Baseline Measurements & Advanced Diagnostics Development In the Sandia / MFDRC Gas-Solid Riser

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Outline of Presentation

- Background & Motivation
- Facility Overview
  - Test Loop and Instrumentation
- Experimental Results
  - Diagnostics details and Experimental Data
- Advanced Diagnostics
  - Plans and Status
- Conclusions

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Background and Motivation

- Gas-solid industrial facillities are notoriously difficult to develop and operate.
- The Multiphase Fluid Dynamics Research Consortium (MFDRC) was formed in 1998 to cooperatively attack the modeling problem.
  - A precompetitive partnership: industry, academia, national laboratories (DOE/OIT).
- End goal: reliable, verified computational models of gas-solid flow
- SNL role: develop testbed and produce high-quality experimental data for model validation

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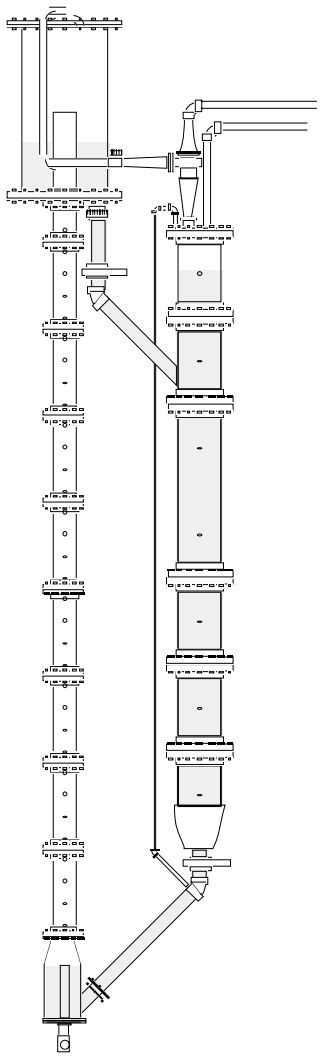
Sandia / MFDRC Gas-Solid Riser



- 14 cm ID, 5.77 m tall riser (L/D ≈ 41)
- 28 cm ID, 4.25 m tall downcomer
- Axisymmetric particle disengagement
- Dry compressed air as motive fluid
- Loaded with equilibrium FCC, ρ_p = 1250 kg/m^3, d(3,2) = 65 μm

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Sandia / MFDRC Riser Instrumentation

- **Differential and reference pressures are measured along the lengths of the riser and downcomer columns, and at critical points in the flow system.**
- **Superficial gas velocity U_g is calculated from orifice-plate pressure measurements.**
- **Bulk mass flux is determined from porous-valve measurements.**
- **Point mass flux is measured using non-isokinetic sampling probes.**

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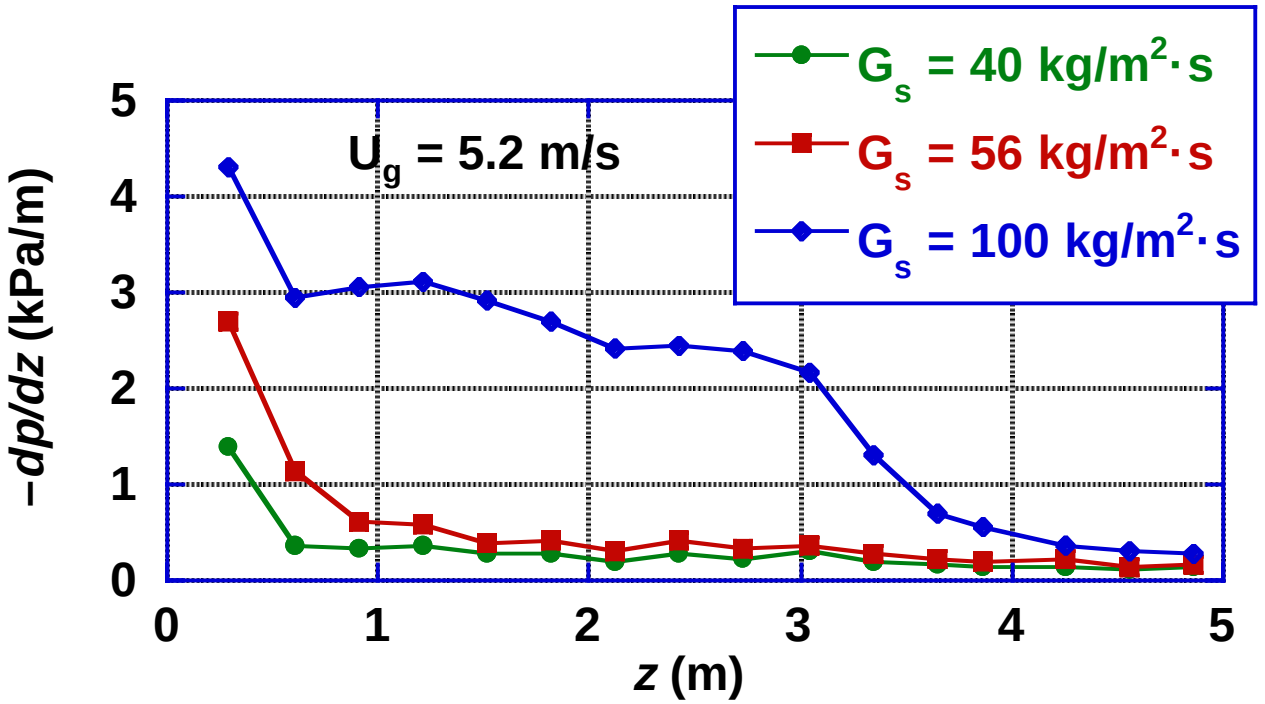
Differential Pressure Measurements

