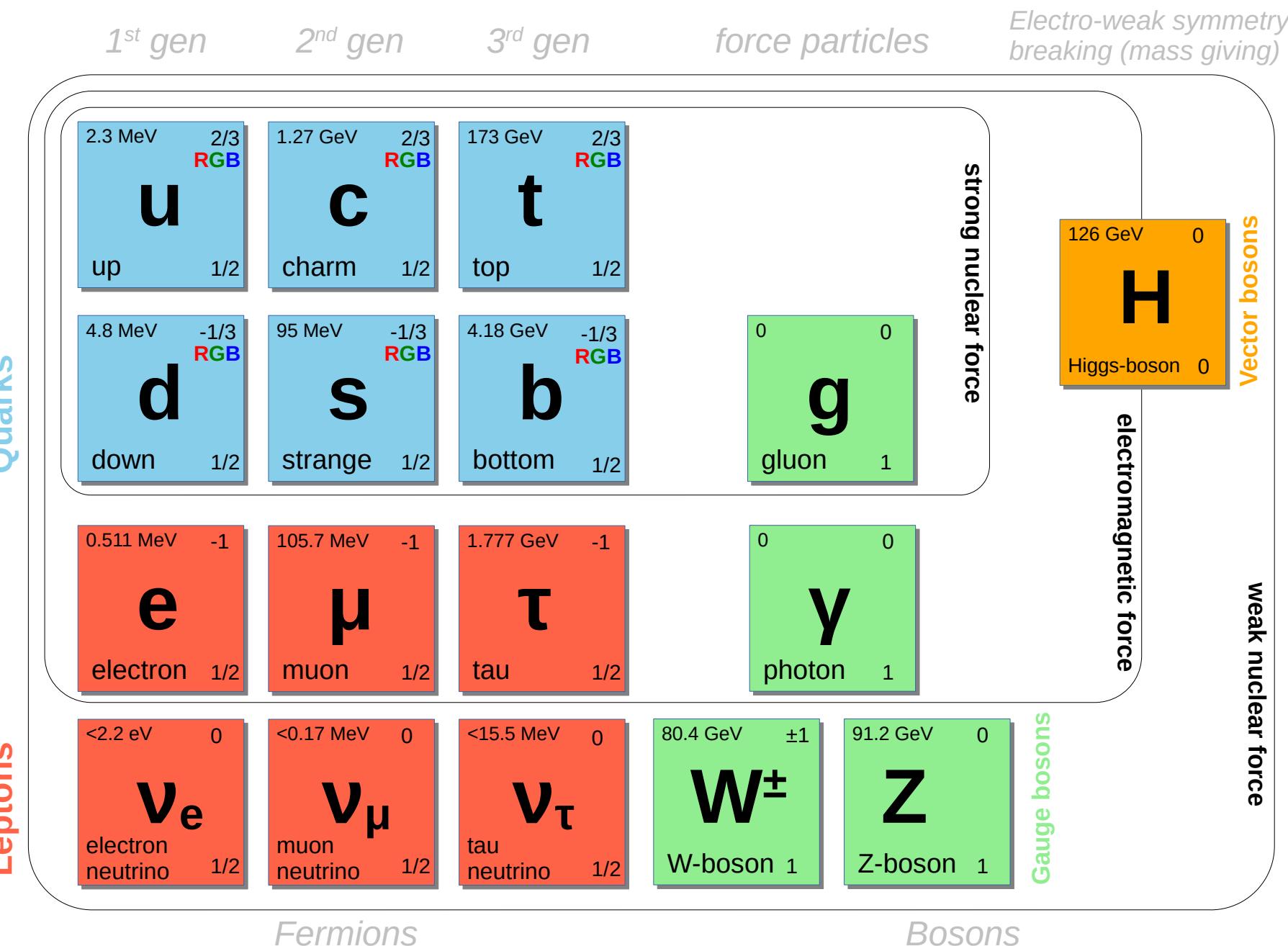
UIC Physics Thesis Preliminary Defense

Advisor: Olga Evdokimov, Ph.D.

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

Hard processes in pp collisions

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

Cross-section factorization

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

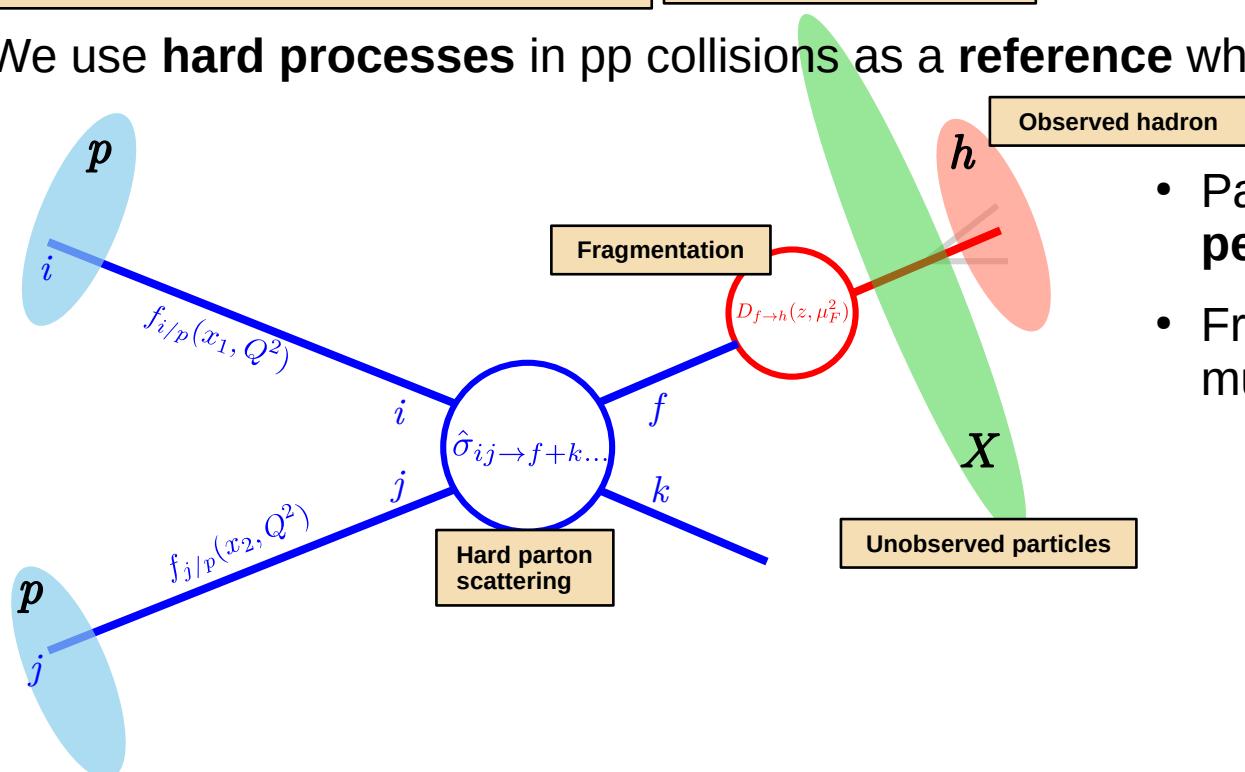
$$d\sigma^{p+p \rightarrow f+X} = \sum_{i,j,k\dots} f_{i/p}(x_1, Q^2) \bigotimes f_{j/p}(x_2, Q^2) \bigotimes \hat{\sigma}_{ij \rightarrow f+k\dots}$$

$D_{f \rightarrow h}(z, \mu_F^2)$: 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



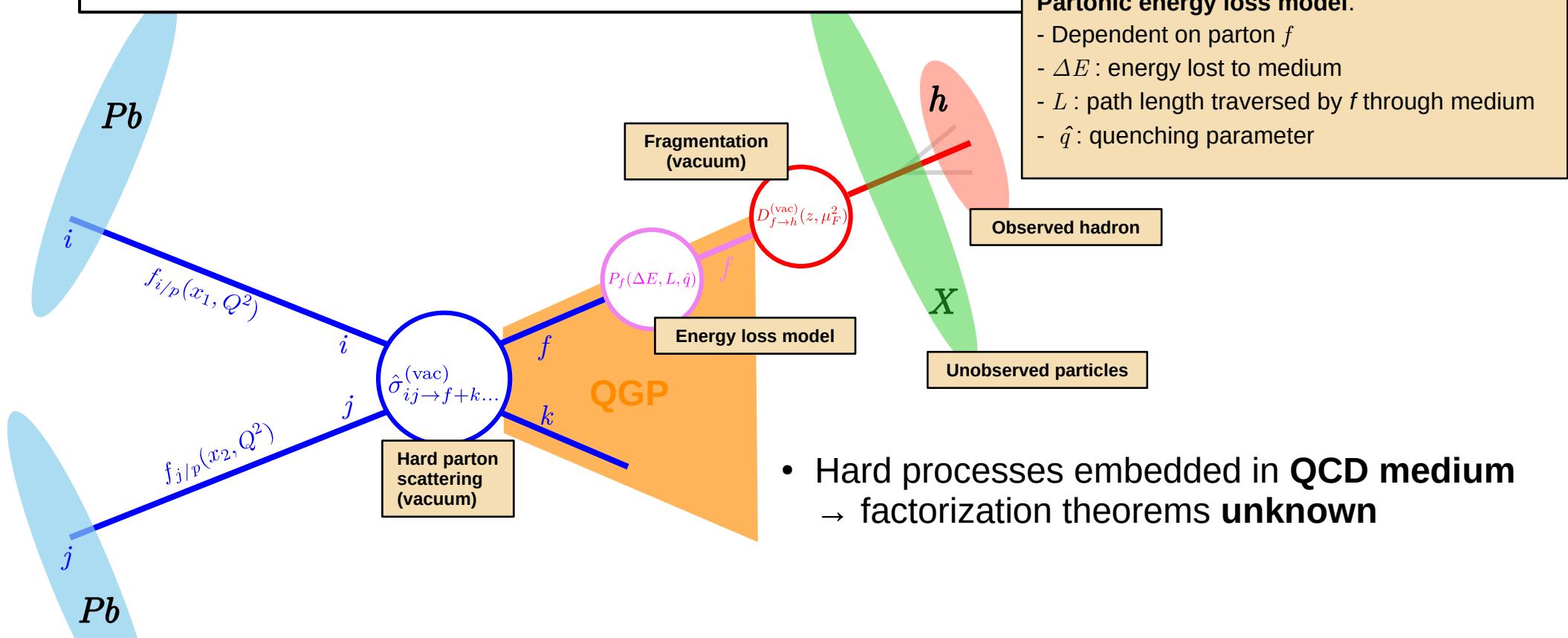
- Partonic cross-section in vacuum is **perturbatively calculable!**
- Fragmentation is non-perturbative → must rely on **QCD-inspired models!**

Hard processes in PbPb collisions

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

Cross-section factorization

$$d\sigma_{(\text{med})}^{A+A \rightarrow h+X} = \sum_f d\sigma_{(\text{vac})}^{A+A \rightarrow f+X} \otimes P_f(\Delta E, L, \hat{q}) \otimes D_{f \rightarrow h}^{(\text{vac})}(z, \mu_F^2)$$



Jets

In reality, fragmentation results in a spray of particles!

