Manufacturing of Large and Highly Transparent Aerogel Tiles with Refraction Indices up to 1.1 for Cherenkov Detectors

DOE SBIR Phase II Program
Grant No. DE-SC0004290

Start Date – 06/19/10
End Date – 08/14/13

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Agenda

- Introduction to Aspen Aerogels, Inc.
- Phase II Program Overview
- Phase II Progress
  - Aerogel Optical Property Optimization
  - Aerogel Performance
  - Aerogel Production Capabilities
- Future work

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Aspen Aerogels, Inc.

- Founded in 2001
- Privately owned
- 160 Employees
- Locations
  - Northborough, MA
    - *(headquarters, R&D laboratories)*
  - East Providence, RI
    - *(manufacturing facility)*
- Current Capacity > 50 million sq.ft./yr.
- World's leading manufacturer of flexible aerogel blankets
- ISO 9001-2000 (BVQi certified)

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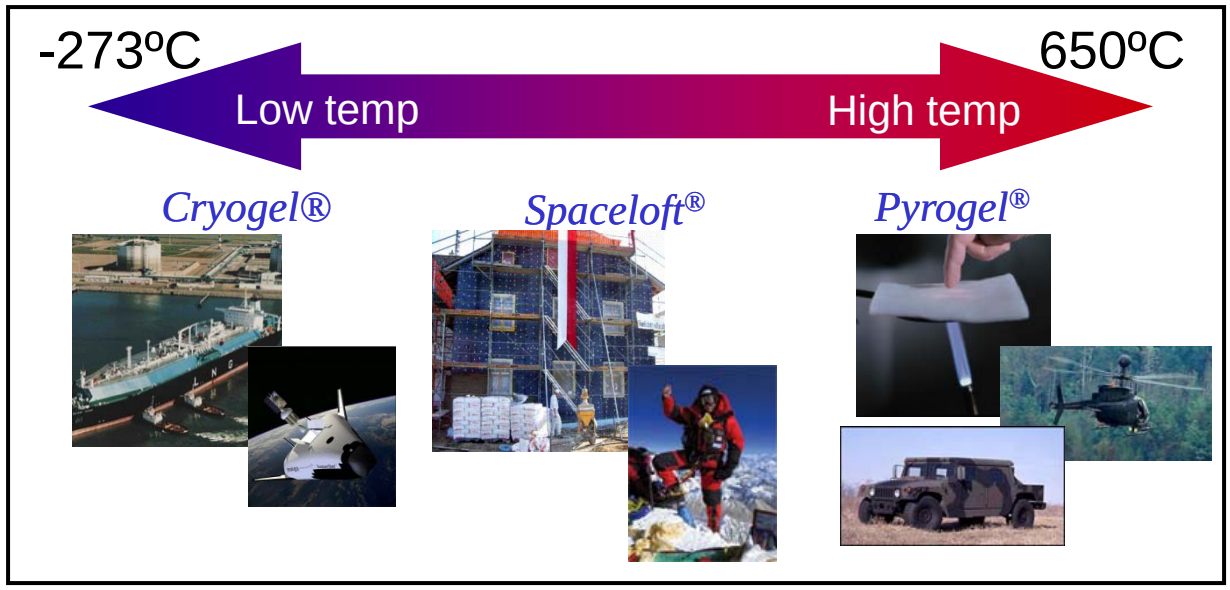
Aerogels in the Mainstream

Two Aspen innovations moved aerogels from lab curiosity to high-volume industrial product:

1. Aspen's supercritical CO_2 extraction process reduces cycle time from days to hours
2. Casting the wet gel into a fibrous batting provides mechanical integrity

Aerogel Monolith

Aerogel Blankets



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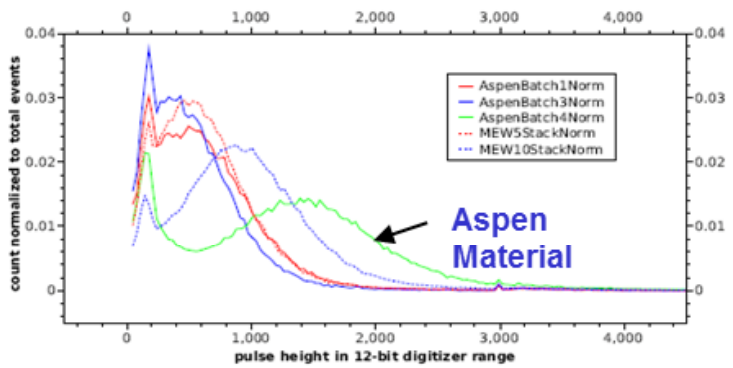
Phase II Program Overview

Description and Objectives

- Domestically produce an array of low cost, high quality Cherenkov detectors with wide availability of index of refractions ranging from 1.010 to 1.1, and high optical transmittance.
- Scale up the size of the tiles to 12” x 12” (4/5” thick).



