A Ground-based 21cm BAO survey

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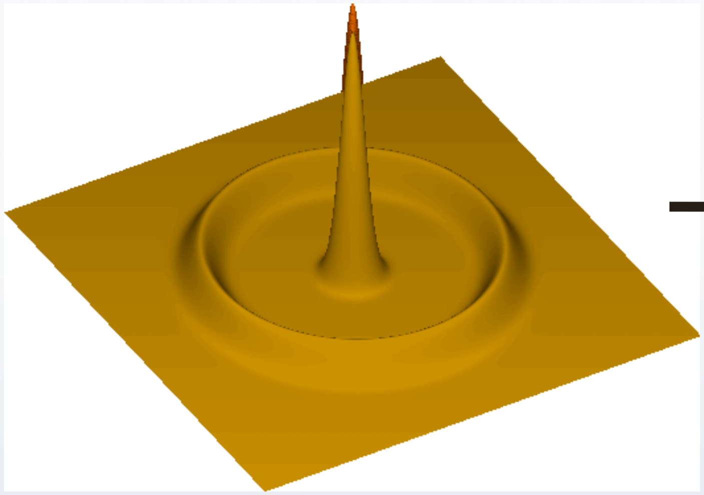
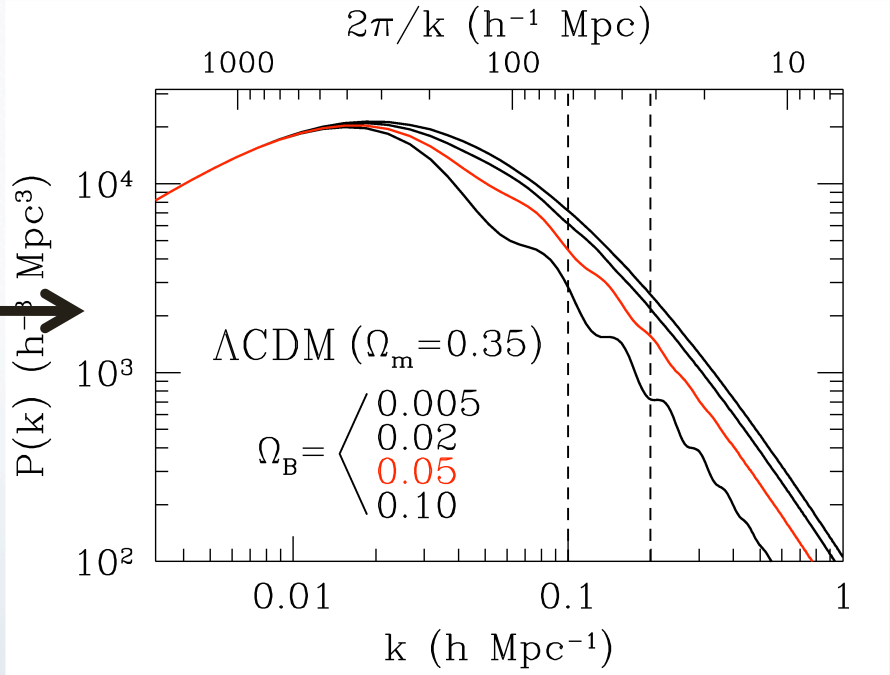
21cm BAO Internal Review April 26 2010

