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Characterization of Forward and Backward Flux Correlations in 1D Stochastic Media

Aaron Olson

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Overview

- **Used SCEPTRE* on Pegasus and Redsky to generate realizations of stochastic meshes**
- **Mined data at points throughout the mesh for forward and backward flux**
- **Discovered five points of interest that define extreme correlation cases in a given stochastic mesh**
  - **Points 1-4: Generated from maximum possible absorption and scattering in regions**
  - **Point 5: Generated as average path length decreases and mesh approaches homogeneity**

*Sandia's Computational Engine for Particle Transport for Radiation Effects

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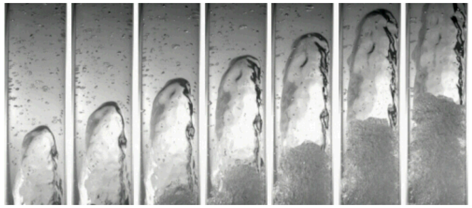
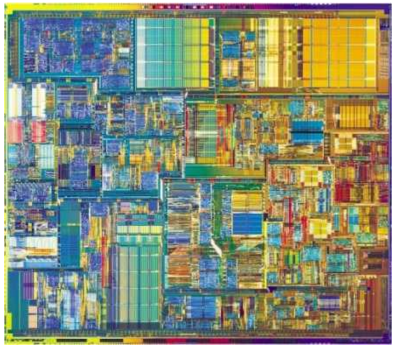
Introduction – Stochastic Media

- Stochastic Media – Two or more materials mixed in a way that cannot easily be exactly modeled
    - Compound mixtures
    - Two-phase flow
    - Small repetitive systems





- Meshes built using
    - average path lengths (λ)
    - and a probability distribution

