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Solid flux in travelling fluidized bed operating in square-nosed slugging regime

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Solid Flux in Travelling Fluidized Bed Operating in the Square-Nosed Slugging Flow Regime

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Fluidization XV

Montebello, Quebec, May 2016

Travelling Fluidized Bed Premise

- Many measurement techniques, some sophisticated (e.g. RPT, PEPT, borescopy, tomography, probes) for measuring key fluidized bed hydrodynamic properties.
- All columns and most particles are one-offs: Direct comparisons are almost impossible.
- Invasive vs non-invasive techniques.
- Comprehensive database needed, with estimates of experimental error, for validation of CFD and other models.

Travelling Fluidized Bed: Objectives

1. Compare measurement techniques under identical operating conditions.
2. Intrusive vs non-intrusive measurements.
3. Provide a comprehensive database for validation of models.
4. Educational tool.
5. Promote collaboration.

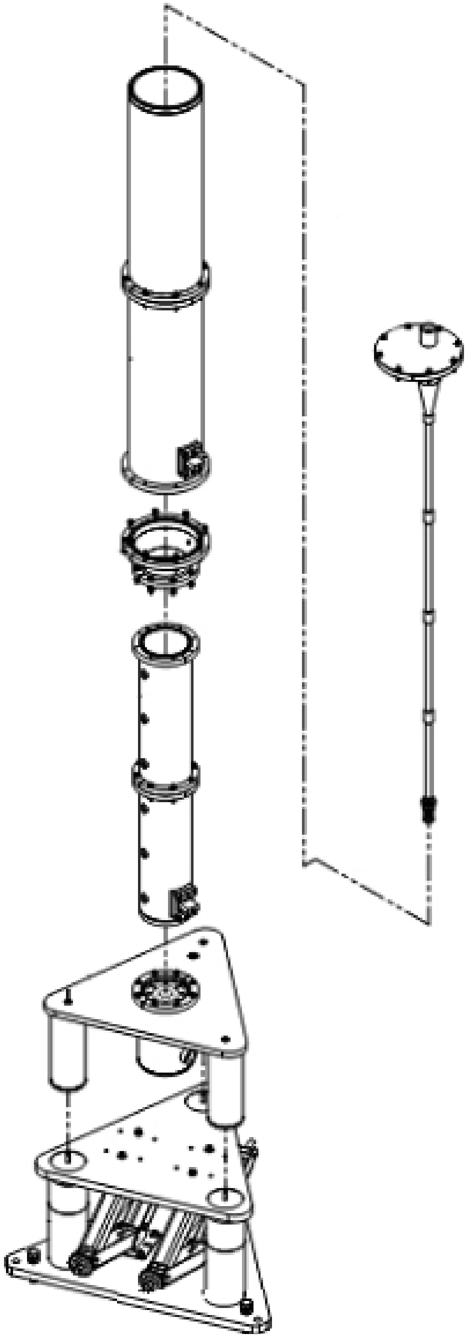
Participants

Column designed & constructed to travel. Initial funding to 5 Canadian Universities:

- **UBC** (Grace, Bi, Ellis, Lim)
- Univ. of Calgary (Kantsas)
- **Ecole Polytechnique** (Chaouki, Patience)
- Univ. of Saskatchewan (Pugsley)
- Univ. of Western Ontario (Zhu)

Later 3 additional collaborating organizations:

- PSRI (Cocco, Hays, Karri)
- University College London (Lettieri)
- **Univ. Birmingham** (Parker, Seville, Leadbeater).



Exploded VIew

Design and Construction

Input from each Participating Institution on their requirements (e.g. ceiling height, instrumentation allowable dimensions.)

Coanda R&D carried out the design and commissioning, working with UBC.

Design included all elements: column, structure, transport boxes, instruments, particles, tools for quick assembly, computer.

FCC and sand particles travel also.