- **Differential pressure transducers sampled at 3 Hz yield pressure profiles along the length of the riser**



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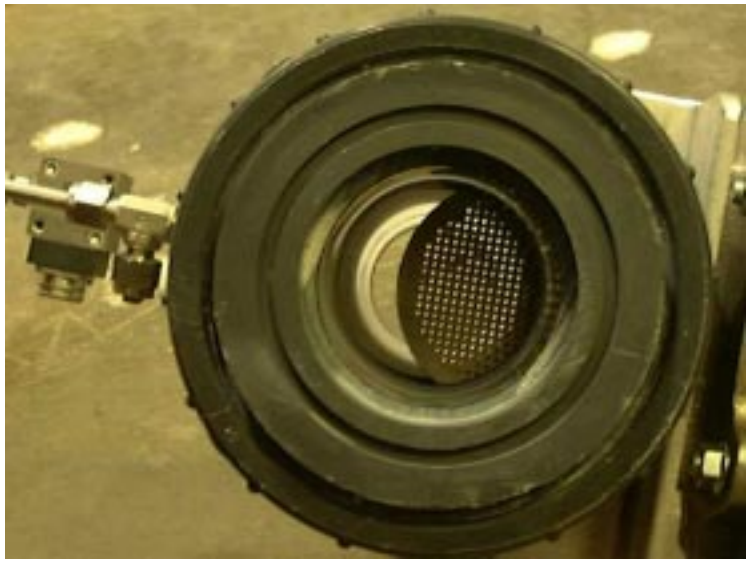
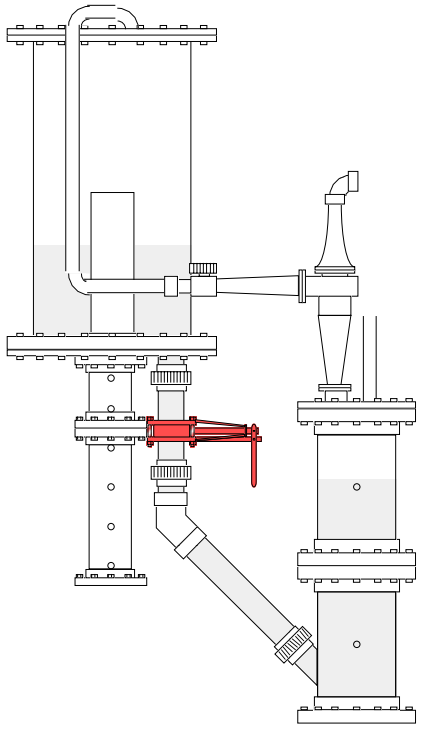
Bulk Mass-Flow Rate Measurements

- **A porous-plate knife valve was constructed and installed in the standpipe returning particles from the disengagement to the downcomer.**
- **Mass Flux is inferred from the rate of downcomer bed-level drop.**





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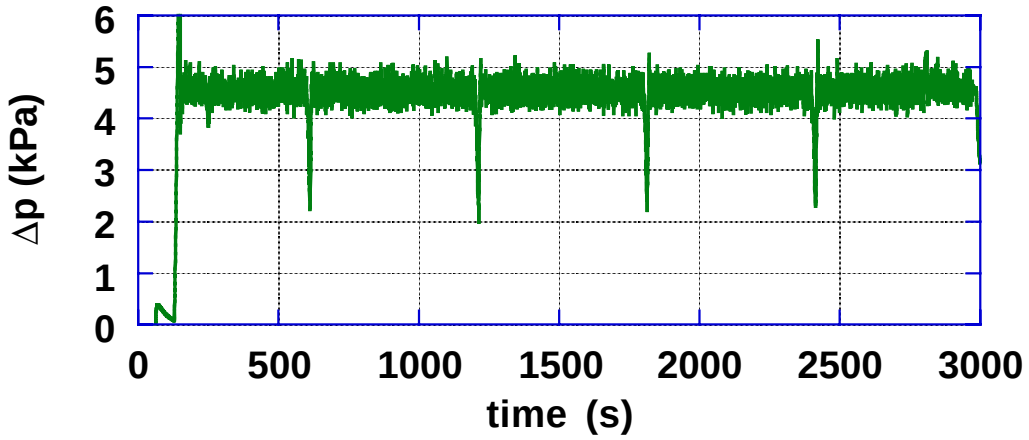
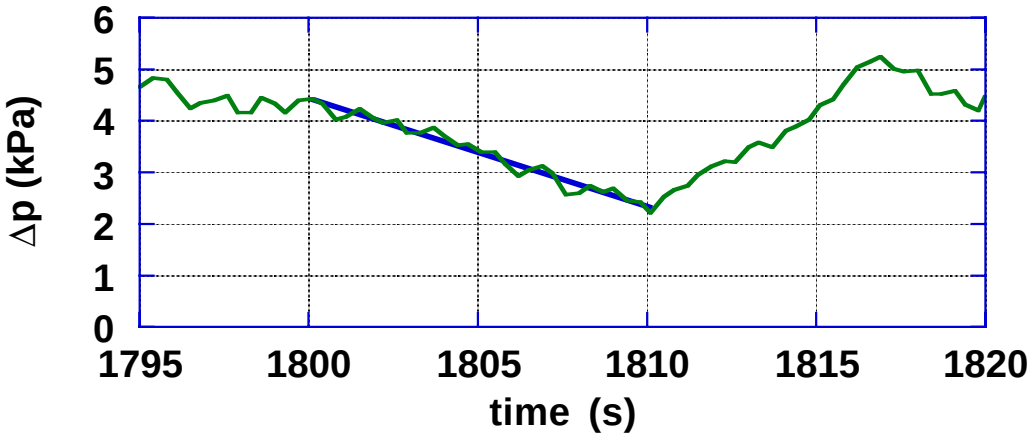
Bulk Mass-Flow Rate Measurements