•Transmittance 83% @ 400 nm
• Refractive Index ~ 1.010 – 1.1

Approach

- Optimization of transparency and refractive index
- Evaluate performance of large aerogel tiles (ASU)
- Process design and verification to scale up transparent aerogel production

Subcontractors/Partners

Arizona State University (ASU)

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Schedule and Deliverables

➢ Annual Report and Final Report

➢ Twenty-four (24) Month Schedule

Potential DOE Applications

Upgrade of Hall C&D, Jefferson Lab.

Upgrade CEBAF

Upgrade RICH 2

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Background and Problem Statement

- **Since the early 1980's, silica aerogels have been widely used as a radiator for Cherenkov Detectors**

- **Aerogels for Cherenkov radiators have several drawbacks, such as:**
  - **medium to low light transmission in the UV-visible wavelength region**
  - **difficult to fabricate in large panels**
  - **not always hydrophobic**
  - **extremely fragile**

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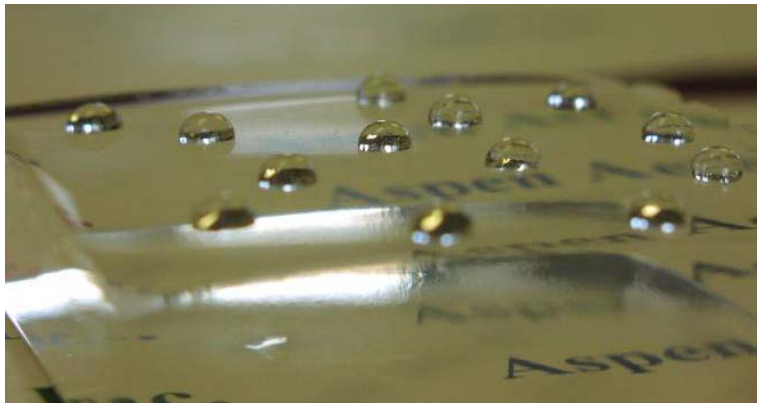
Phase II Progress

Optimization of transparency & refractive index

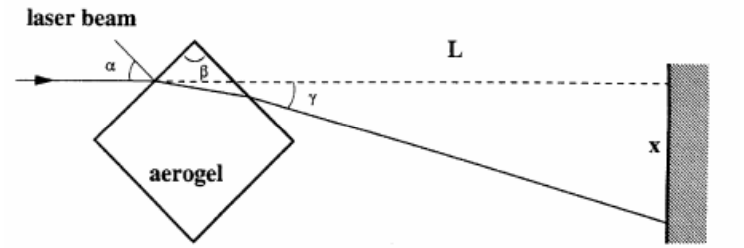
- Sol Gel optimization using Design Of Experiment method
- Transmittance: (Hunt Equation)

$$T = \frac{I}{I_o} = Ae^{\left(-d/L_{SC}(\lambda=400)^4\right)} = Ae^{-Cd/\lambda^4}$$



- Refractive Index [1]:

$$\gamma = \alpha - \beta + \arcsin\left(n \cdot \sin\left(\beta - \arcsin\left(\frac{\sin\alpha}{n}\right)\right)\right)$$



1. *A.R. Buzykaev, A.F. Danilyuk, S.F. Ganzhur, E.A. Kravchenko, A.P. Onuchin, Nucl. Instr. Methods in Physics Research* ***A 433*** *(1999) 396) 400*

