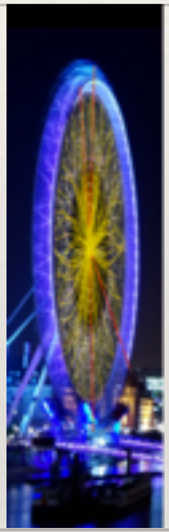
Boost 2014 workshop, UCL, London, August 2014

FastJet & FJContrib



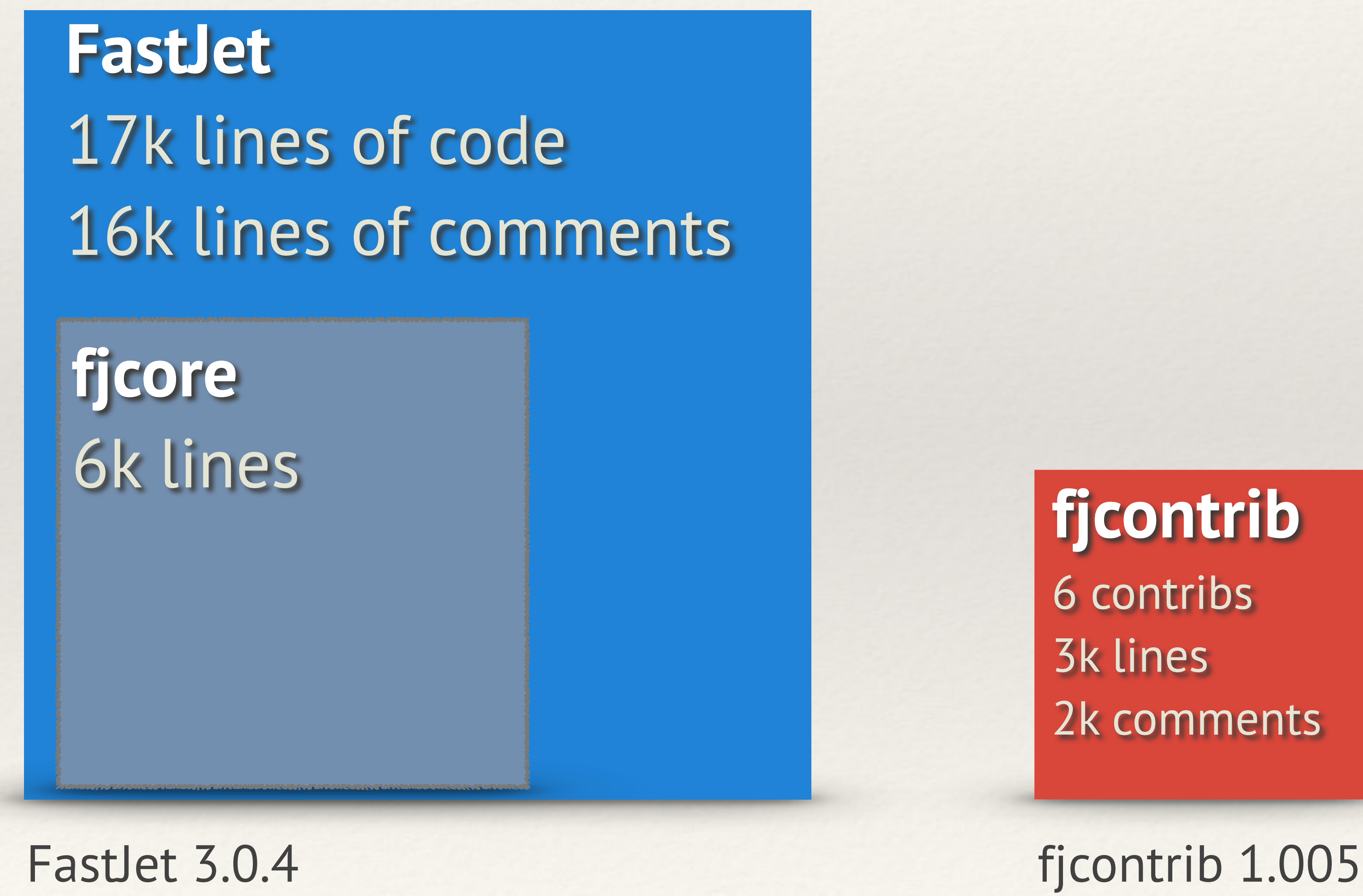
Matteo Cacciari (Paris)

Gavin Salam (CERN)

Gregory Soyez (Saclay)

22 additional FJContrib authors

Lines of code - 1 year ago



Lines of code - today

FastJet
20k lines of code
19k lines of comments

fjcore
8k lines of code

fjcontrib
12 contribs
9k lines of code
5k comments

FastJet 3.1.0-beta.1

fjcontrib 1.014

FastJet 3.1

β.1 released last Friday

New things include

- speed gains
- hadron masses in area subtraction
- facilities of help in FJContrib

FastJet → Fast*er*Jet ?

FastJet chooses different code variants,

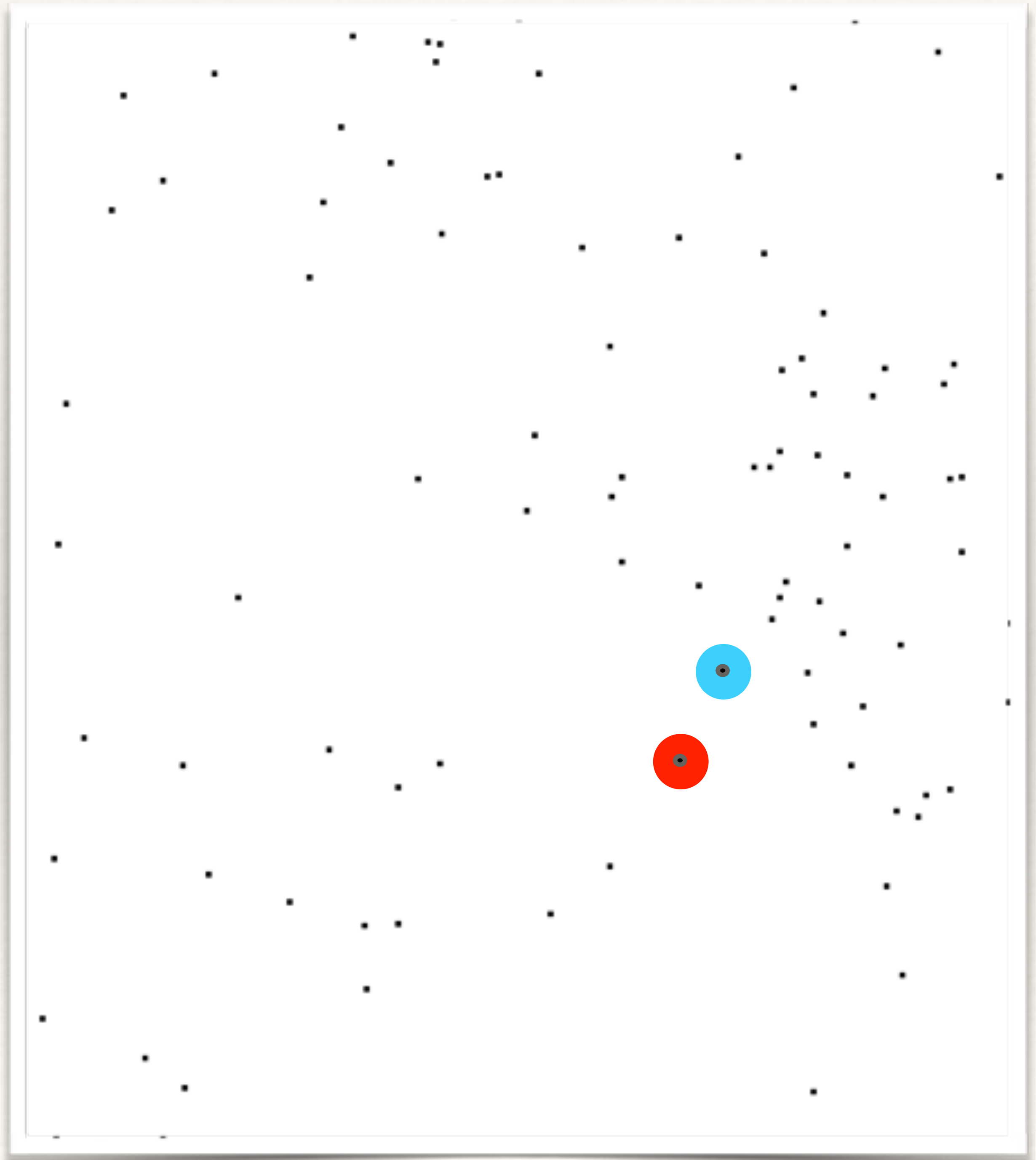
"strategies"

for clustering based on event multiplicity & R

`N2Plain`	a plain N^2 algorithm (fastest for $N \lesssim 30$)
`N2Tiled`	a tiled N^2 algorithm (fastest for $30 \lesssim N \lesssim 400$)
`N2MinHeapTiled`	a tiled N^2 algorithm with a heap for tracking the minimum of d_{ij} (fastest for $400 \lesssim N \lesssim 15000$)
`NlnN`	the Voronoi-based $N \ln N$ algorithm (fastest for $N \gtrsim 15000$)
`NlnNCam`	based on Chan's $N \ln N$ closest pairs algorithm (fastest for $N \gtrsim 6000$), suitable only for the Cambridge jet algorithm
`Best`	automatic selection of the best of these based on N and R

From FastJet 3.0 manual

FastJet lemma (recall)

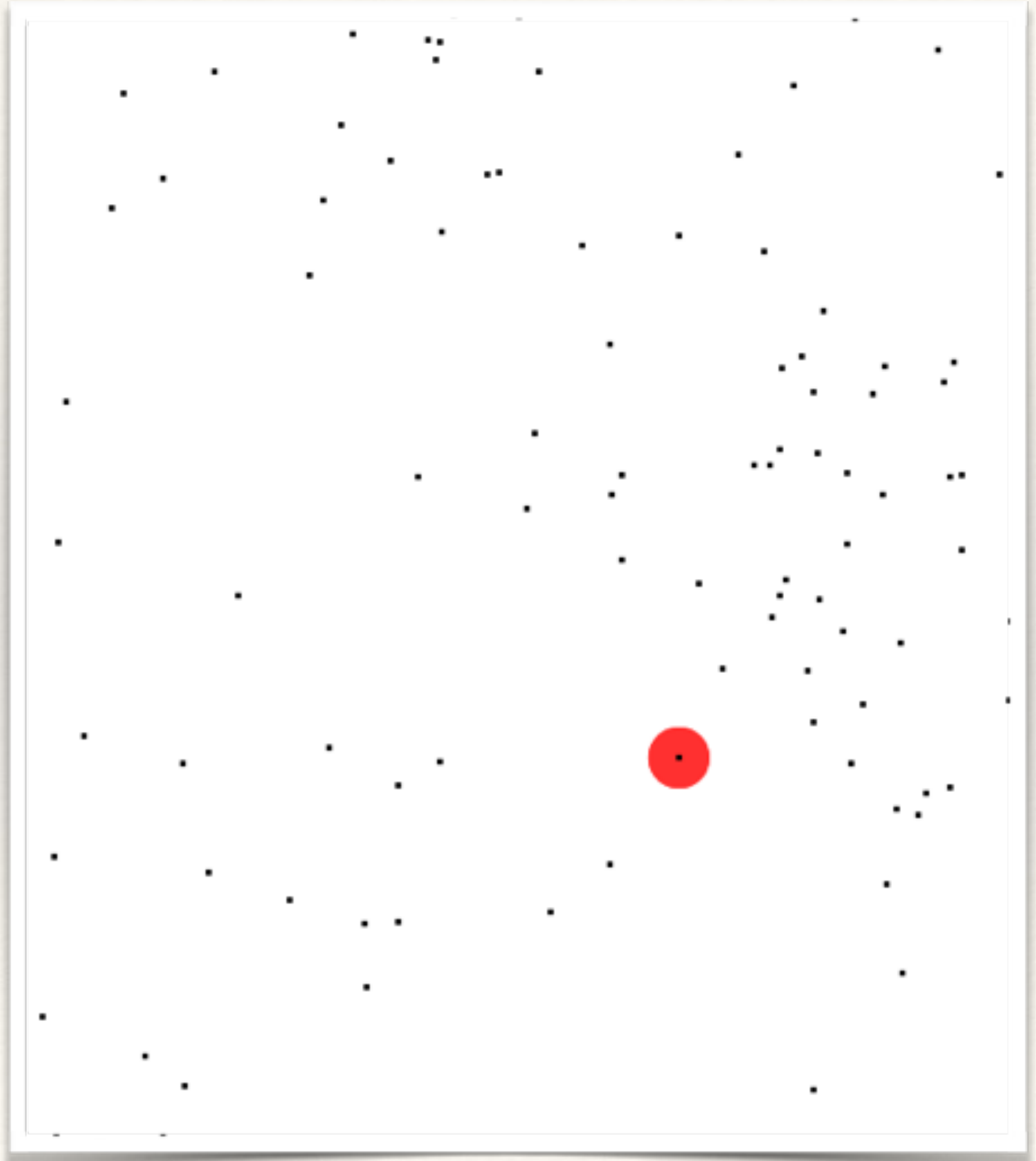


You need to find smallest of the N^2 d_{ij}

$$d_{ij} = \max(p_{ti}^{-2}, p_{tj}^{-2})\Delta R_{ij}^2$$

FJ never looks through all N^2 d_{ij}, but instead exploits lemma that for given **particle *i***, smallest d_{ij} must come from i's **geometrical nearest neighbour**