- In practice, the downcomer bed level is inferred from the differential pressure traces.
- A linear fit is reasonable and reliable for relatively short porous-valve closures.

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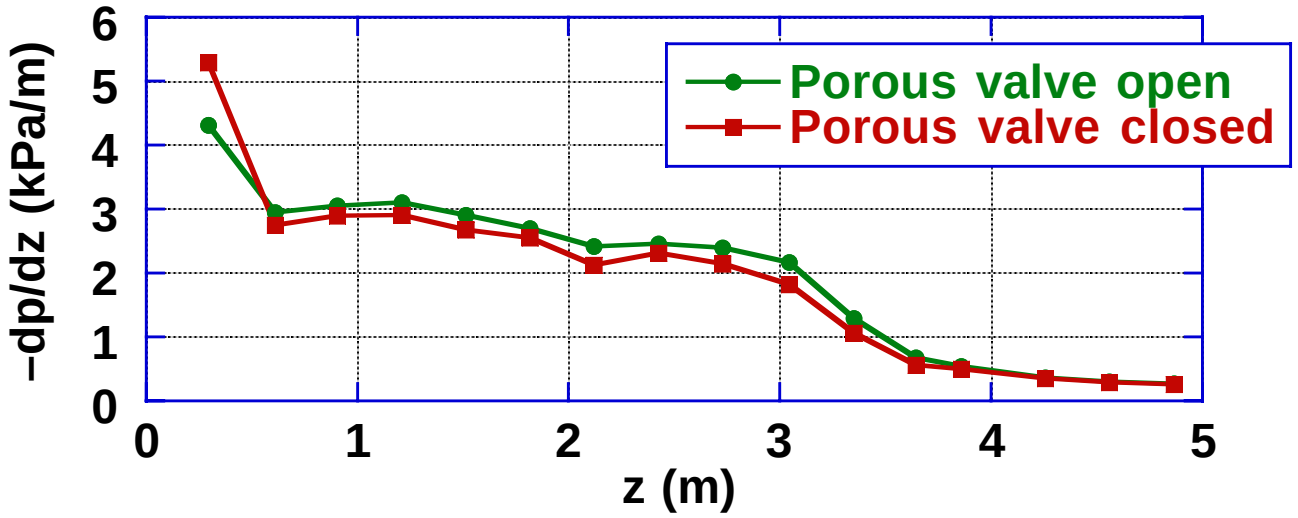
Bulk Mass-Flow Rate Measurements

- **The effect of the porous valve's closure on the system can be seen by examining the ∆p profile.**



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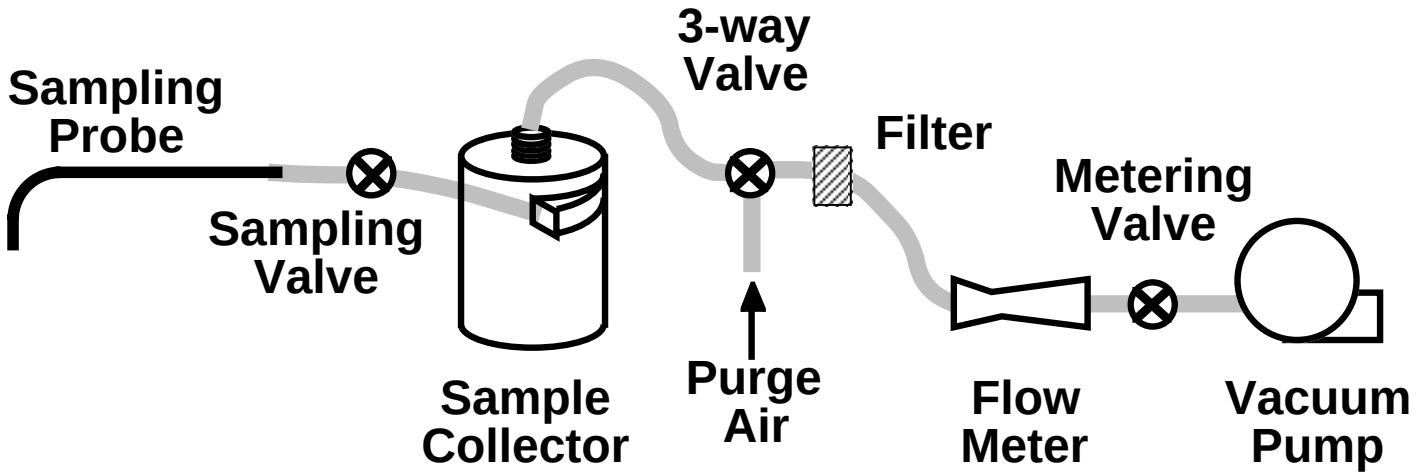
Non-Isokinetic Sampling Probe