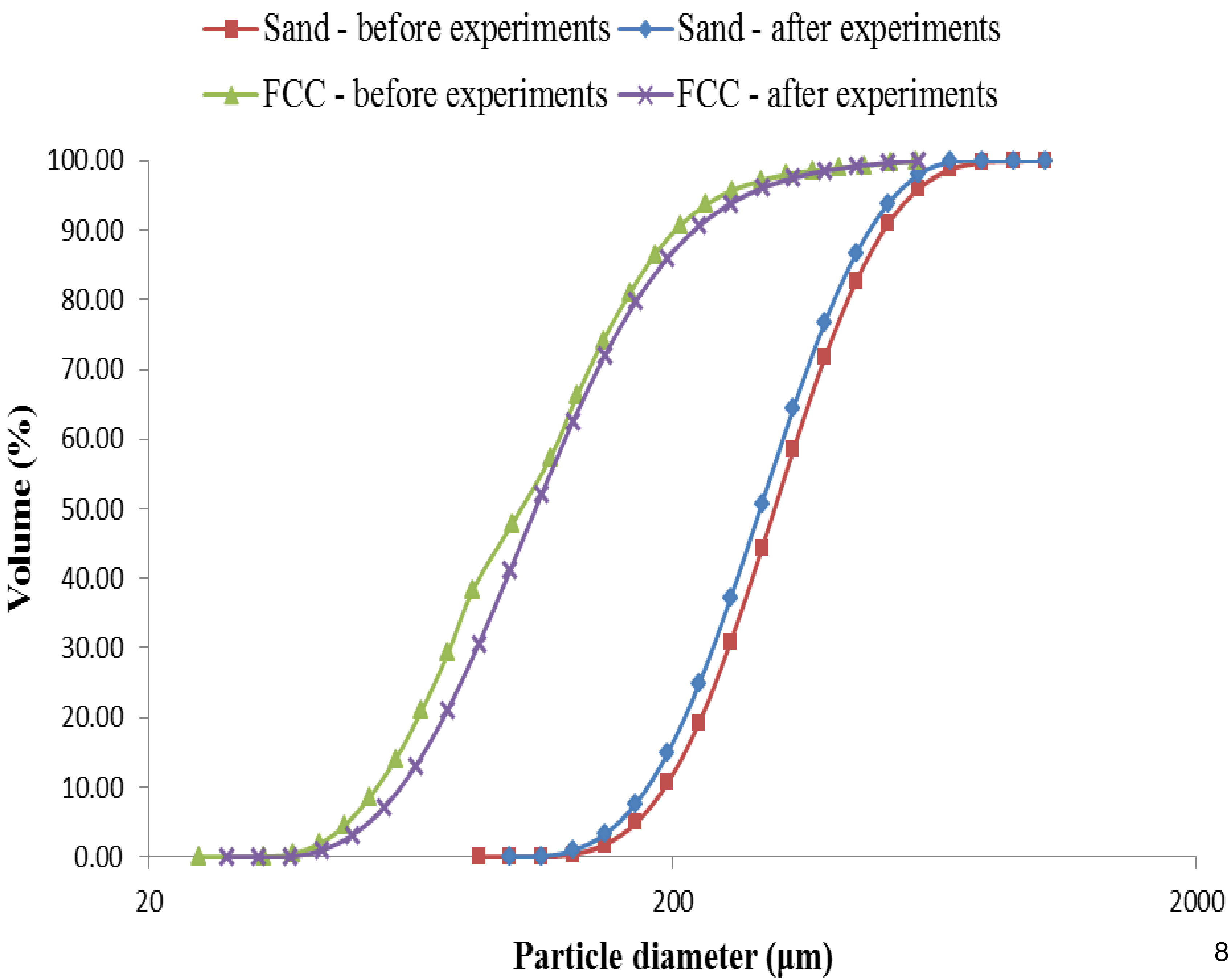
Travelling fluidized bed and transport boxes in UBC's Clean Energy Laboratory

Assembly: 1 working day

Disassembly including packing: ~ 4 hours

Repeatable Operating Conditions

- Extra-dry (RH=3%) air at T=25°C as the fluidizing gas.
- Atmospheric temperature and pressure.
- FCC (d_{sv}≈ 100 μm, Group A) and Silica sand (d_{sv}= 312 μm, Group B). H_o = 0.8 m.
- Radial profiles at 3 measurement heights.
- Bubbling and turbulent flow regimes, U = 0.30, 0.40, 0.50, 0.60 m/s.