N2Plain strategy

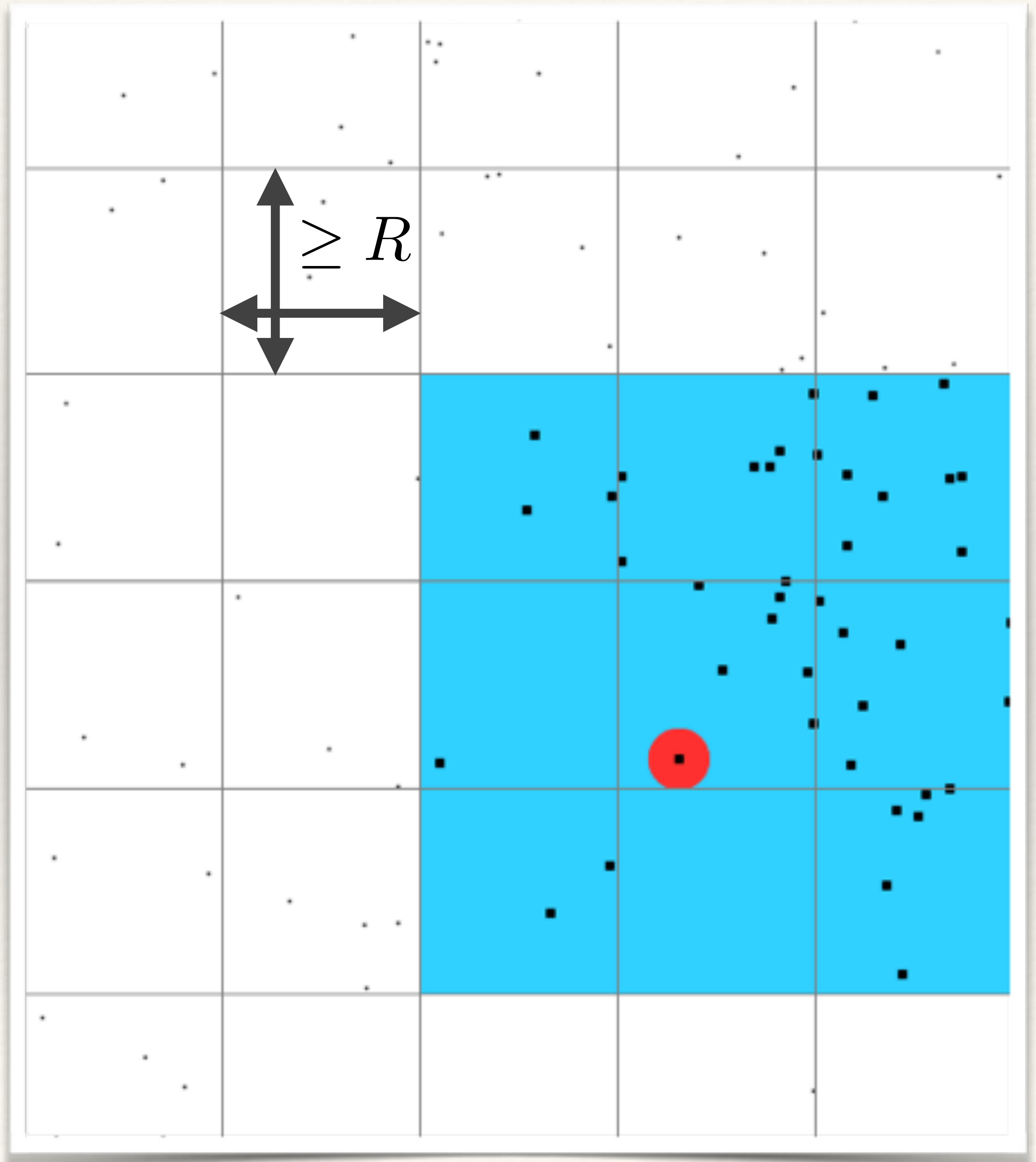


Look for **geometrical nearest neighbour (GNN)** among all N particles.

Why is this fast?

Because particle i is GNN of only O(1) other particles; so when you remove it, updates of other particles' GNNs costs $O(N)$ → **$O(N^2)$ total time**

N2Tiled & N2MinHeapTiled

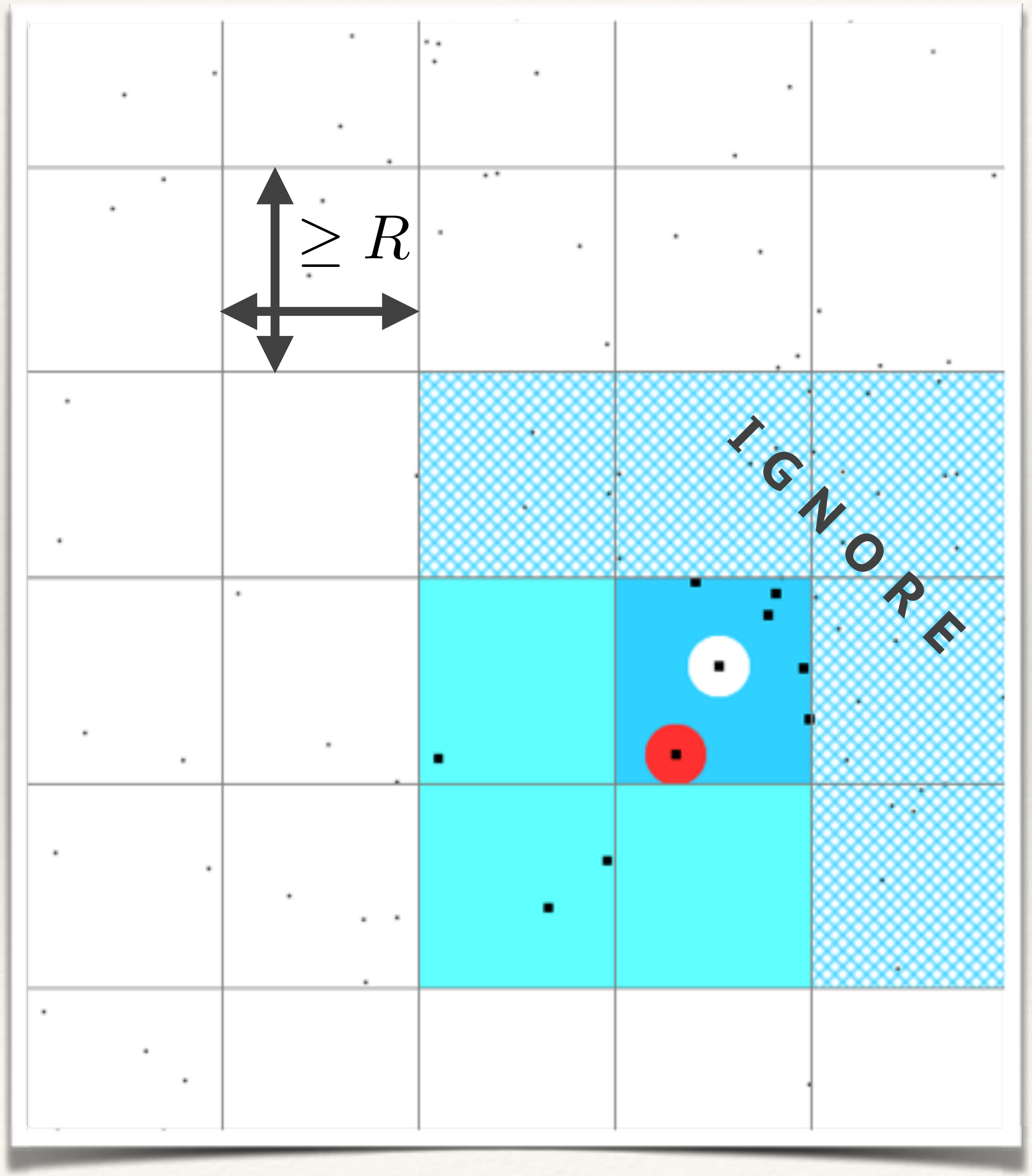


Particles only cluster with others within ΔR < R

Arrange particles on grid of spacing ~R. Look for geometrical nearest neighbour (GNN) within 3x3 group of tiles.

Gives alg that's O(*Nn*)
n is # of particles in a tile + grid setup overhead.

