Analysis of LBM/VLES Data
Related to the Source Diagnostic Test Cases

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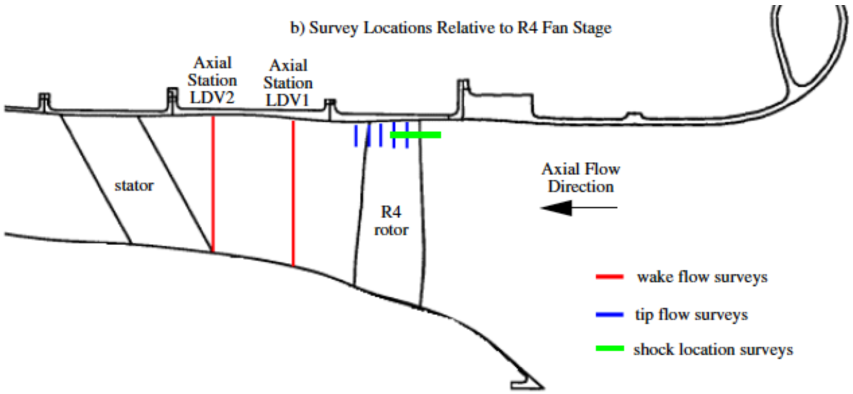
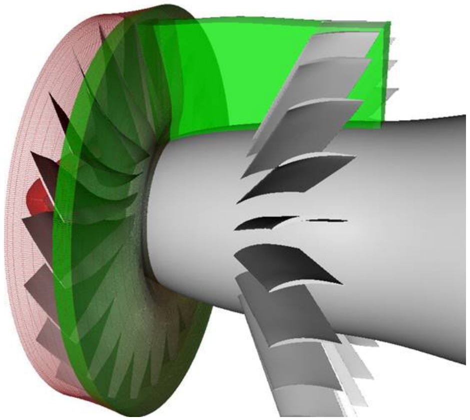
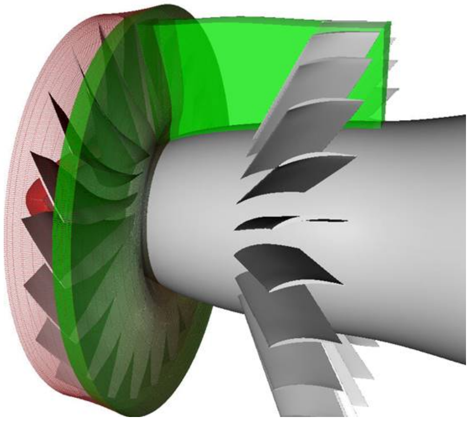
Tasks: in support of improving low-order modeling





1. Determination of turbulence isotropy
2. Determination of length scales
3. Turbulence spectrum
4. Analysis of flow field for other rotor speeds
5. Analysis of streamwise evolution of flow
6. Analysis of unsteady vane surface pressure

Today



Reminder – what is the big picture on this project

Discussion of some outcomes from the LBM data analysis
Original tasks not options

Discuss application of low-order method to ACAT benchmark

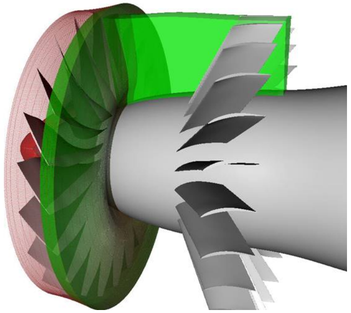
Discuss results from new wake-evolution prediction project