- **A suction-driven, non-isokinetic sampling system has been developed and installed in the Riser.**



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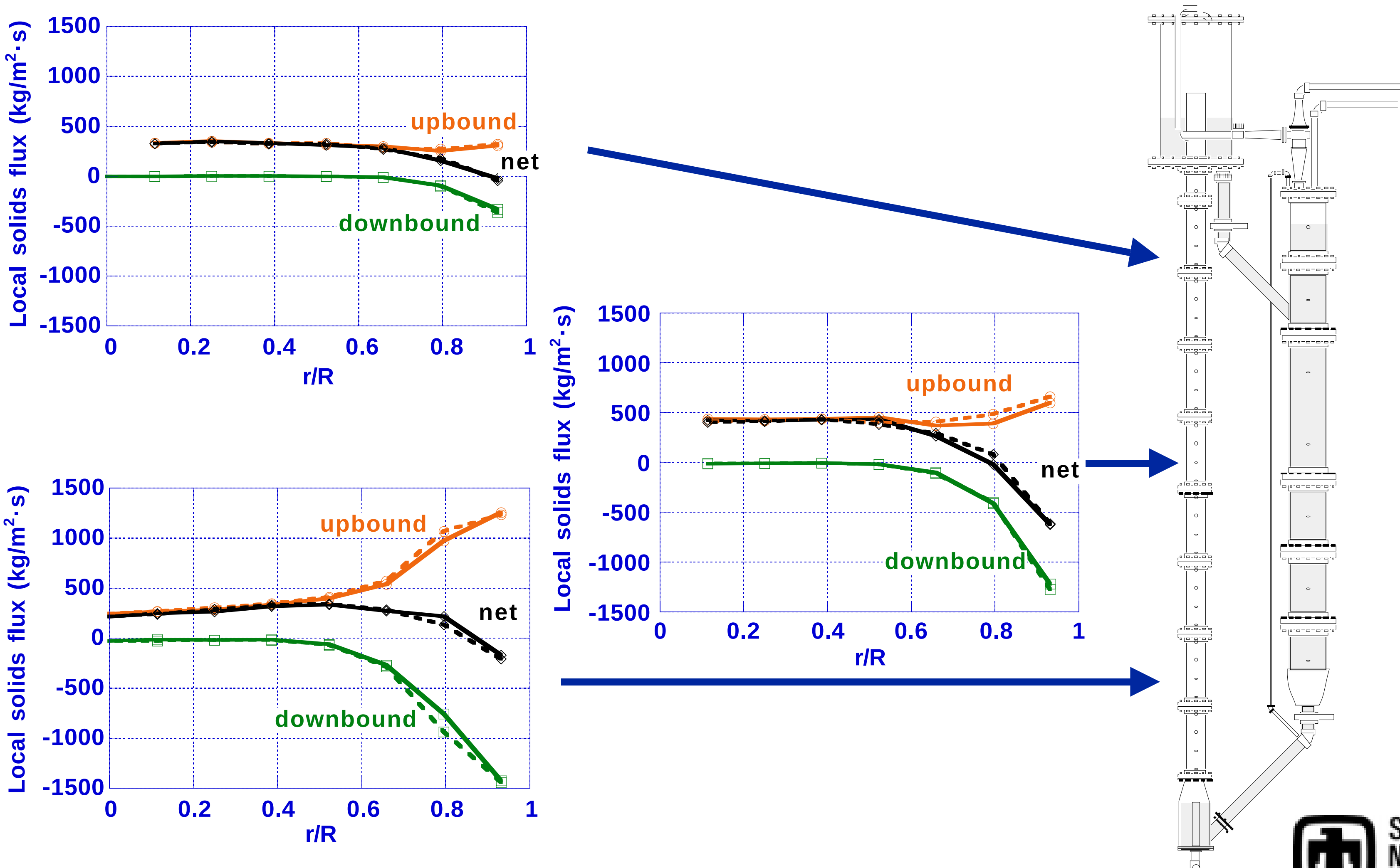
Results: Non-Isokinetic Sampling