New: N2MHTLazy9

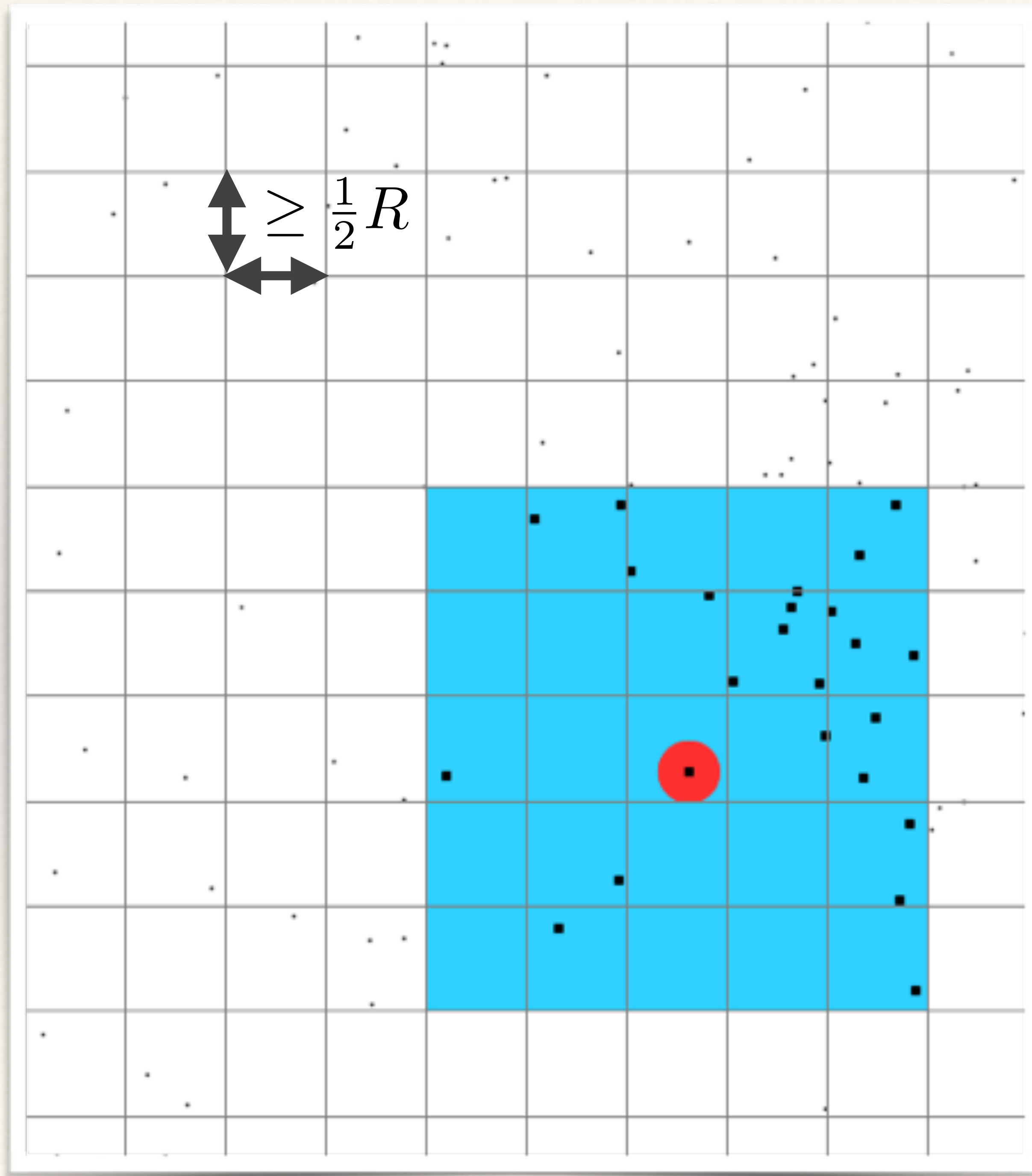


1. Look **in 1 tile** for GNN
2. Consider only surrounding tiles whose edge is closer than in-tile GNN

Still O(Nn), but with a smaller coefficient at high densities.

[Price of extra bookkeeping compensated by smaller # of tiles to search through]

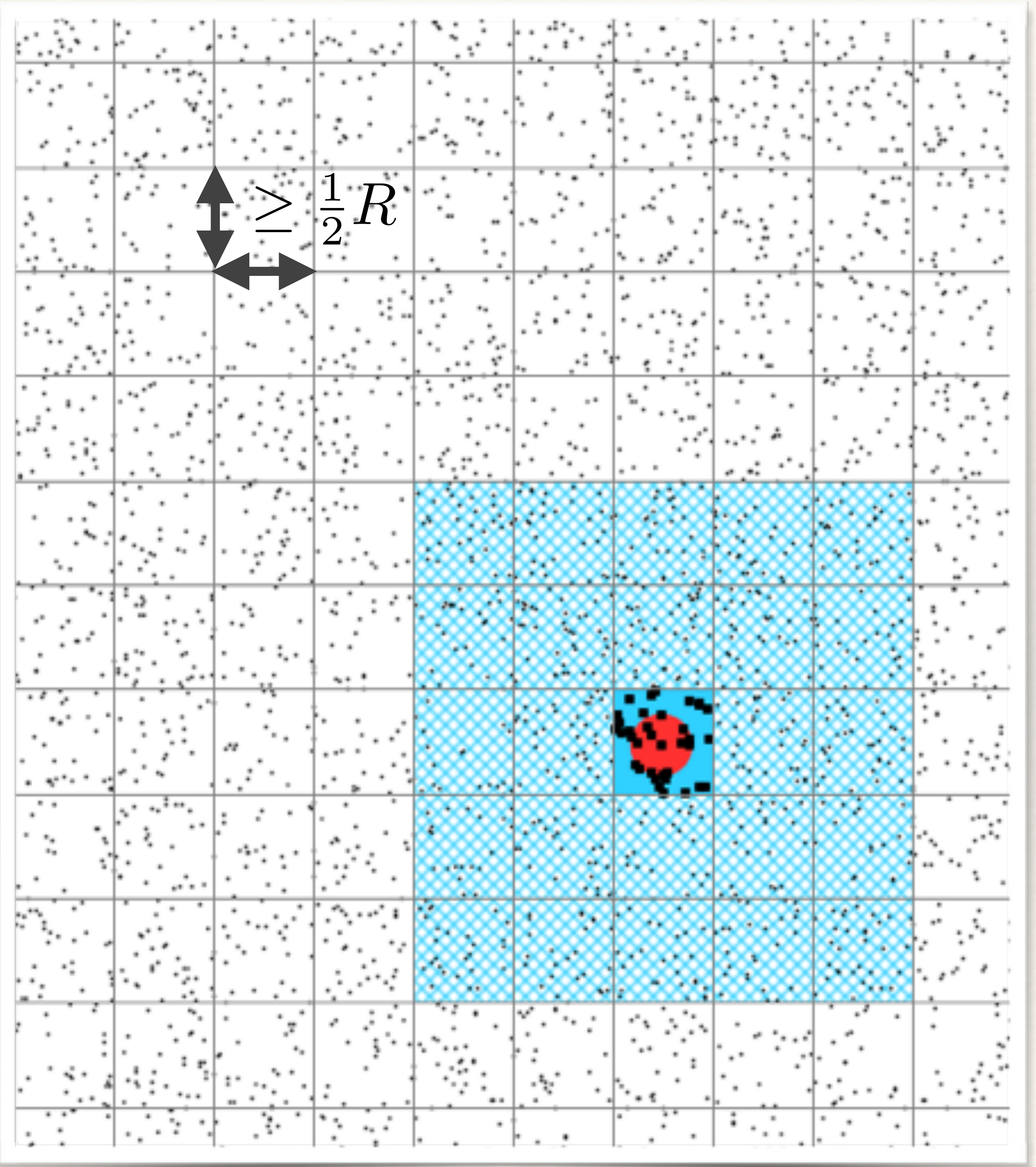
New: N2MHTLazy25



Like Lazy9 but instead of 3x3 neighbourhood of tiles of size R, use 5x5 neighbourhood of tiles of size ½R.

Some overheads grow, but at high densities, net gain from reduced area over which to search for GNN.

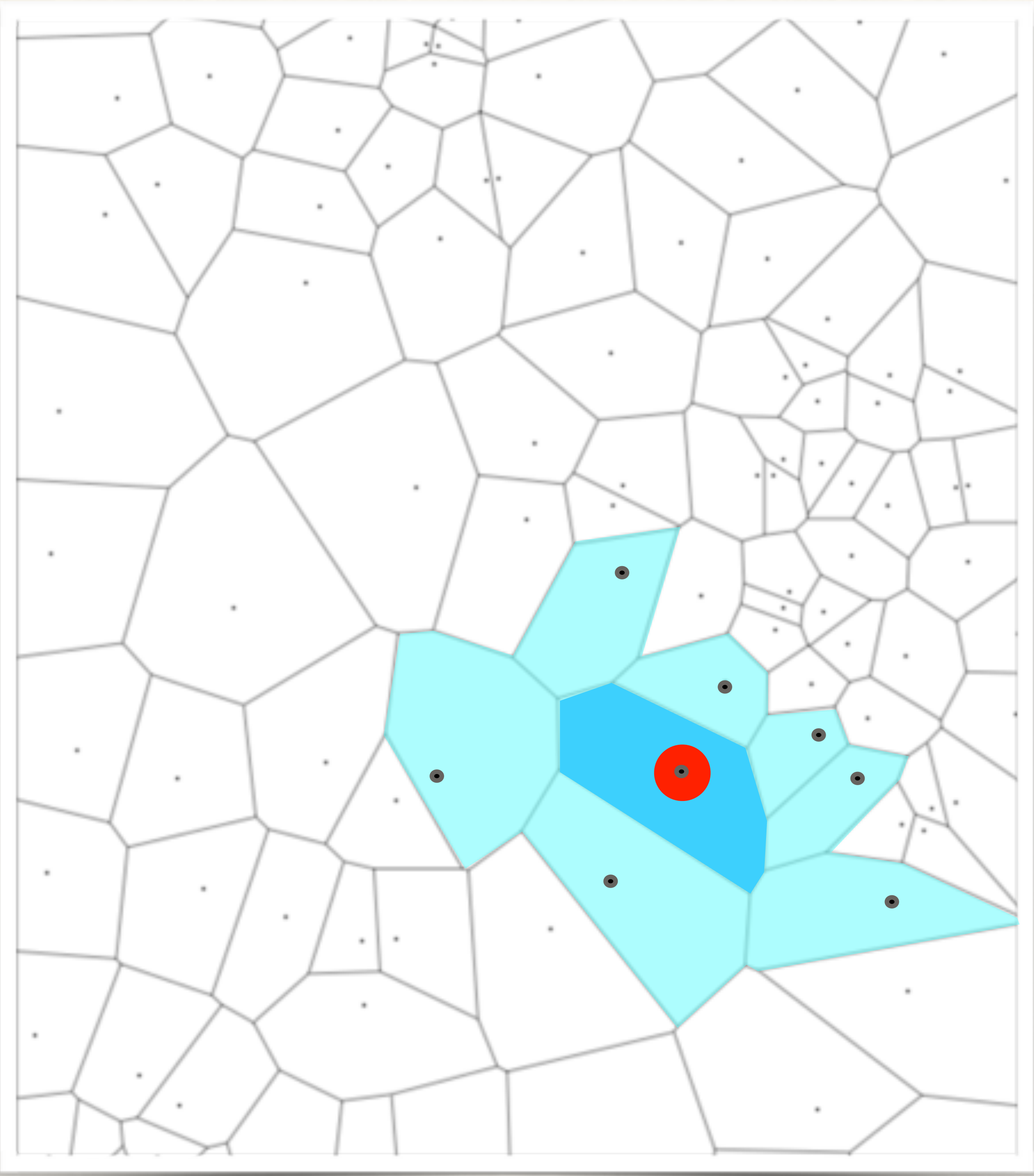
New: N2MHTLazy25



Like Lazy9 but instead of 3x3 neighbourhood of tiles of size R, use 5x5 neighbourhood of tiles of size ½R.

Some overheads grow, but at high densities, net gain from reduced area over which to search for GNN.