Big picture :
low-order computation of fan-FEGV broadband interaction noise

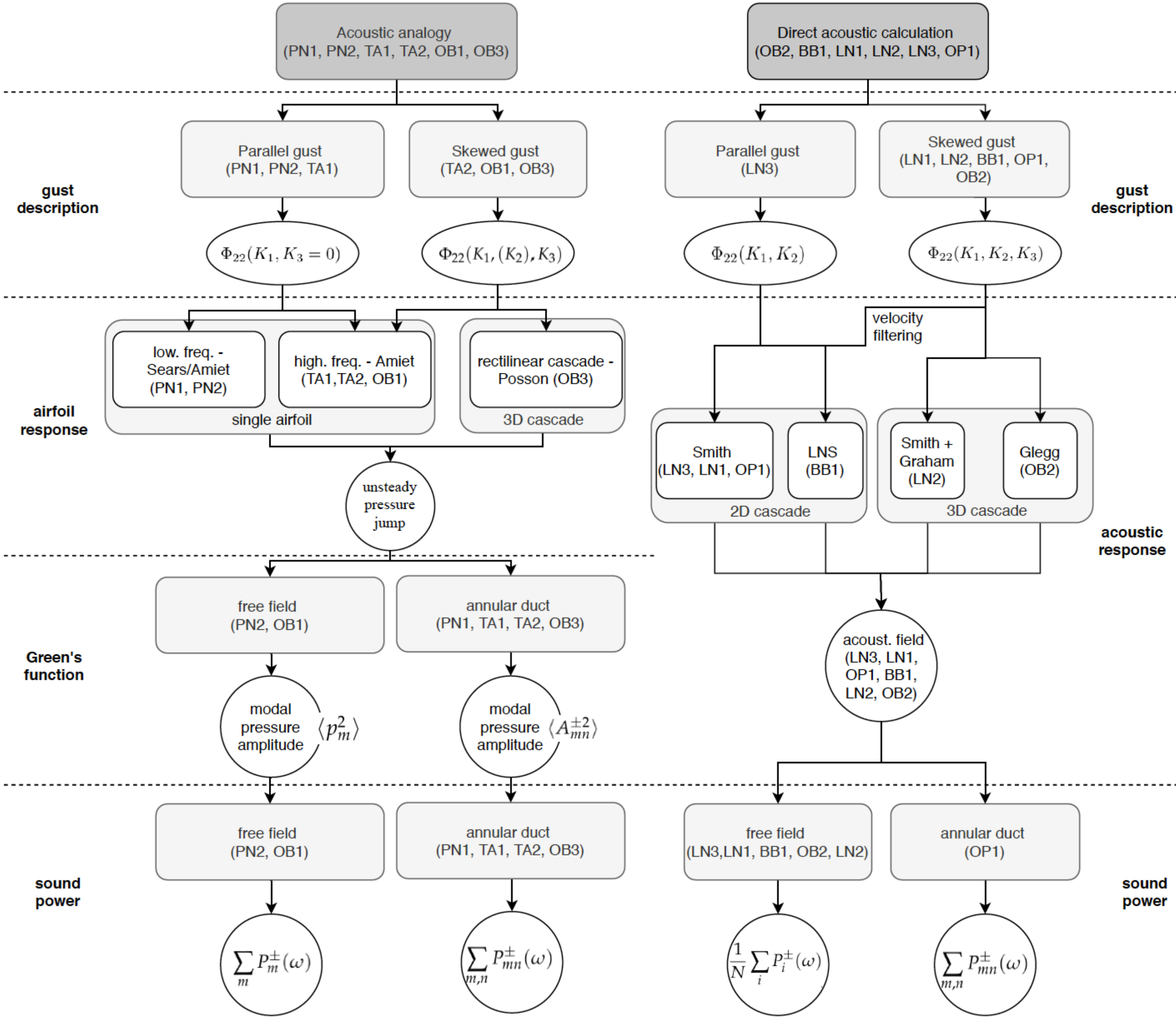
Low-order method grew out of work by Nallasamy/Envia (based on Ventres)

Models FEGV as 2D flat plate cascades using strip theory – response : Ventres
Models duct acoustics using Green's method (annular duct modeled)

