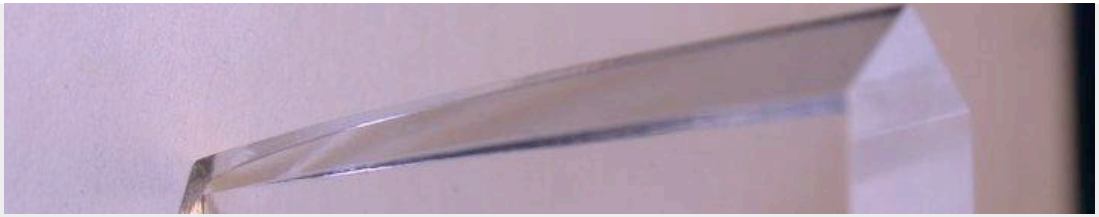
ETH Institute for
Particle Physics



SST Winston Cones

07.09.2010

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ETH Zurich

Winston Cones

- ideal:
  - Light from mirror (Signal) $\theta <= \theta_C$: completely collected
  - Light from larger angles (Background): rejected

f/D	θ_C
1.	30°
1.2	27°
1.4	21°
1.6	18°
1.8	16°
2.	14°

ideal

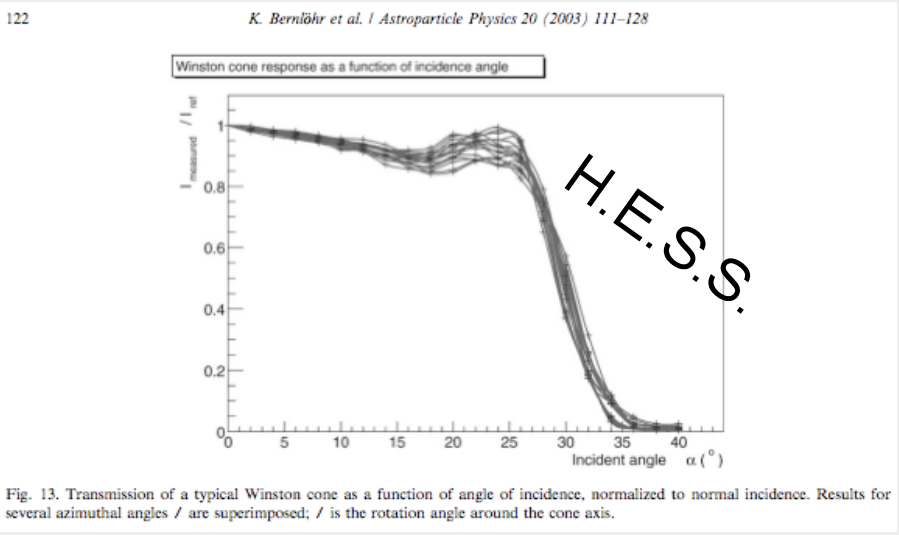
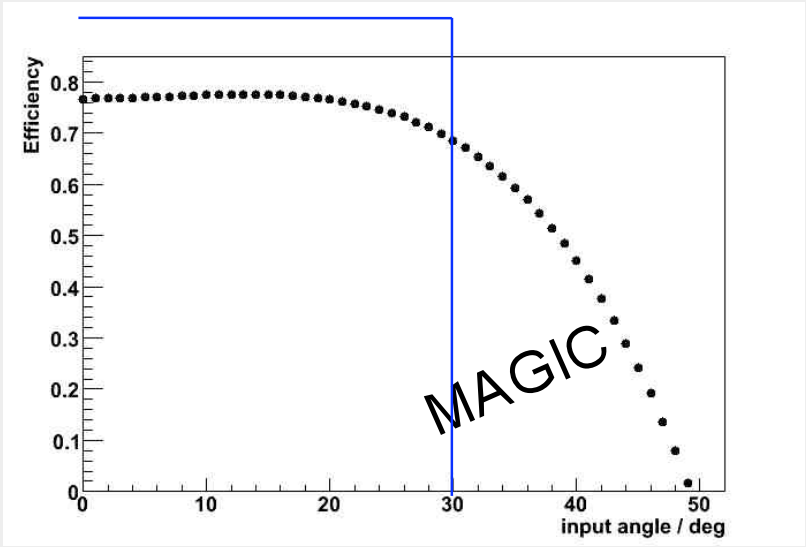
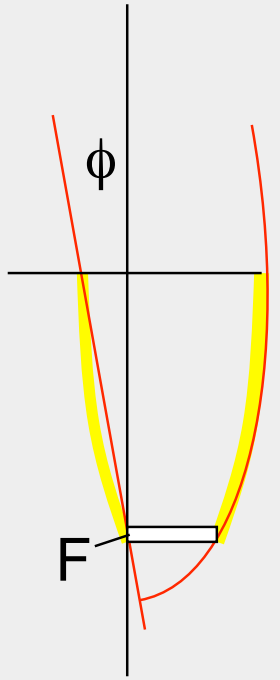


Fig. 13. Transmission of a typical Winston cone as a function of angle of incidence, normalized to normal incidence. Results for several azimuthal angles / are superimposed; / is the rotation angle around the cone axis.