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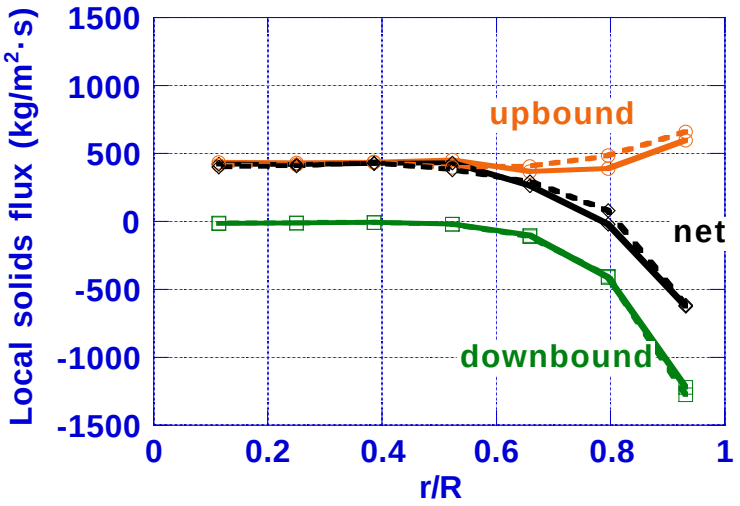
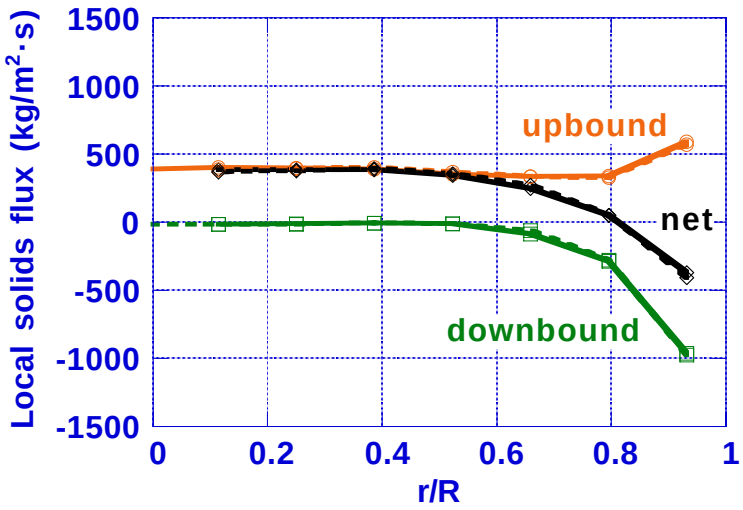
Sensitivity of Sampling to Suction Velocity

- Small changes in suction velocity drive large changes in integrated flux.
- Qualitative results (zero-crossing) remain essentially unchanged.



3.4Ug, 32 & 54 kg/sq.m·s



2.5Ug, 89 & 86 kg/sq.m·s

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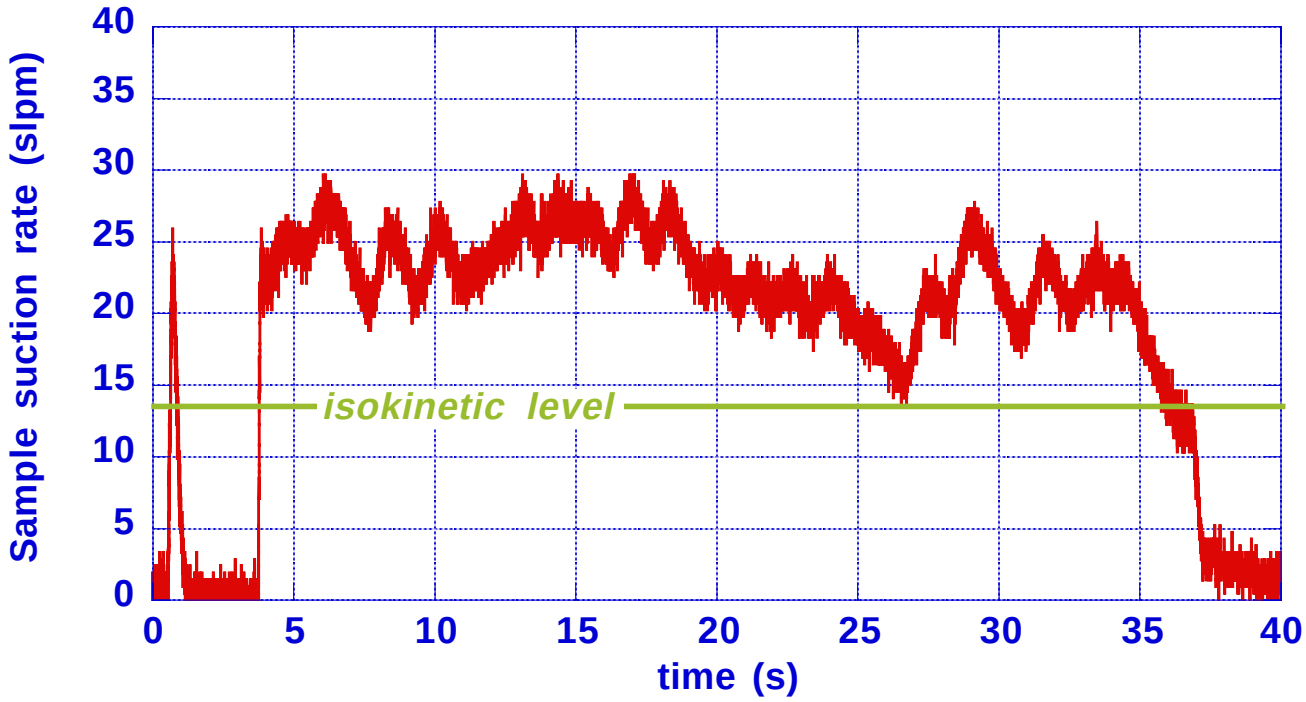
Electronic Metering Reveals Suction Details

- **Not just isokinetic, but *any* chosen suction velocity is difficult to maintain as solids loading varies in sampling system.**