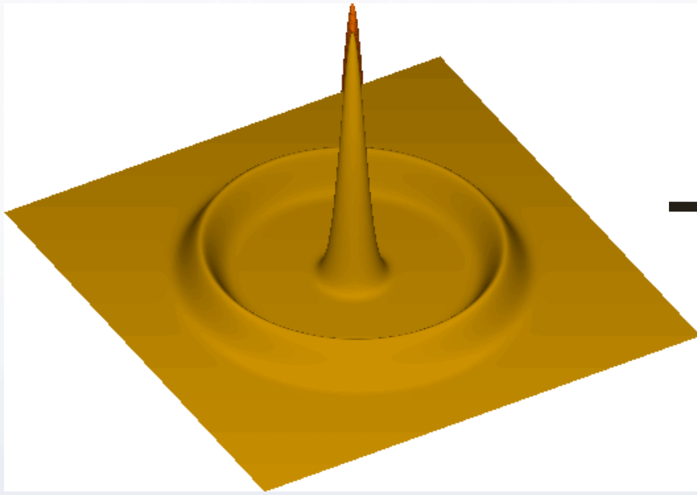
BAO

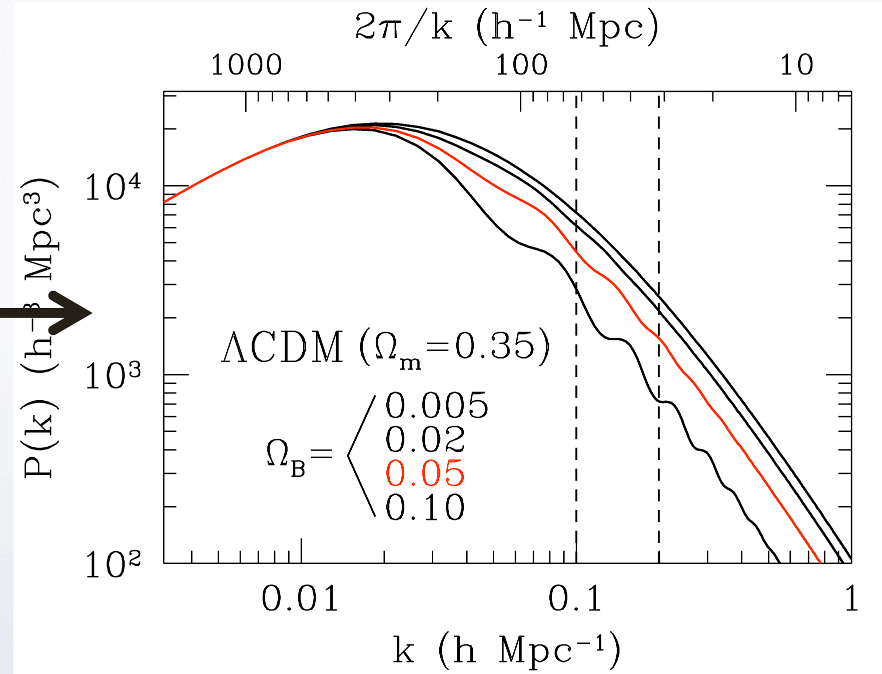




- A robust standard ruler - most systematics free.
- Mostly considered in optical/IR surveys.

BAO

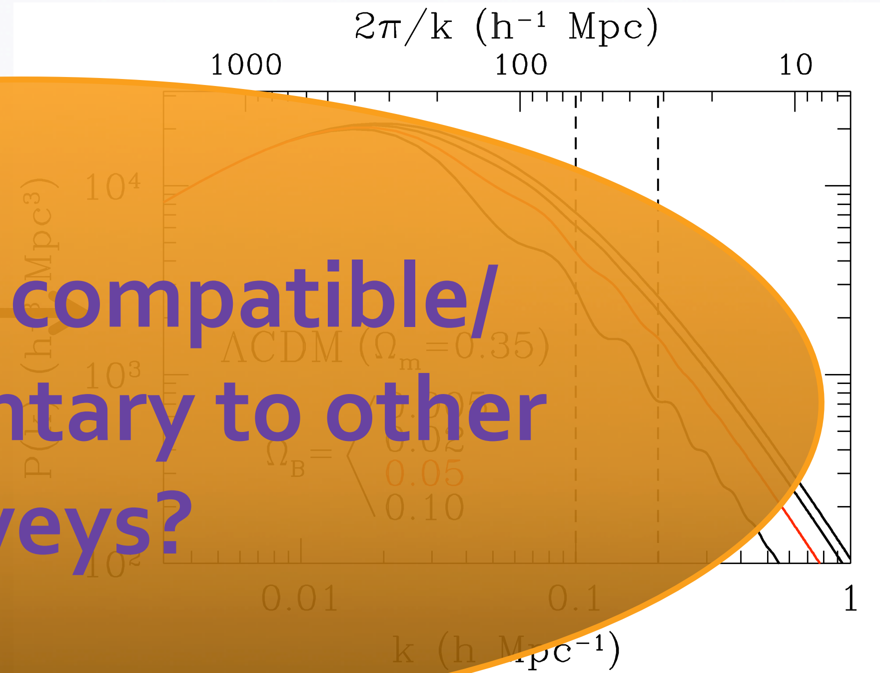




In Radio wavelengths?