Leading hadron factorization → 1st order jet

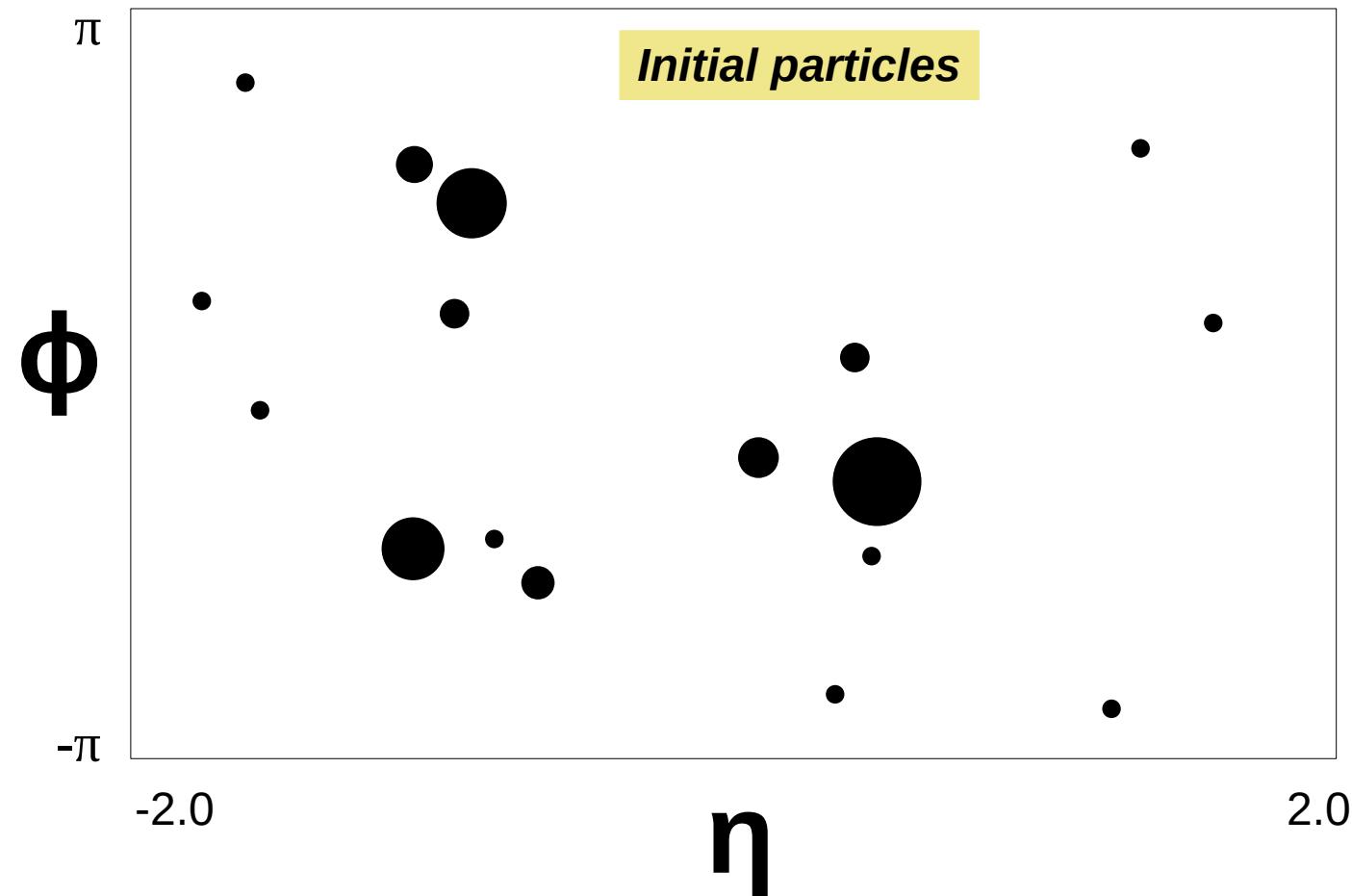
Jet (theory)