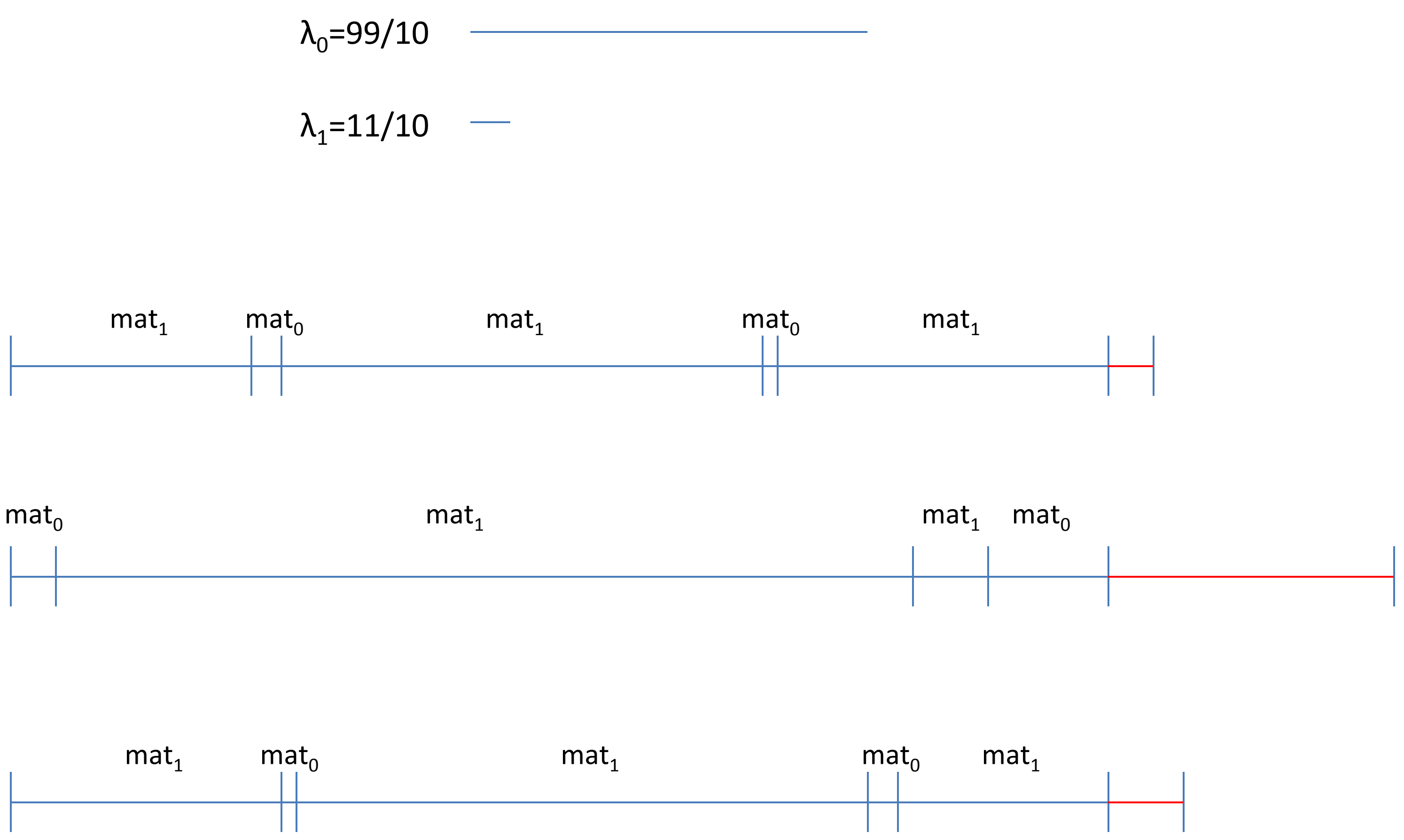
λ_0=99/10

Examples

λ_1=11/10

Examples

Introduction – Building Stochastic Meshes



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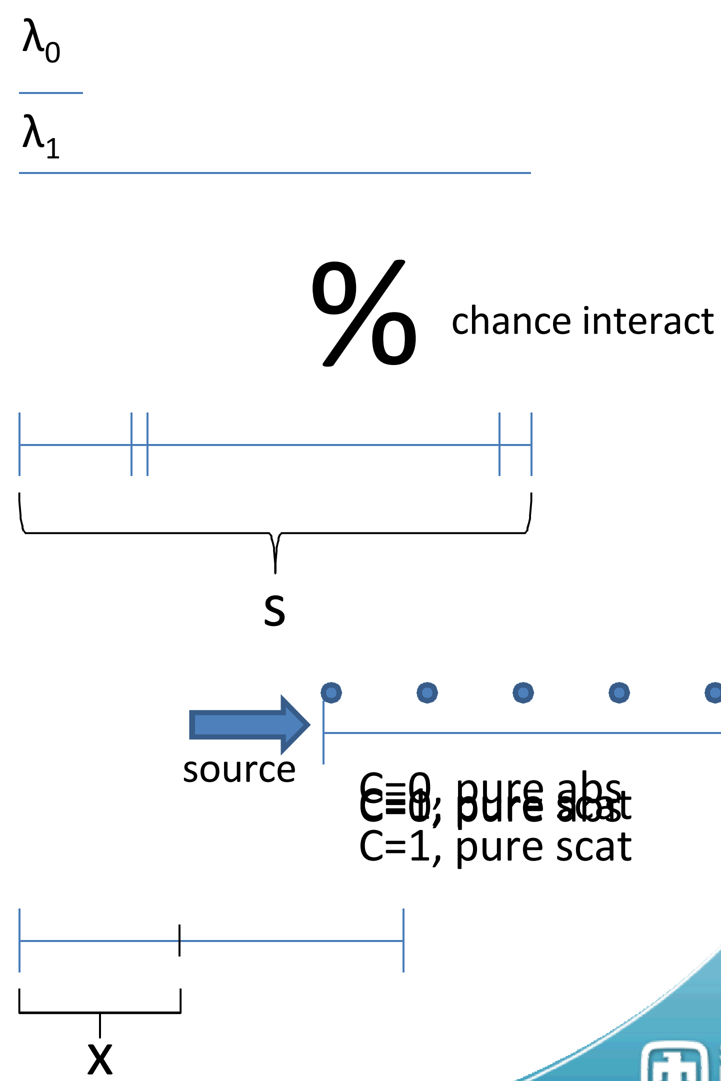
Introduction – Stochastic Mesh Parameters

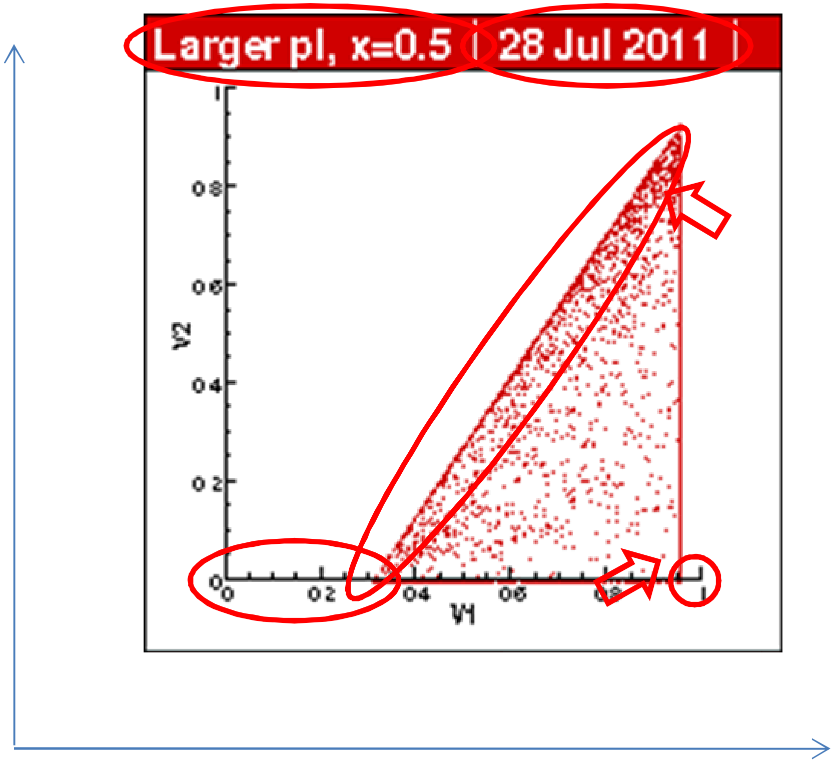
Stochastic Parameters Reference	
λ	**Average path length** (of material segment)
σ	**Cross-section** (of interaction)
s	**Total length** (of mesh)
c	**Scattering ratio** (σs /σt, 0=pure abs, 1=pure scat)
x	**Position in mesh** (relative to left boundary)