- Very large survey volume easily achievable in a short time
- Electronics are cheap and easy to build
- Good redshift resolution but poor angular resolution (arcminutes at best)

BAO



Is 21cm BAO compatible/ complimentary to other future surveys?

Feasibility for a ground-based 21cm intensity mapping (Chang et al. 2008, Withe et al. 2008)

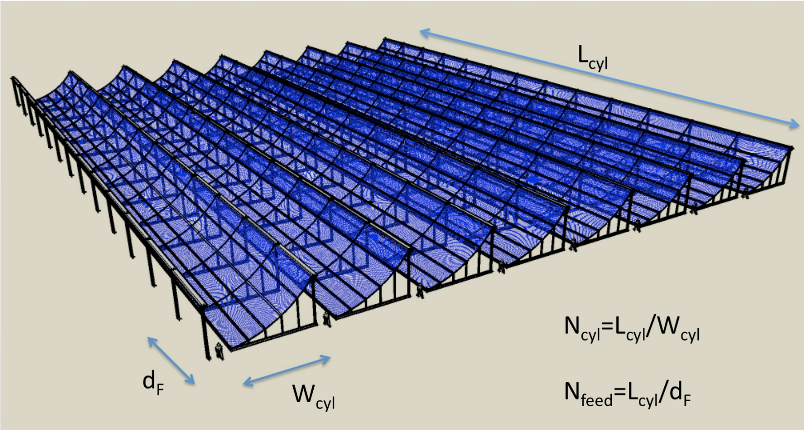
=> We consider engineering reality and the effect of angular resolution more seriously.

Outline

Is 21cm BAO compatible/ complimentary to other future surveys?

1. Fiducial CRT telescope
2. Effect of Angular resolution (Fisher matrix and Monte Carlos)
3. FoM as a function of CRT telescope parameters
4. Maximization of FoM