- a collimated set of hadronic decay products from a parent parton
-

Jets – Clustering

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

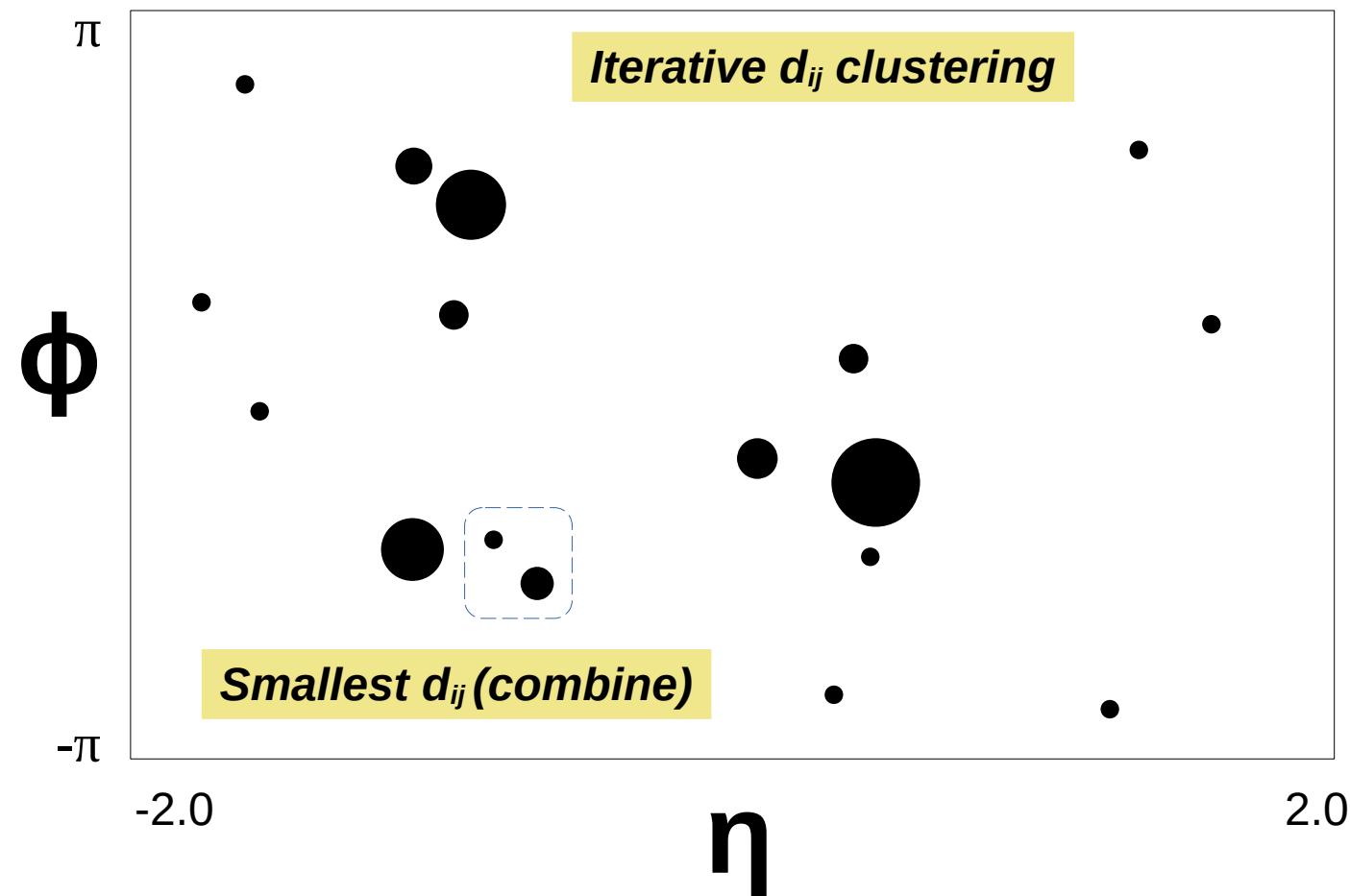
Detector η - ϕ Phase Space



Jets – Clustering

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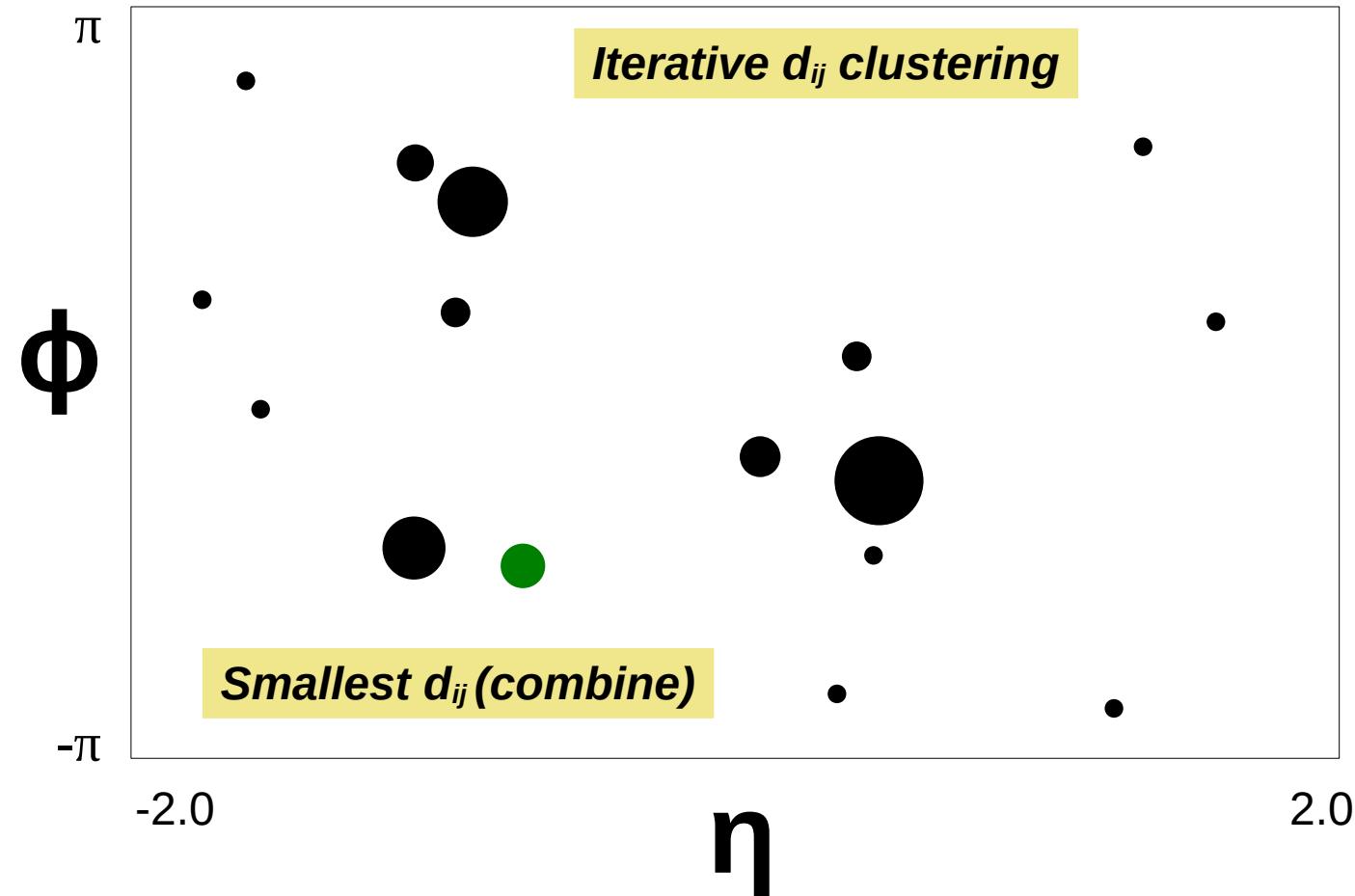