Introduction – Correlation Plots

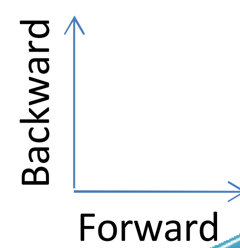
- Smaller λ later slides
- At x=0.5 (of s=10)
- Date I created this plot on

Backward Flux



Forward Flux

- Each dot represents the fluxes with a given mesh
- Example 1: Lots of absorbing
- Example 2: Lots of scattering past x=0.5
- At least 30% always gets here
- About 5% never gets here
- Must have forward to have backward



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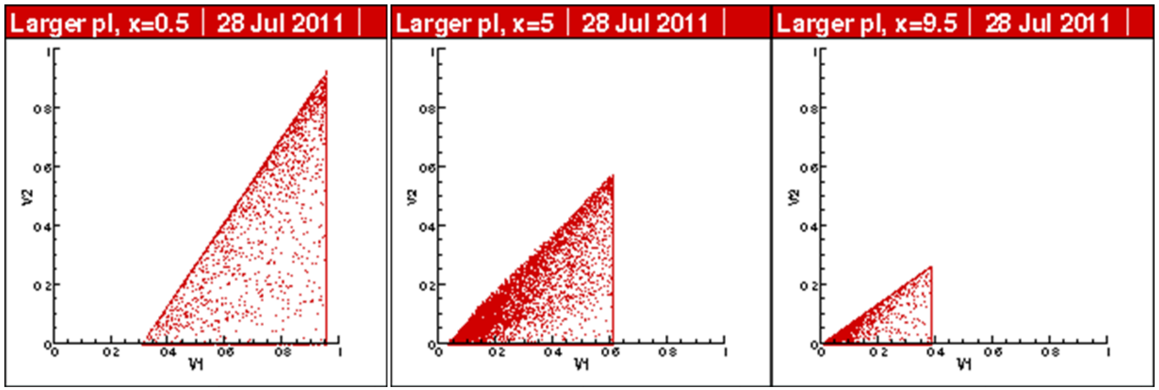
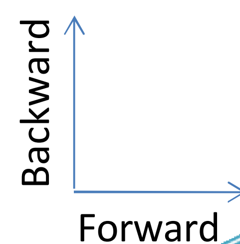
Results & Analysis – Material Depth



Mesh Parameters	
s=	10
mat0	
λ_0=	99/10
σ_0=	10/99
c_0=	0 (abs)
mat1	
λ_1=	11/10
σ_1=	100/11
c_1=	1 (scat)

As data is taken further through the mesh:

- there is a lower flux
- the backwards flux dies more than the forward flux



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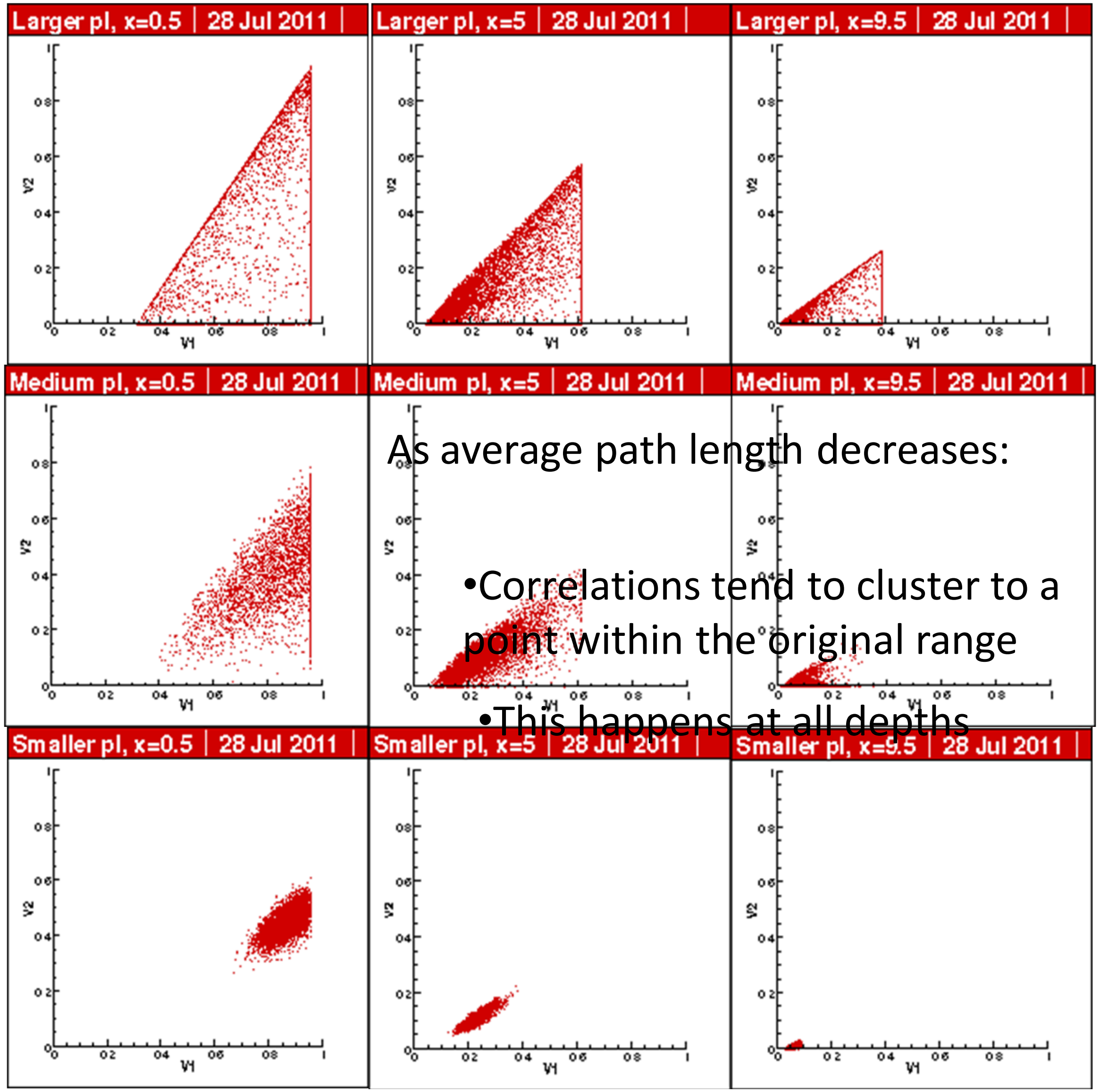
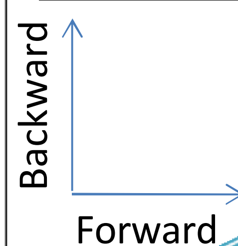
Results & Analysis – Average Path Length