Winston Cones

- Definition
  - Parabola
  - Tilted by desired Cutoff angle
  - Shifted



- Equation

$(r\cos\phi + z\sin\phi)^2 + 2ar(1+\sin\phi)^2 - 2az\cos\phi(2+\sin\phi) - a^2(1+\sin\phi)(3+\sin\phi) = 0$

not $(r\cos\phi + z\sin\phi)^2 + ar(1+\sin\phi)^2 - 2az\cos\phi(1+\sin\phi) - a^2(1+\sin\phi)(3+\sin\phi) = 0$

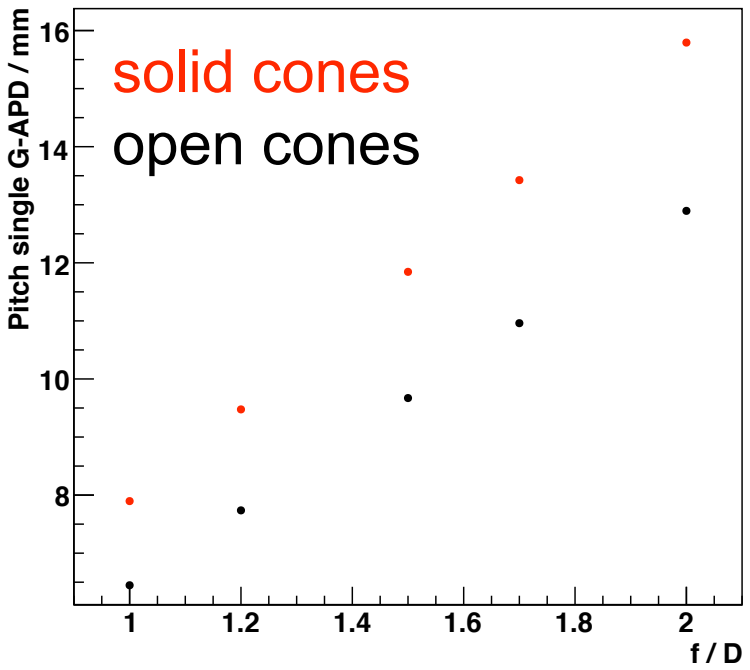
or $(r\cos\phi + z\sin\phi)^2 + 2ar(1+\sin\phi)^2 - 2az\cos\phi(2+\sin\phi)^2 - a^2(1+\sin\phi)(3+\sin\phi) = 0$

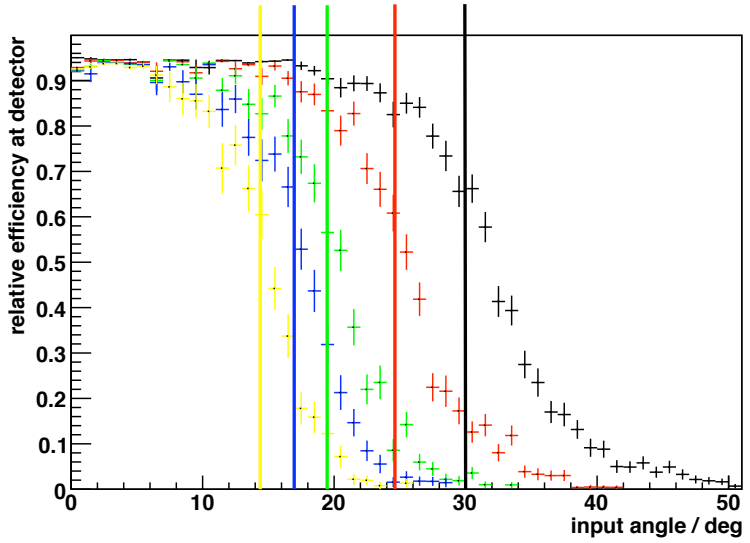
- Relations
  - Do/Di -> ϕ -> Height
    - ϕ = asin(Do/Di)
    - H = (Do+Di)/2./tan(ϕ)

f/D	C_{Area}
1.	4.0
1.2	5.8
1.4	7.8
1.6	10.2
1.8	13.0
2.	16.0

Winston Cones

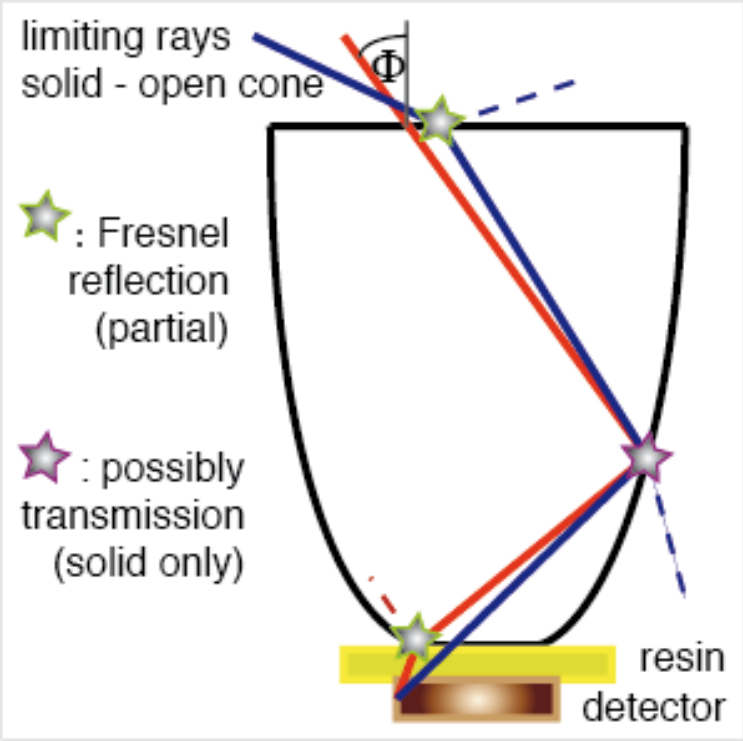
- Single mirror optics
- 3mm G-APD
- scales to 5 mm