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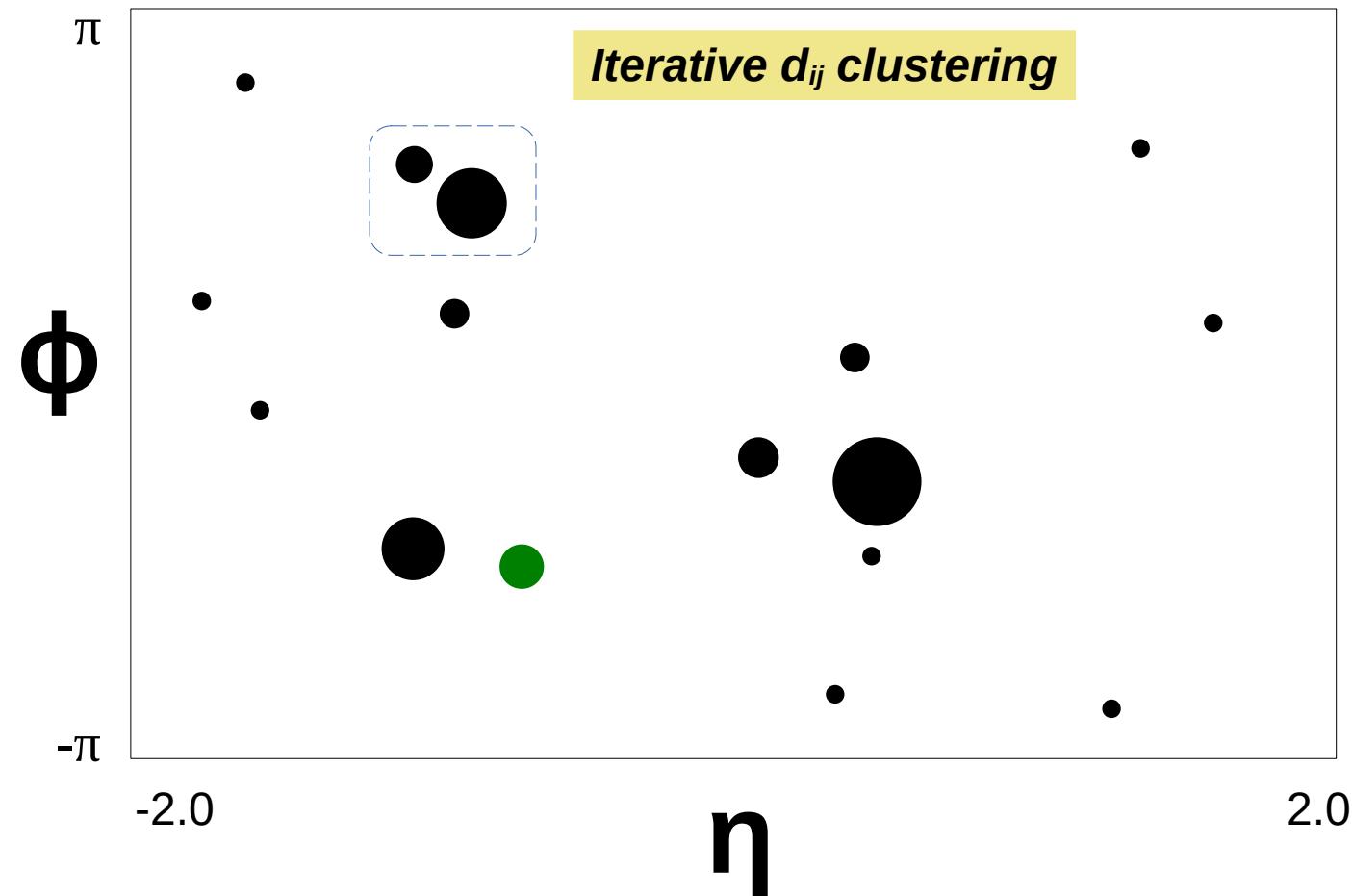
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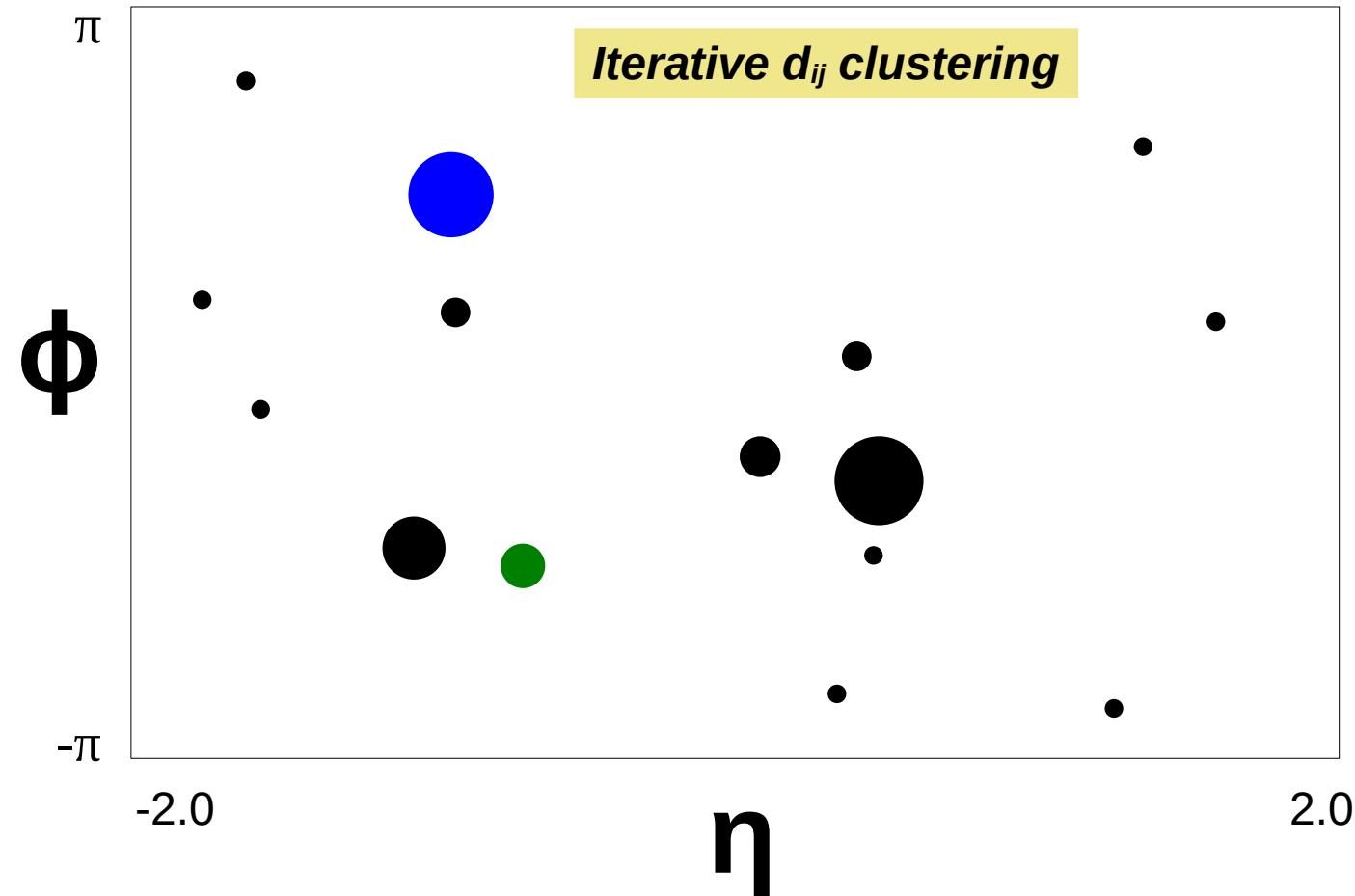
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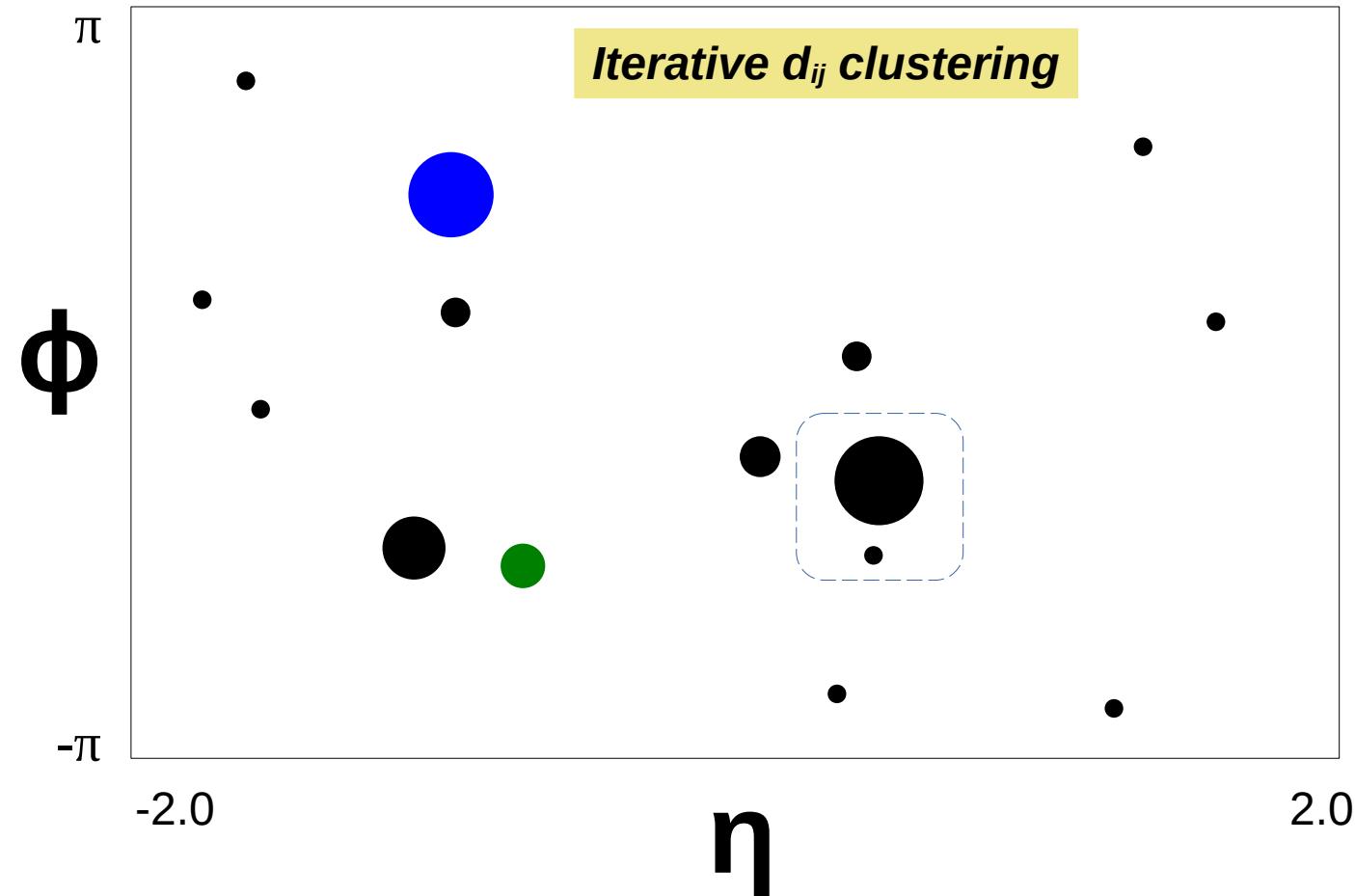
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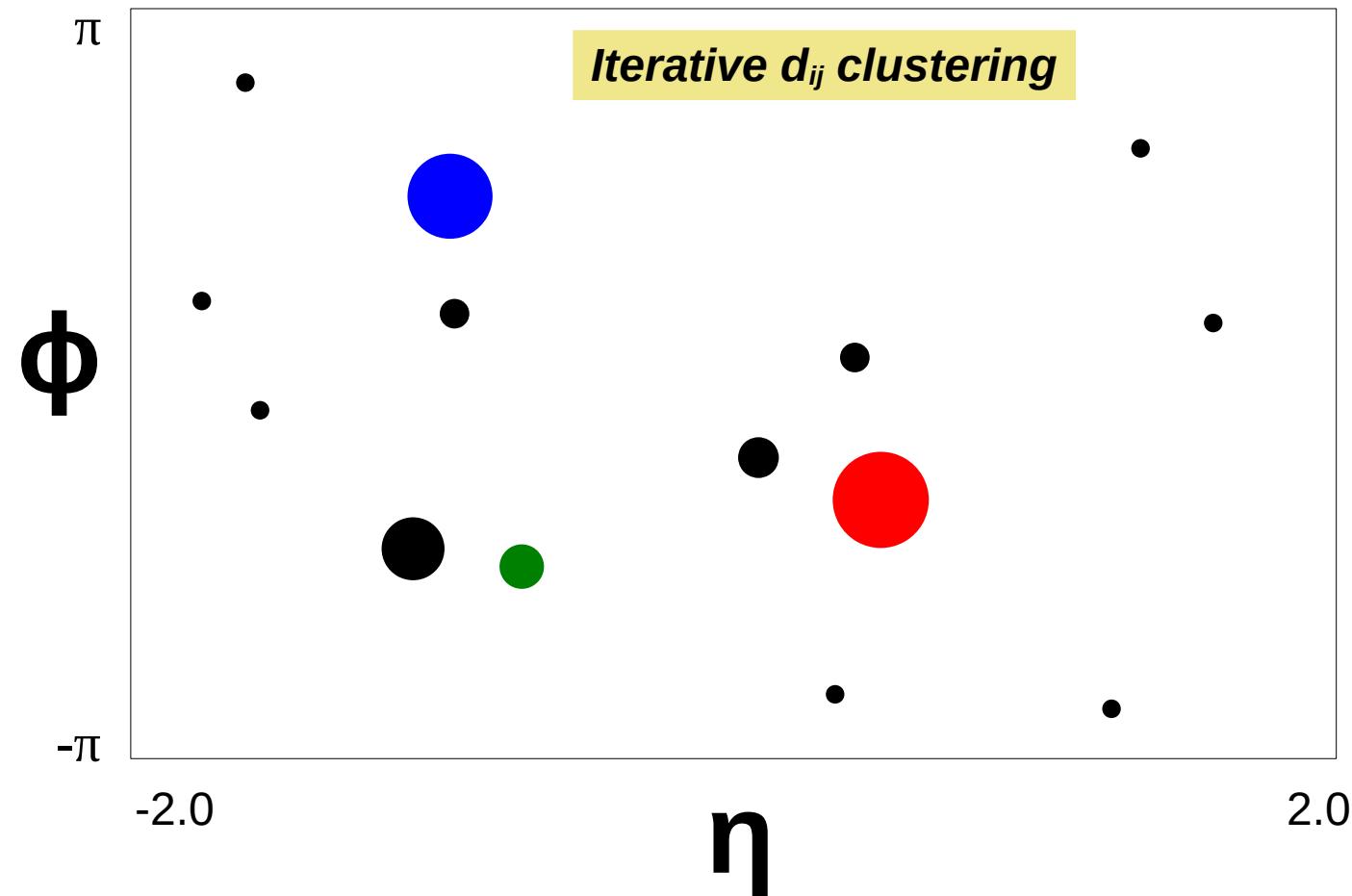
