NATIONAL ENERGY TECHNOLOGY LABORATORY

# Simulation of fine material elutriation of binary mixture dense gas-solid fluidized bed

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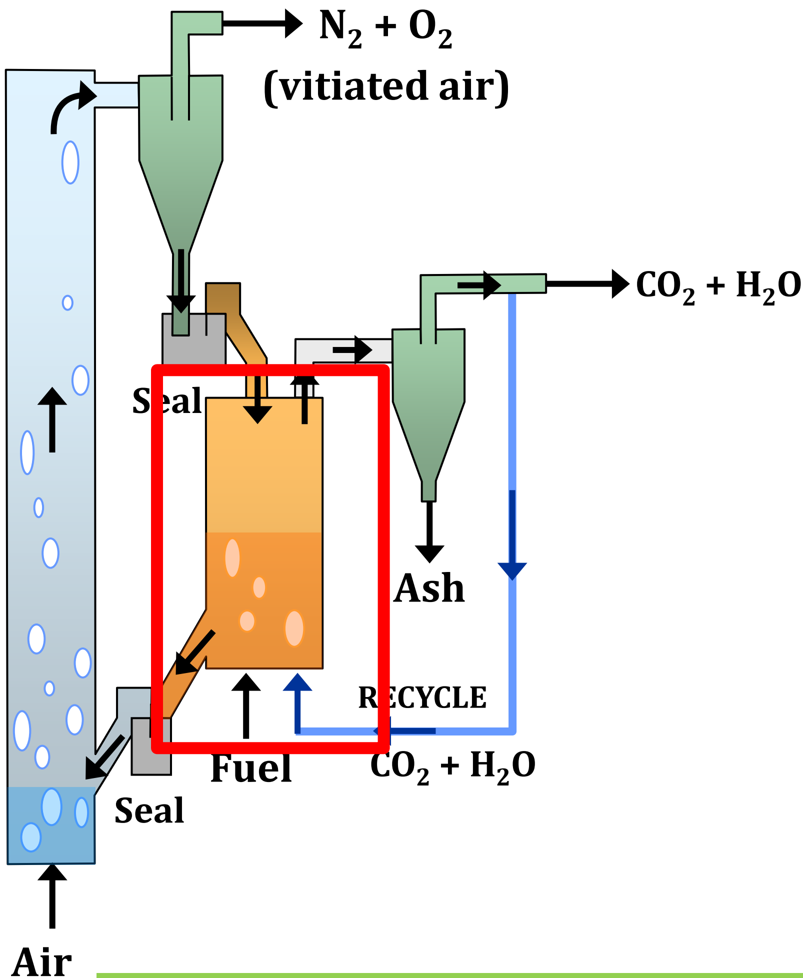
# Chemical Looping Combustion (with *in situ* gasefication of solid fuel)




## Fuel reactor

- Coal gasification ⇨ Ash
- Syngas (from gasification) reduces oxygen carrier

## Problem

- Ash accumulation in the fuel reactor will have an adverse affect on the operation

## Selected solution

- Elutriate the ash from the fuel reactor

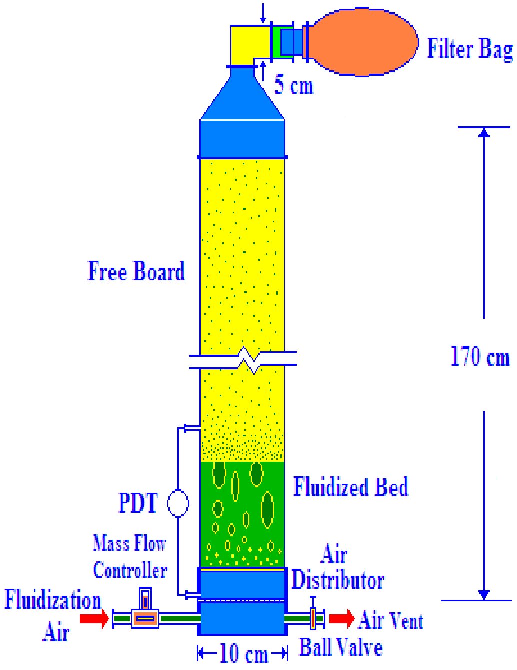
**How well can CFD predict the elutriation from a binary mixture bed**