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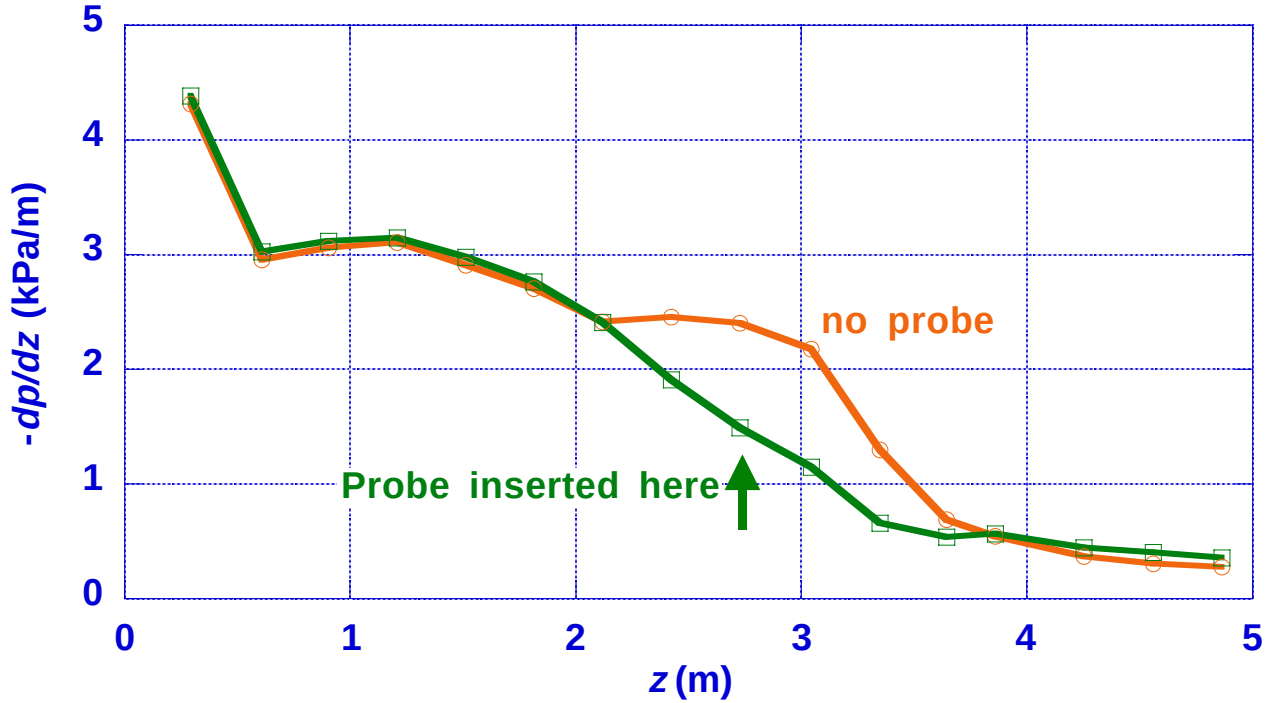
Invasiveness of Sampling Probe

- **Flux probe insertion significantly affects riser flow; measured bulk mass flux is unchanged.**



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Advanced Diagnostics

- Several advanced diagnostics are in development for application in the riser.
- Emphasis is on well-characterized, high-quality non-invasive techniques, including:
  - Particle Image Velocimetry (PIV)
  - Gamma-Densitometry Tomography (GDT)
  - Electrical-Impedance Tomography (EIT)

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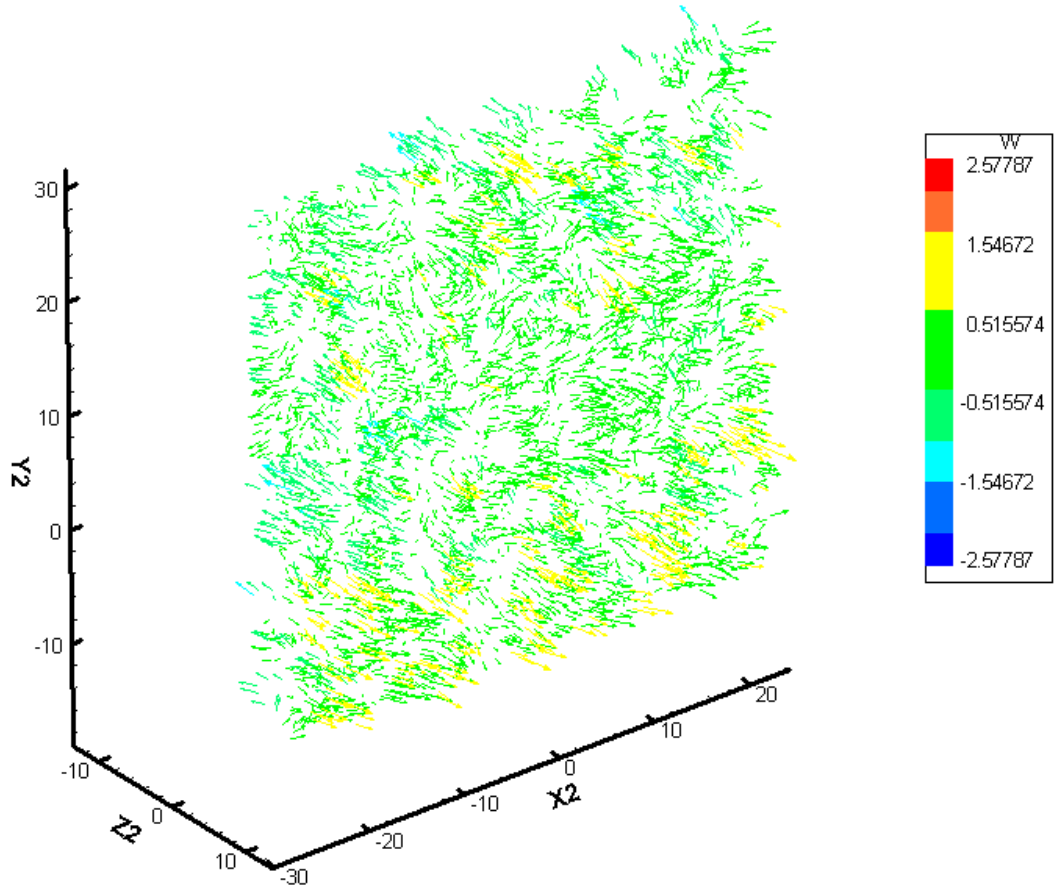
Particle Image Velocimetry