Need input data upstream of the FEGV



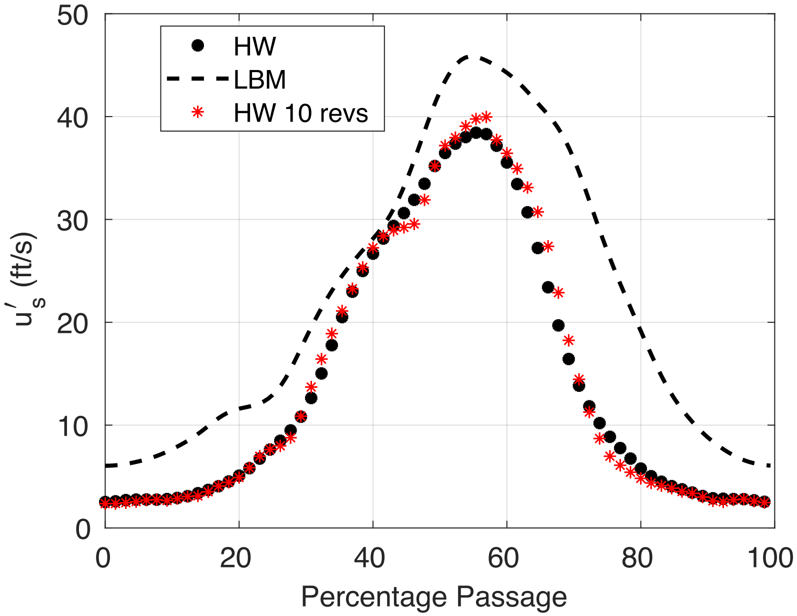
Love this chart from ACAT1 benchmark paper (Guerin et al)

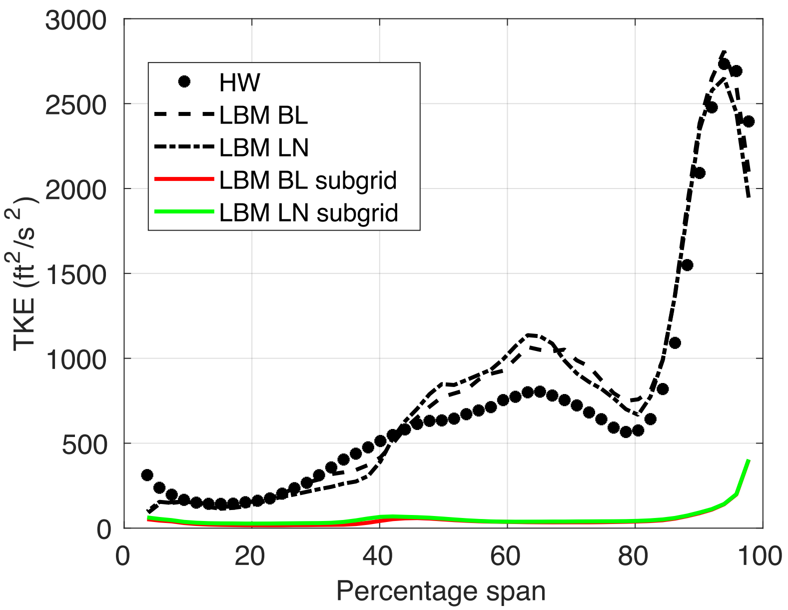


There are also implementation differences

Dealing with the input :

How is passage behavior modeled





History on this project

1. Data that are available – SDT

a. Hotwire: two locations, low noise configuration, low speed
   3 components of velocity (like the turbulence values)

b. LDV: two locations, low noise configuration, low speed
   2 components of velocity (like the mean values)