Fiducial CRT Configuration



Assume a packed rectangular CRT array

$\Delta\theta=\lambda/L_{cyl}$

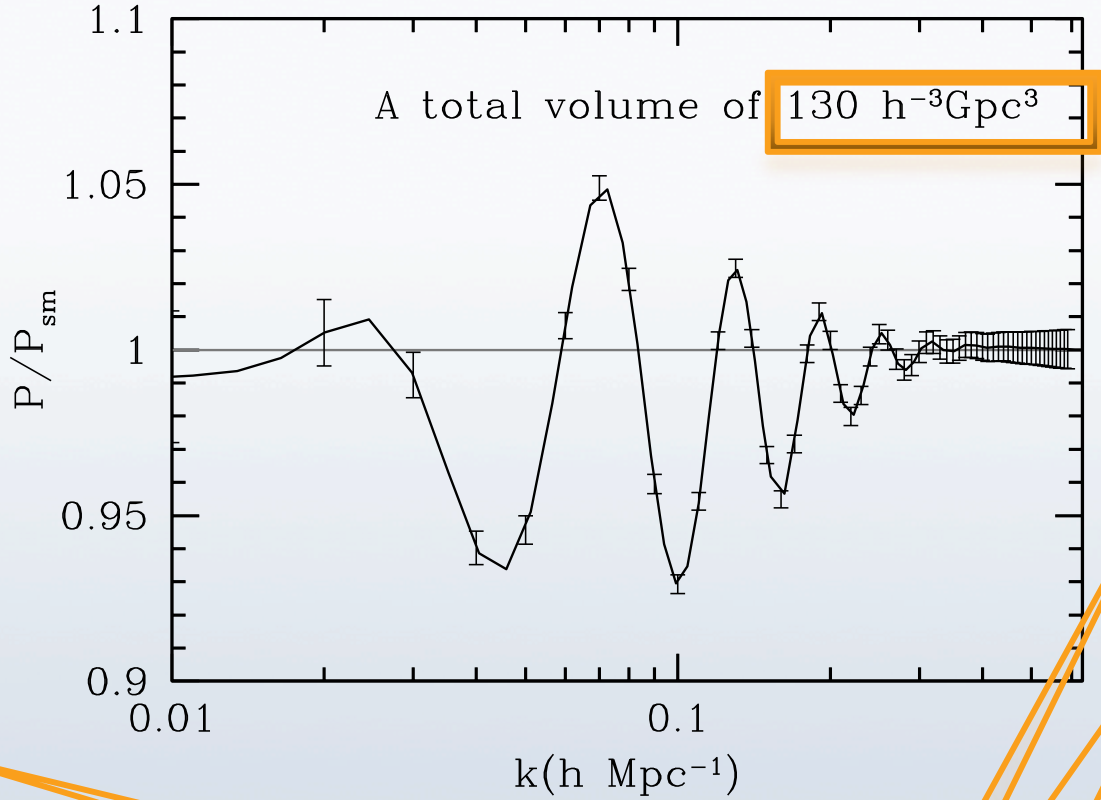
$A_{survey} = 2\pi\lambda/d_F$

$t_{int} = N_{year}\, D_f\, \lambda/(2\pi W_{cyl})$

TABLE 1
FIDUCIAL CRT CONFIGURATION.

Parameters	Low redshift $0.66 < z < 1.24$	High redshift $1.22 < z < 2.11$
Length of Cylinder, $L_{\rm cyl}$ (m)	99.8	142.8
Feed spacing, d_F (m)	0.39	0.558