As average path length decreases:

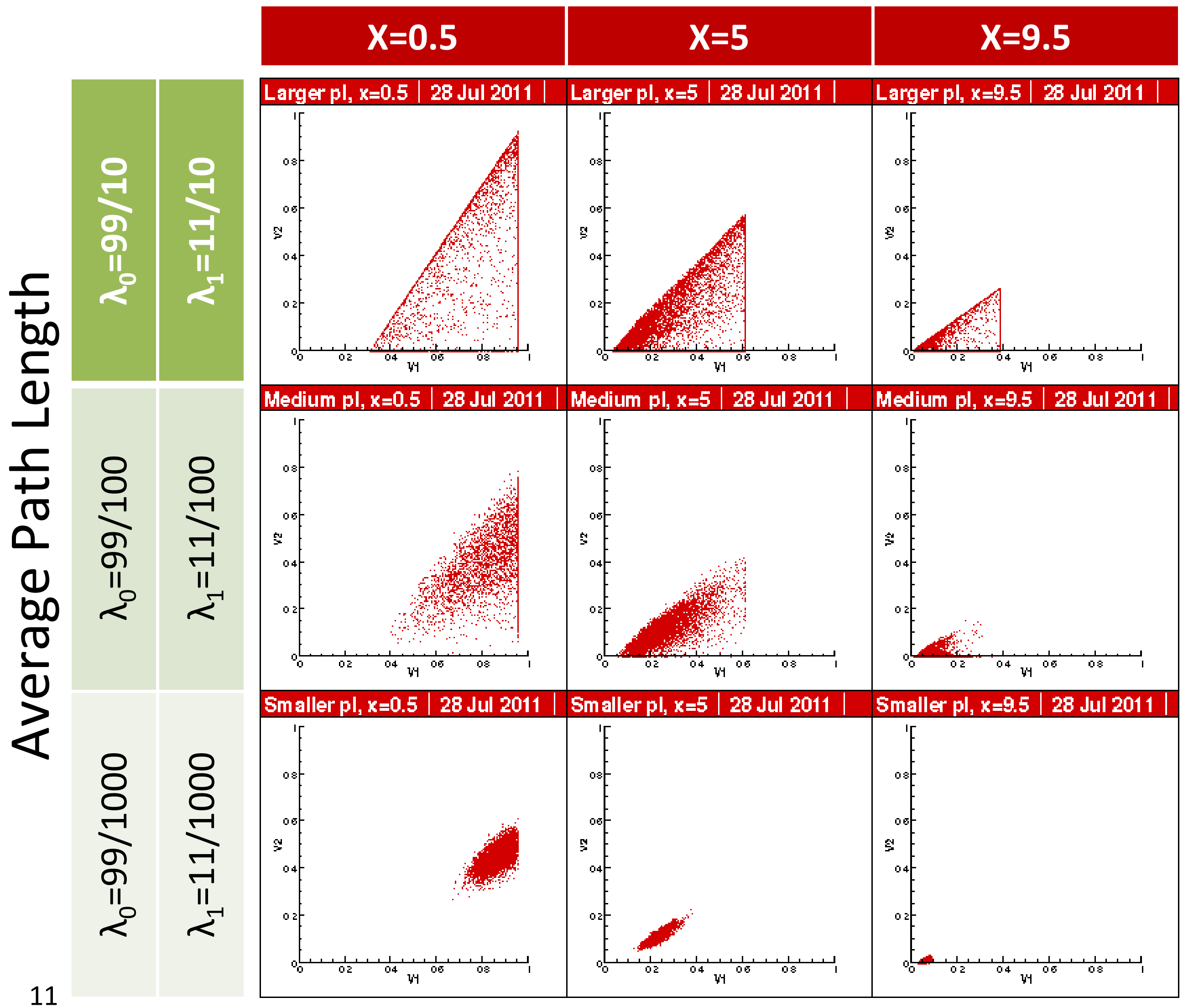
- Correlations tend to cluster to a point within the original range
- This happens at all depths