- **Optical-quality glass section fabricated and installed.**
- **Commercial Stereo PIV system applied**
- **Measurements were successful only in very dilute cases.**

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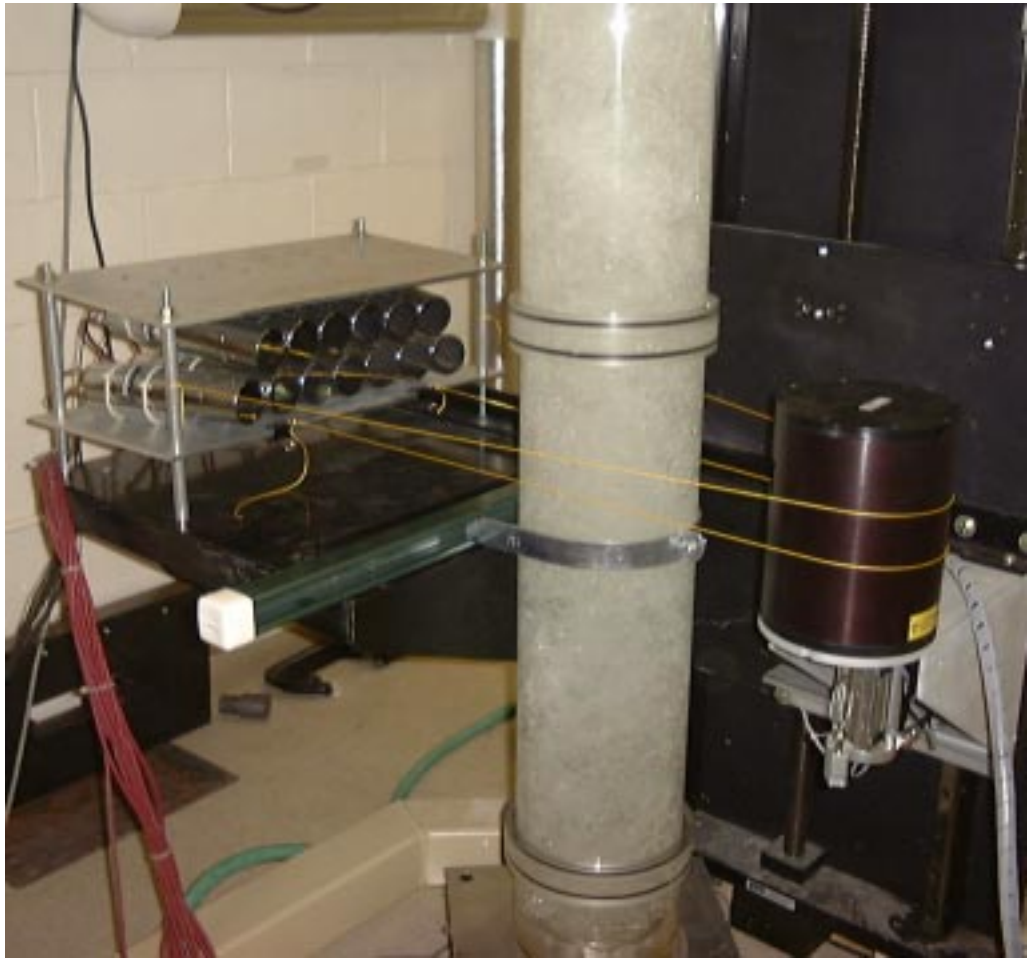
Gamma-Densitometry Tomography



- 100 mCi ^{137}Cs source emitting a fan-shaped beam
- 13 NaI scintillation detectors
- Axisymmetric distribution assumed
- In development on 19-cm ID air/water bubble column