"N ln N" (CGAL Voronoi)



Original FastJet idea

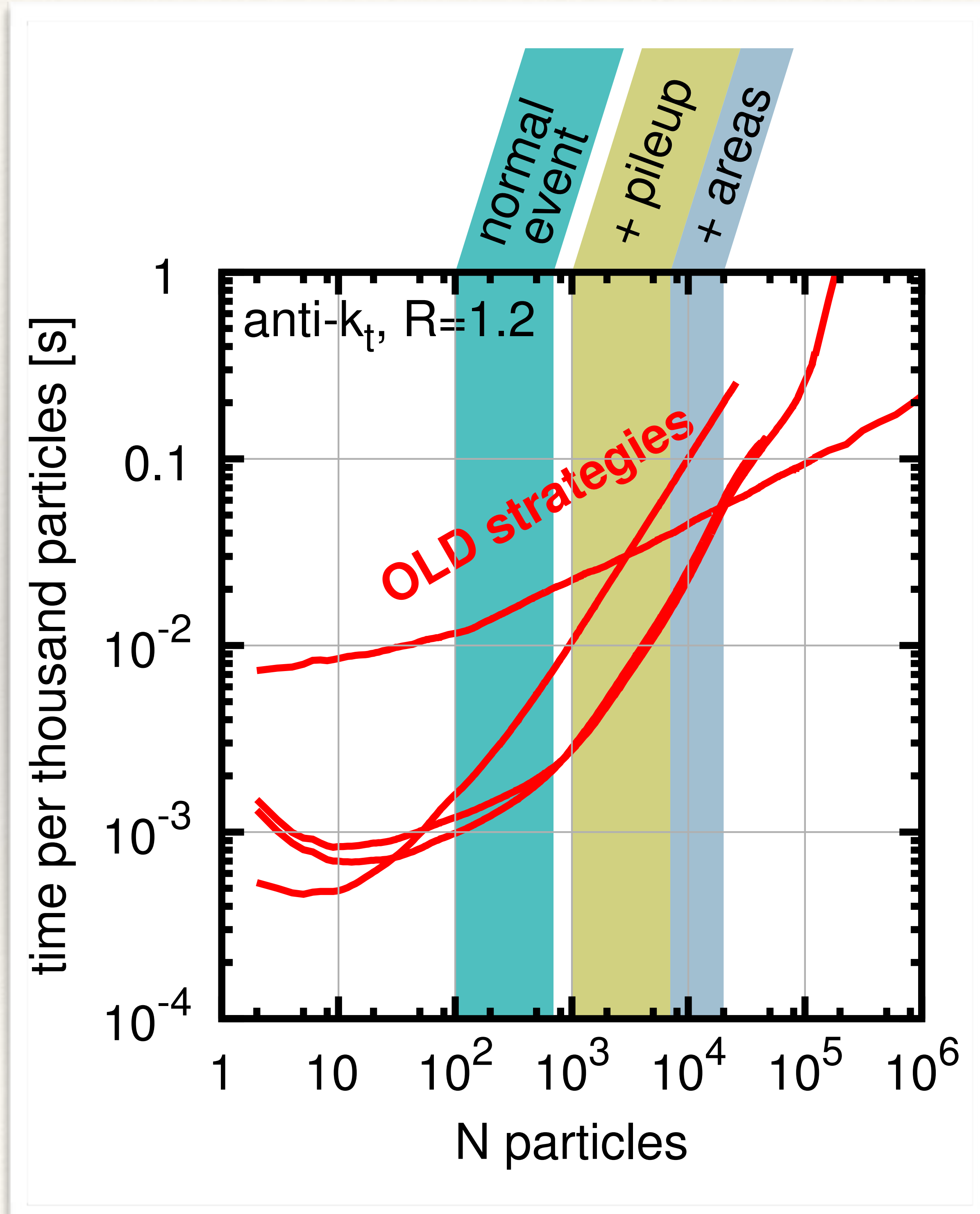
Restrict GNN search to nearby Voronoi cells:

- typically only O(10) to search through [except for anti-k_t]
- but high coefficient of ln N in order to maintain Voronoi diagram

NB: for anti-k_t, alg is $N^{3/2}$

FJ 3.1 fixes a coincident point issue

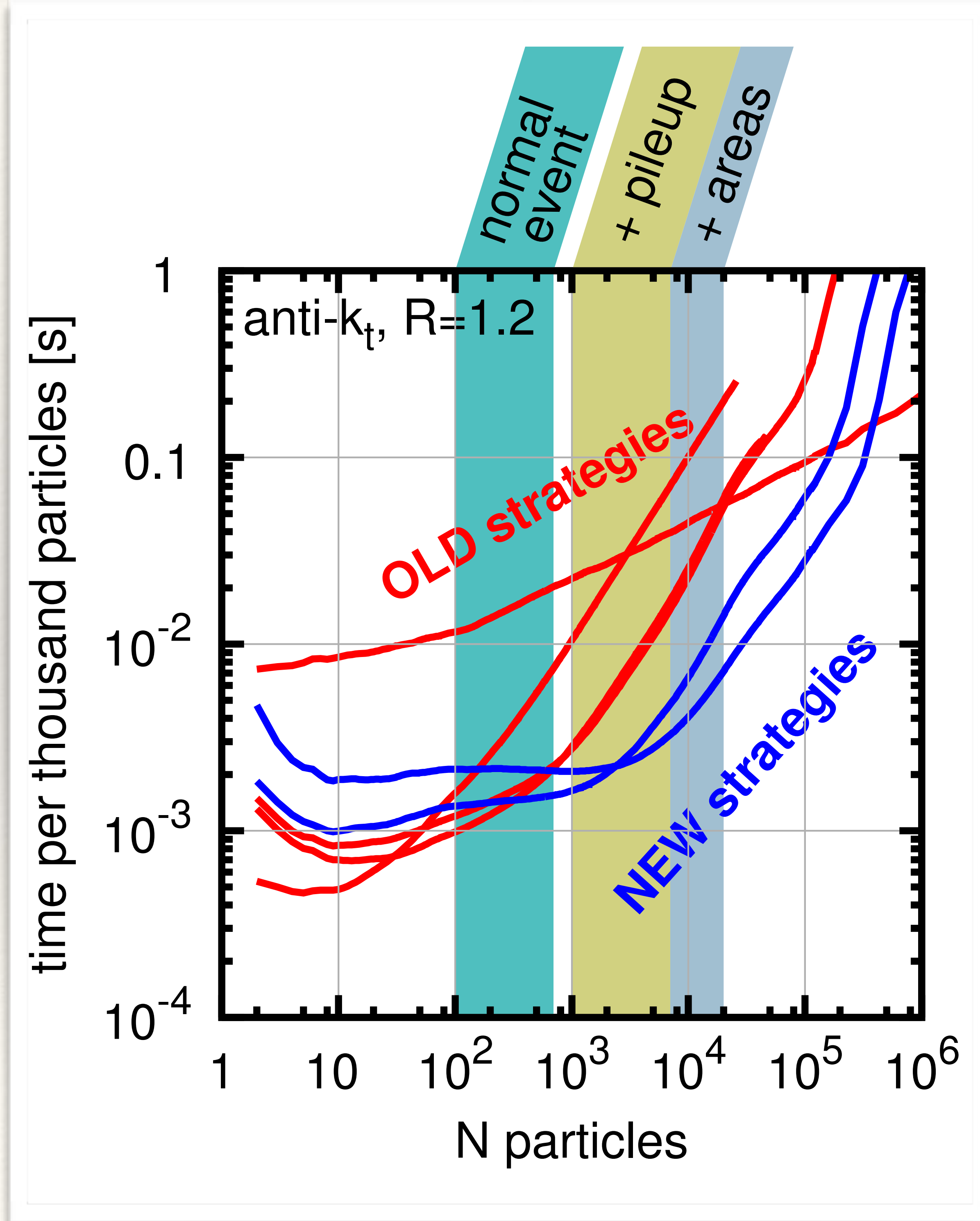
How do they compare?



Time to cluster N particles (per thousand particles)

Shown here for R=1.2

How do they compare?



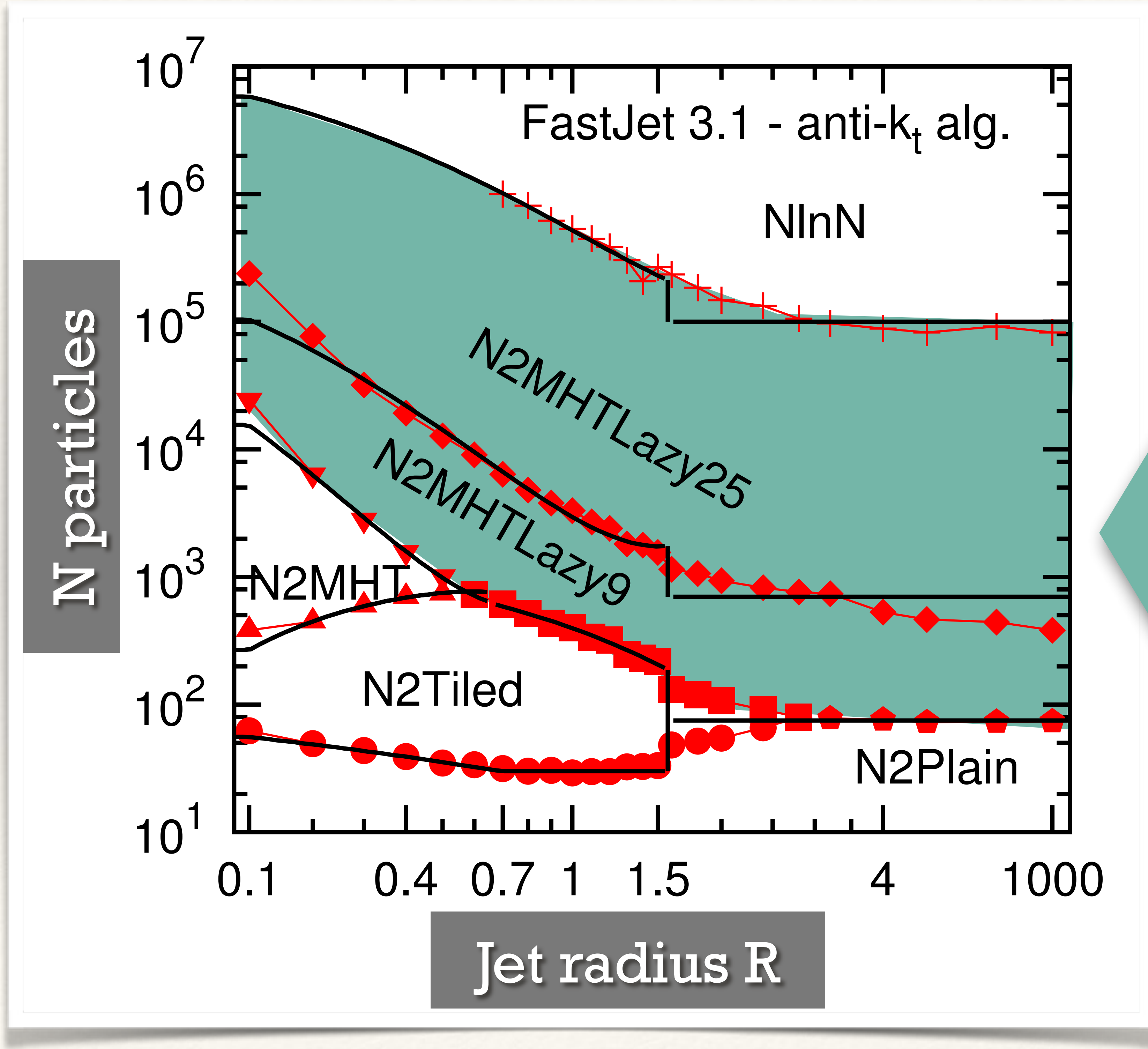
Time to cluster N particles (per thousand particles)