Width of Cylinder, $W_{\rm cyl}$ (m)	14.3	14.3
Duty factor, D_f	0.5	0.5
$N_{\rm year}$ (years)	1.40	0.87
$\Omega_{\rm HI}$	0.0005	0.0005
bias	1.0	1.0
Sky temperature, $\bar{T}_{\rm sky}$ (K)	10	10
Antenna temperature, $\bar{T}_a$ (K)	50	50
gain, g	0.8	0.8
$P_{\rm shot}$	100.0	100.0

Fiducial CRT Configuration



The total survey volume

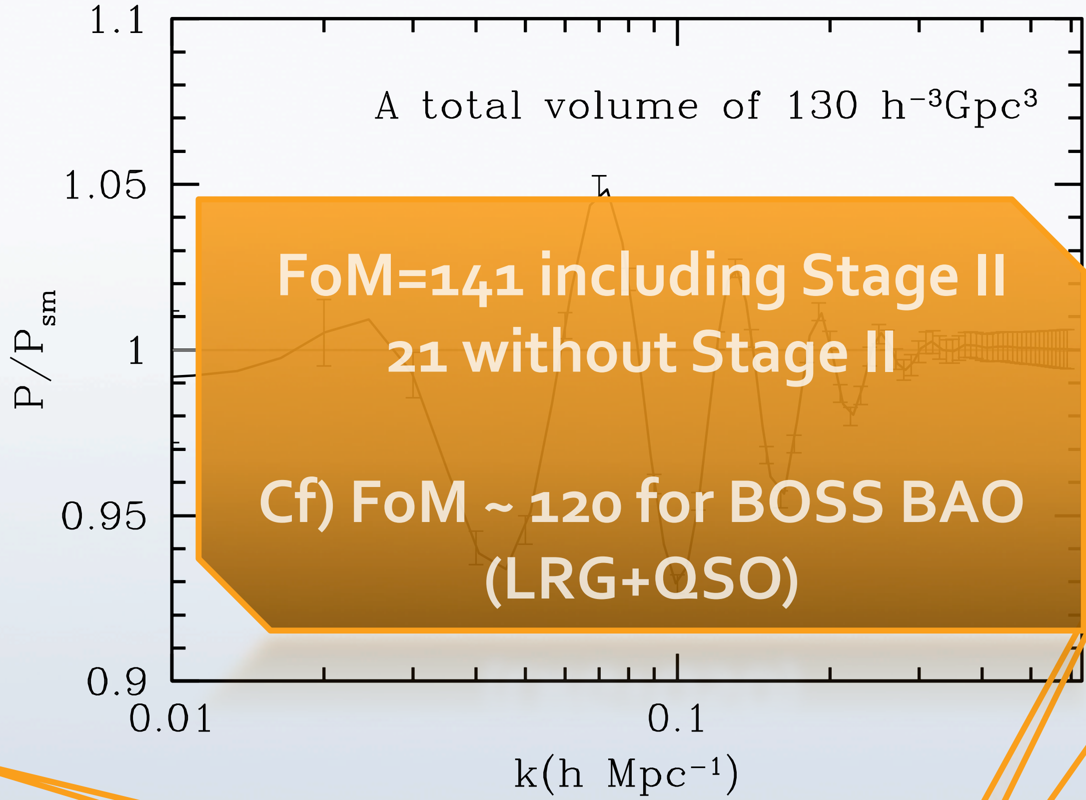
Power due to the large scale structure of HI