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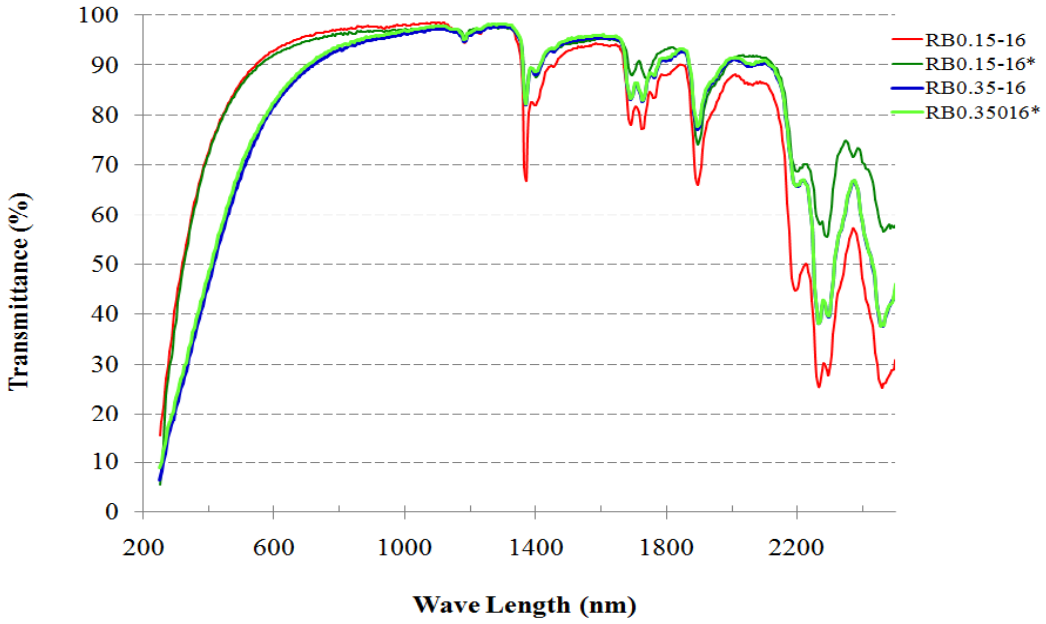
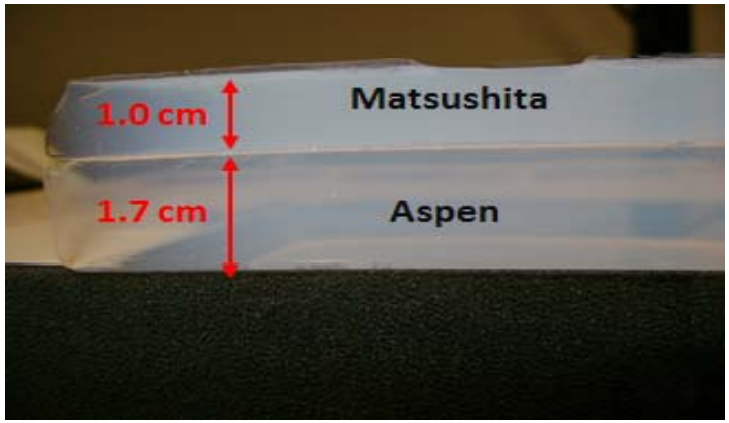
Phase II Progress

Optimization of transparency & refractive index

Sample # ID	Thick. (cm)	C(μm^4/cm)	A	Lsc (cm)	n	% T (@ 400 nm)
RB0.05-17	1.7	0.00484	1.00	5.3	1.013	83.1
Matsushita(SP-20)	1.0	0.00627	0.94	4.1	1.026	78.7





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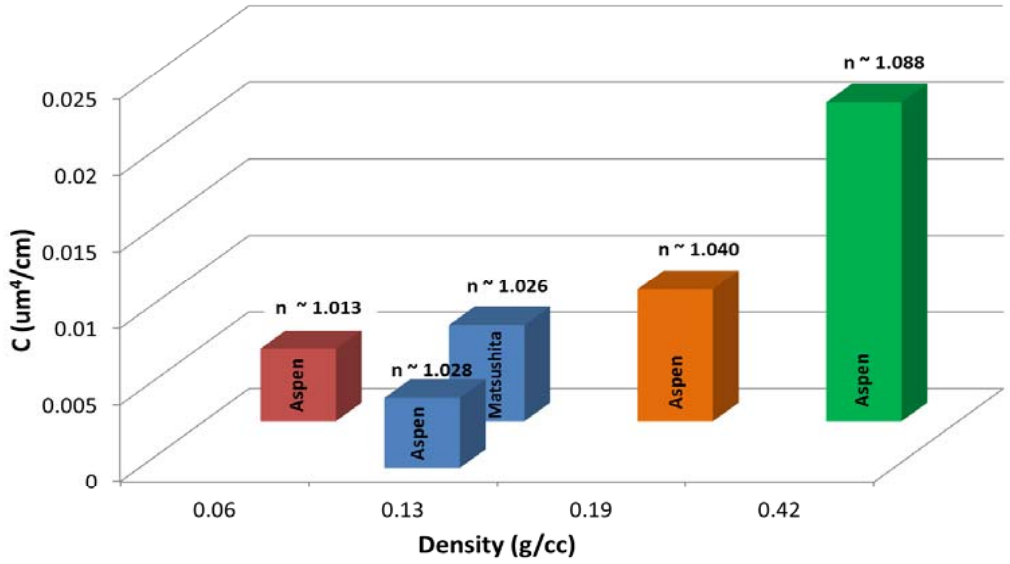
Phase II Progress

Optimization of transparency & refractive index



- High refractive index (1.088) samples show relatively low transmittance at 400 nm.
- the clarity coefficient (*C*) increases (thus, low transmittance) as the refractive index increases, too.