Shown here for R=1.2

Gain starts for N=500, largest around 10k

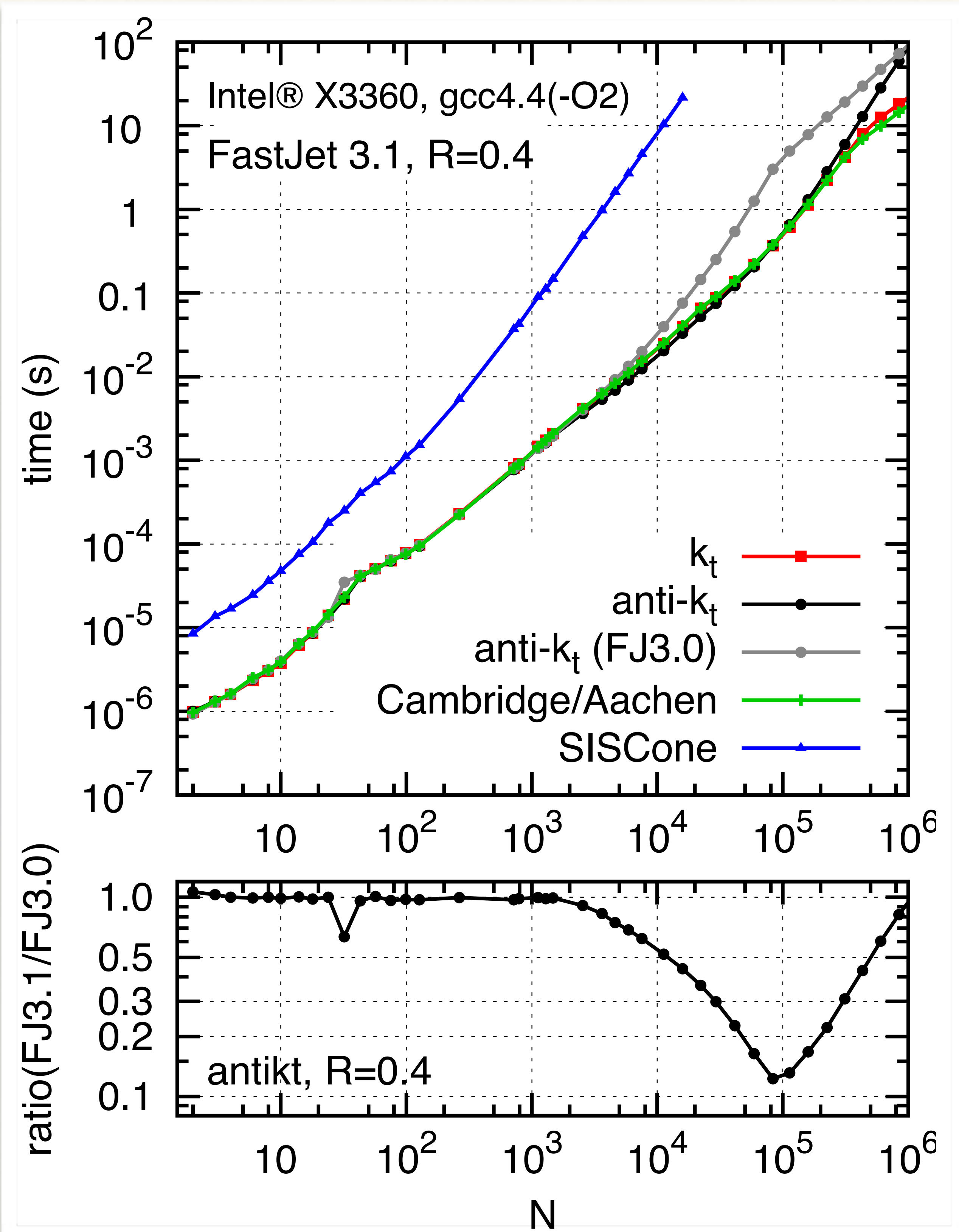
Automated strategy choice

Based on events with particles up to |y| = 5



region where new strategies are optimal

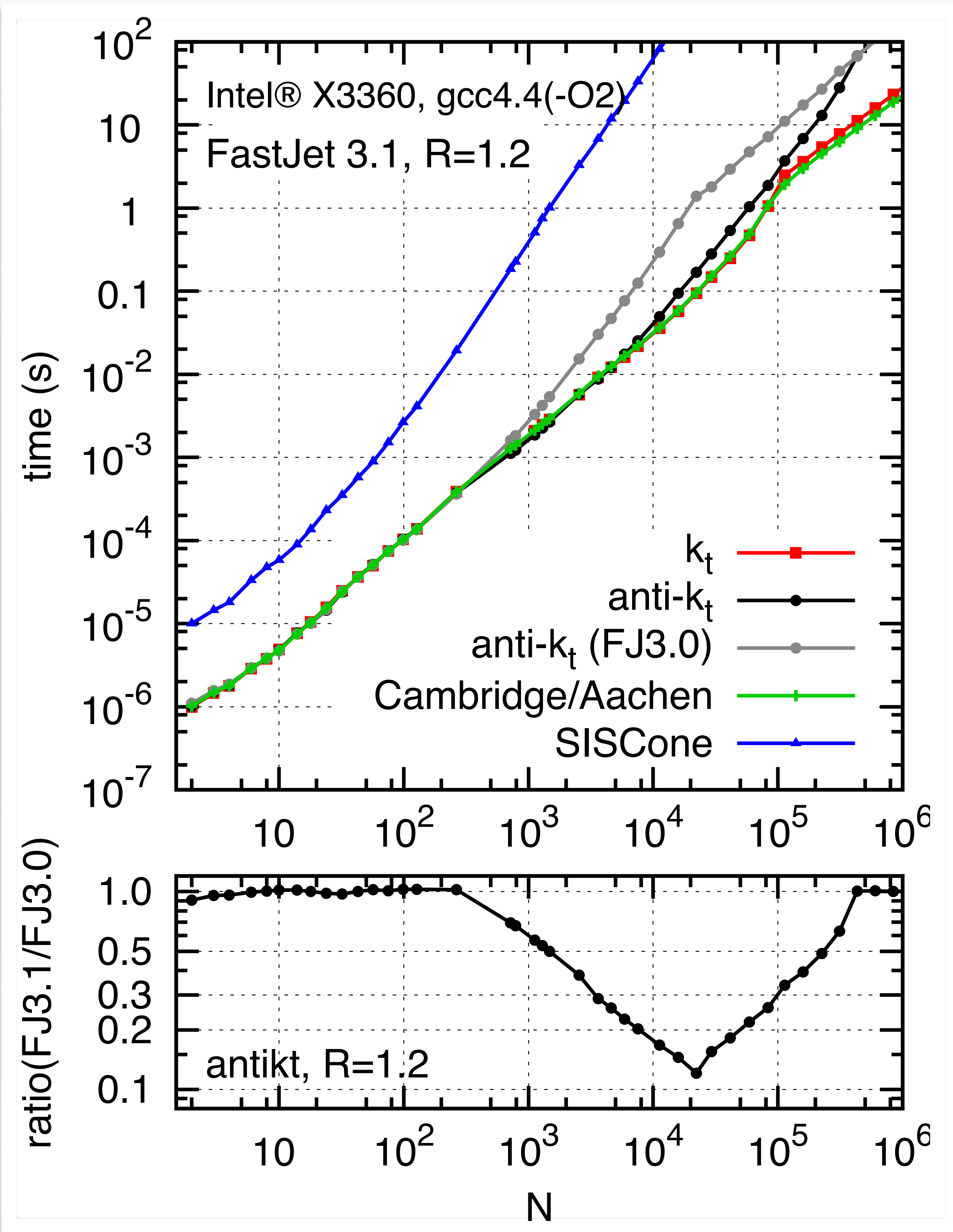
3.0 → 3.1 speed gains (R=0.4)



Time to cluster N particles

Improvement wrt FJ 3.0.x, **factor of 2 for 10k**

3.0 → 3.1 speed gains (R=1.2)



Time to cluster N particles

Improvement wrt FJ 3.0.x, **factor of 6 for 10k**

Other speed "things"

- **`N2MHTLazy9AntiKtSeparateGhosts`**
  Anti-k_t only, clusters ghosts separately (but no ghost jets)
  Still preliminary, but worth looking at if speed matters
- Automated strategy choice not optimal for jet reclustering
- There may still be room for improvement for large R, large N

PU subtraction & jet masses

New facilities in FJ3.1

The wisdom of including hadron masses

PU subtraction & hadron masses

- FastJet 3.0 provides you with $\rho = p_t$ per unit area.
- If your "hadrons" have masses, you also need ρ_m, m_δ per unit area: [Soyez et al, 1211.2811]

$$m_\delta = \sum_{i \in \text{area}} \left(\sqrt{m_i^2 + p_{t,i}^2} - p_{ti} \right)$$

- Subtraction then has extra longitudinal terms

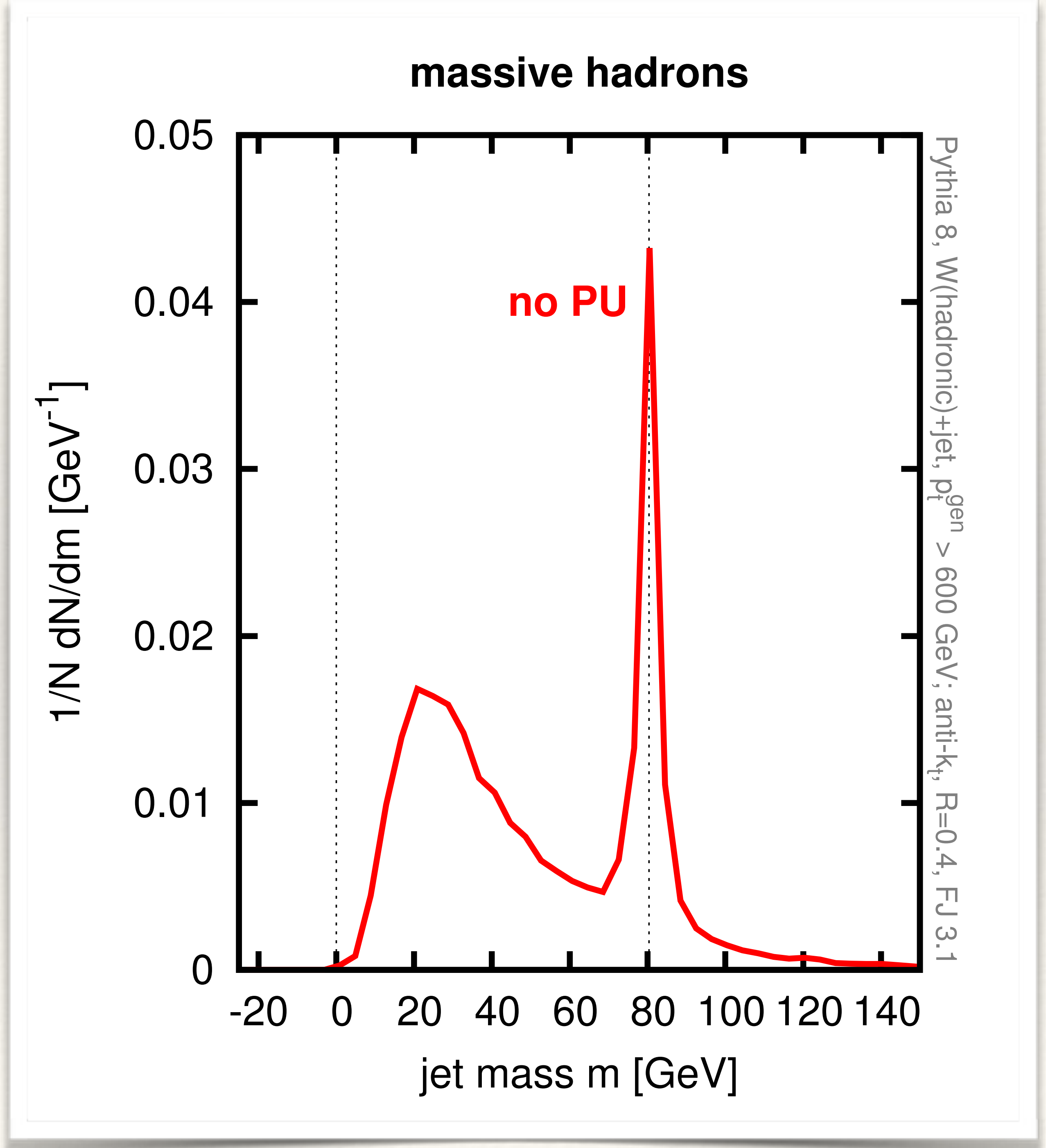
$$p^\mu_{\text{jet,sub}} = p^\mu_{\text{jet}} - [\rho A^x_{\text{jet}},\ \rho A^y_{\text{jet}},\ (\rho + \rho_m) A^z_{\text{jet}},\ (\rho + \rho_m) A^E_{\text{jet}}]$$

In FJ 3.1

- BackgroundEstimators have new `bge.rho_m()` method
- **Enable** its use in Subtractors with `subtractor.set_use_rho_m()`