# Outline

- **NETL elutriation experiment**
- **Binary mixture bed hydrodynamic modeling**
- **Results**
  - Influence of the PSD of the fine material
  - Effects of the eddy-particle interactions
  - Influence of the mesh refining
- **Conclusions – Future plans**

# NETL elutriation experiment

- **Weber et al. (2012)**
  - Well characterized material
    - size, sphericity and aspect ratio distributions, etc..
  - Entrainment flux measurements
    - Effect of coarse density, fine content, fluidization velocity, …

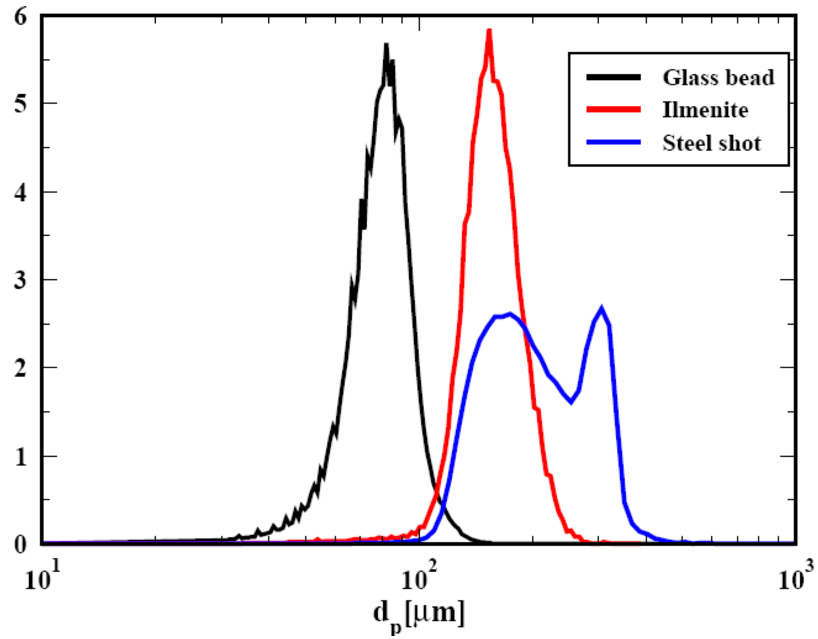



**Binary mixture**
  - Glass beads (fine/lighter material) + …
    - Ilmenite (54.1%)
    - Steel shot (37.3%)
  - Fluidization velocity sets in terms of $d_{50}$ (fine material) terminal velocity

# NETL elutriation experiment

| Particle Properties | | | |
|---|---|---|---|
| | Glass Beads | Ilmenite | Steel Shot |
| Density ($kg/m^3$) | 2462 | 4457 | 7890 |
| Geldart group | A/B | B | B |
| $d_{50}$ (μm) | 76 | 155.46 | 199.65 |
| Span | 0.63 | 0.44 | 0.88 |
| $V_t$ (m/s) | 0.39 | 3.26 | 9.52 |

**Size Distribution**




| **Terminal velocity: $V_t$ ($d_{50}$ glass beads)** | **0.39 m/s** | | |
|---|---|---|---|
| Fluidization velocity: $V_f$ | $0.8V_t$ | $1.0V_t$ | $1.2V_t$ |
| Expected regime (mono-disperse) | $V_f < V_t$ Bubbling bed | $V_f > V_t$ Entrainment | |

# Elutriation

- **Several sub-processes effect the measured amount of solids elutriated**
  - Segregation
  - Particle Ejection
  - Entrainment
  - Disengagement
- **Individually each process is a challenge to modeling,**
  - particularly for larger scale systems

# Binary mixture bed hydrodynamic modeling

- **MFIX (www.mfix.org) - SIMPLE**
- **Euler-Euler**
  - KTGF: Gourdel, Simonin & Brunier (1999)
  - Poly-disperse RDF: Modified Mansoori / max. packing: 0.64
  - Drag: Wen & Yu and Ergun (Gobin et al., 2003)
  - Smooth wall boundary conditions: Sakiz & Simonin (1999)
  - Fluid turbulence: k-ε
  - Fluid - particle velocity covariance, Turbulent drift velocity
- **Discretization**
  - Spatial – Superbee
  - Temporal – Backward Euler
  - Cylindrical coordinate mesh: 5x201x10
- **Simulation parameters**
  - particle/particle restitution coefficient: $e_c$=0.97
  - particle/wall friction and restitution coefficients: $\mu_w$=0.1 and $e_w$=0.97
  - Initial bed height: 7.62 cm