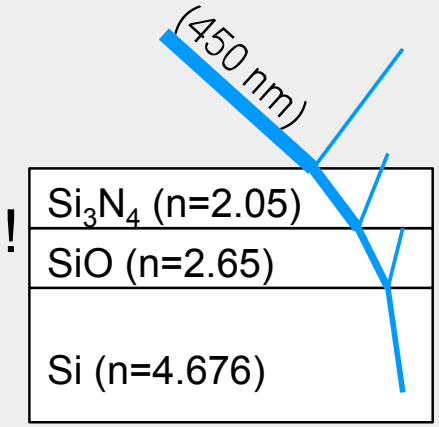
Simulation (3D)

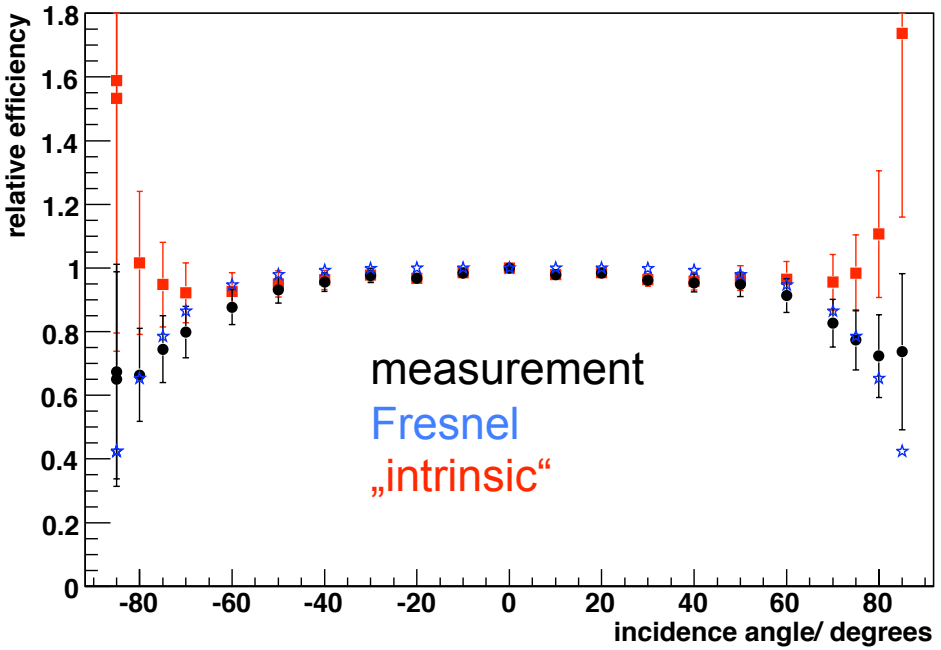
- Fresnel Reflection
- Refraction
- Transmission (Plexi 7N, input: Cherenkov spectrum at 2 km)
- surface roughness
- (optical cross-talk)
- G-APD (resin, angular & spectral acceptance)



G-APD angular acceptance

- Hamamatsu MPPC S10362-33-50C
- resin removed for the measurement
- normalized to 1 for vertical incidence





Vertical incidence

- Careful with tests –illumination for individual angles is not homogeneous!