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Phase II Progress

Aspen Aerogels Performance

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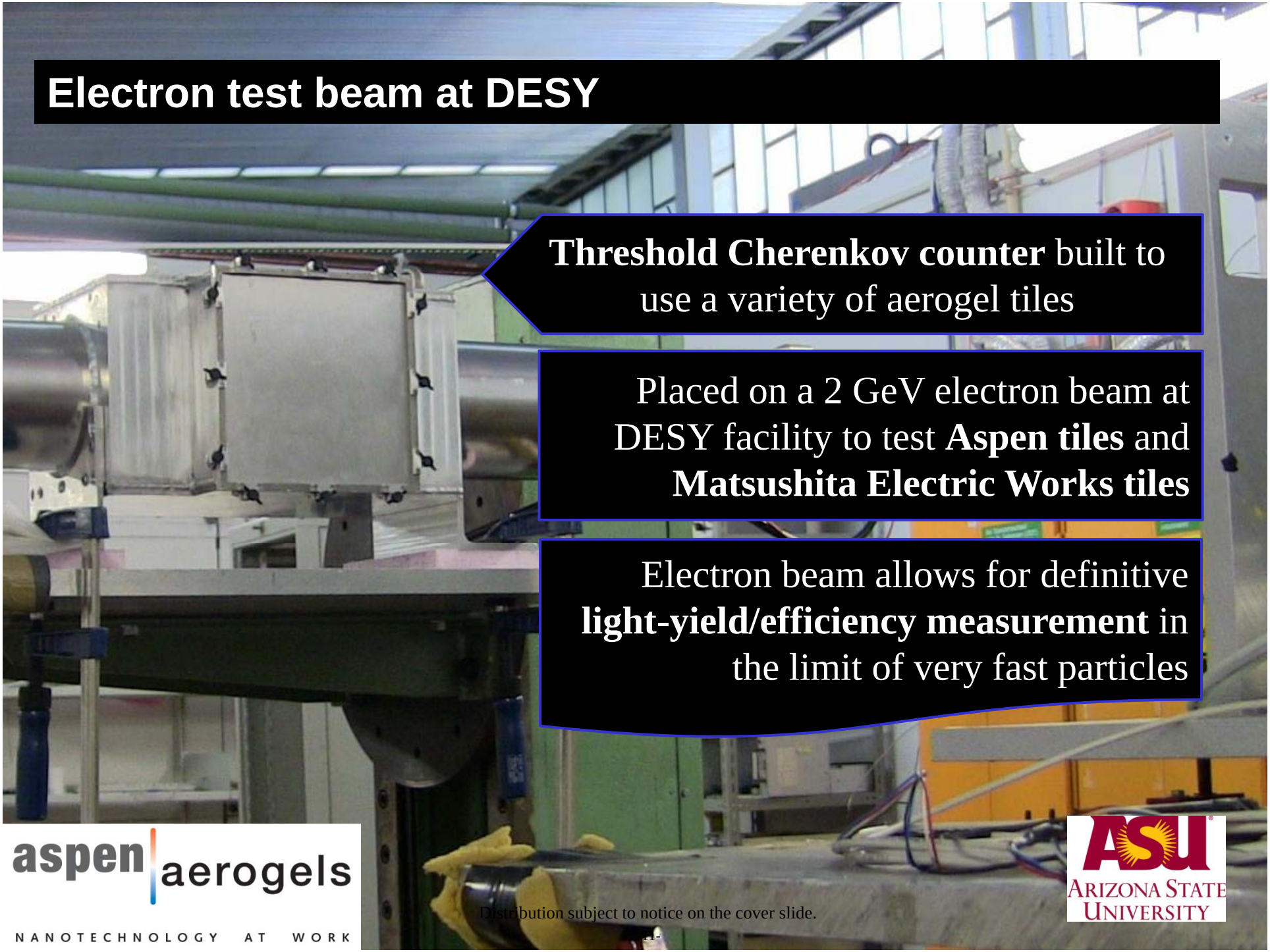
Electron test beam at DESY