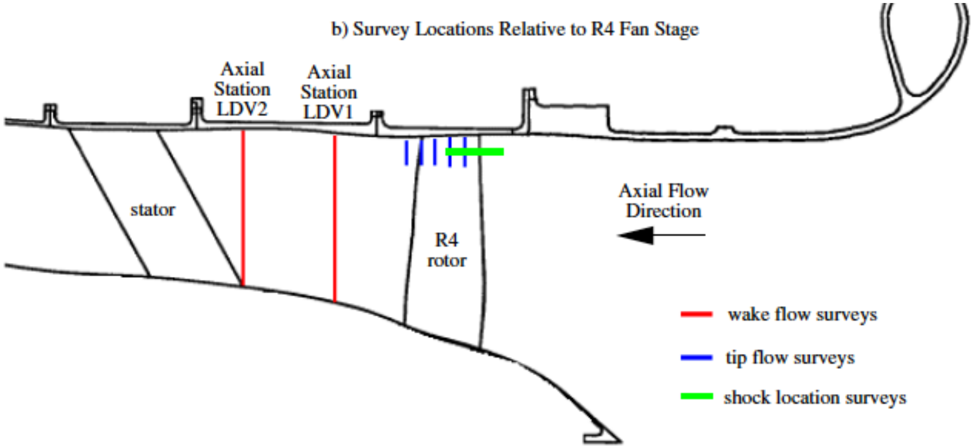
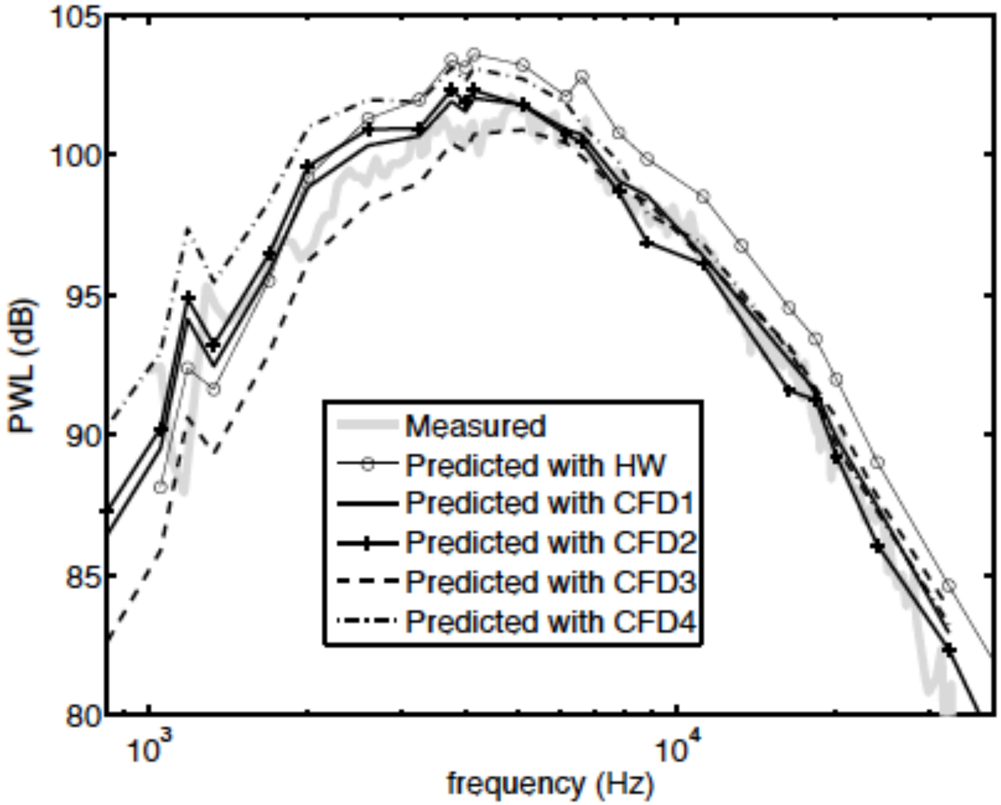


Figure rom Podboy et al (2003)