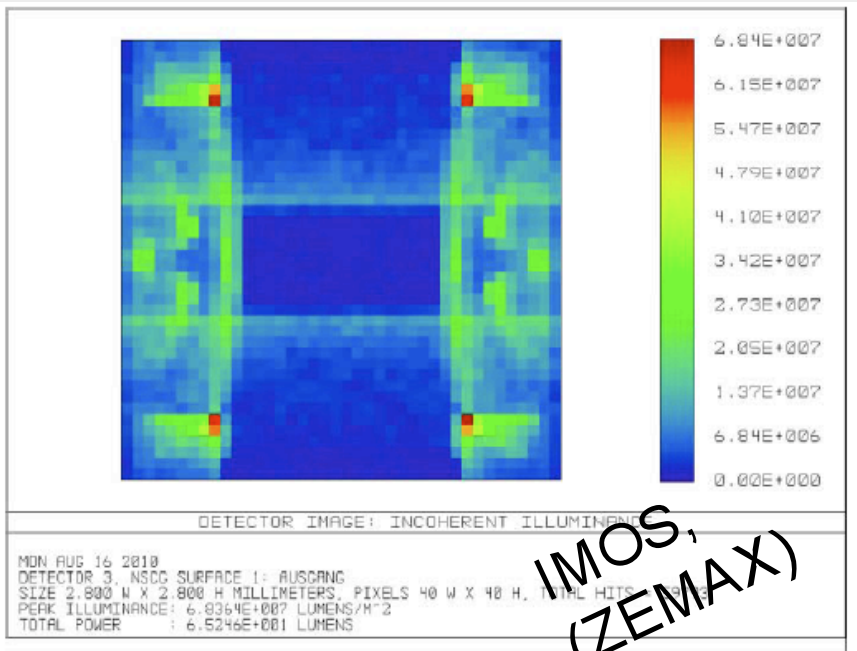
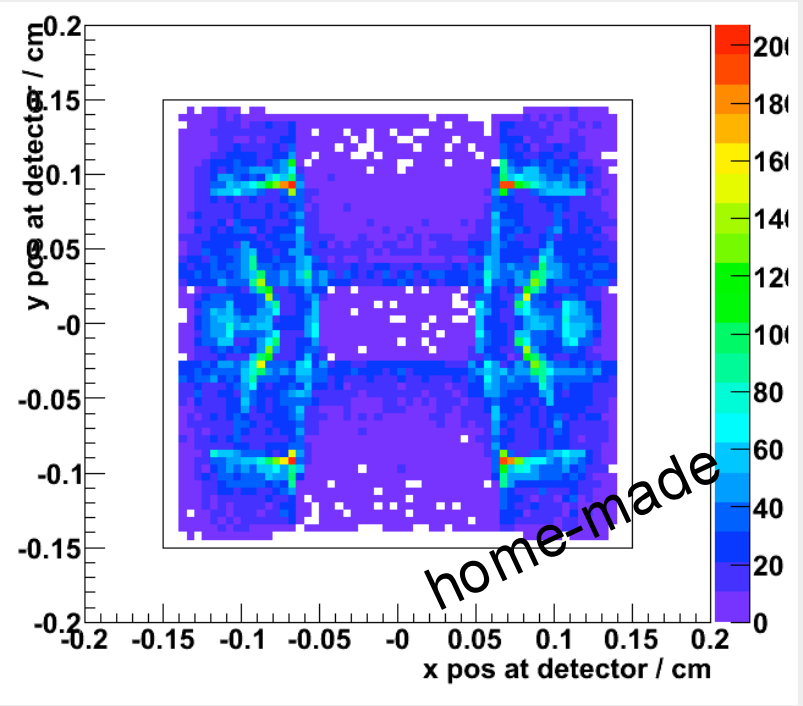


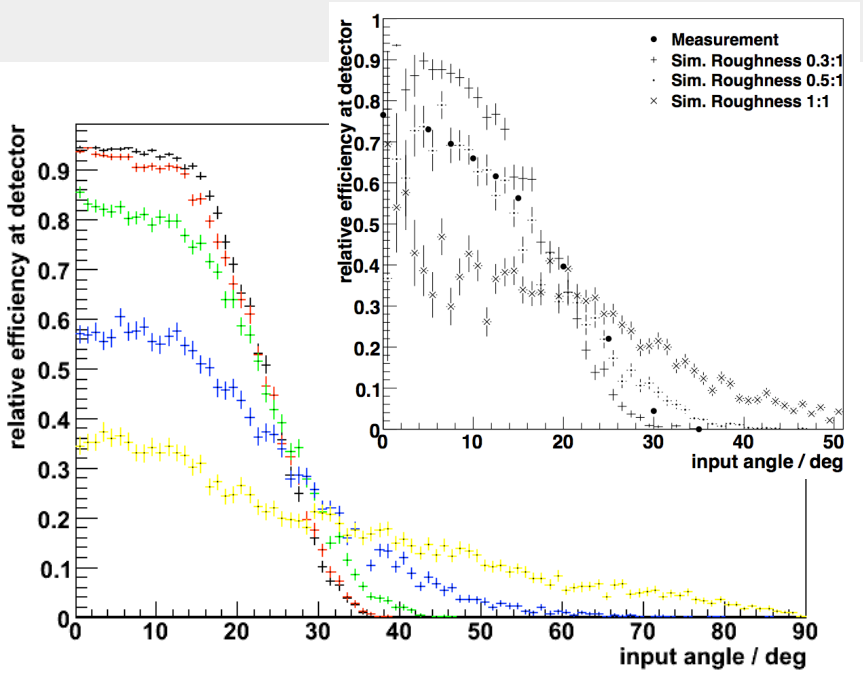
Bild 6: Simulationsergebnis für die Lichtverteilung