Sand - before experiments
Sand - after experiments
FCC - before experiments
FCC - after experiments
Volume (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
20
200
2000
Particle diameter (μm)

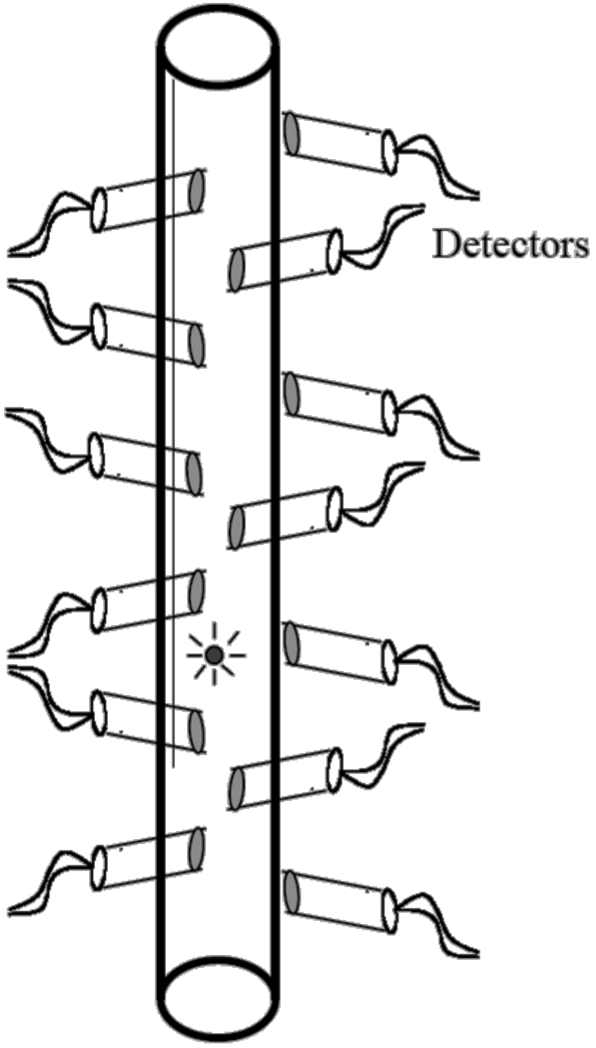
Techniques Compared – Solids Flux

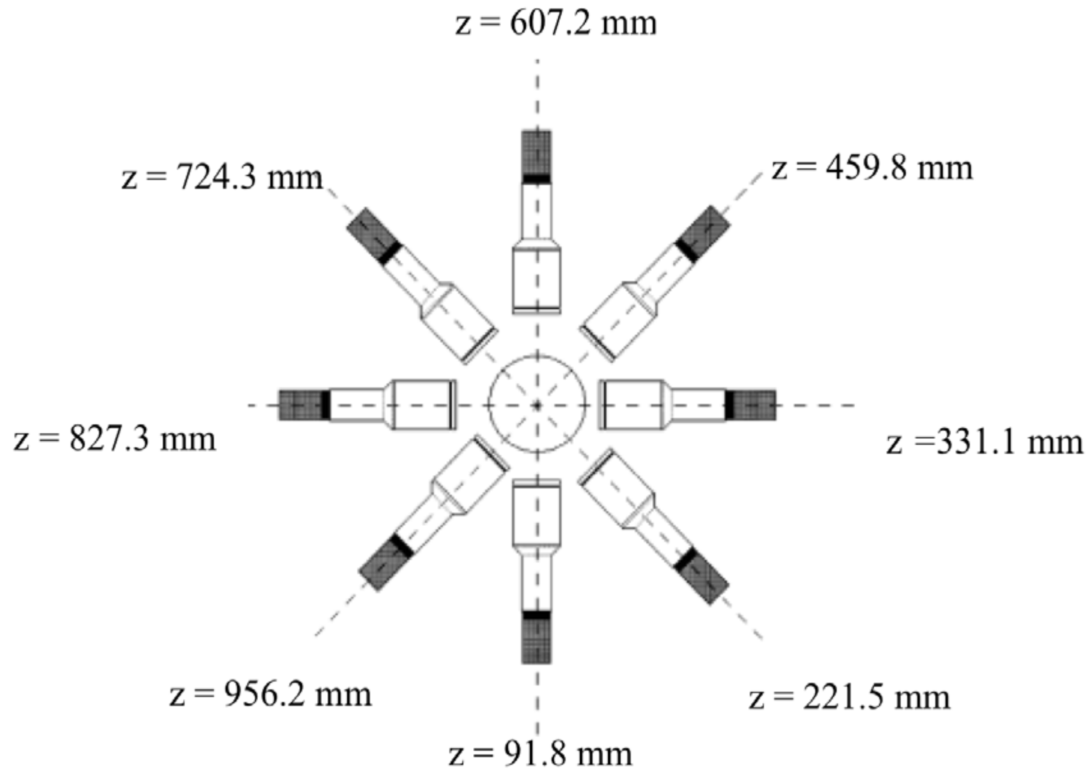
Non-invasive:

- Radioactive particle tracing (RPT)
- Positron emission particle tracking (PEPT)

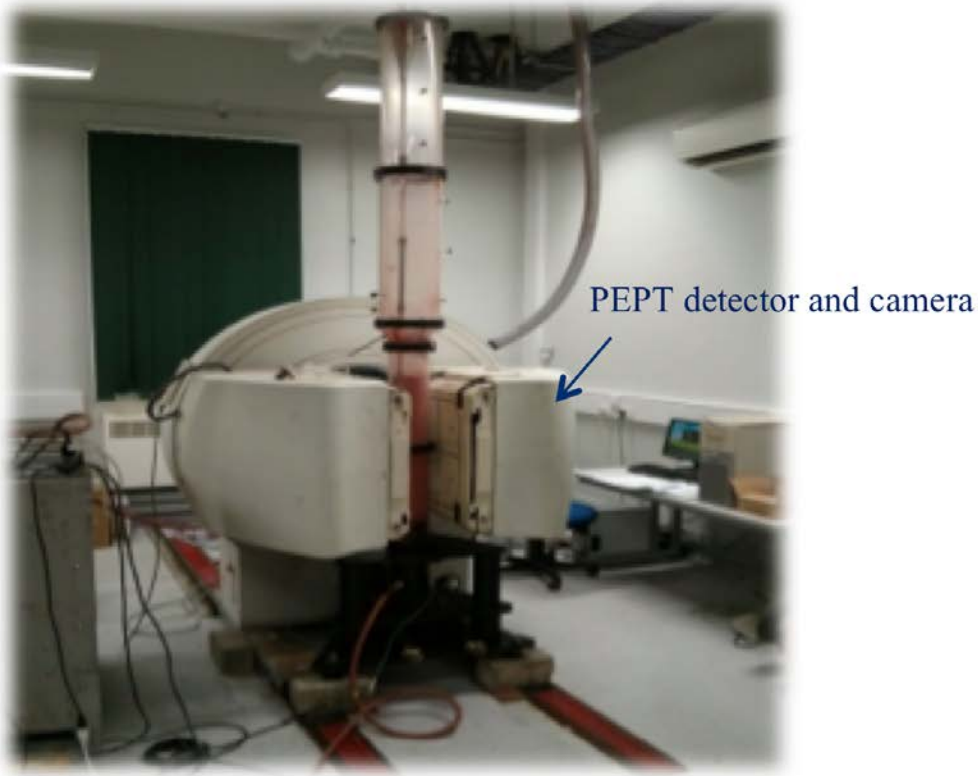
Invasive:

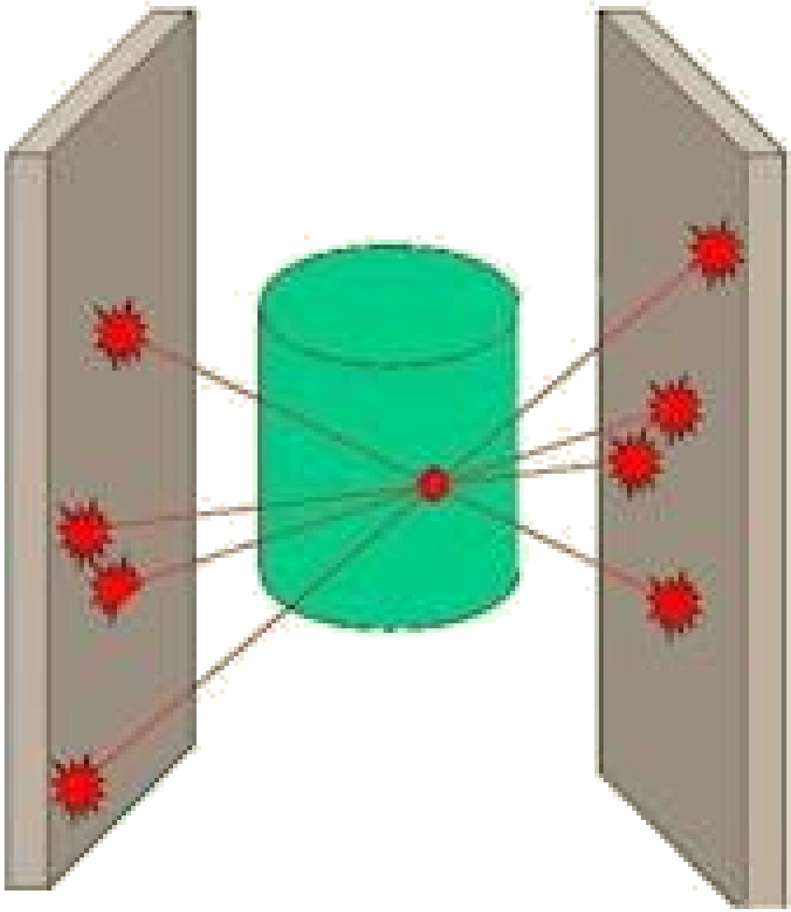
- Borescope: not found to be acceptable due to uncertain depth of field.