dT/T_{sig}

Shot noise

$$\frac{S}{N} = \sqrt{\frac{4\pi k^2 dk V_{\rm survey}}{2(2\pi)^3}} \frac{P_{\rm HI}}{P_{\rm HI} + \left[\frac{(g\bar{T}_{\rm sky} + \bar{T}_a)}{g\bar{T}_{\rm sig}\sqrt{t_{\rm int}\Delta f}}\right]^2 V_R + \frac{1}{\bar{n}}}$$

Fiducial CRT Configuration



FoM=141 including Stage II
21 without Stage II

Cf) FoM ~ 120 for BOSS BAO
(LRG+QSO)

Power due to the large scale structure of HI

dT/T_{sig}

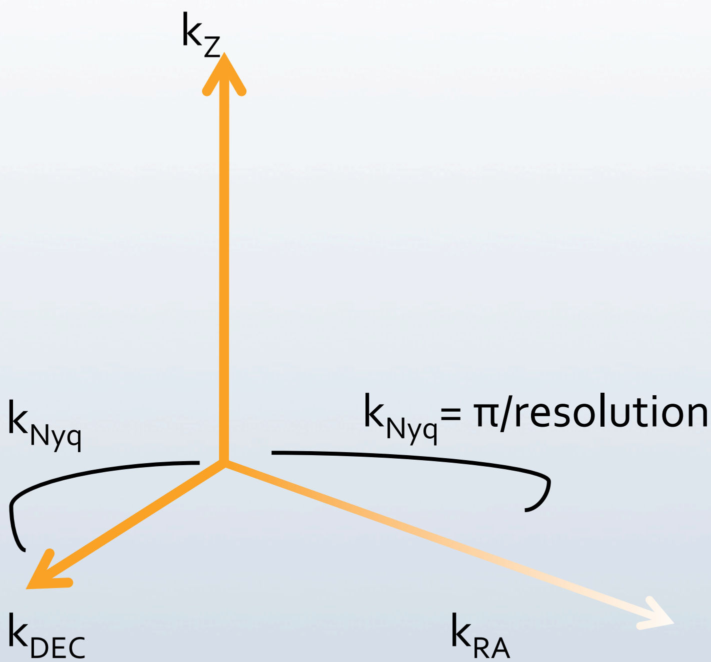
Shot noise

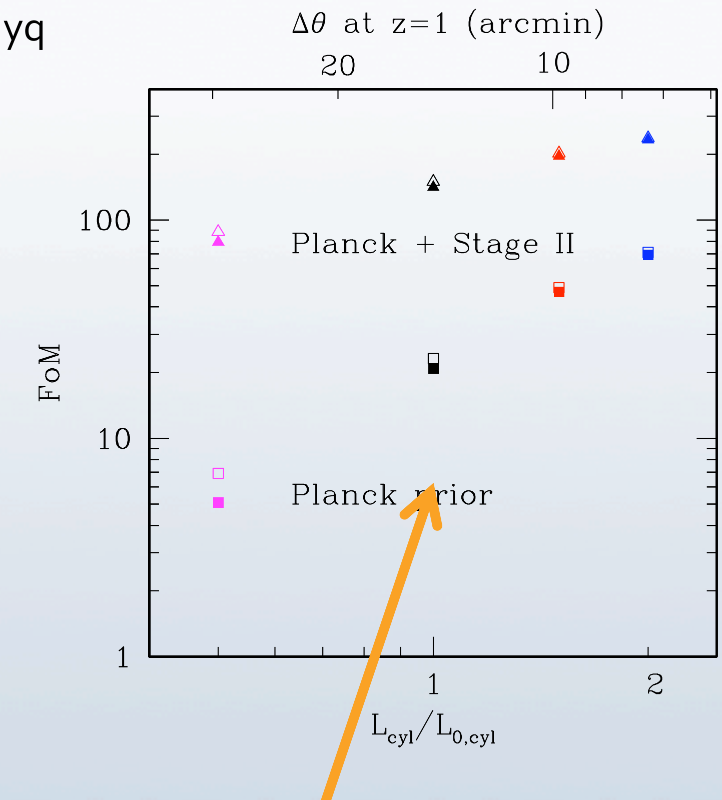
The total survey volume

$$\frac{S}{N} = \sqrt{\frac{4\pi k^2 dk V_{\rm survey}}{2(2\pi)^3}} \frac{P_{\rm HI}}{P_{\rm HI} + \left[\frac{(g\bar{T}_{\rm sky} + \bar{T}_a)}{g\bar{T}_{\rm sig}\sqrt{t_{\rm int}\Delta f}}\right]^2 V_R + \frac{1}{\bar{n}}}$$