Threshold Cherenkov counter built to use a variety of aerogel tiles

Placed on a 2 GeV electron beam at DESY facility to test **Aspen tiles** and **Matsushita Electric Works tiles**

Electron beam allows for definitive **light-yield/efficiency measurement** in the limit of very fast particles

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Cherenkov test counter

Designed to be **highly uniform**, with **diffusely reflective** internal surfaces

Uniformity helps to allow for **comparable results** between batches of aerogel

Two large (5") photomultiplier tubes used to produce a signal proportional to amount of Cherenkov light

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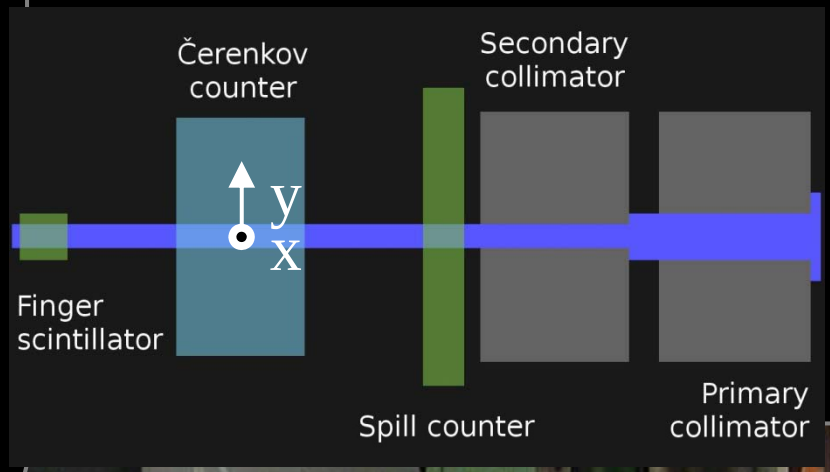
Experimental setup

Counter mounted to x-y table to precisely position beam through aerogel

Collimated beam (blue) ~1 cm wide

Two-scintillator trigger used (green), approx. 10 m apart, with counter in-between

Downstream scintillator is ~2 cm wide, eliminating divergent paths



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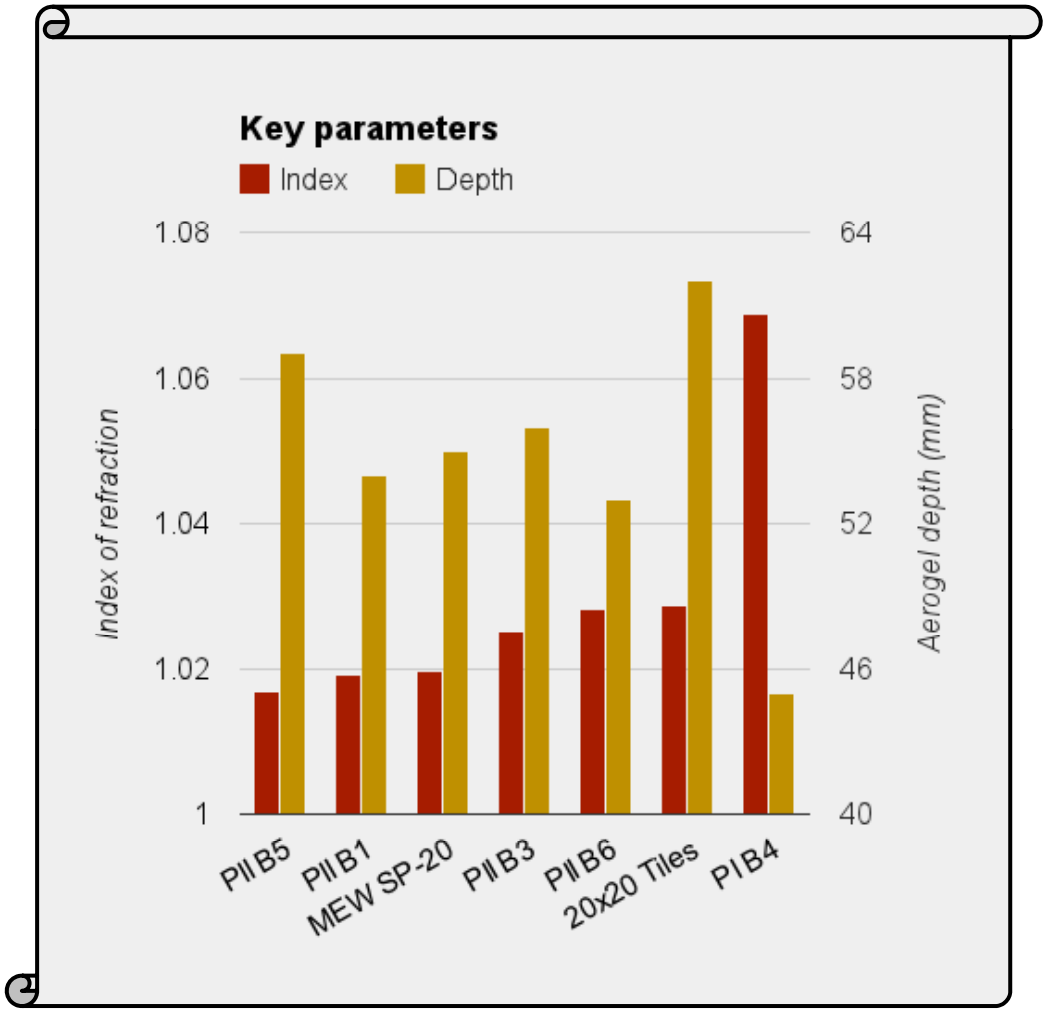
Aerogel Key Parameters