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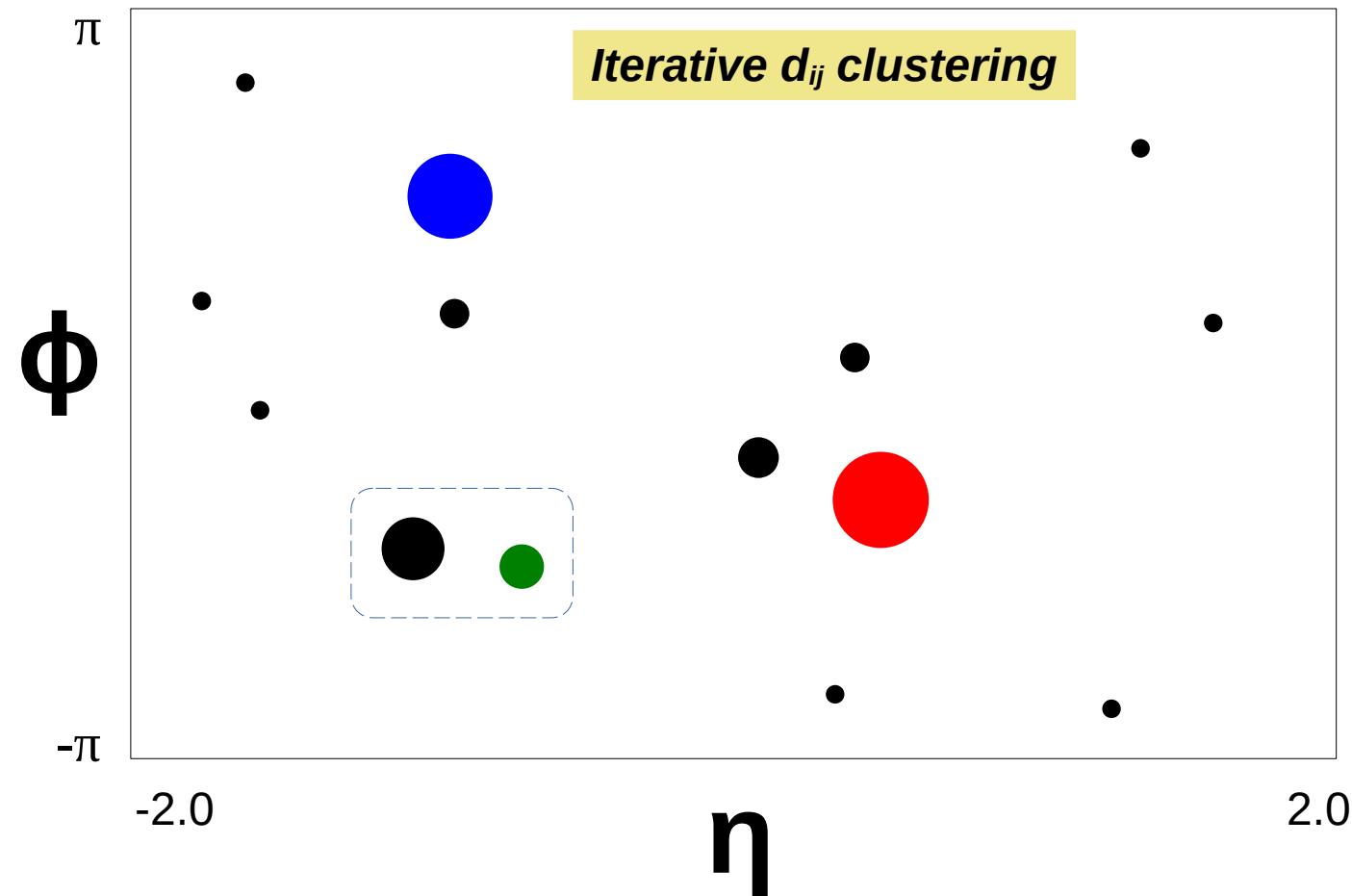
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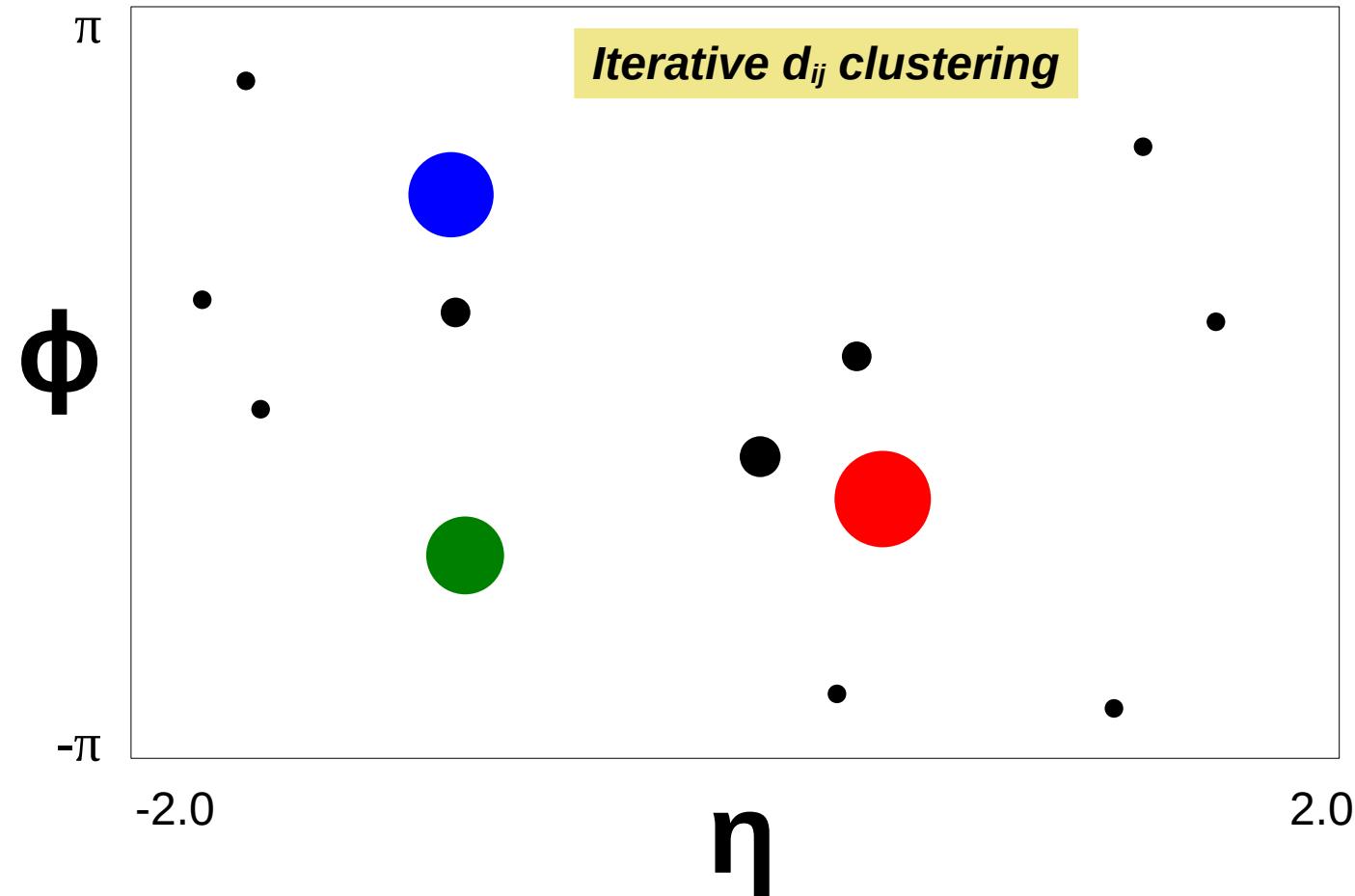
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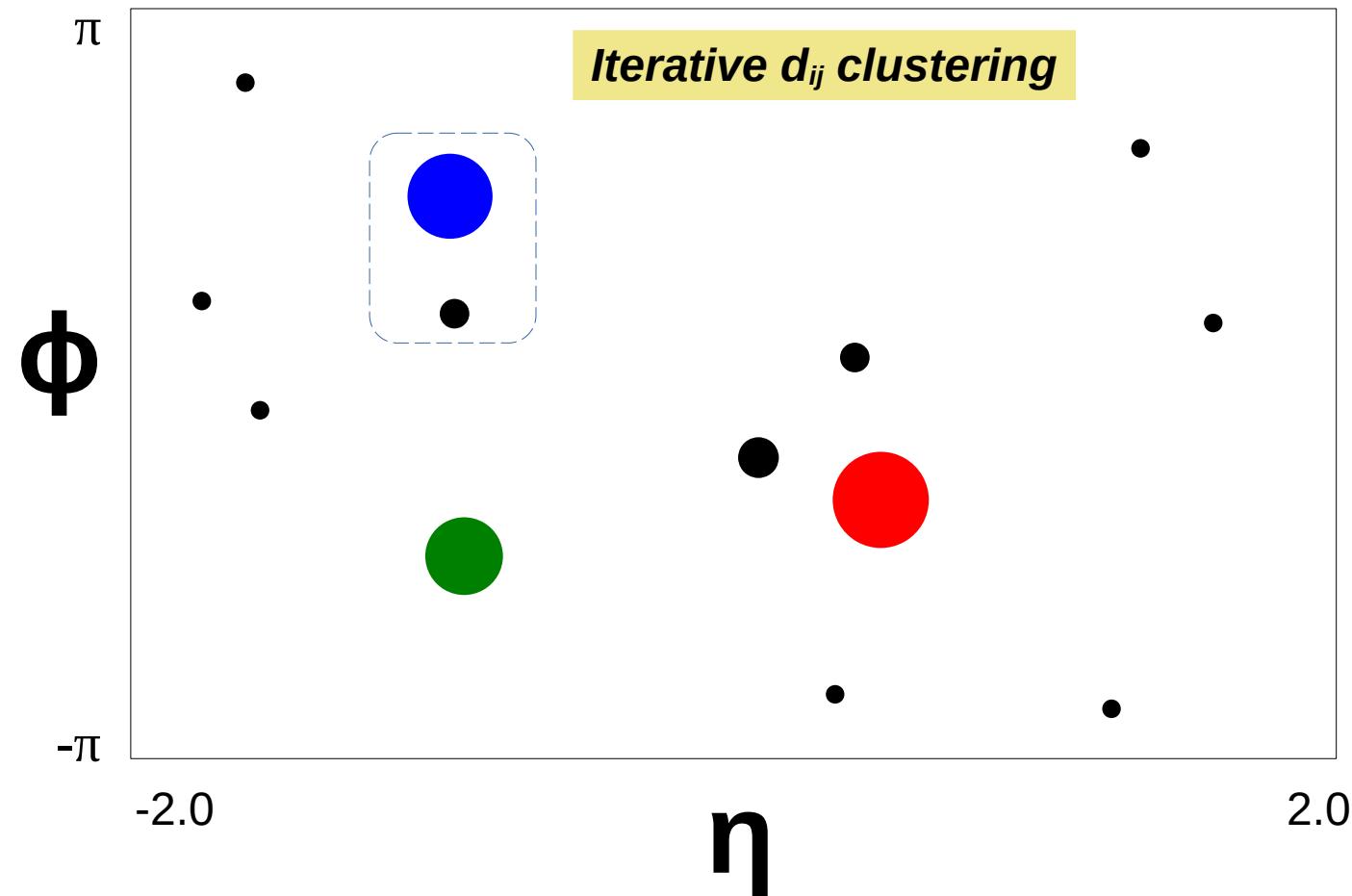
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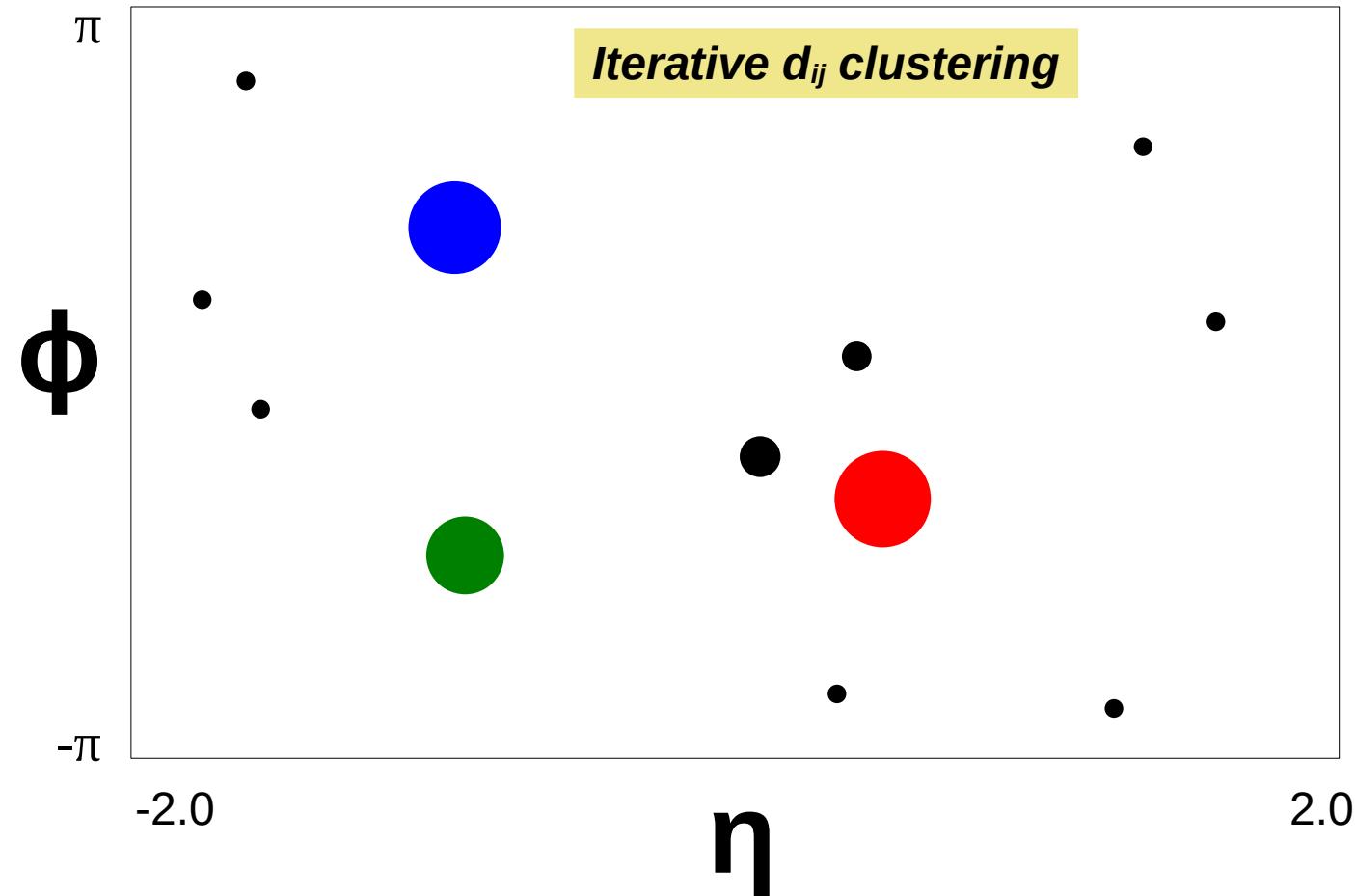