Effect of an angular resolution

1. Increases the noise per pixel through V_R
2. Wavenumber cutoff near k_{Nyq}

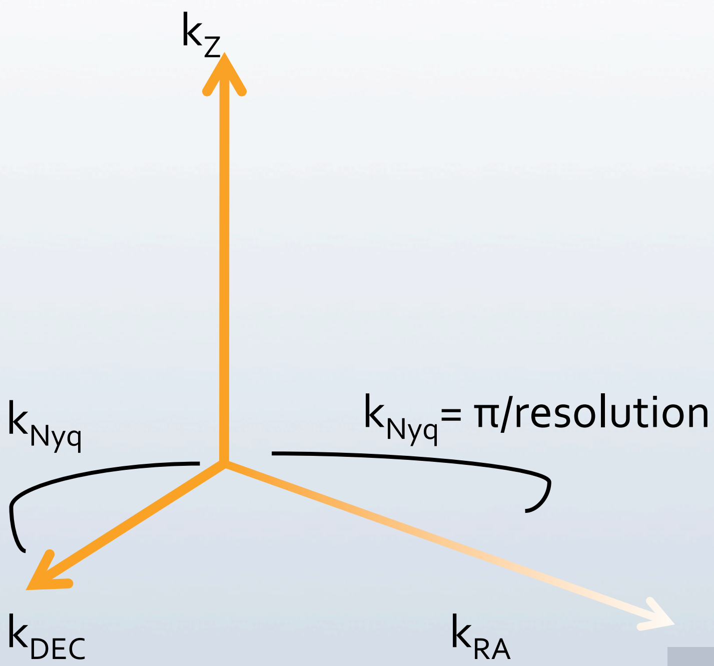




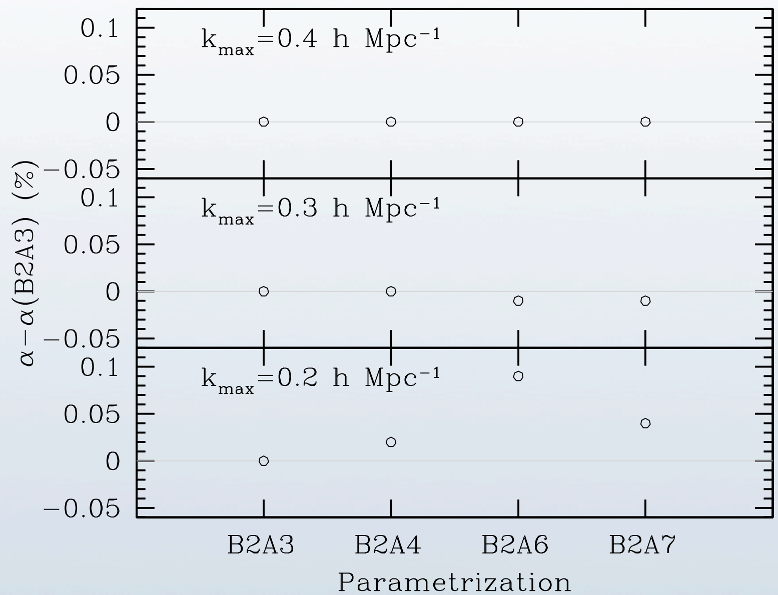
Effects on FoM are small for a CRT array with a size of 100-150 meters (i.e., an angular resolution of 10 – 14 arcmin at z ~ 1).