Batches ordered from lowest index of refraction to highest (1.017 - 1.069)

B1 and SP-20 are closely comparable with mean indices 1.019 (5) and 1.020 (6) respectively



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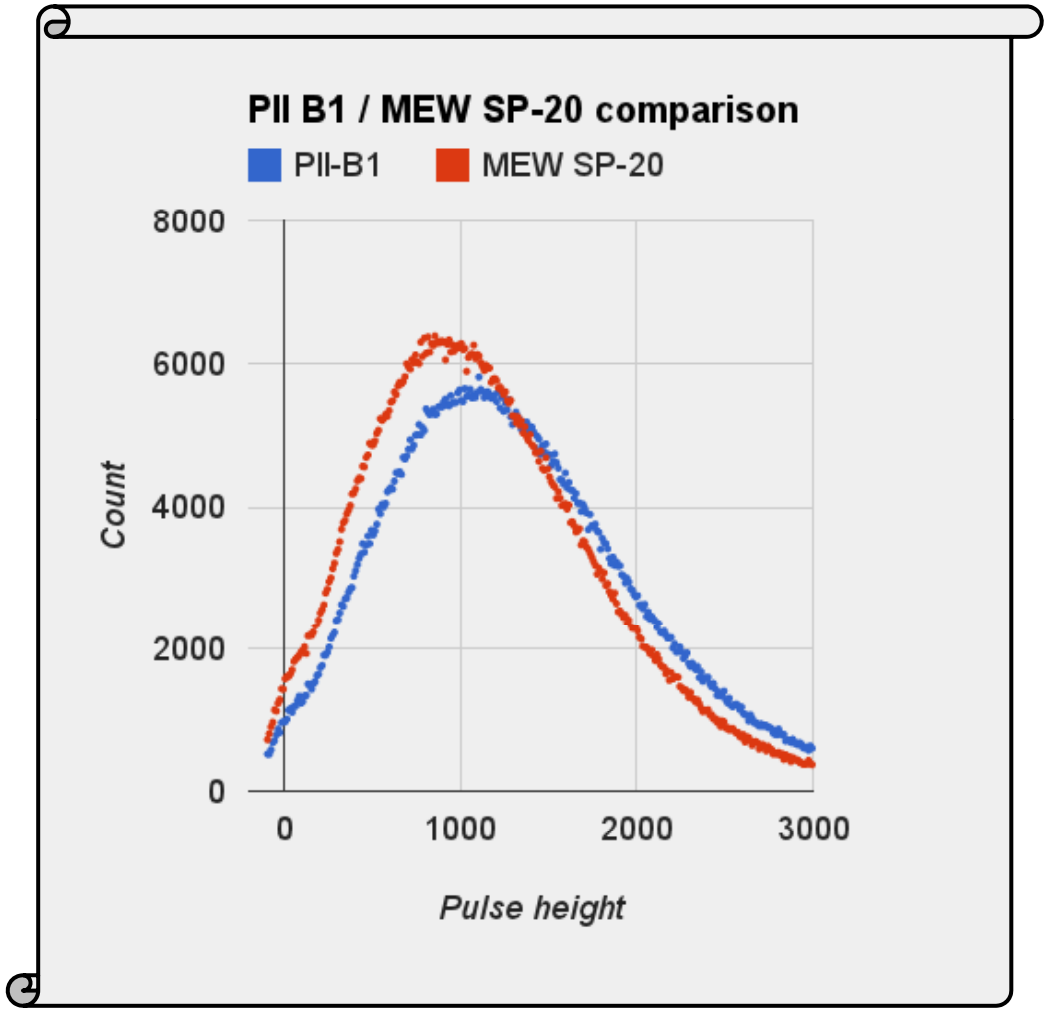
Direct Comparison

Pulse height spectrum shows distribution of pulses from PMTs

Phase II Batch 1 yields more measurable light than MEW SP-20.