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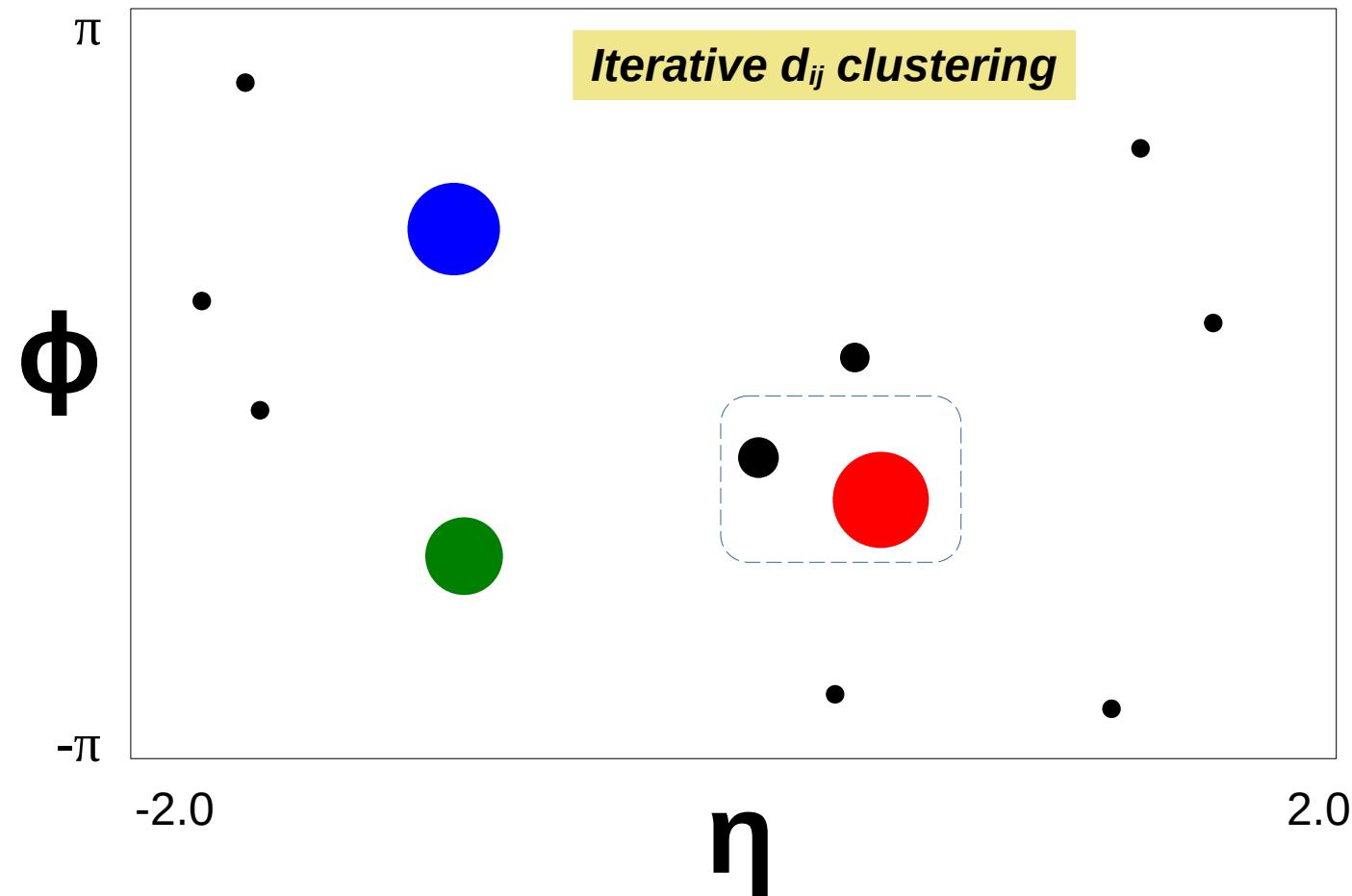
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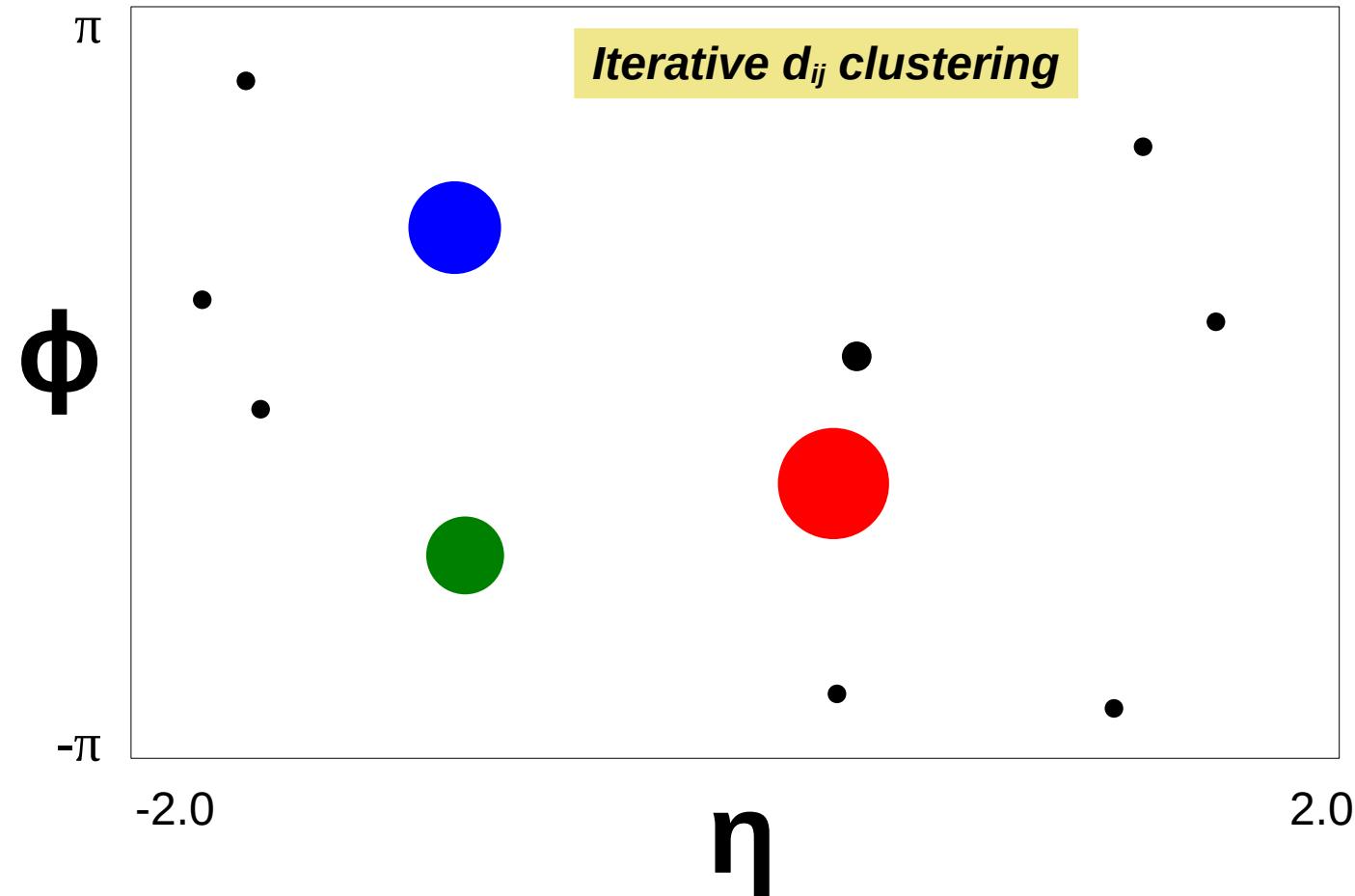
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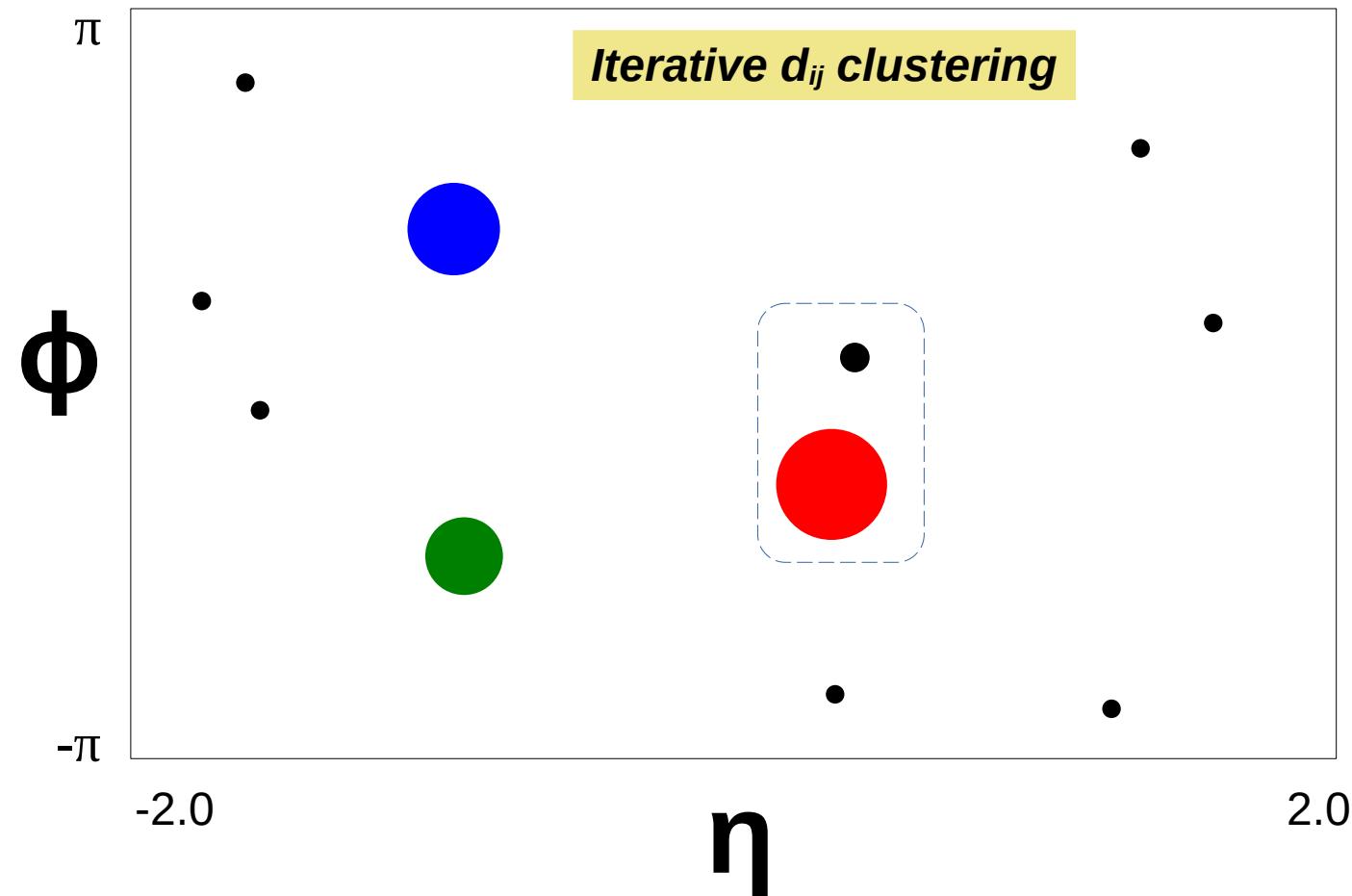
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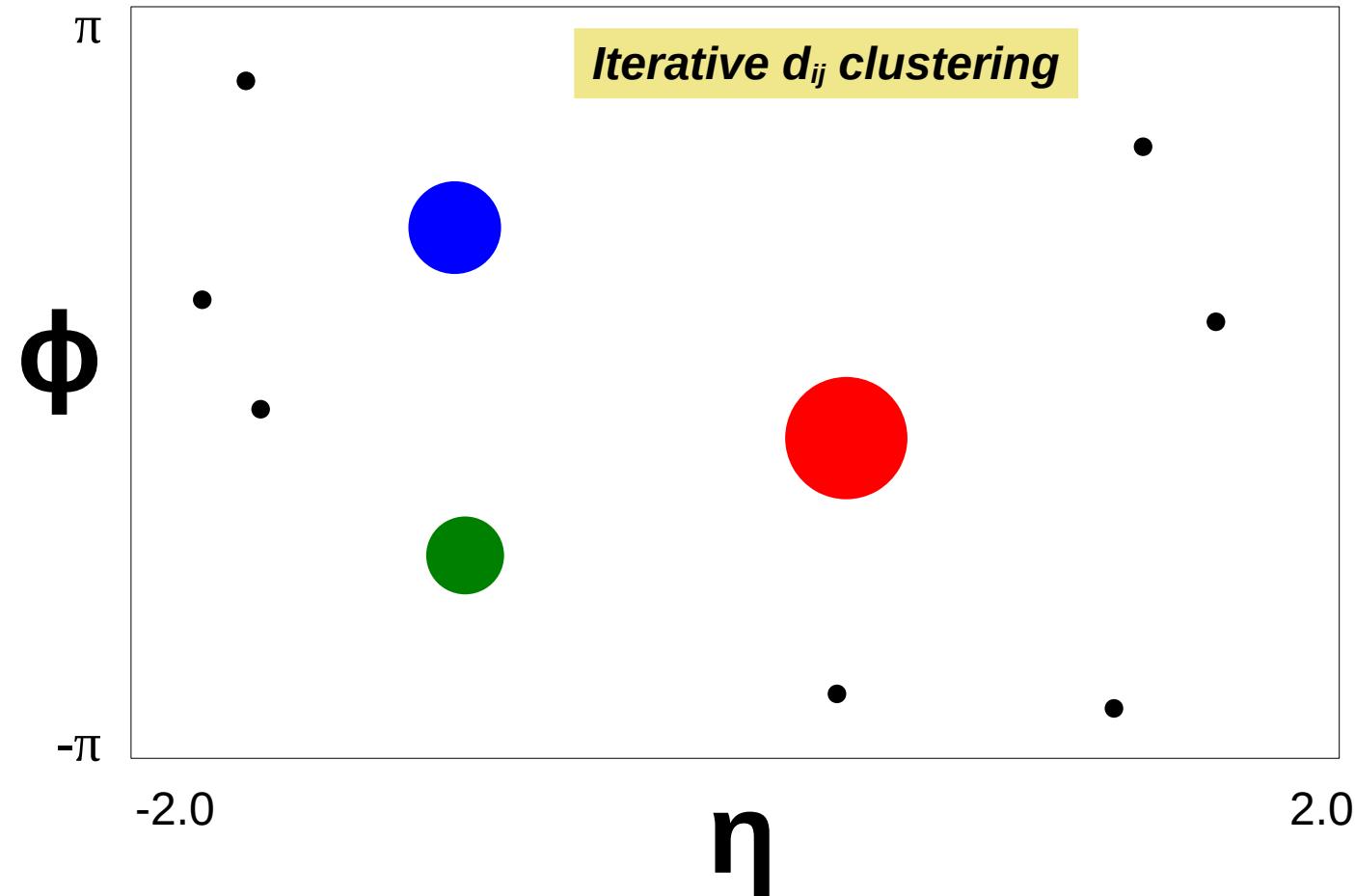