Illustration

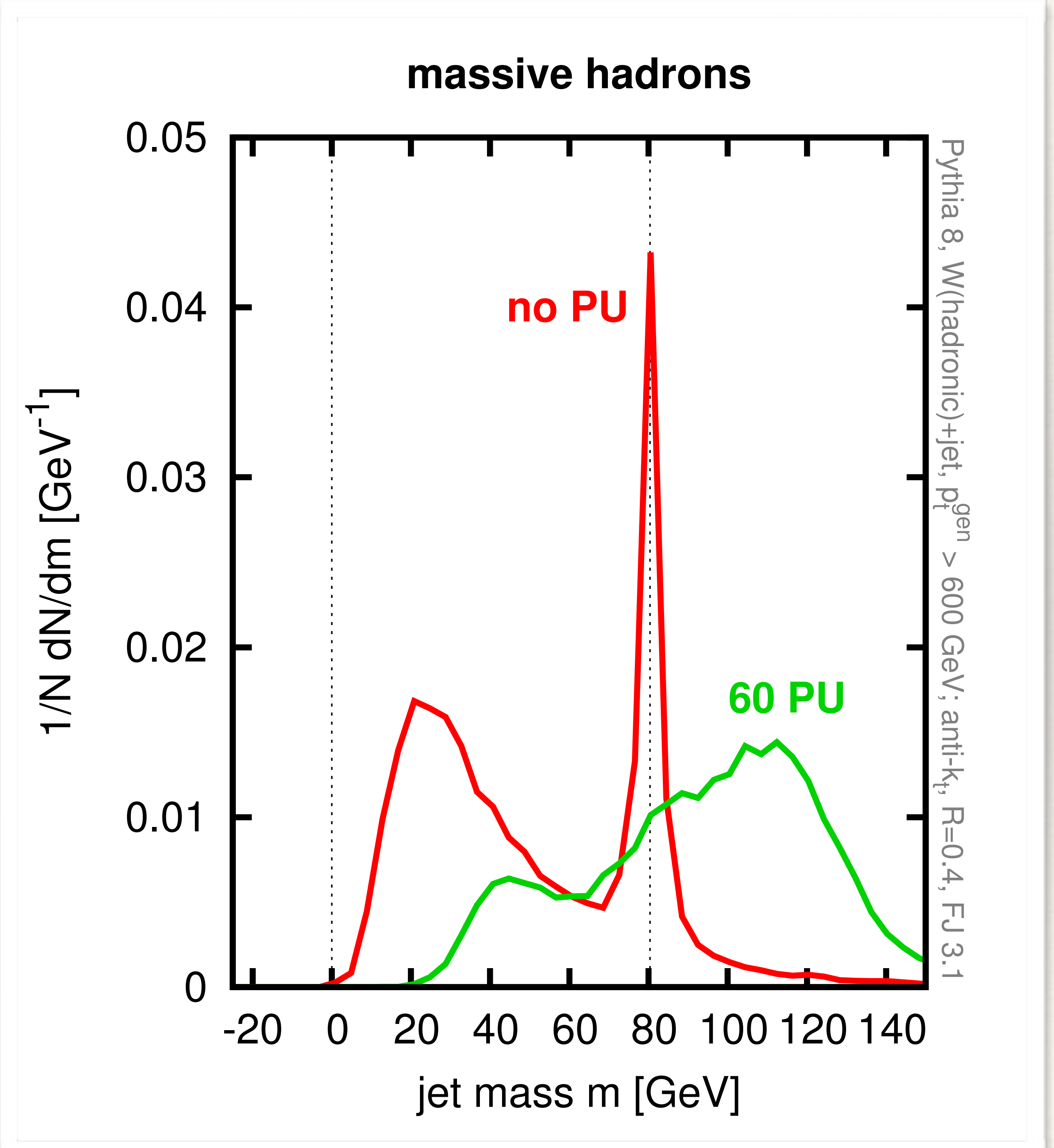
Start with W peak
& QCD continuum



Illustration

Start with W peak
& QCD continuum

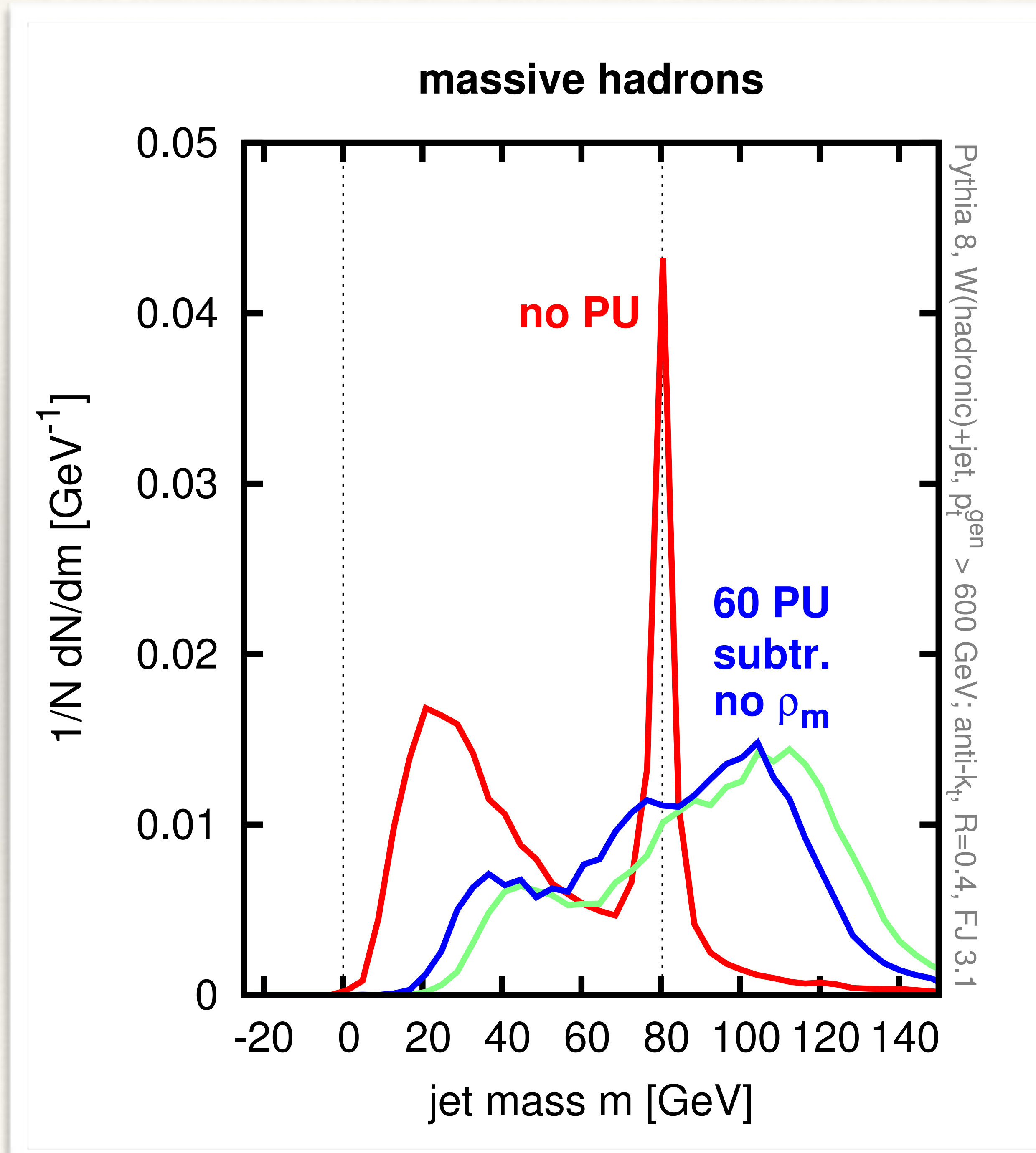
- Add pileup



Illustration

Start with W peak & QCD continuum

- Add pileup