With this comes greater efficiency in the same application



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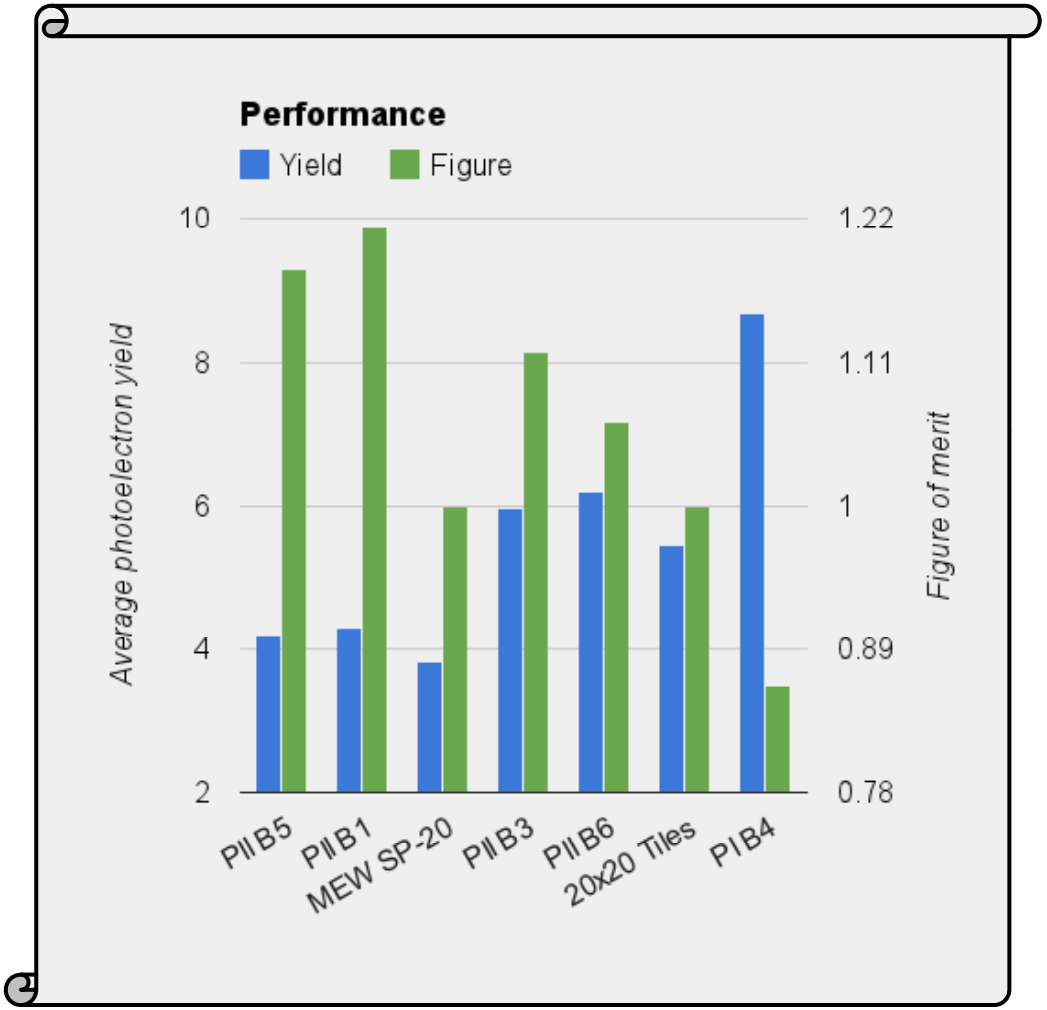
Test Beam Results

Raw photoelectron yields are somewhat comparable, but do not give a concrete comparison

Figure of merit uses MC to remove non-goodness related factors (geometry and refractive index)

Higher figures of merit indicate more favorable optical properties of the aerogel