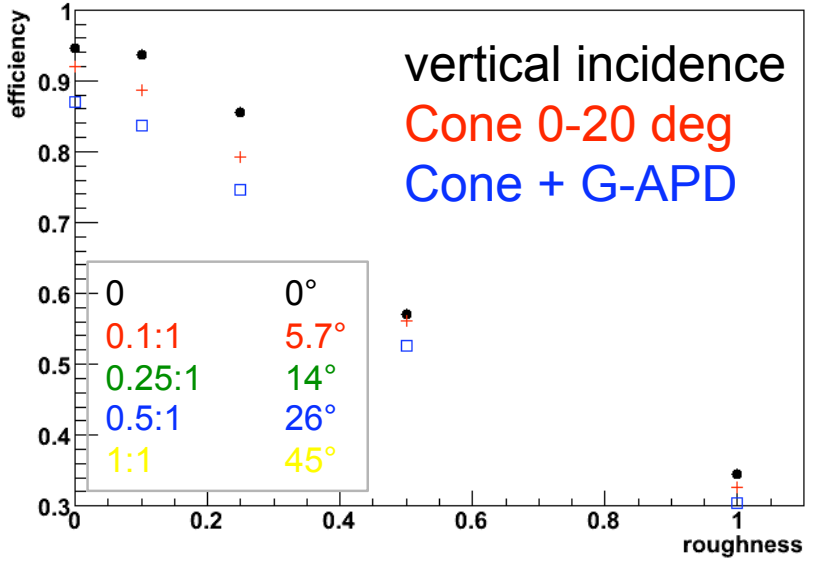


- hex – square, 9.5 – 2.8mm, parabolic

Simulation Roughness

- absolute changes not so problematic, but changes in slope





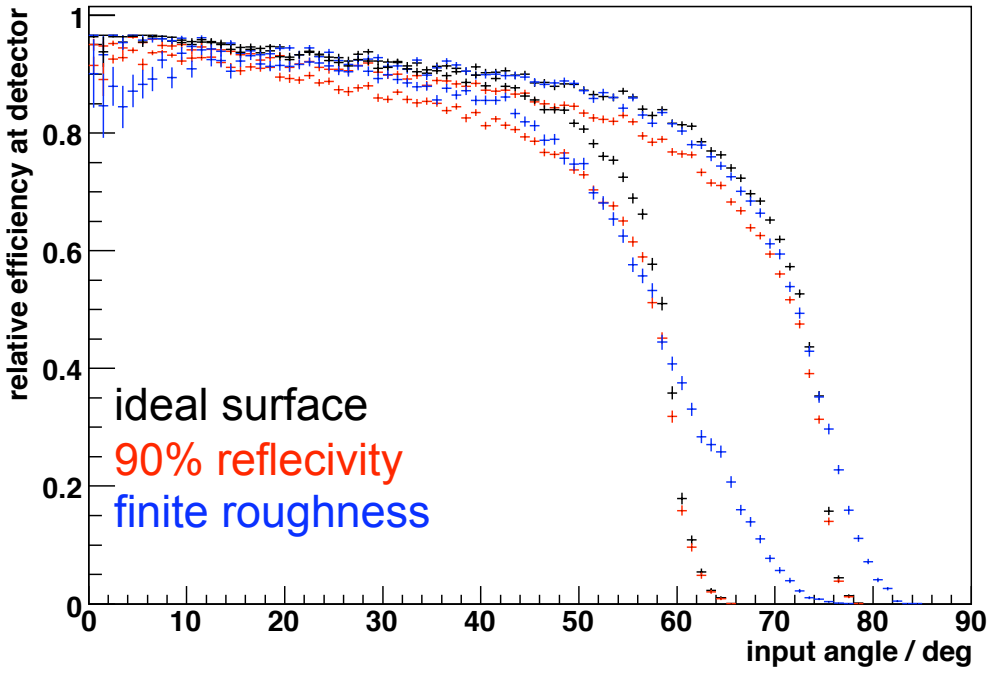
- => changes shape of angular acceptance curve

Secondary Optics (Open Cones)

- square-square Winston Cones
- incidence angles of 60° and 75°
- G-APD, 0.2 mm resin

- 60°:
  - 3.46 -> 3 mm
  - h = 1.9 mm

- 75°:
  - 3.1 -> 3 mm
  - h < 0.8 mm!



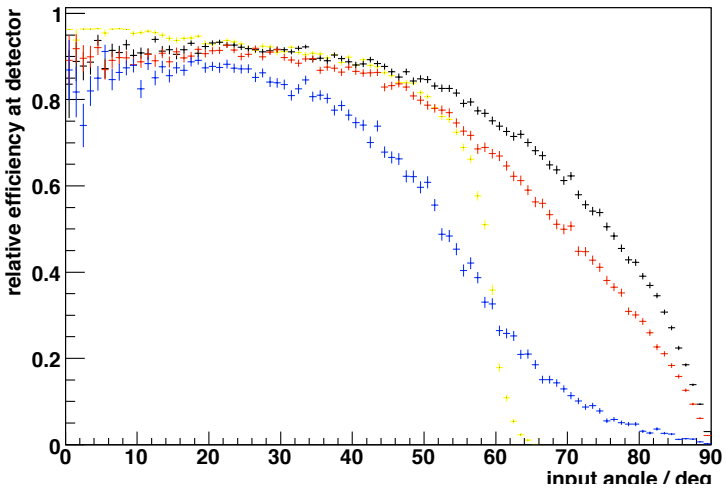
- => theoretically possible, but barely producable