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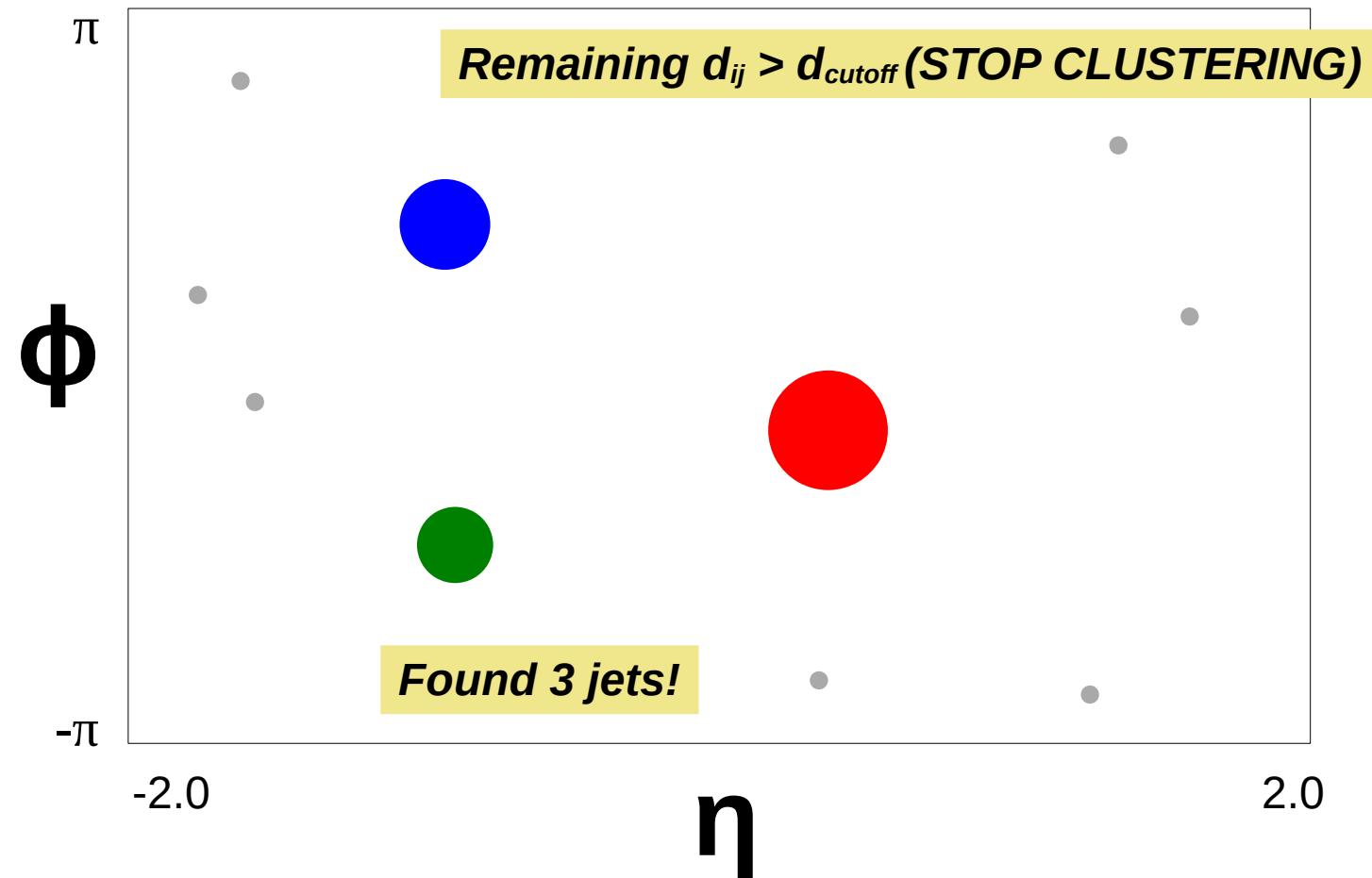
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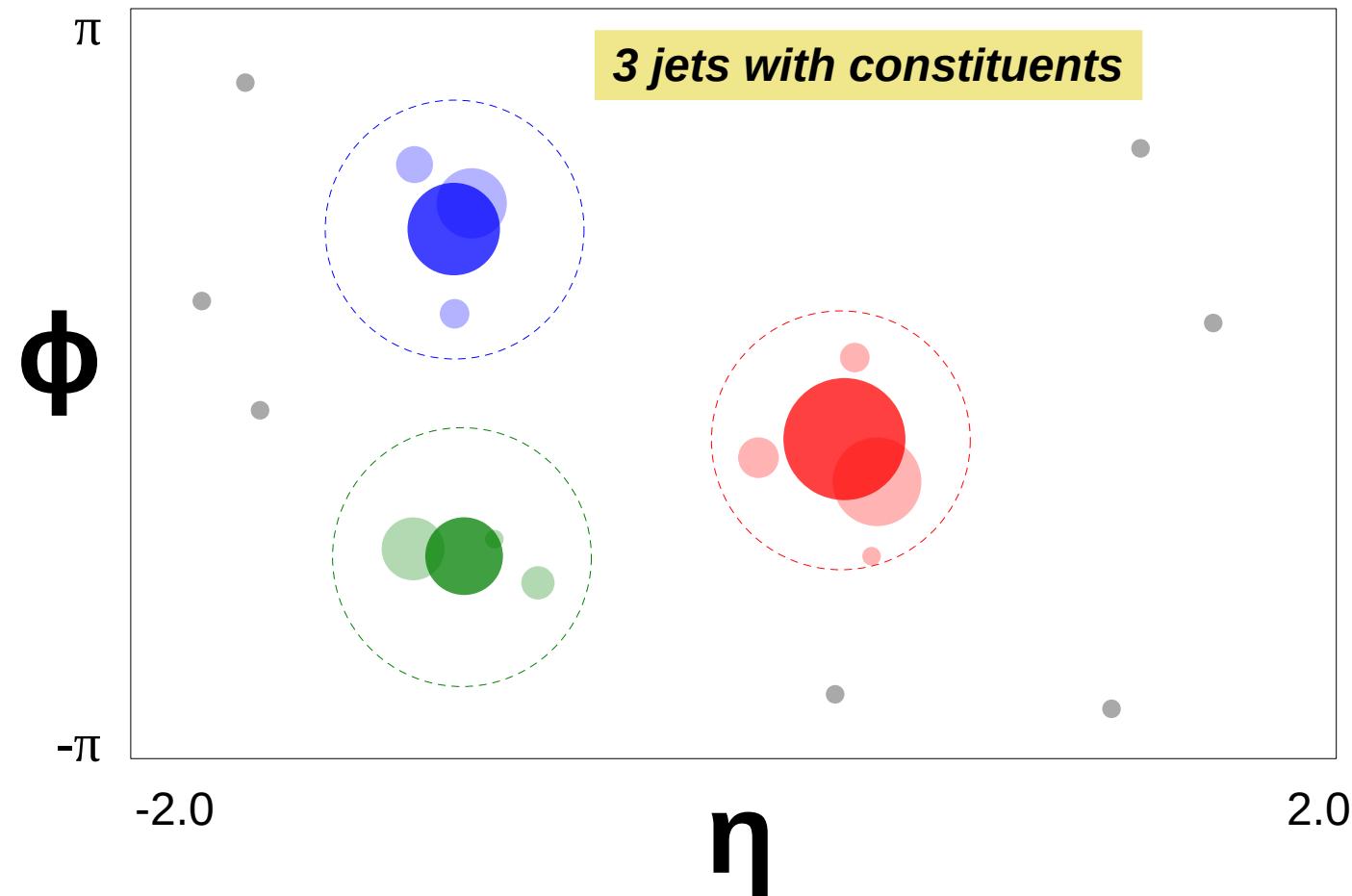
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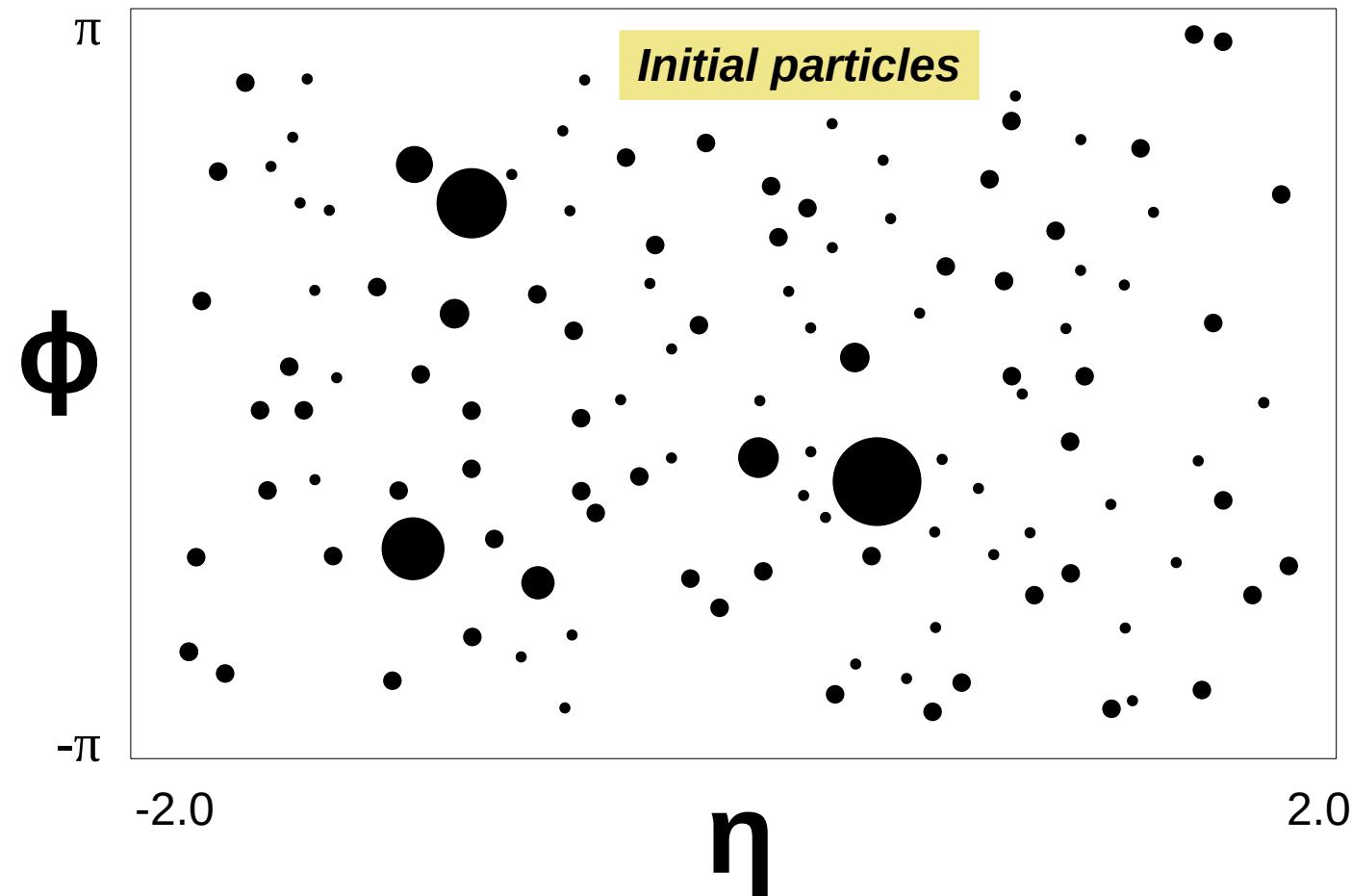
Detector η - ϕ Phase Space