Effect of an angular resolution

1. Increases the noise per mode through V_R
2. Wavenumber cutoff near k_{Nyq}

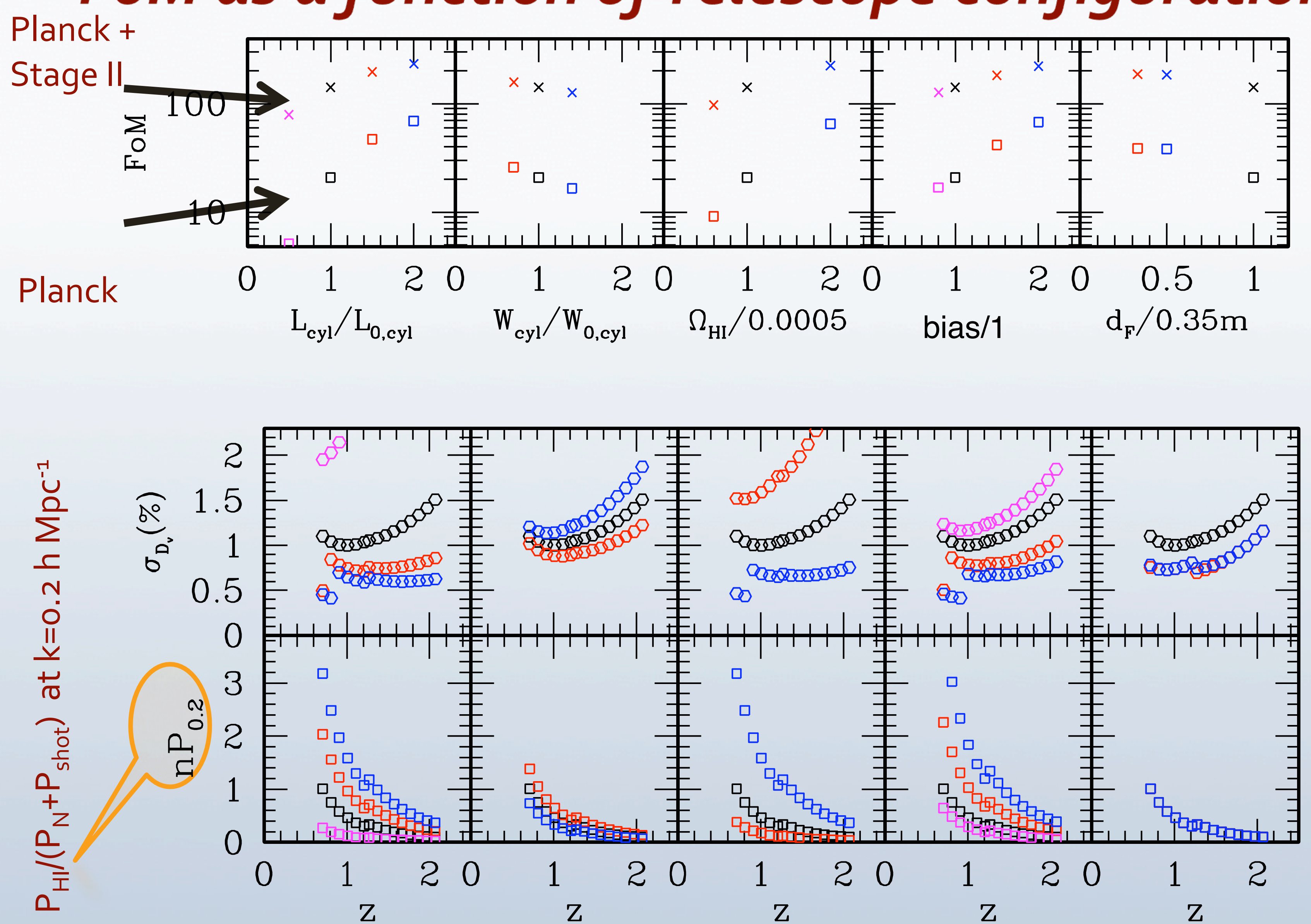


Monte Carlos



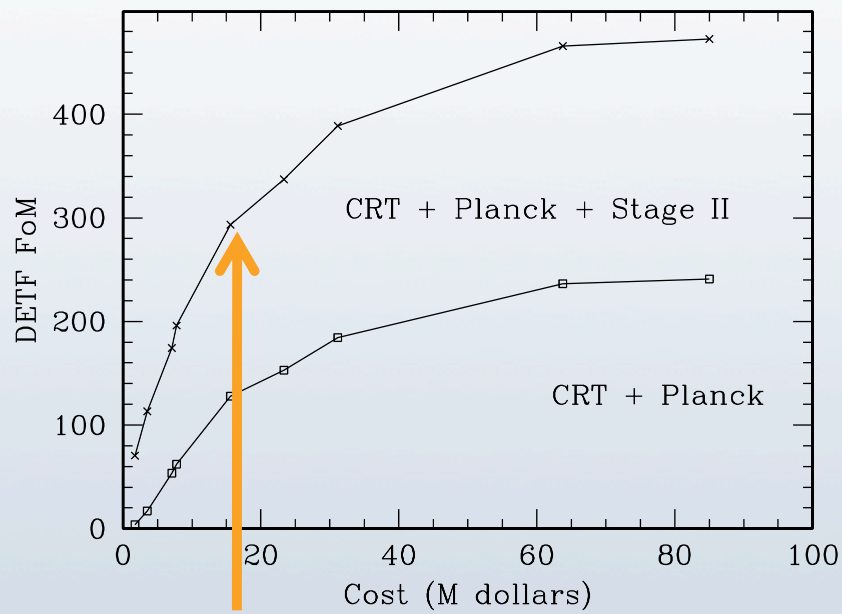
However, the data are harder to fit reliably with a poor angular resolution – i.e., at z > 1.5 for 100-150m CRT.

FoM as a function of Telescope configuration



Maximization of FoM

Optimize the CRT telescope configuration while holding the cost fixed. The cost includes, the cost of the digital electronics, the cost of the cylinder feed line, and the cost of the reflector surface.



FoM = 300 can be achieved with $15-20 million according our cost model.

We generated a publicly available optimization tool.

Summary

We tested the feasibility of measuring BAO using a ground-based CRT with an emphasis on the engineering reality and the angular resolution effect.

1. Angular resolution limits the wavenumber range available for the BAO standard ruler test – for 100-150m CRT telescope, the effect on FoM is small.

On the other hand, the data are harder to fit reliably ($z > 1.6$ for 100-150m CRT telescope).

2. We investigated the performance of a telescope as a function of various telescope configuration.
3. We have optimized the telescope configuration for the maximum FoM – we find that we can achieve FoM~300 for a reasonable cost. We generated a publicly available optimization tool.