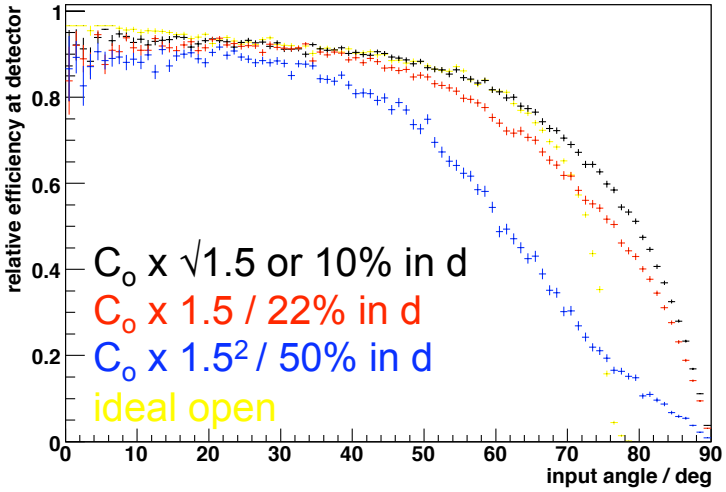
Secondary Optics (Solid Cones)

- assume medium with n = 1.5
- surface roughness (estimate)
- transmission of Plexiglas 7N
- increased area concentration
- prize: less background suppression

=> at least comparable signal, but more sensitive area

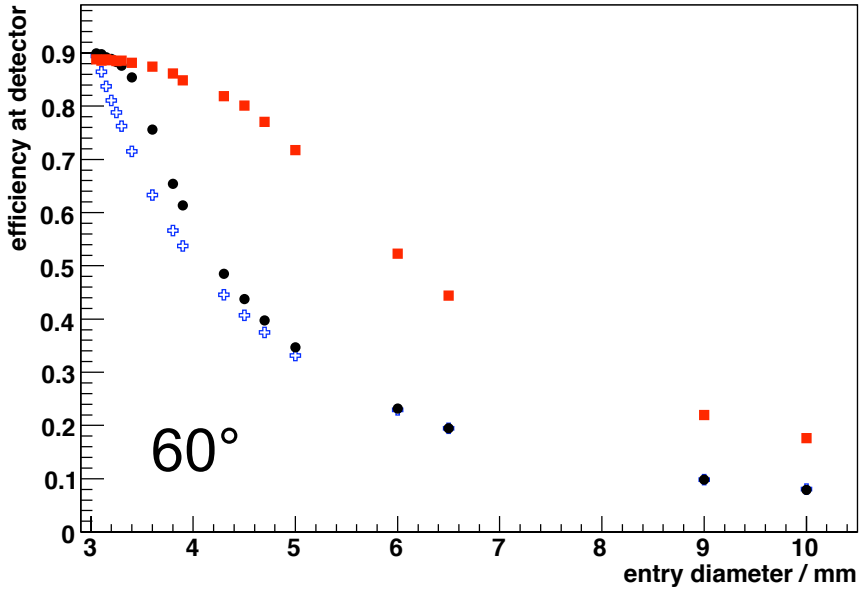
=> mouldable!

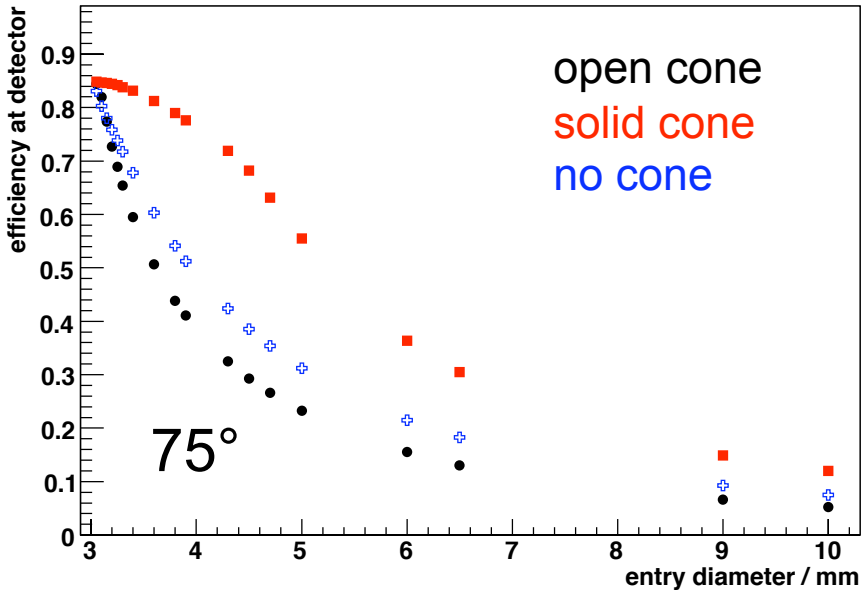




Secondary Optics (No Cones?)