Radioactive Particle Tracking at the Ecole Polytechnique, Montreal





Positron Emission Particle Tracking at the University of Birmingham, England

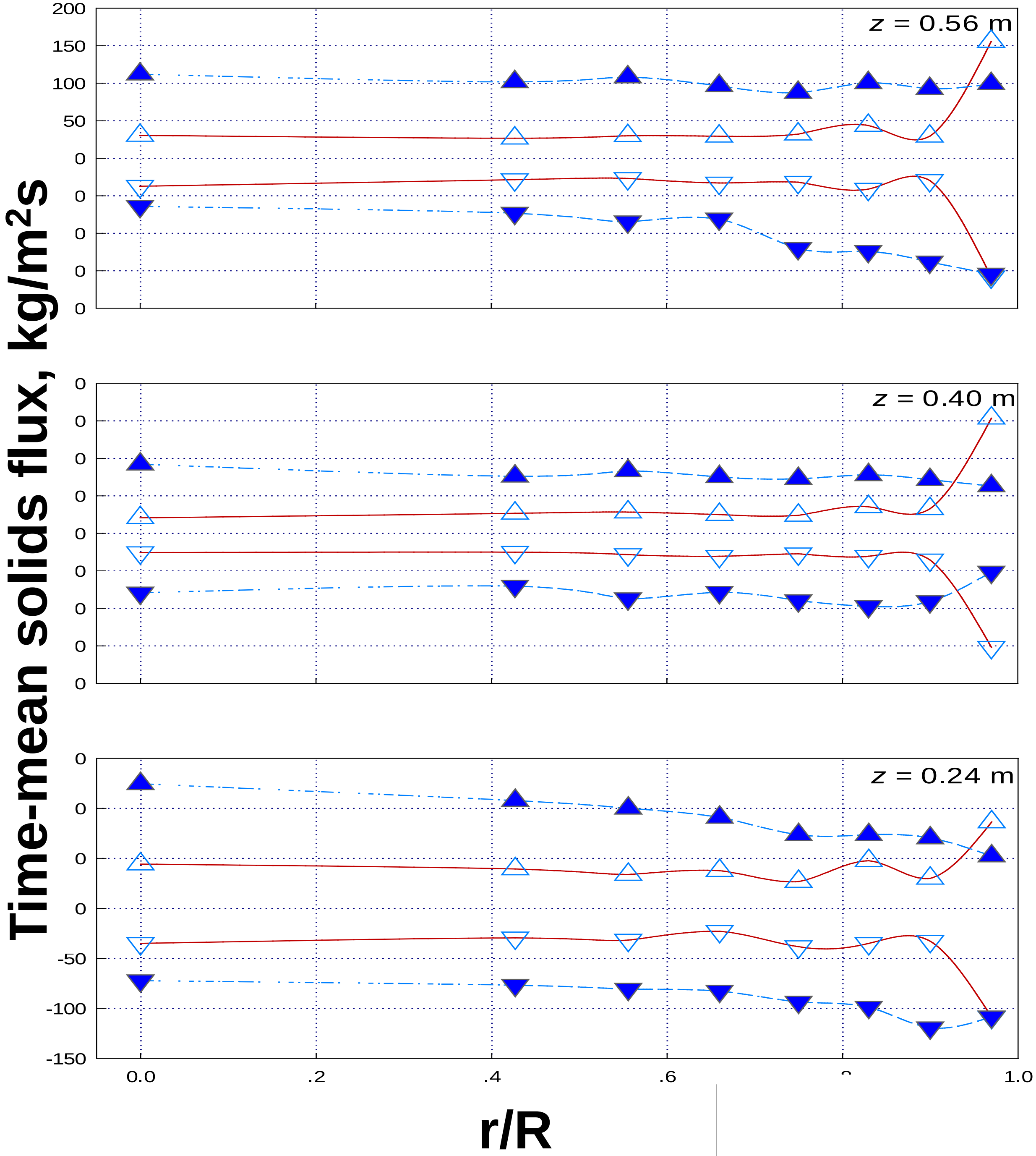
Properties of Sand and Tracer Particles

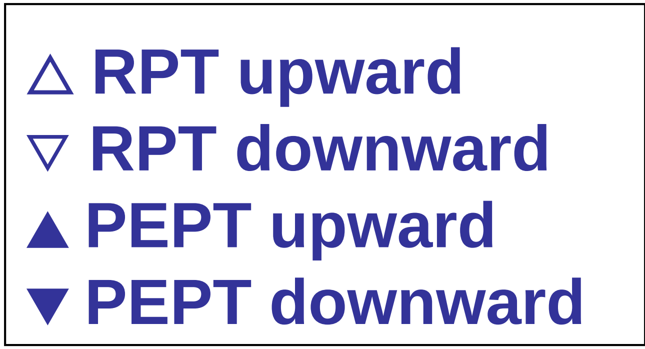
	Bulk sand	RPT tracer	PEPT tracer
d_p (μm)	332	400	300
ρ (kg/m^3)	2644	2000	3000
Shape	Irregular	Spherical	Irregular
v_T (m/s)	0.73	2.35	0.91

Methodology: If the tracer particle is truly representative of the bulk bed particles, then the number of times the tracer crosses a measurement plane during a long time interval can be used to estimate the solids flux across that plane.