- Subtract without ρ_m

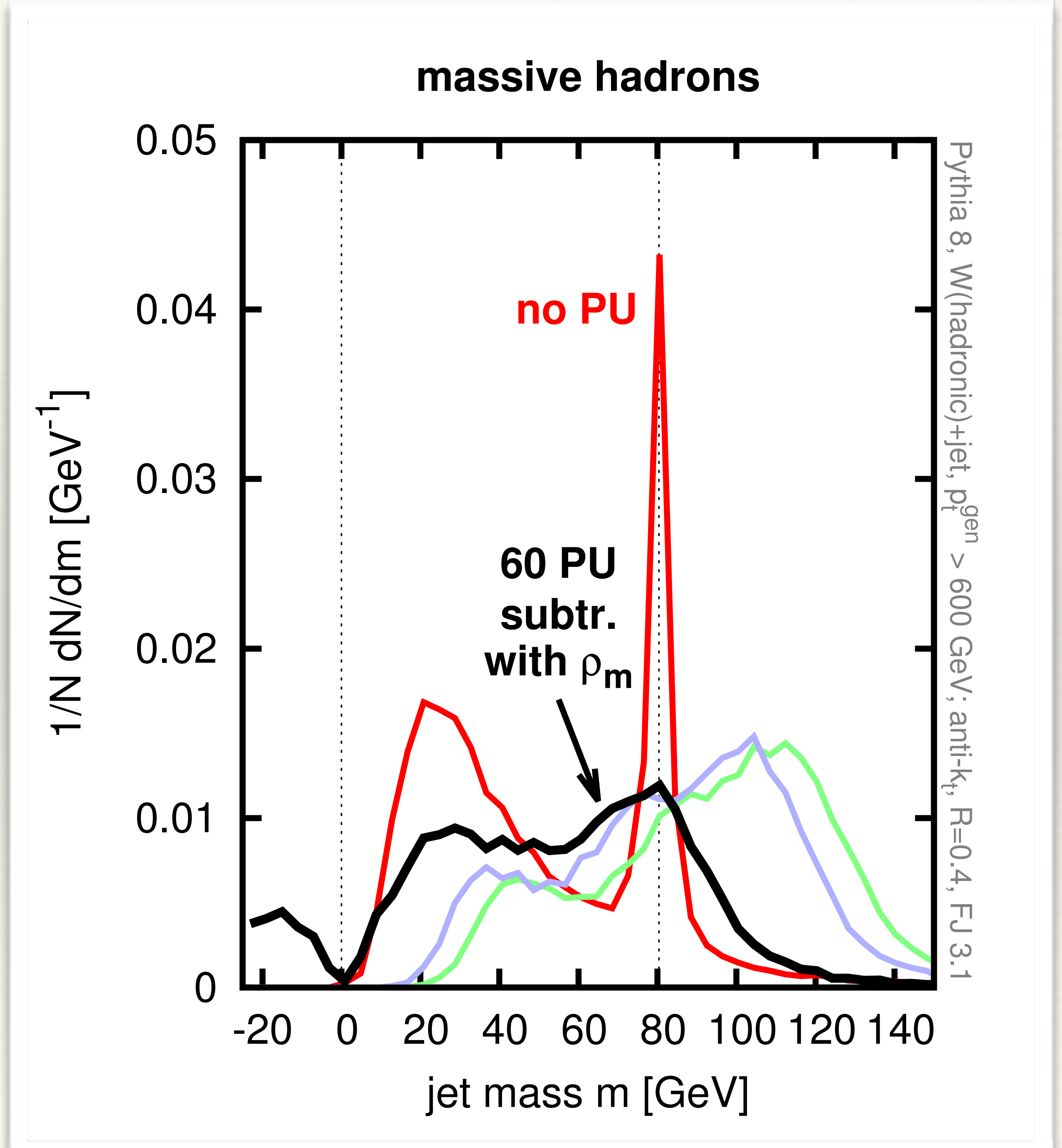


Illustration

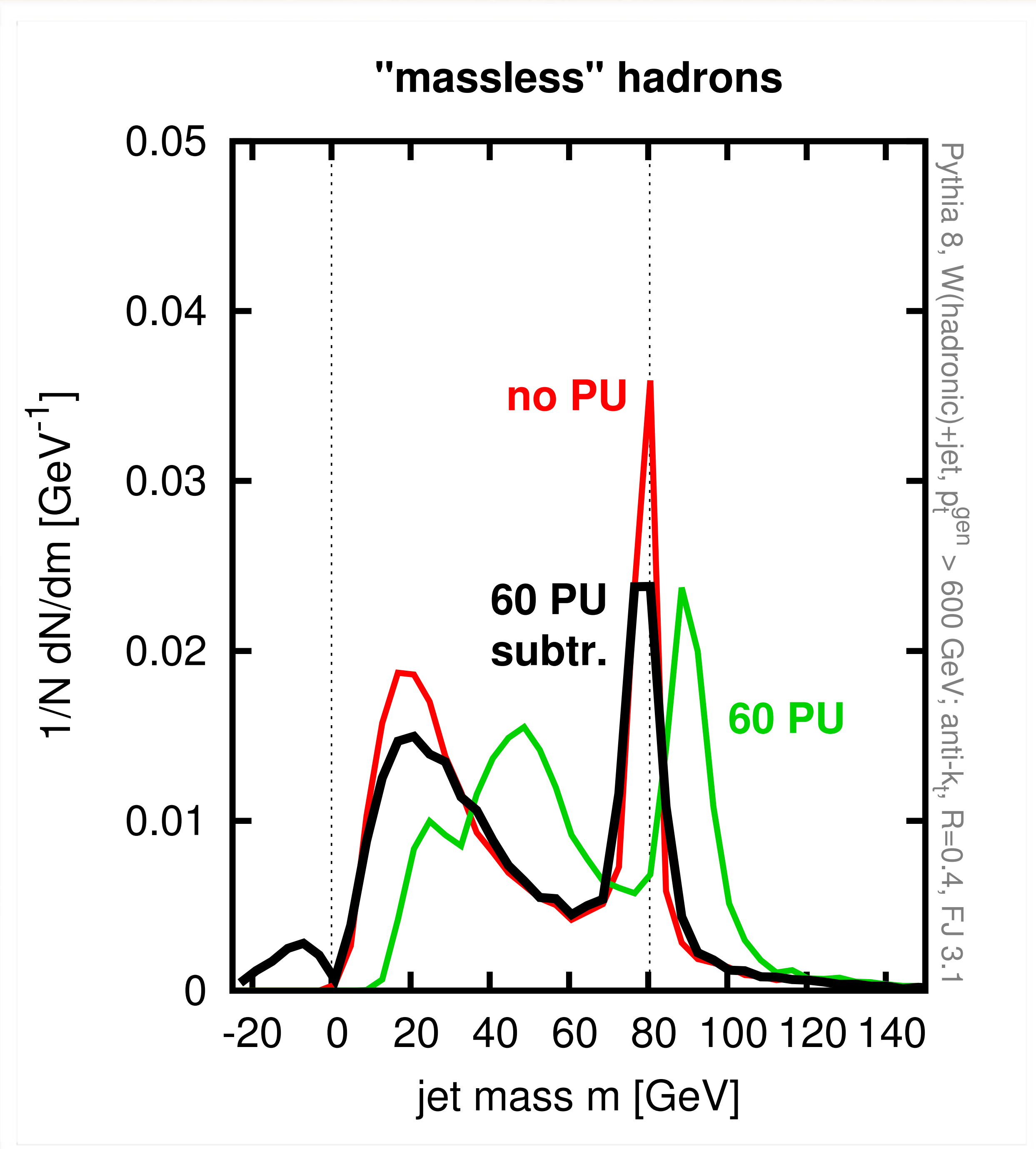
Start with W peak & QCD continuum

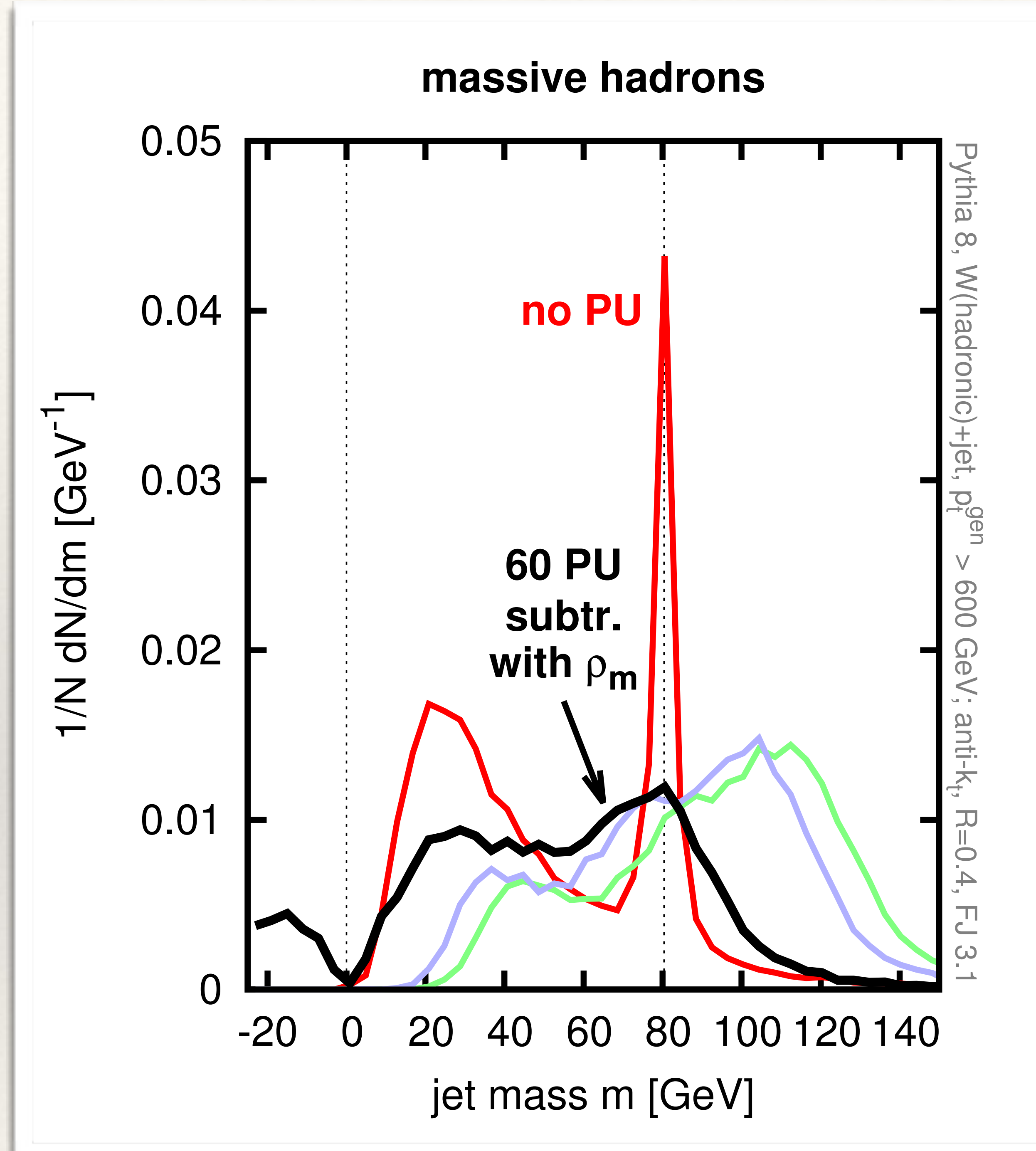
- Add pileup
- Subtract without ρ_m
- Instead subtract with ρ_m