- area fill factor, but also: sensor properties (resin + angular acceptance)





=> solid always better than no cone, open can be worse than none for 75°

=> solid better than open above 7% (2%) diameter gain for 60° (75°)

Secondary Optics (Summary)

		open			solid		
60°			surface			$C_{max}^{open}*$	
		ideal	90%	rough	$\sqrt{n}$	n	n^2
	C_A	1.33	1.33	1.33	1.63	2.0	3.0
	d/mm	3.5	3.5	3.5	3.5	4.2	5.2
	h/mm	1.9	1.9	1.9	2.7	3.6	5.8
	ϵ/%	82	76	78	86	82	67
	fill factor	75	75	75	61	50	33
	$\epsilon_{(\mathrm{No\,Cone})}$/%	68	68	68	55	45	30
75°		ideal	90%	rough	$\sqrt{n}$	n	n^2
	C_A	1.07	1.07	1.07	1.3	1.6	2.4
	d/mm	3.1	3.1	3.1	3.4	3.8	4.7
	h/mm	0.8	0.8	0.8	1.8	2.7	4.6
	ϵ/%	81	77	80	83	79	63
	fill factor	94	94	94	76	62	41
	$\epsilon_{(\mathrm{No\,Cone})}$/%	79	79	79	65	53	35

theoretical gain, but ε too low

mechanics difficult

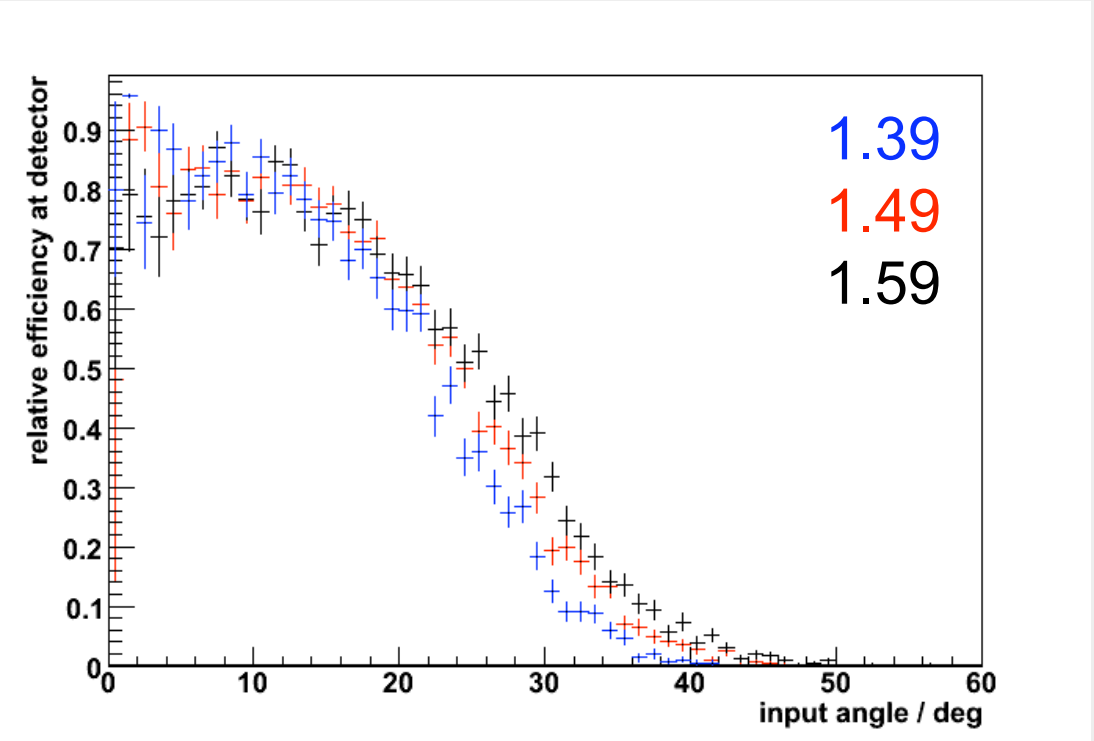
⇒ there are realistic solutions for solid cones in a secondary optics telescope