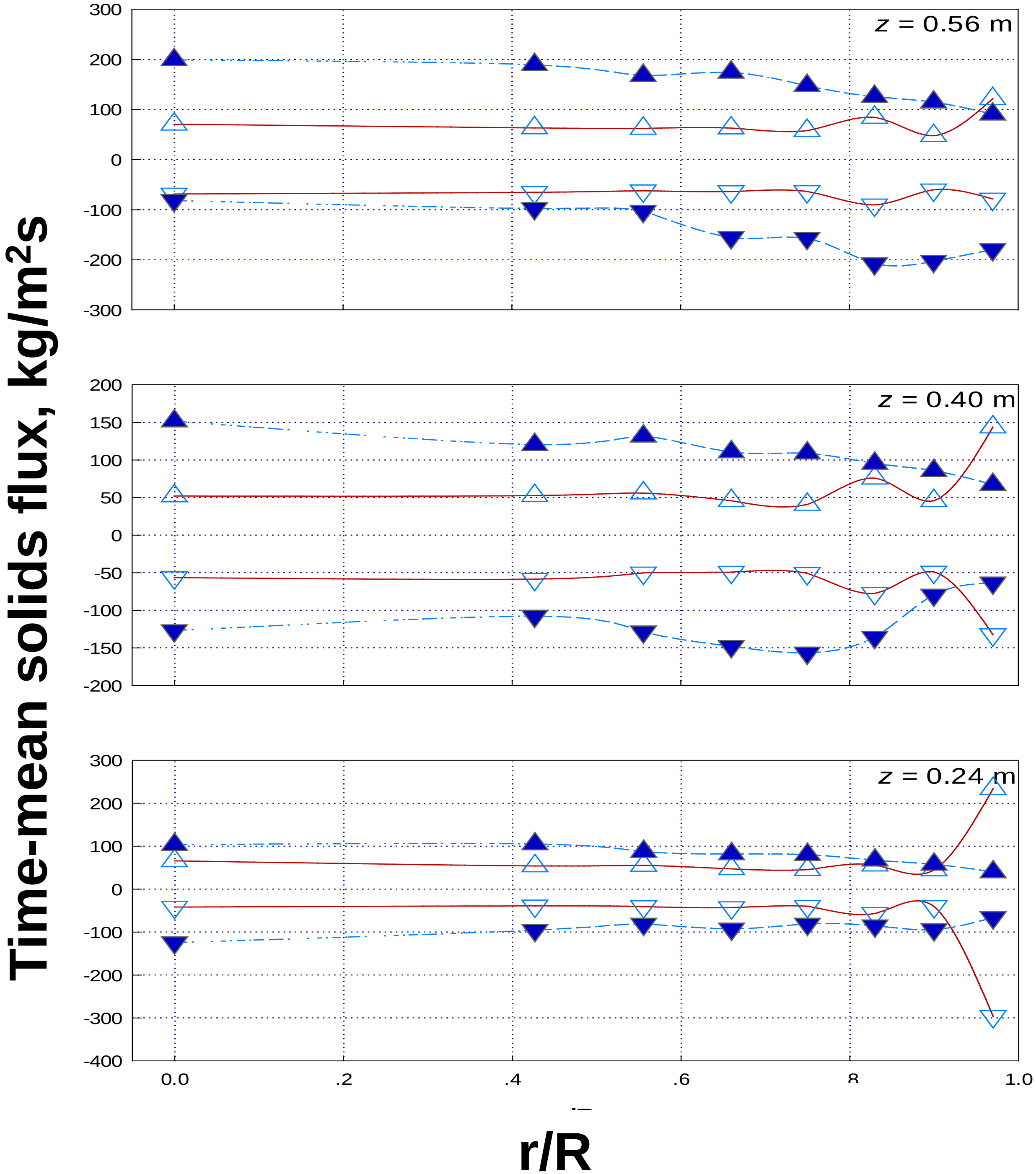
Square-Nosed Slug Flow Regime

- This flow regime is of little practical interest. It is found in smooth-walled columns of limited diameter with group B or D solids.
- The regime facilitates comparison of both experimental techniques and of models.