# Influence of the PSD of fine material

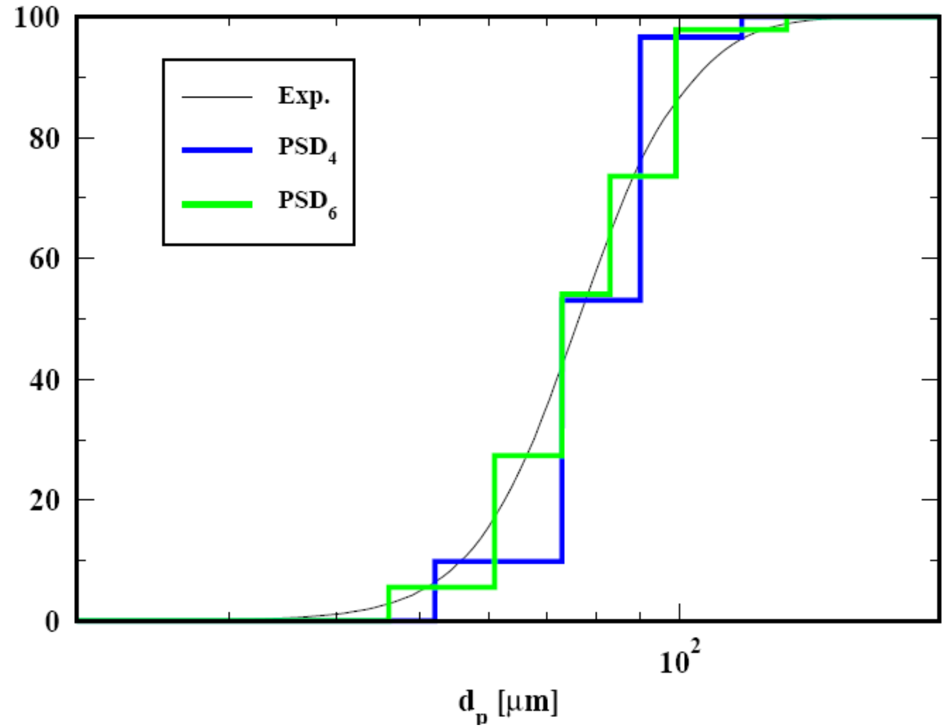
## Fine material: Glass beads

$d_{50}$ = 76 μm

| 4 bins | |
|---|---|
| $d_{50}$ (μm) | % Mass |
| 52 | 9.87 |
| 73 | 43.24 |
| 90 | 43.55 |
| 118 | 3.34 |

| 6 bins | |
|---|---|
| $d_{50}$ (μm) | % Mass |
| 46 | 5.58 |
| 61 | 21.81 |
| 73 | 26.70 |
| 83 | 19.52 |
| 99 | 24.27 |
| 133 | 2.12 |