Jets – Clustering

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

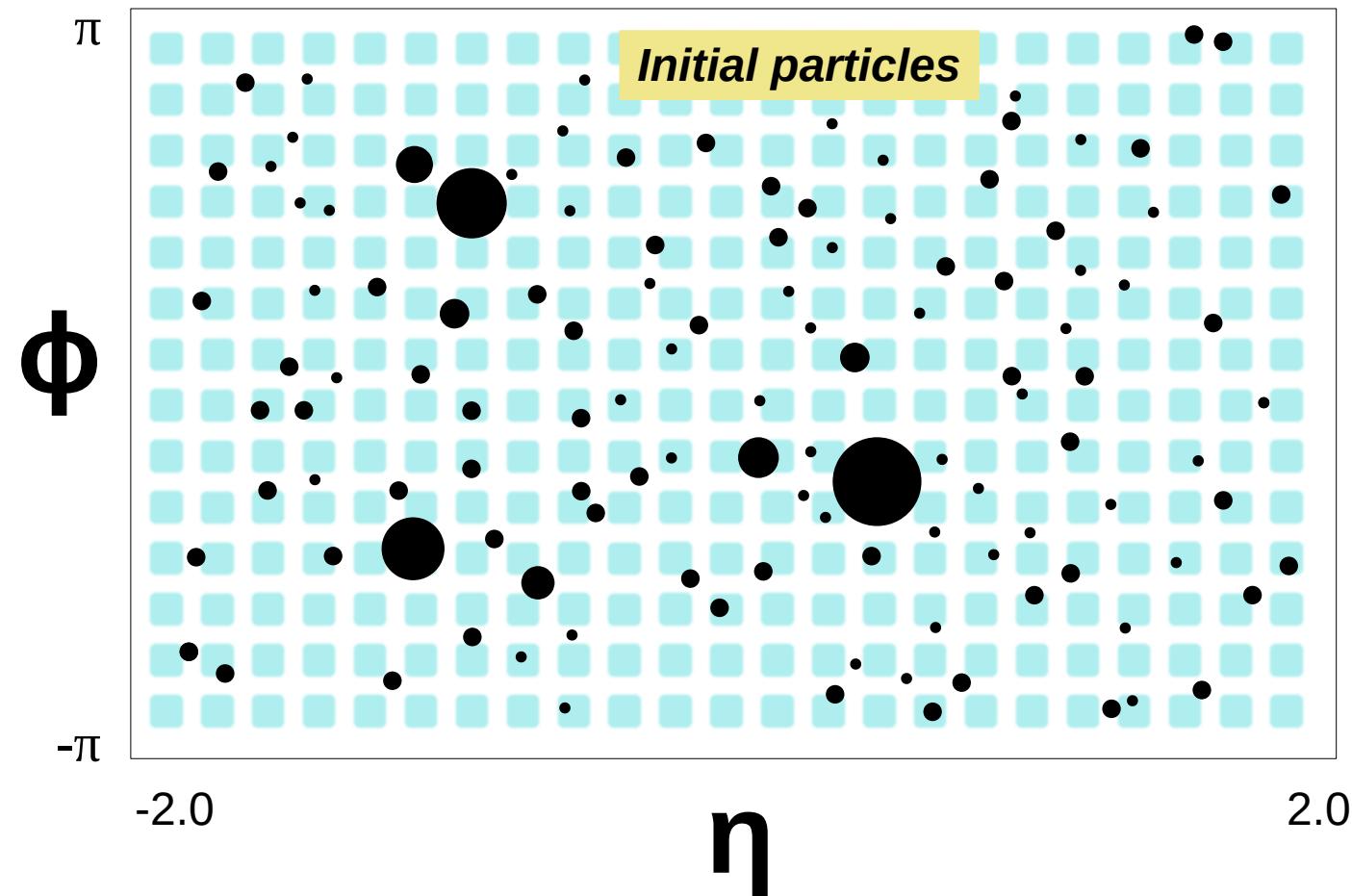
Detector η - ϕ Phase Space



Jets – Clustering

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Detector η - ϕ Phase Space



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

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

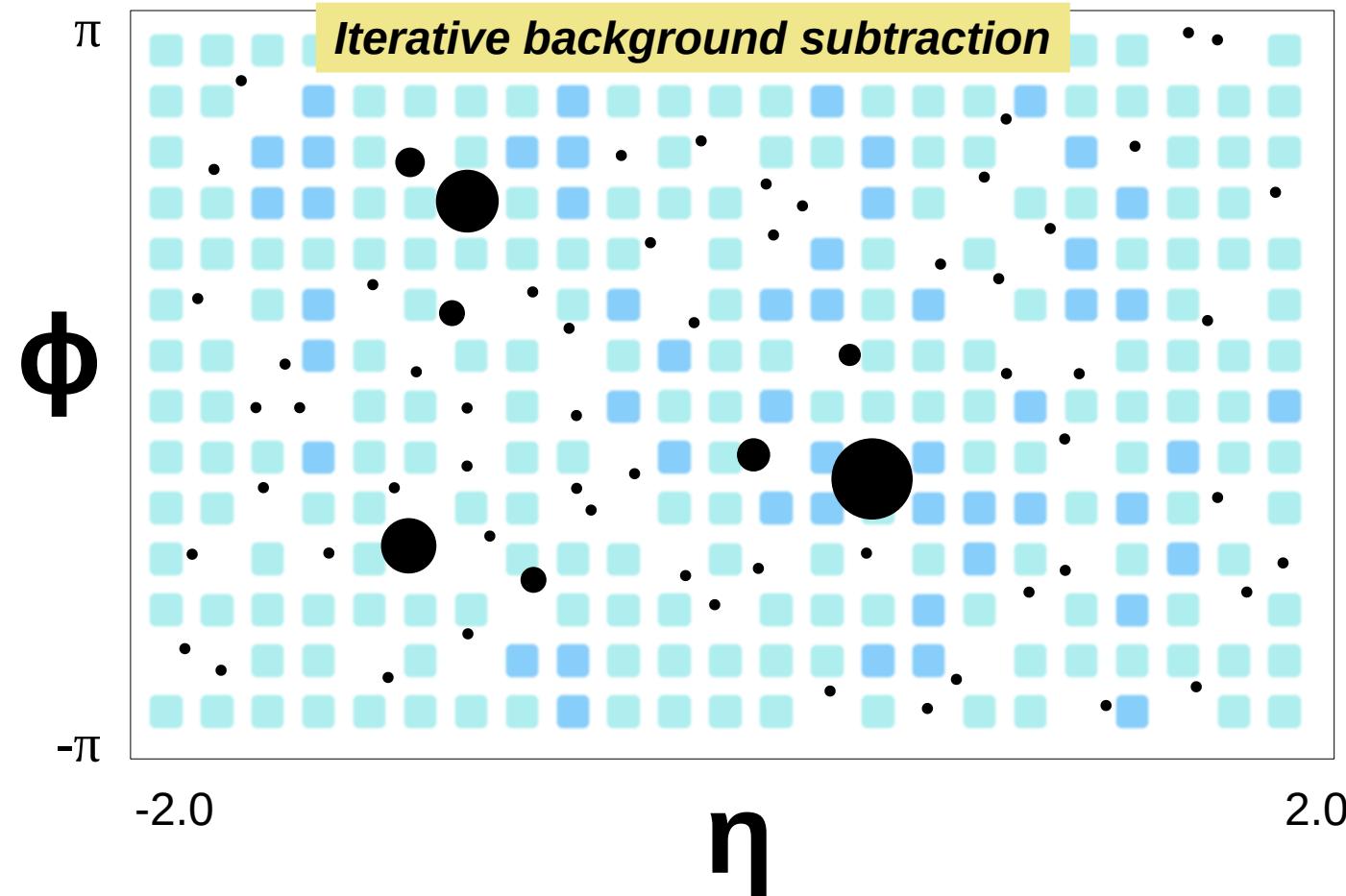
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Jets – Clustering

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Detector η - ϕ Phase Space



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

Then $p_{T,i} - p_{T,k}^g$ & $p_{T,k}^g \rightarrow 0$

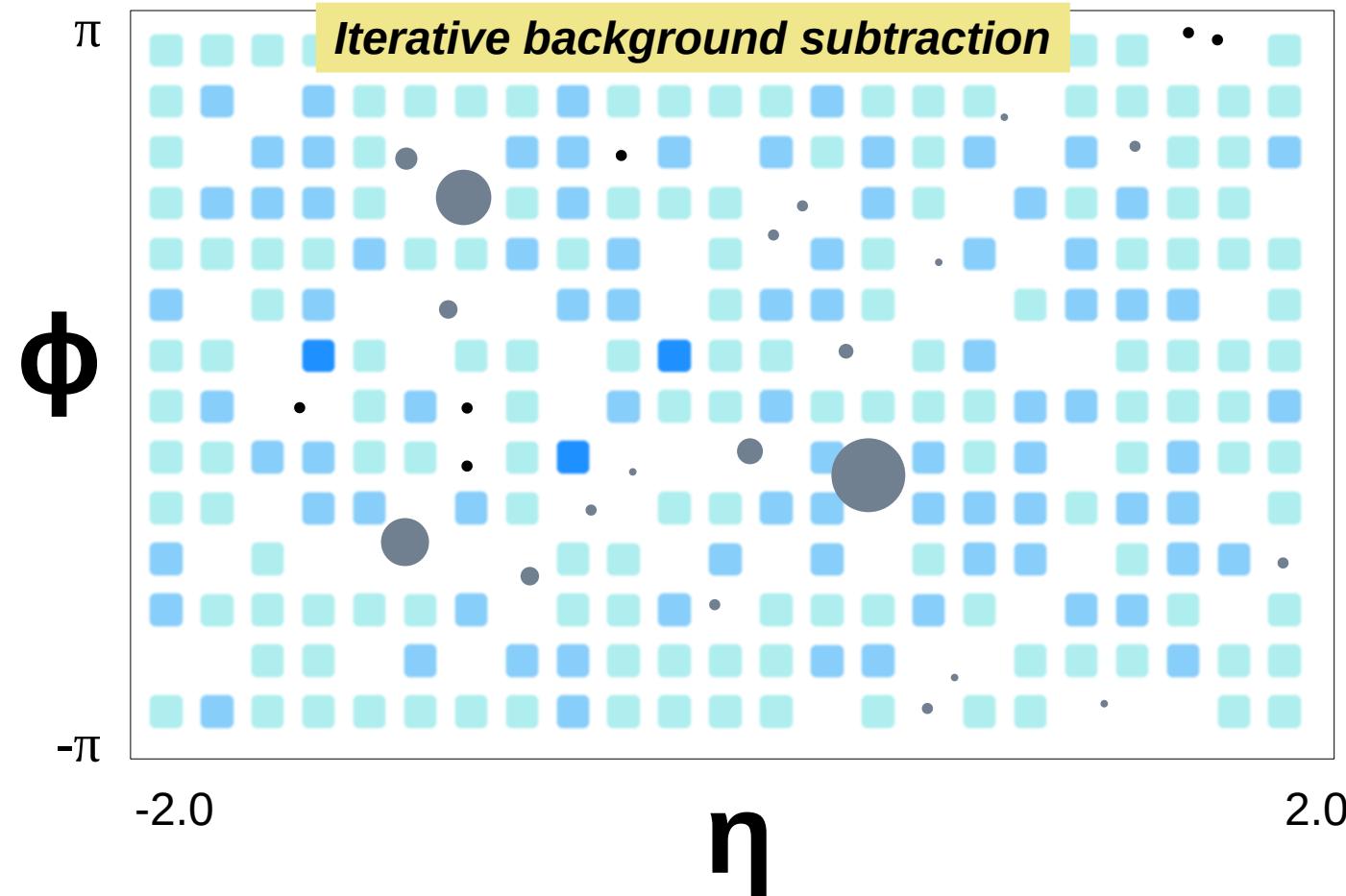
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Then $p_{T,i} - p_{T,k}^g$ & $p_{T,k}^g \rightarrow 0$

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

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The Compact Muon Solenoid (CMS)

CMS DETECTOR

Total weight : 14,000 tonnes

Overall diameter : 15.0 m

Overall length : 28.7 m

Magnetic field : 3.8 T

STEEL RETURN YOKE

12,500 tonnes

SILICON TRACKERS

Pixel ($100 \times 150 \mu\text{m}$) $\sim 1\text{m}^2 \sim 66\text{M}$ channels

Microstrips ($80 \times 180 \mu\text{m}$) $\sim 200\text{m}^2 \sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID

Niobium titanium coil carrying $\sim 18,000\text{A}$

MUON CHAMBERS

Barrel: 250 Drift Tube, 480 Resistive Plate Chambers

Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

PRESHOWER

Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

FORWARD CALORIMETER

Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL
ELECTROMAGNETIC
CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator $\sim 7,000$ channels

<https://cms.cern/detector>

CMS Signatures

Bend particles!

- Measure Q and p

Identify tracks!

- Charged particles interact (γ) w/ Si ("hit")
- Clusters of hits \rightarrow 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