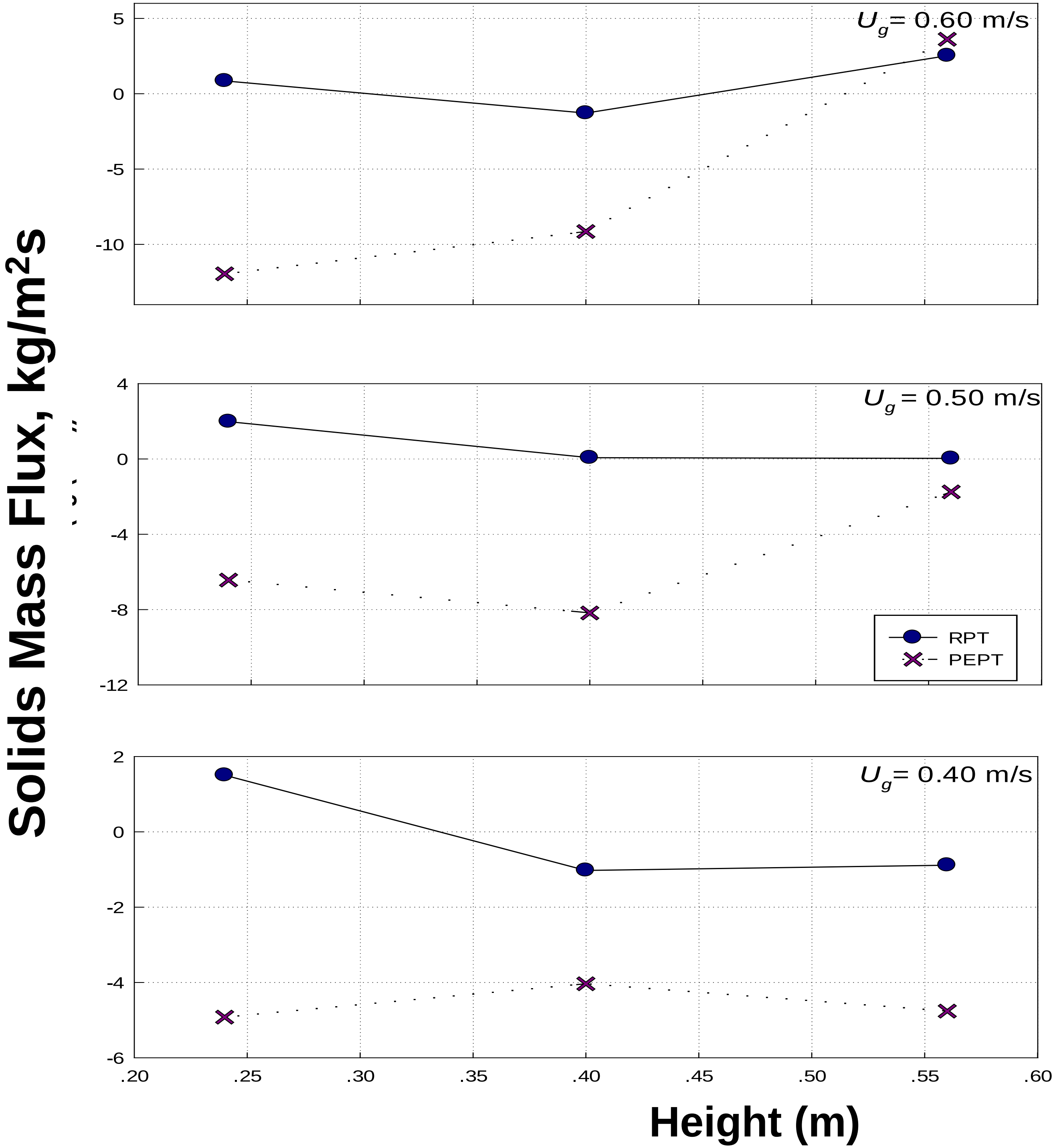




Radial profiles of upward and downward time-average solids mass flux at three levels for sand fluidized at 0.40 m/s.



Radial profiles of upward and downward time-average solids mass flux at three levels for sand fluidized at 0.60 m/s.



RPT

PEPT

Time-average sand net mass flux (over entire measurement time period: 3.5 h for PEPT, 8 h for RPT) at three levels for three gas velocities.

Factors Contributing to Differences between RPT and PEPT data:

- Tracer particles differed from each other and from the bulk bed particles.
- PEPT, with variable and, in some cases, faster sampling than RPT, captured raining particles more often than RPT.
- Possible saturation of RPT detectors when the tracer particle was in the wall region, reducing sensitivity and producing unphysical data near the wall.

Summary of Findings for Solids Flux

- The two tracking techniques are in reasonable qualitative agreement, but there are significant quantitative differences in measurements.
- Factors contributing to the differences include:
  - ➢ Tracer particles differ from bulk properties.
  - ➢ Limited spatial resolution in particle tracking.
- Probe intrusiveness is less important than excellent matching of tracer particle properties.

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