**Cumulative Size Distribution**



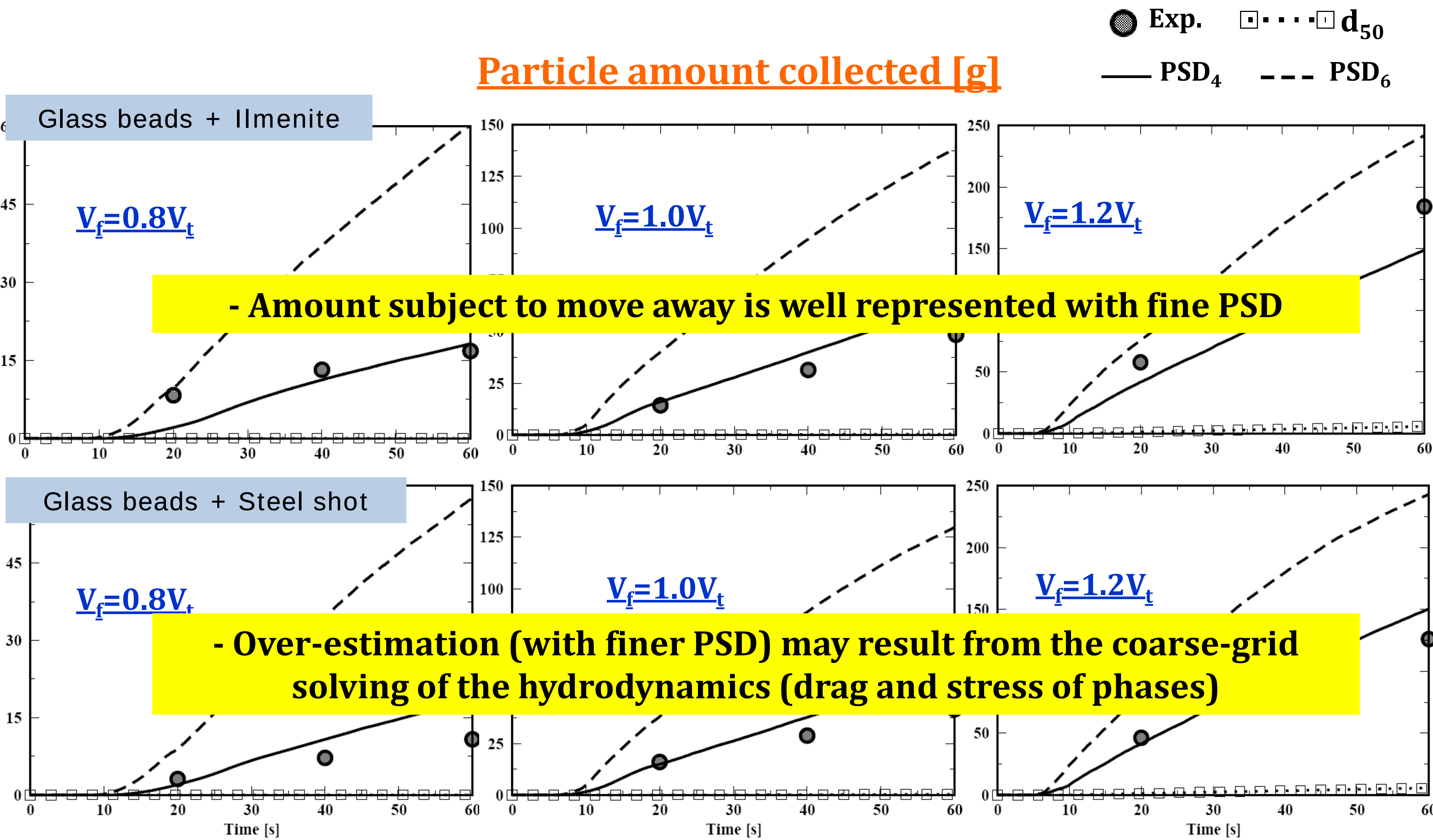

=> 6 bins PSD better represents the fine materials (expected to be elutriated)

## Coarse material: Metal oxide

$d_{50}$(ilmenite) = 155.46 μm and $d_{50}$(steel shot)=199.65 μm

# Results: Influence of the PSD of fine material

## Particle amount collected [g]




**- Amount subject to move away is well represented with fine PSD**

**- Over-estimation (with finer PSD) may result from the coarse-grid solving of the hydrodynamics (drag and stress of phases)**