Mesh Parameters	
s=	10
mat0	
λ_0=	varies
σ_0=	10/99
c_0=	0 (abs)
mat1	
λ_1=	varies
σ_1=	100/11
c_1=	1 (scat)

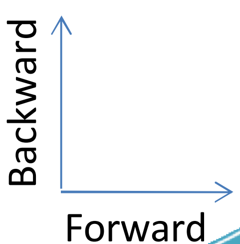


Results & Analysis – Material Depth and Length Effects Summarized

Depth in Mesh



Mesh Parameters	
s=	10
mat0	
λ_0=	varies
σ_0=	10/99
c_0=	0 (abs)
mat1	
λ_1=	varies
σ_1=	100/11
c_1=	1 (scat)



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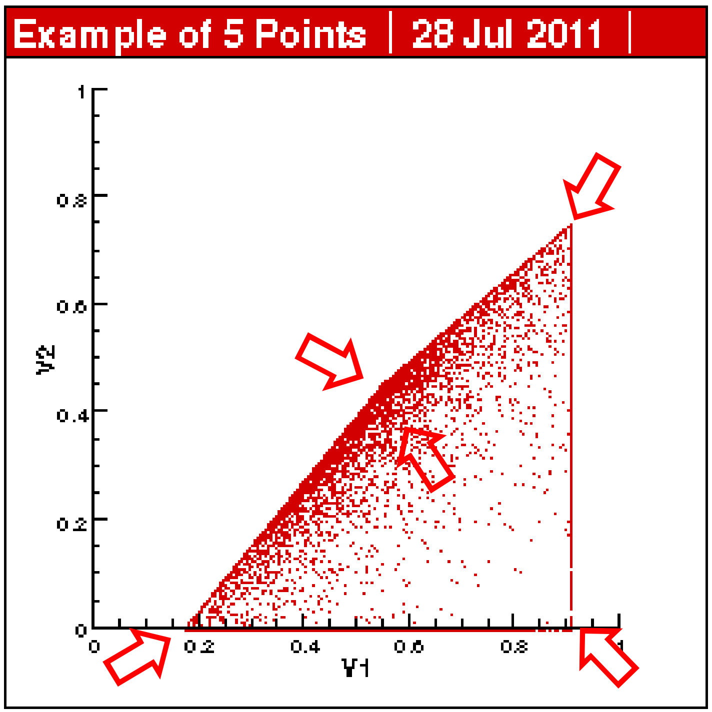
Results & Analysis – Boundary Points

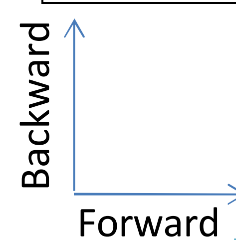
- What phenomenon caused these points?

- What can that tell us about the lines between them and where the points lie?



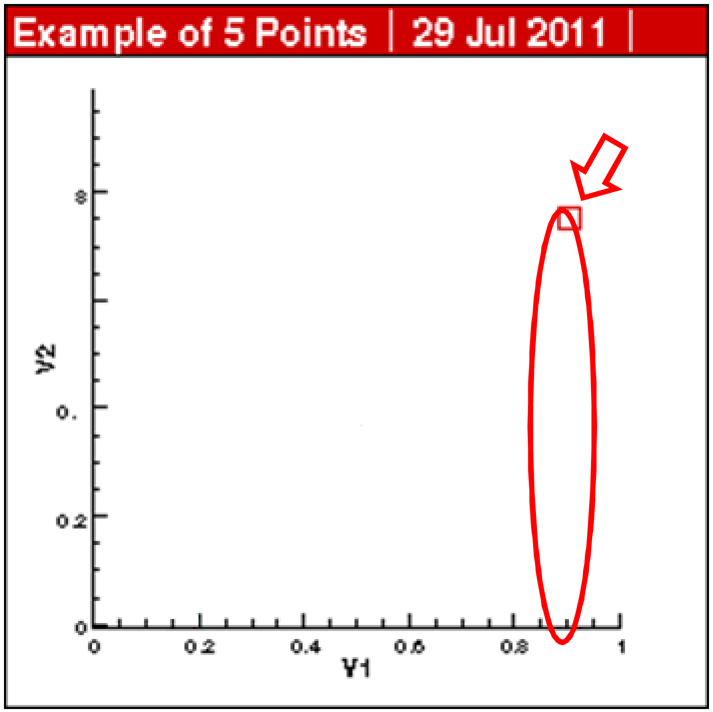
- Must examine extreme cases

Mesh Parameters	
$s=$	10
mat0	
$\lambda_0=$	101/20
$\sigma_0=$	2/101
$c_0=$	0 (abs)
mat1	
$\lambda_1=$	101/20
$\sigma_1=$	200/101
$c_1=$	1 (scat)