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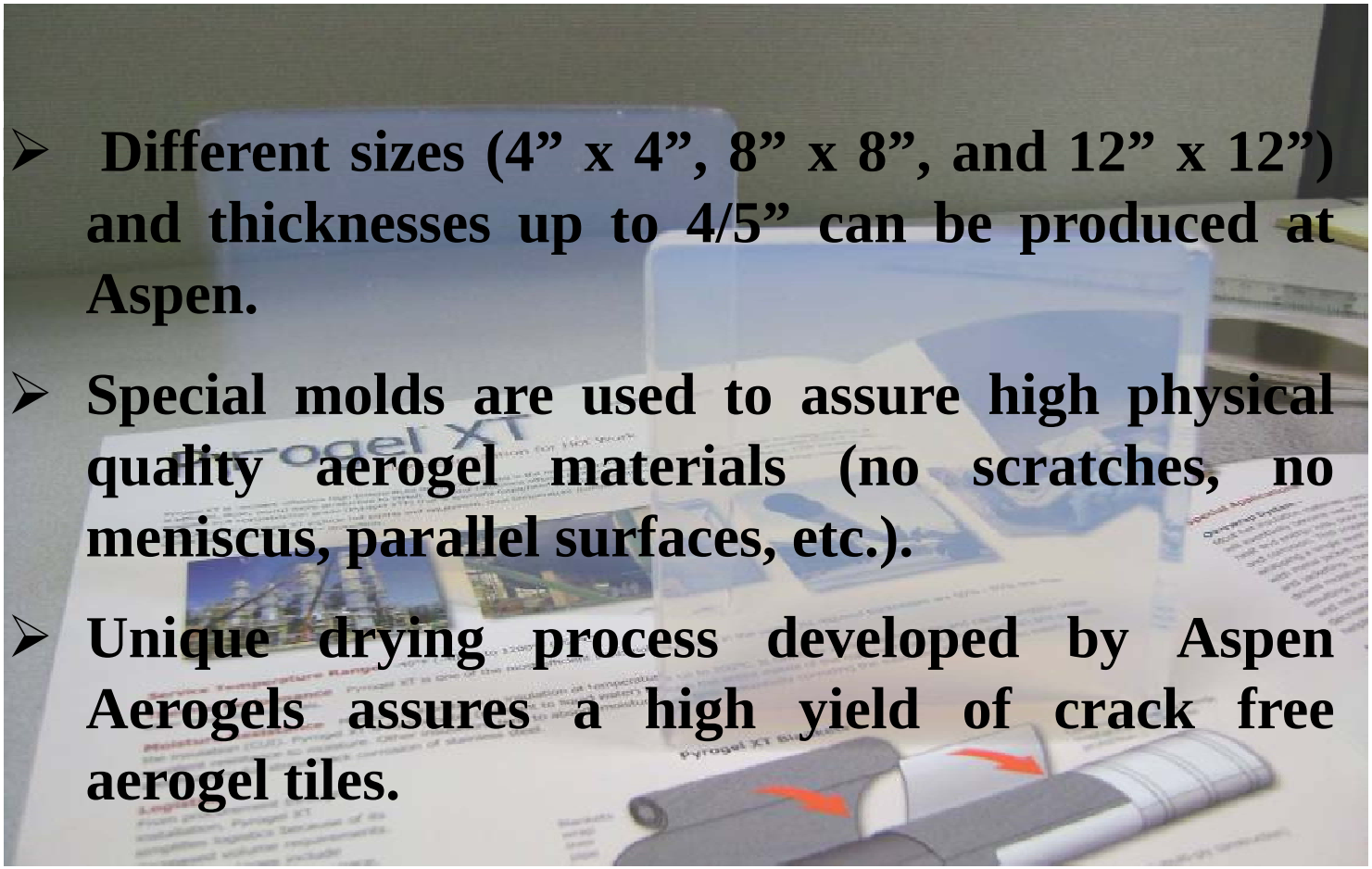
Phase II Progress

Aspen's Aerogel Production Capabilities



- Different sizes (4" x 4", 8" x 8", and 12" x 12") and thicknesses up to 4/5" can be produced at Aspen.
- Special molds are used to assure high physical quality aerogel materials (no scratches, no meniscus, parallel surfaces, etc.).
- Unique drying process developed by Aspen Aerogels assures a high yield of crack free aerogel tiles.

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Future Work

- Define the optimum sol-gel, and supercritical drying conditions to produce high quality and high yield crack-free aerogel tiles (> 8 x 8 inch^2)
- Define and demonstrate process of making 12 x 12 inch^2 tiles using large capacity vessel (120 liter system).
- Evaluate the refractive index and complete testing of new batches with cosmic rays at ASU
- Design and build a prototype detector capable of doing ring imaging with the best suitable Aspen aerogel tiles.

➢ Aspen is aiming to be the major transparent aerogel tile supplier for the high energy physics community.

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Thank You

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