⇨ $d_{50}$ approximation systematically fails

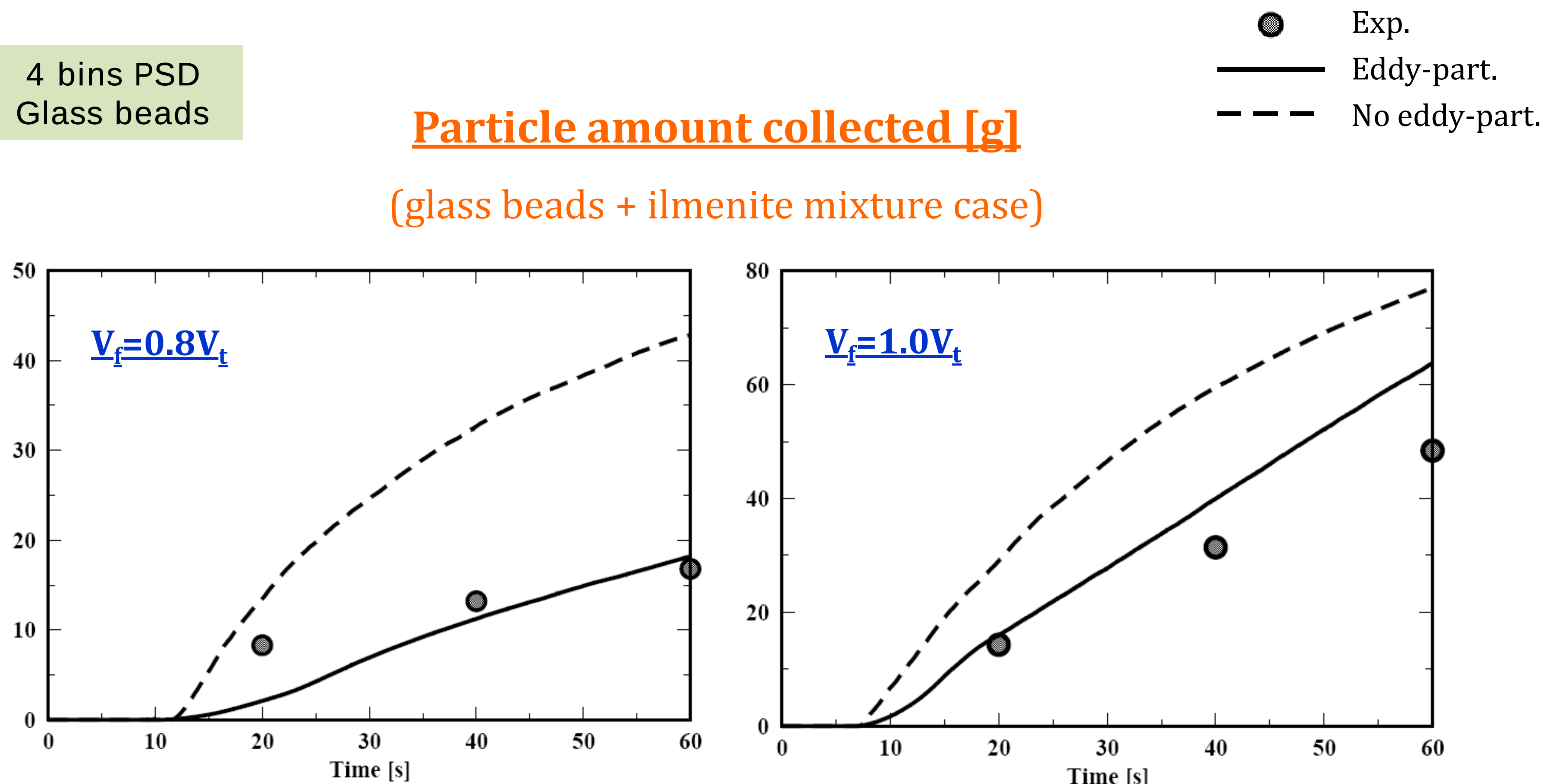
⇨ $PSD_4$ leads to satisfactory elutriation

# Results: Effects of the eddy-particle interactions

4 bins PSD
Glass beads

**Particle amount collected [g]**

(glass beads + ilmenite mixture case)