Results & Analysis – Boundary Points Identified

- **In this mesh:**
  - Scattering blocks more than absorbing

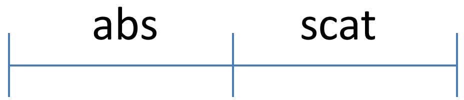


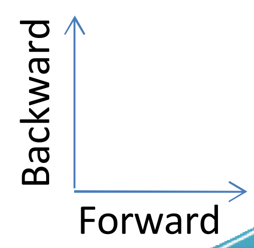
•Absorption lets the most through

- Highest Forward Flux

•Scattering after reflects the most back

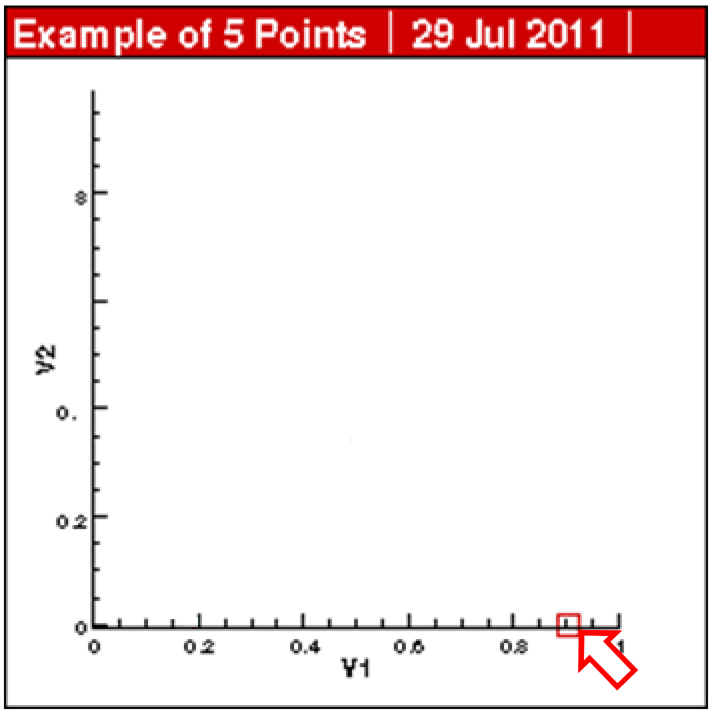
- Highest Backward Flux





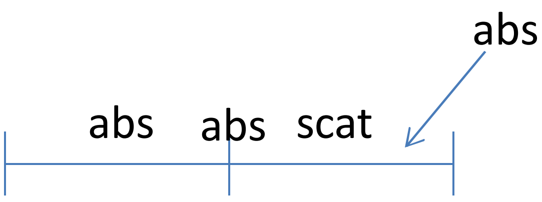
Results & Analysis – Boundary Points Identified

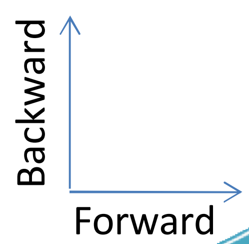
- **In this mesh:**
  - **Scattering blocks more than absorbing**



•If you add absorption to the scattering side…

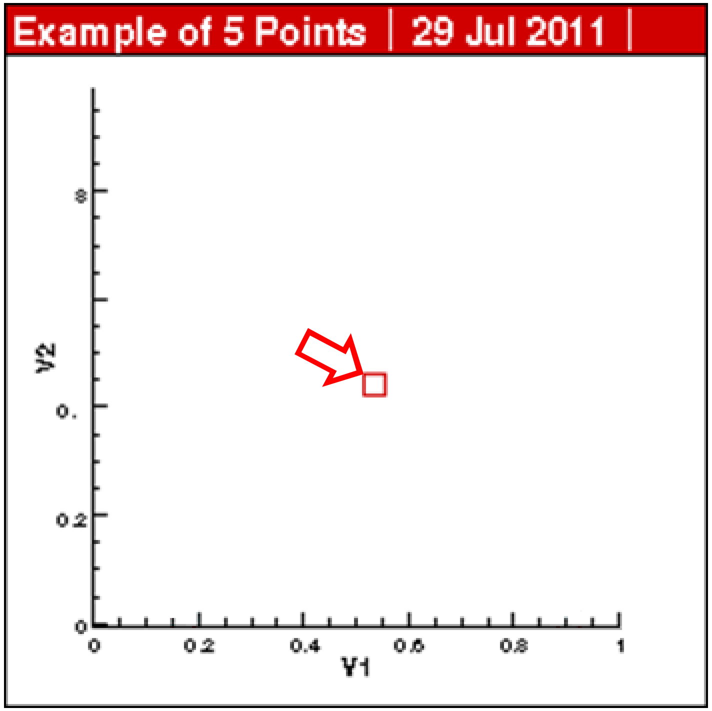
•Forward Flux will stay the same, Backward flux will go to zero





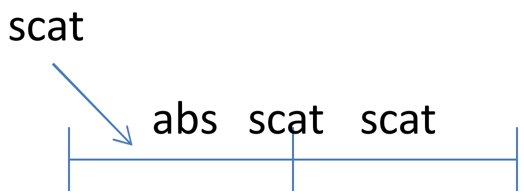
Results & Analysis – Boundary Points Identified