W peak is back where it should, though very smeared out



Massless v. massive hadrons

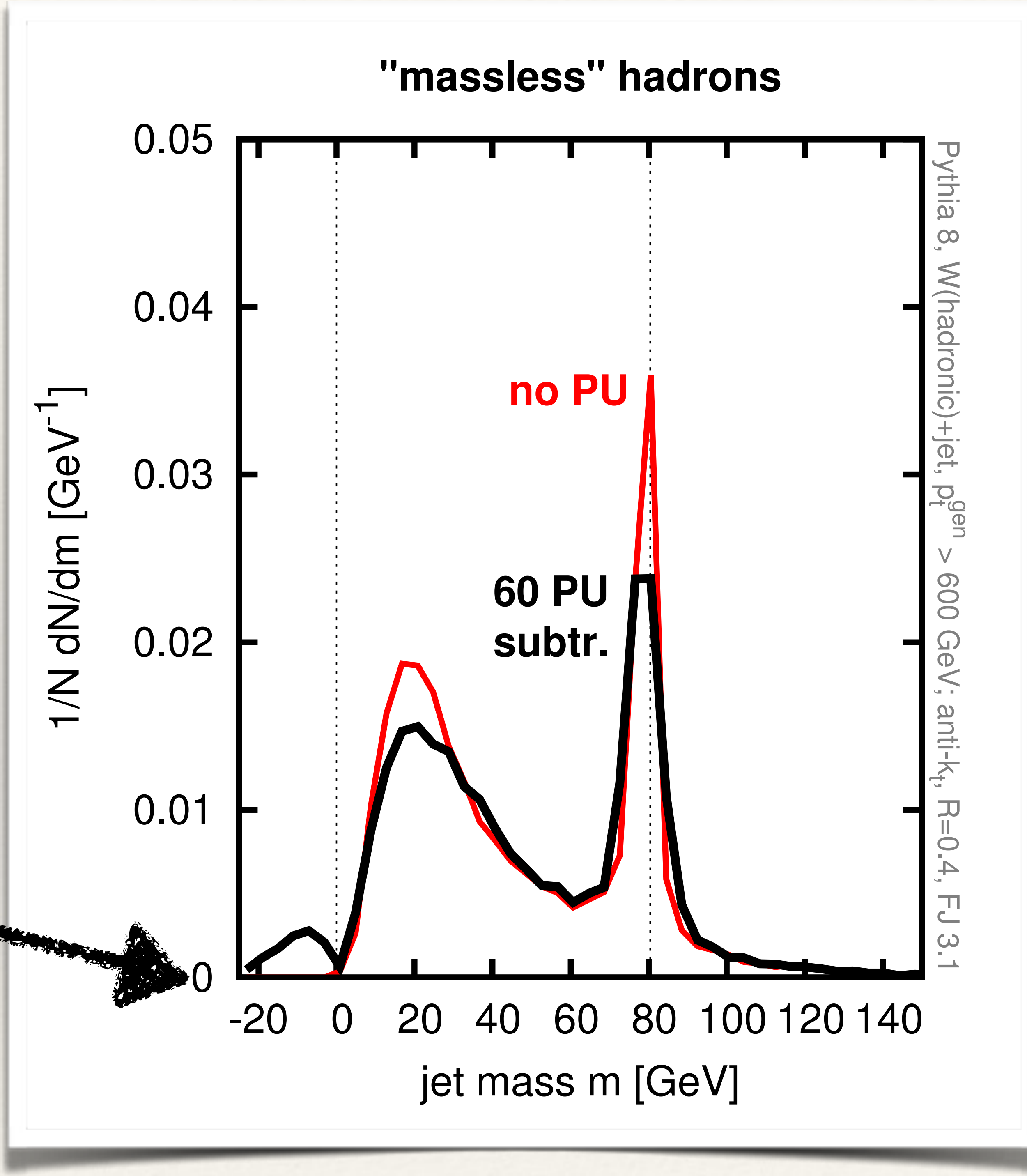




There is perhaps no good reason for including hadron masses

negative jet masses

Unphysical negative m^2
Give negative mass in FJ

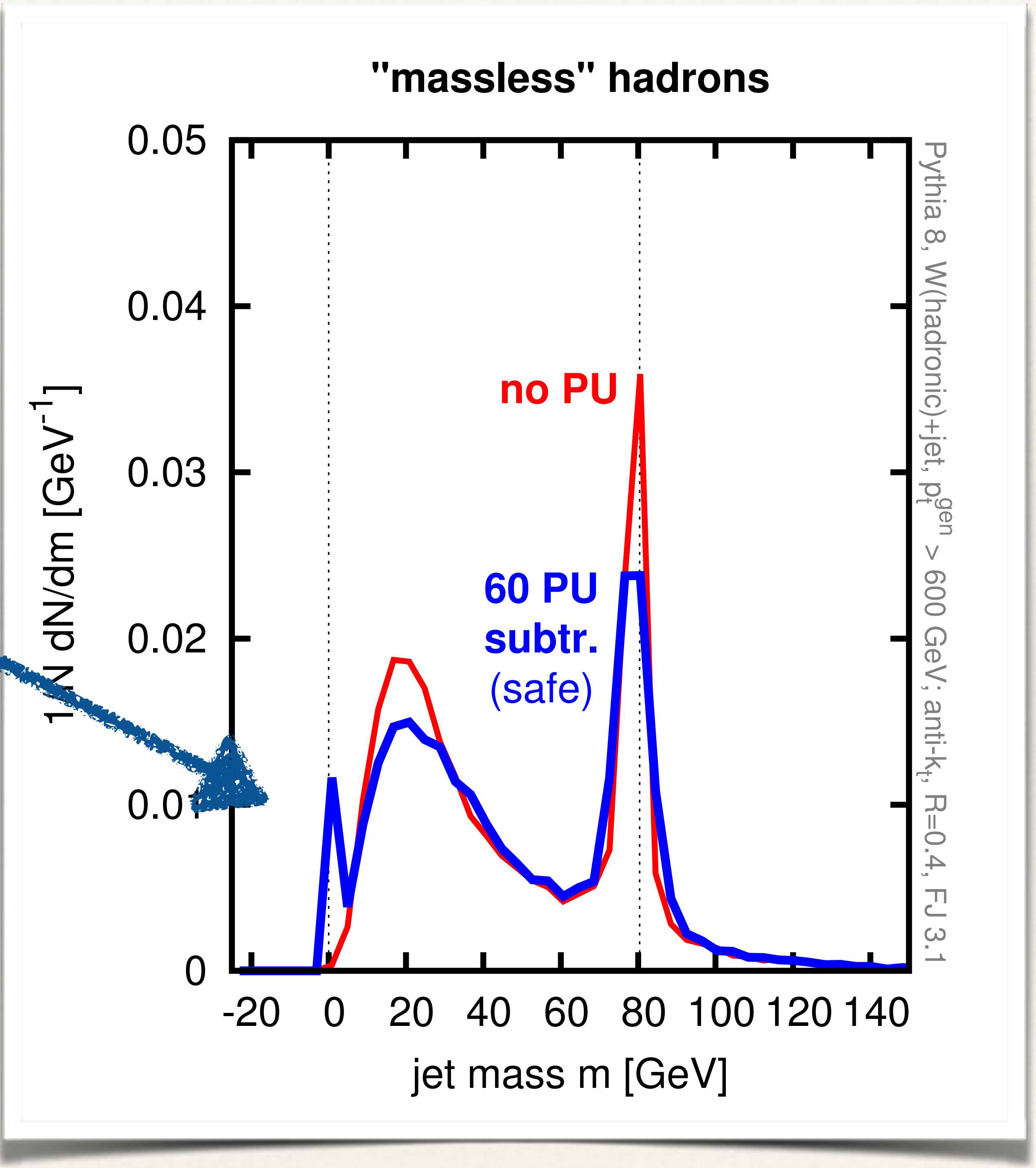


positive jet masses

```
subtractor.set_safe_mass()
```

forces m ⩾ 0

This can have a noticeable effect on performance plots



3rd party extensions to FastJet

FJContrib

9 releases since last Boost

6 new contribs

25 contributors

Peter Berta
Daniele Bertolini
Matteo Cacciari
Souvik Dutta
Sonia El Hedri
Anson Hook
Martin Jankowiak
Jihun Kim
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Jeff Tseng
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Lian-Tao Wang
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Version 1.005 of FastJet Contrib is di

Package	Version
GenericSubtractor	1.2.0
JetFFMoments	1.0.0
VariableR	1.0.1
Nsubjettiness	1.0.2
EnergyCorrelator	1.0.1
ScJet	1.1.0

Version 1.014 of FastJet Contrib is distril

Package	Version
ConstituentSubtractor	1.0.0
EnergyCorrelator	1.0.1
GenericSubtractor	1.2.0
JetCleanser	1.0.1
JetFFMoments	1.0.0
JetsWithoutJets	1.0.0
Nsubjettiness	2.1.0
RecursiveTools	1.0.0
ScJet	1.1.0
SoftKiller	1.0.0
SubjetCounting	1.0.1
VariableR	1.1.1

FJ 3.1 facilities for fjcontrib etc.

`Recluster`

`RectangularGrid`

`FASTJET_VERSION_NUMBER`

Recluster

It’s easy enough to recluster the particles in a jet

```
JetDefinition jet_def(cambridge_algorithm, 1000.0);
PseudoJet reclustered_jet = jet_def(jet.constituents())[0];
```

But what if the jet had areas? A non-standard recombiner?

```
// simplified illustration of handling of areas
const ClusterSequence * cs = jet.associated_cluster_sequence();
if (cs) {
  if (cs->has_explicit_ghosts()) {
    vector<PseudoJet> particles, ghosts;
    SelectorIsPureGhost.sift(jet.constituents(), ghosts,
                                                    particles);
    double ghost_area = ghosts[0].area(); //+ case without ghosts
    auto csa = new ClusterSequenceActiveAreaExplicitGhosts(
                          particles, jet_def, ghosts, ghost_area);
    reclustered_jet = SelectorNHardest(1)(csa->inclusive_jets());
    csa->delete_self_when_unused();
  }
```

Recluster

It's easy enough to recluster the particles in a jet

```
JetDefinition jet_def(cambridge_algorithm, 1000.0);
PseudoJet reclustered_jet = jet_def(jet.constituents())[0];
```

But what if the jet had areas? A non-standard recombiner?

Quickly becomes painful. Instead use Recluster:

```
// Recluster looks at the input jet and automatically
// - reclusters with areas if it detects (explicit) ghosts
// - reclusters with the original jet's recombiner
// - looks into pieces to see if they share a CS
#include "fastjet/tools/Recluster.hh"

Recluster recluster_CA(cambridge_algorithm);
PseudoJet reclustered_jet = recluster_CA(jet);
```

Also exploits new FJ31 facility: **jet_def_B.set_recombiner(jet_def_A)**

RectangularGrid

e.g. `GridMedianBackgroundEstimator`
`GridJet, SoftKiller`

New class gives common interface, more flexible grid layout

```
#include "fastjet/RectangularGrid.hh"

// can specify asymmetric rap lims, separate y & phi spacings
double ymin = -5.0, ymax=-2.0, dy=0.5, dphi = twopi/12;
RectangularGrid lhcb_grid(ymin, ymax, dy, dphi);
SoftKiller soft_killer(lhcb_grid);

// facility to remove subset of tiles from grid
Selector not_central = !SelectorRapRange(-2.5,2.5);
RectangularGrid forward_grid(-5.0, 5.0, dy, dphi, not_central);
GridMedianBackgroundEstimator forward_bge(forward_grid);
```

FJ version detection

E.g. you want your new contrib to exploit FJ3.1 facilities if available, but also stay compatible with FJ3.0.

```
#include “fastjet/config.h”

// version xx.yy.zz has FASTJET_VERSION_NUMBER = XXYYZZ
// e.g. test for version >= 3.1.0
#if FASTJET_VERSION_NUMBER >= 30100
#include “fastjet/RectangularGrid.hh”
#endif

class MyNewContrib {
// provide constructor only when used with FJ3.1 and higher
#if FASTJET_VERSION_NUMBER >= 30100
  MyNewContrib(const RectangularGrid & grid);
#endif
```

Outlook

FastJet

Our aim is to concentrate FJ development on core features.

- Next major milestone is **thread safety**
- Is there scope for further speed improvement?
(At least in terms of strategy selection)

FJContrib

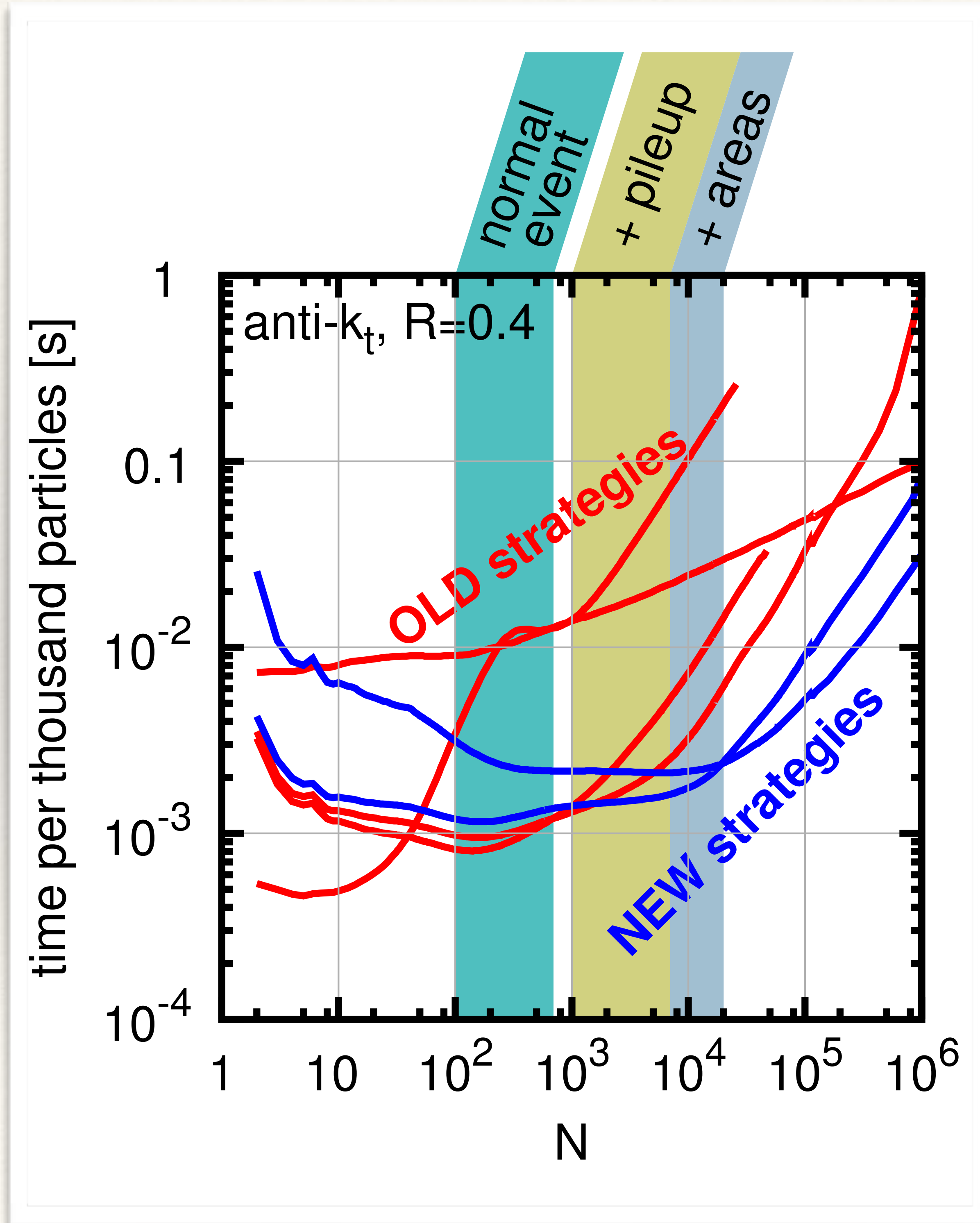
Our experience so far is positive. **What is yours?**

Issues that we see include:

- **Dependencies** (between contribs, on external libs)
- Shared library support
- **Review** of new contribs & updates is getting slow
(we are short of time; insightful feedback takes time)
- **Long-term maintenance** for a “distributed” project. If a tool is useful it may stay in use for 10–20 years.

Backup slides

How do they compare?



Time to cluster N particles (per thousand particles)

Shown here for R=0.4

Gain starts for N=2k, largest around 100k