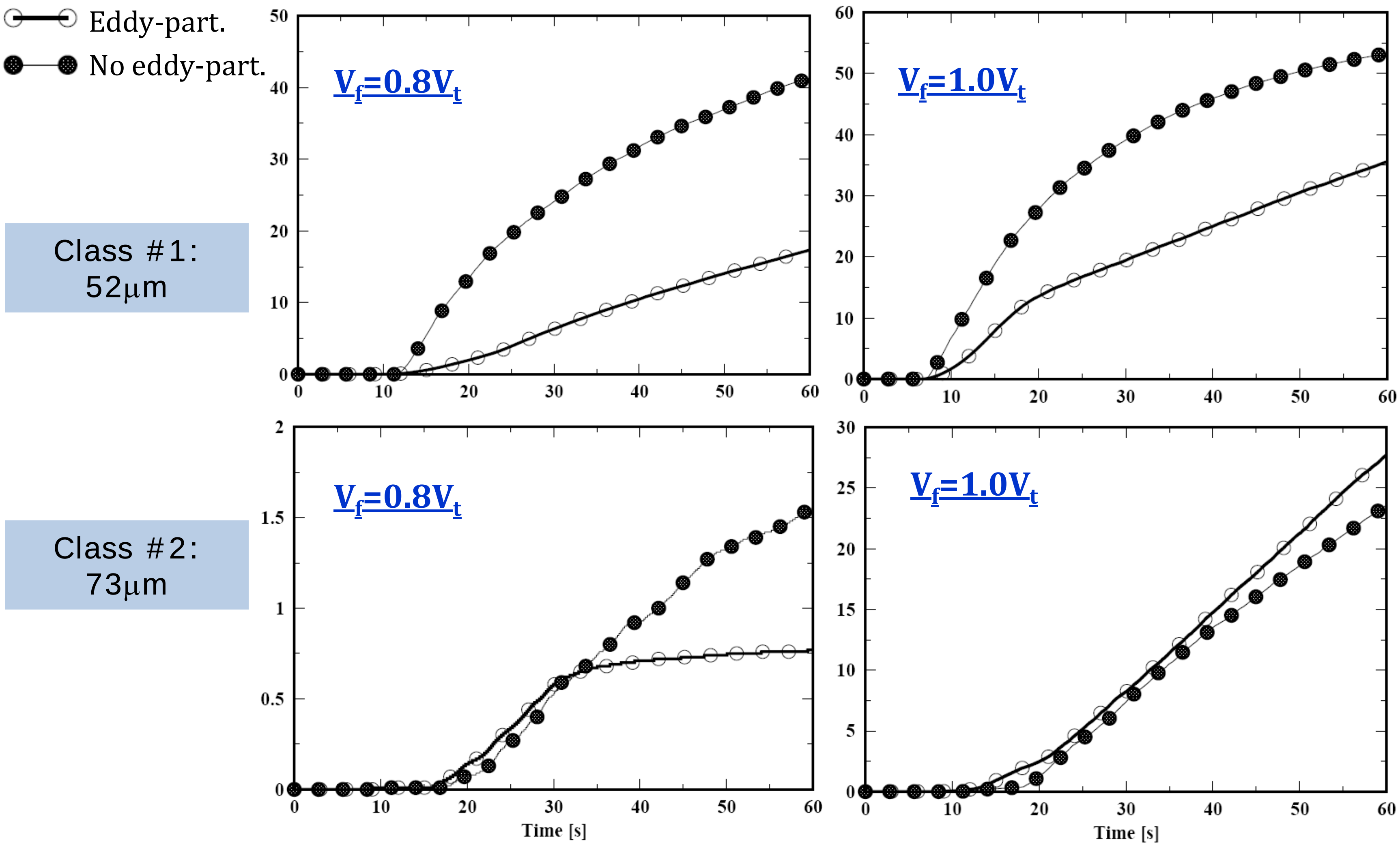



**Large fluid turbulent eddies strongly effect of the particle transport (and consequently the elutriation)**

**Fluid turbulent eddies enhance the particle dispersion**

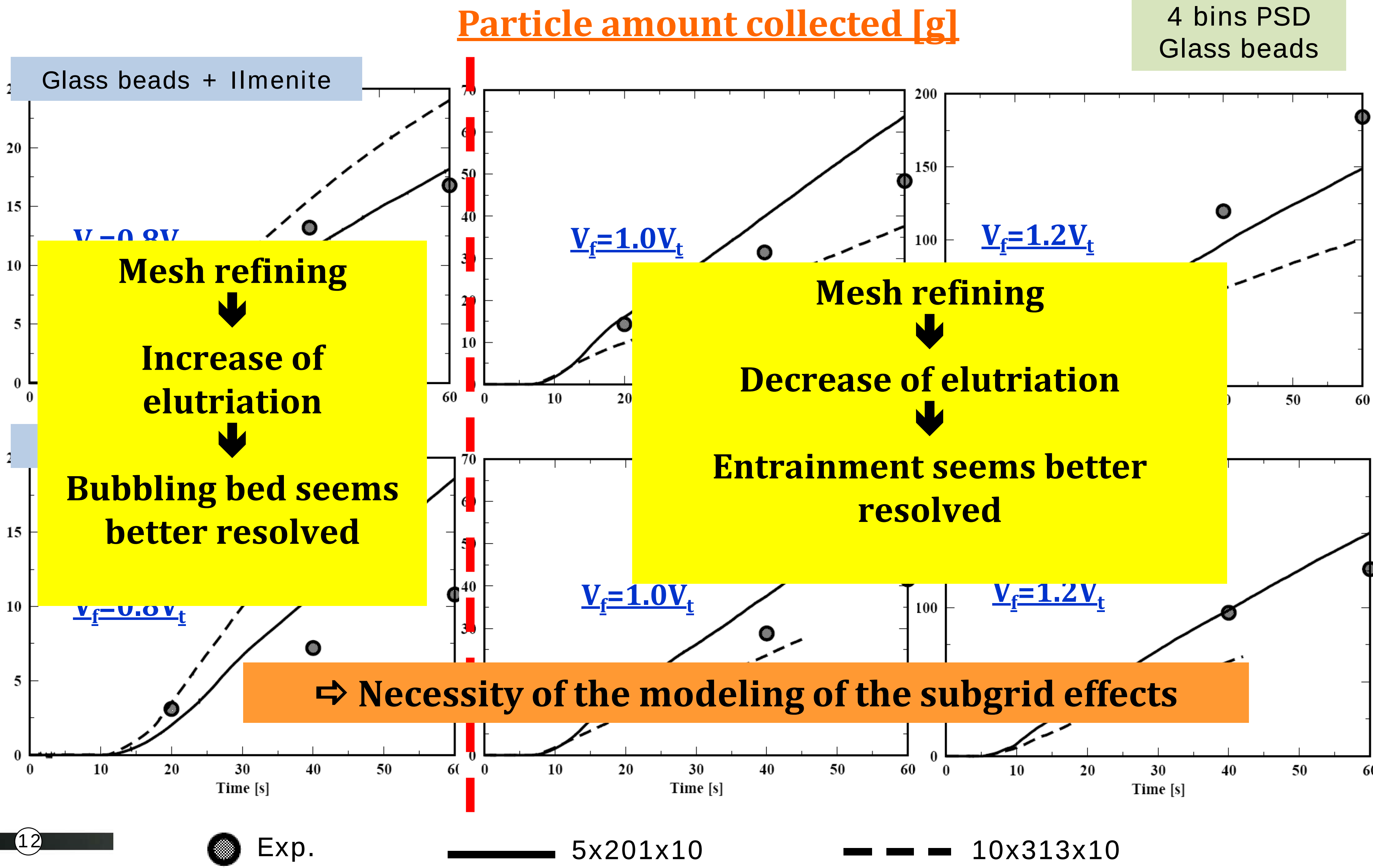
# Results: Effects of the eddy-particle interactions

Particle amount collected per class [g] (glass beads + ilmenite mixture case)




**Fluid large scales significantly reduce the elutriation the smaller particles while the large particles elutriation is marginally affected**

# Results: Effects of the mesh refining



# Conclusions

- Satisfactory 3D Euler-Euler predictions of the elutriation of fine materials from a binary mixture (Weber et al., 2012) are performed
- Resolution of the fine material is critical for accurate prediction of the elutriation
- Strong influence of the eddy-particle interactions on the elutriation of those finer materials
- The accuracy of elutriation prediction is related to grid resolution of hydrodynamics.
  - The bubbling bed segregation
  - The entrainment of the finer materials

# Future Work

- **Improve Results**
  - Refine the PSD for convergence
    - *Moment Methods ?*
  - Investigate full SGS models (*drag, kinetic and collisional stresses*)
    - *Igci & Sundaresan (2011), Parmentier et al. (2012), Ozel (2011)*

- **Numerical Techniques**
  - Adopt Cut-Cell technique instead of the cylindrical coordinate system (*which introduces spurious effects on the hydrodynamics*)

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