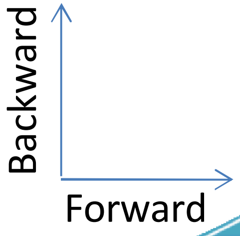
- **In this mesh:**
  - Scattering blocks more than absorbing



•Going back to the first extreme condition, if you add scattering to the absorption side…

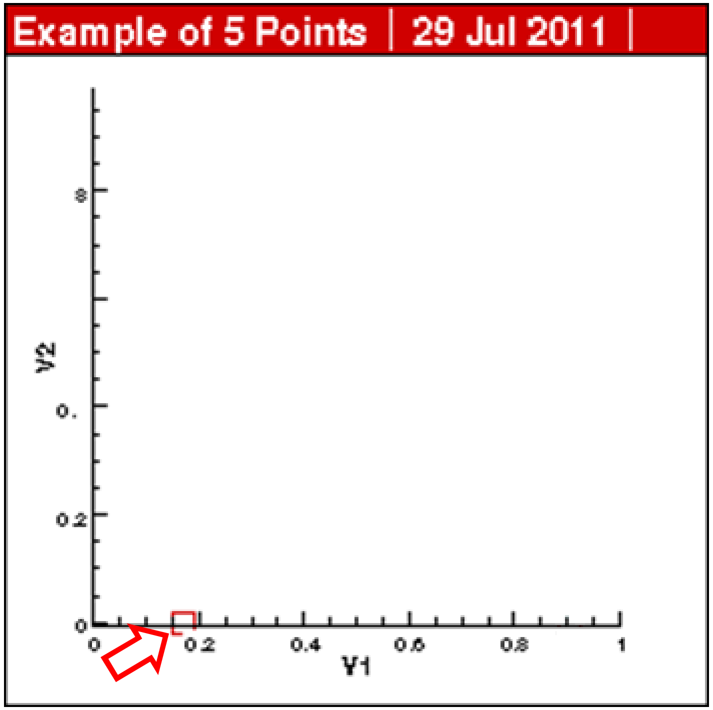
•Forward Flux will decrease some, Backward flux will as a result decrease some





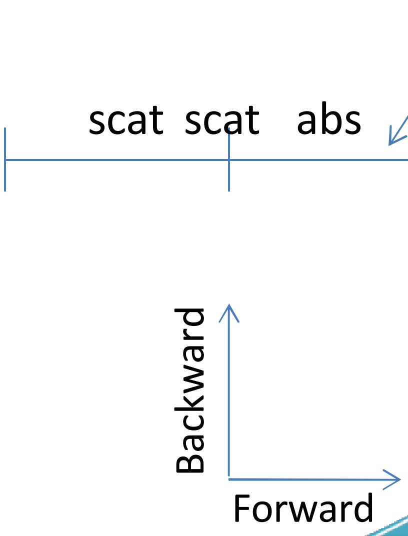
Results & Analysis – Boundary Points Identified

- **In this mesh:**
  - Scattering blocks more than absorbing

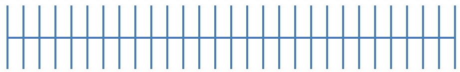


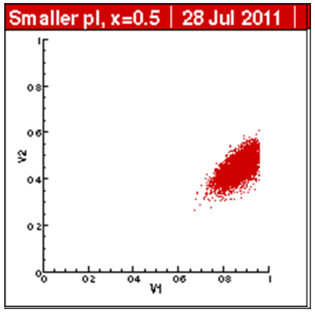
•Continuing from the previous, if we add absorption after the mining point…

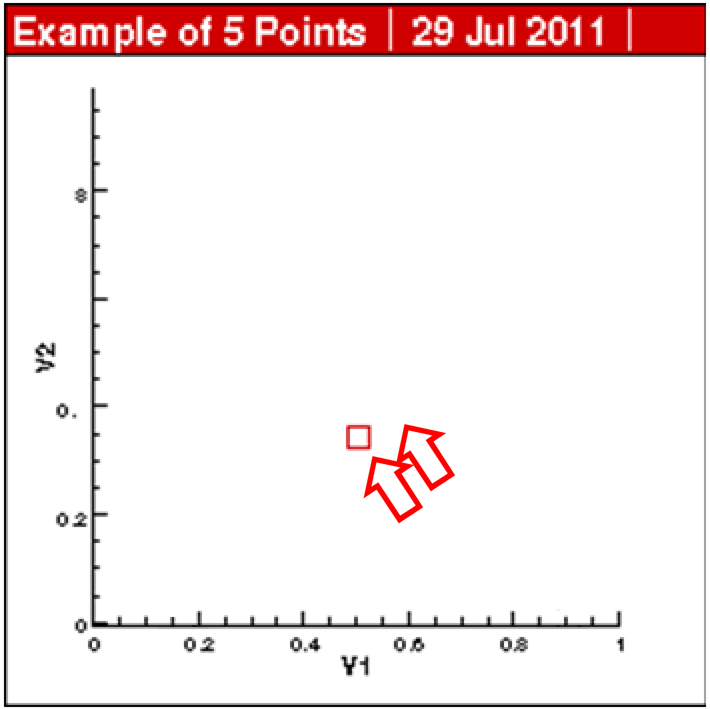
•Forward Flux will decrease some, Backward flux will go to zero