⇒ gain in area concentration reduces the effective camera cost

Backup

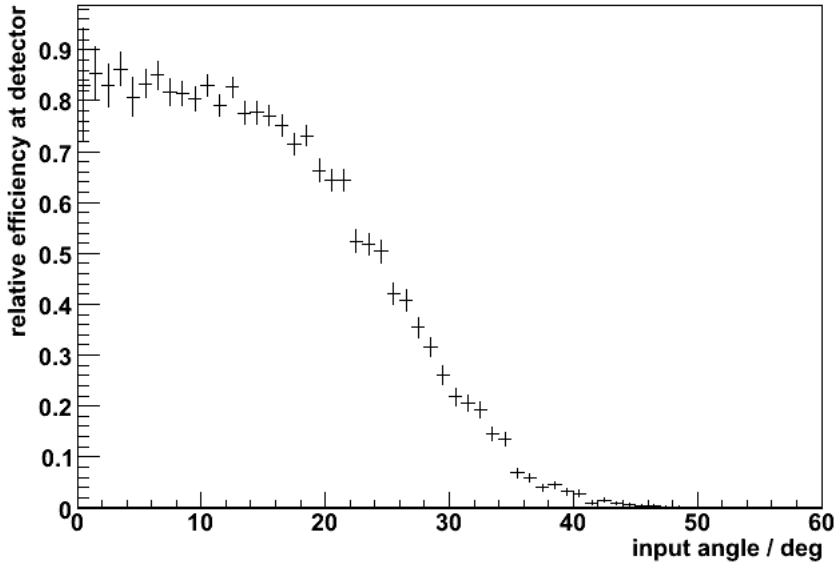
Influence Refractive index

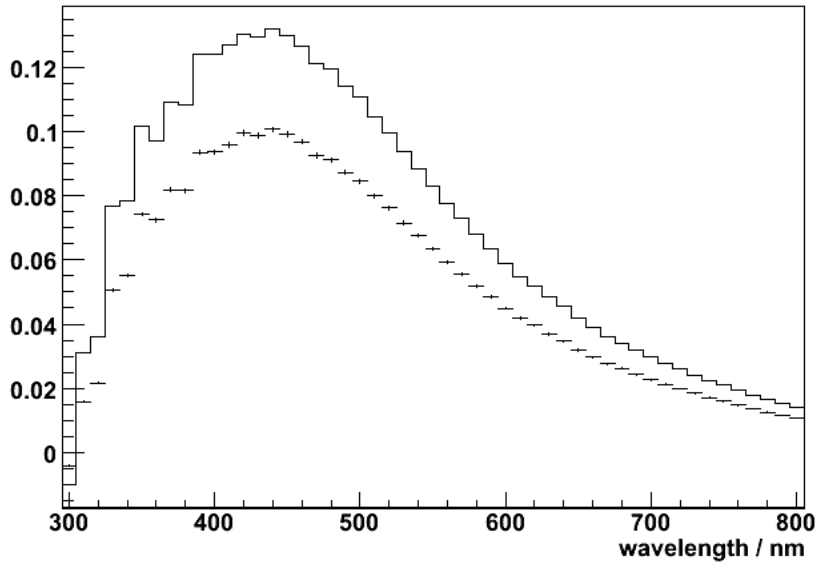
- vary Index for whole Cone by +/- 0.1
- all directions



Simulation results

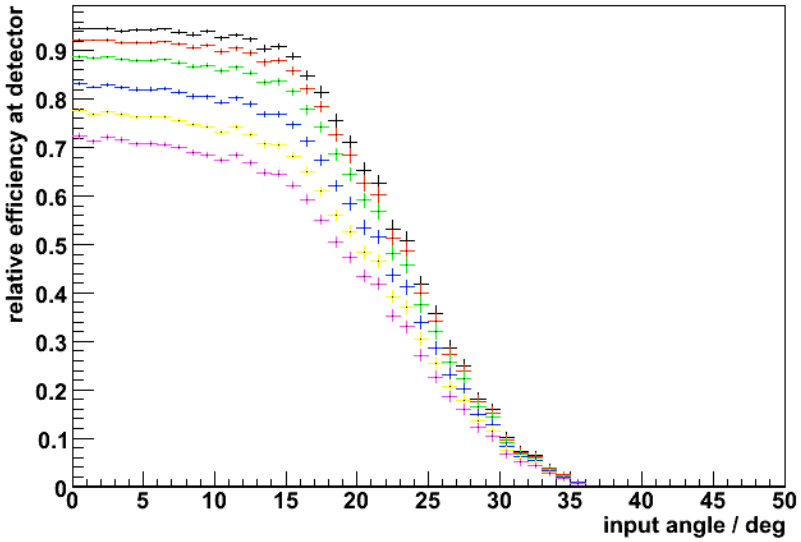
- Assumptions:
  - Total reflection
  - assumed surface roughness
  - G-APD angular acceptance
  - G-APD resin (thickness & index)
  - Fresnel

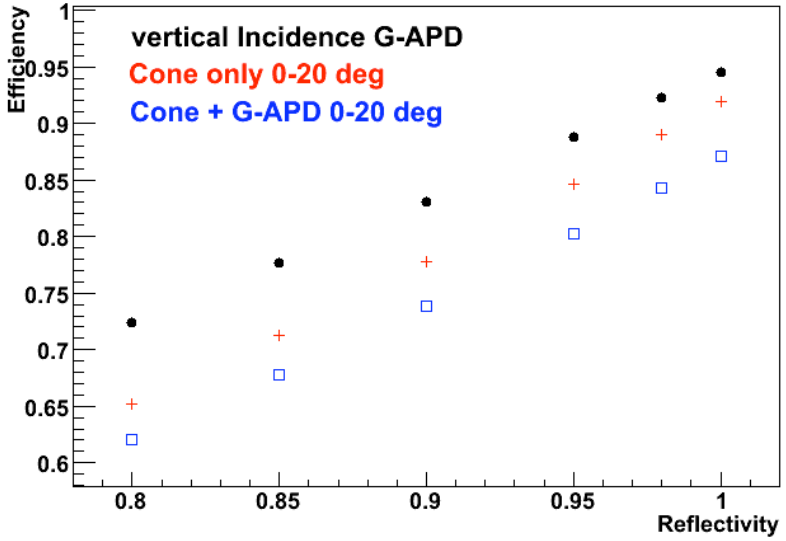




Simulation Reflektivity

- analogue to reflective surfaces





Simulation Transmission

- scale complete transmission curve