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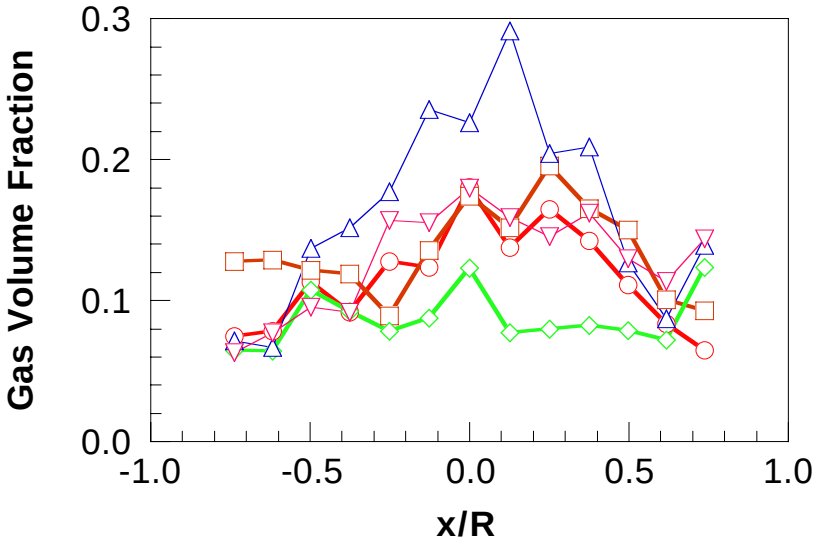
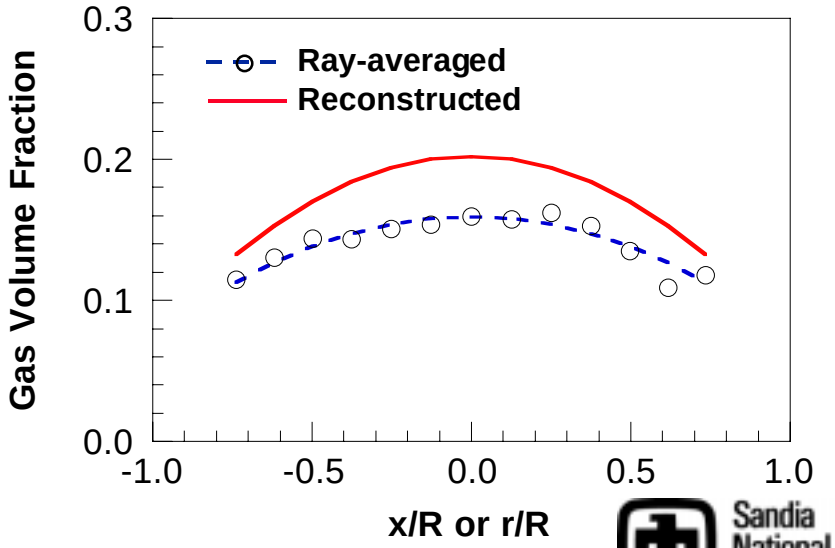
Gamma-Densitometry Tomography



Transient Data

Axisymmetric Tomographic Reconstruction of Average Data



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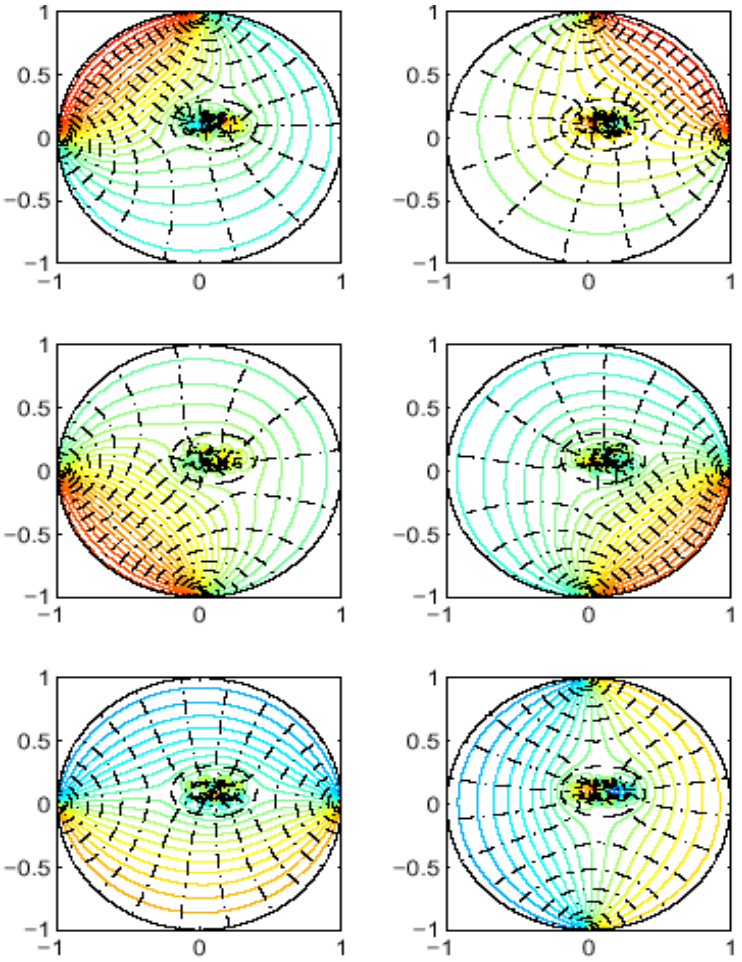
Electrical-Impedance Tomography



- Will be used to measure time-resolved, three-dimensional void fraction distribution in the riser.
- Based on injection & withdrawal of current from electrode pairs and inferring resulting impedance distribution via voltage measurements.
- Bulk $\Rightarrow$ 2D $\Rightarrow$ 3D

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Conclusions

- A gas-solid riser testbed has been designed and installed at Sandia National Laboratories.
- Basic diagnostics – differential pressure, bulk gas mass flux, bulk solids mass flux – have been installed and are yielding useful data.
- Sampling-probe mass flux measurement capability is being developed and characterized.
- Advanced non-invasive diagnostics are also in development.

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Acknowledgements

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