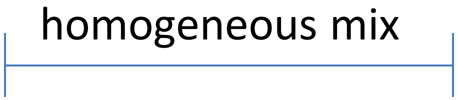
Results & Analysis – Boundary Points Identified

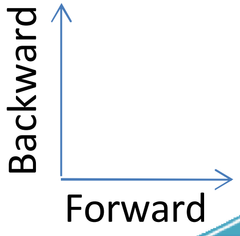






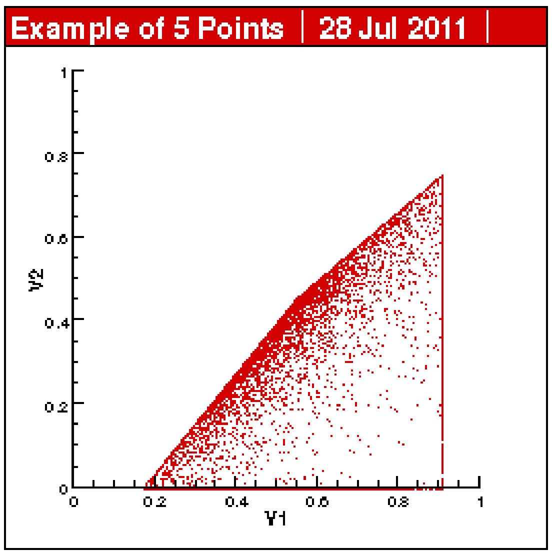
- The fifth Point of Interest is generated a little differently
- As the average path length (λ) decreases, the mesh approaches homogeneity
- So the last point of interest is defined by a homogeneous mix

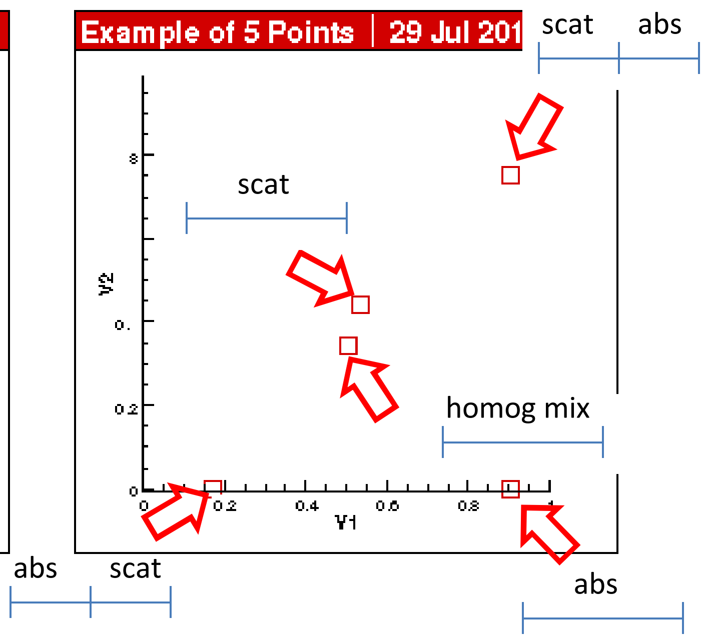




Results & Analysis – Boundary Points Summarized

In summary of these five points of interest:





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σ_0=	2/101
c_0=	0 (abs)
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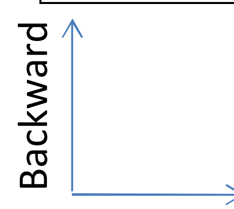
λ_1=	101/20
σ_1=	200/101
c_1=	1 (scat)



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Conclusions

- **With distance from the source flux decreases**
- **As path length decreases correlations approach homogeneity**

- **With large path lengths**
  - Four boundary points define the outer boundaries of flux relationships
  - Tend to cluster around the borders of the quadrilateral

- **With smaller path lengths**
  - One boundary point defines homogeneous mixture
  - Tend to cluster inside quadrilateral and around convergence point.

Acknowledgments/References

A Thanks to:

Mentor – Shawn Pautz

Strong collaborator – Brian Franke

Technical/Coding Help – Clif Drumm, Mike Rigley, and Peter Sabaiya

Everything and anything else, our own wonderful – Trish St. John

Papers referenced:

- **M. L. Adams, E. W. Larsen, G. C. Pomraning, "Benchmark Results for Particle Transport in a Binary Markov Statistical Medium,"** ***J. Quant. Spectosc. Radiat. Transfer*****, 42, pp. 253-266 (1989).**
- **S. D. Pautz, B. C. Franke, "Generation of Accurate Benchmarks for Transport in Stochastic Media by Means of Dynamic Error Control,"** ***Proc. Int. Conf. on Mathematics and computational Methods Applied to Nuclear Science and Engineering*****, Rio de Janeiro, Brazil (2011).**
- **B. C. Franke, A, K. Prinja, "Flux-Probability Distributions From the Master Equation for Radiation Transport in Stochastic Media,"** ***Proc. Int. Conf. on Mathematics and computational Methods Applied to Nuclear Science and Engineering*****, Rio de Janeiro, Brazil (2011).**

Questions

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