History on this project

Started with RANS & URANS computations to provide input data

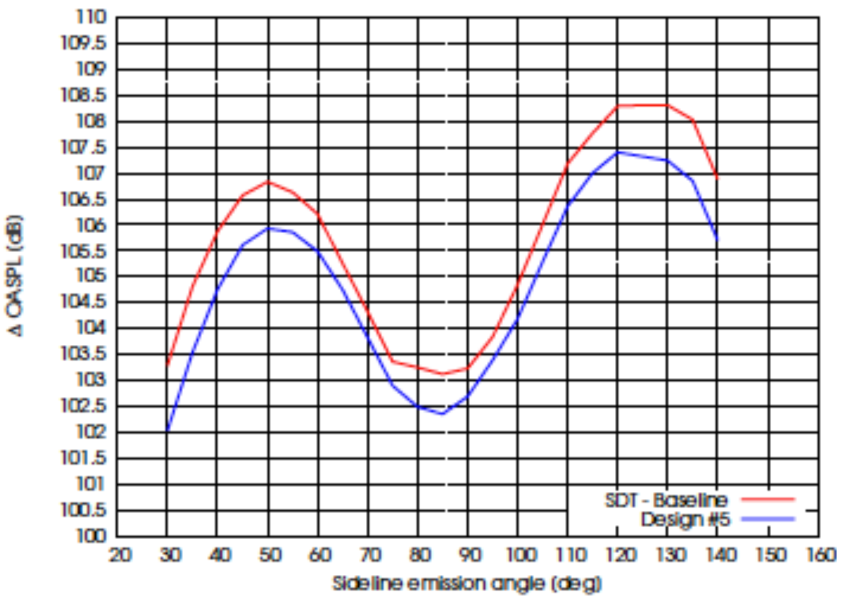


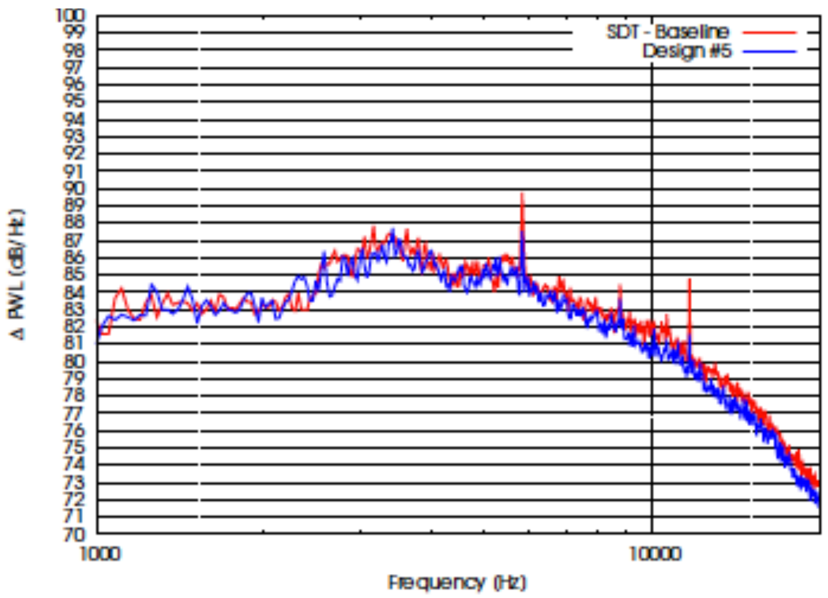
History on this project

Started with RANS & URANS computations to provide input data

The length scale has a strong influence on the results
wondered if higher fidelity simulations would provide better insights

PowerFLOW emerged with Fan BB calcs showing good predictions

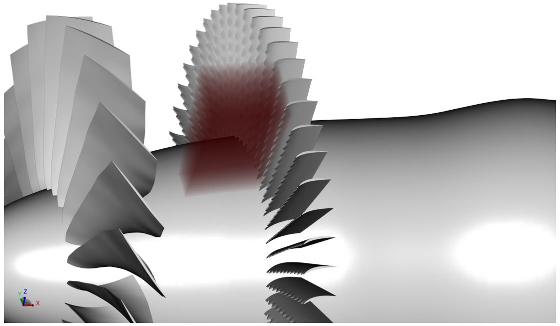




Could we learn something from analyzing the flow upstream of the FEGV
How would results look if the low-order used input from LBM-VLES

Original attempts

Focused on approach rotor speed (most experimental data : HW and LDV)



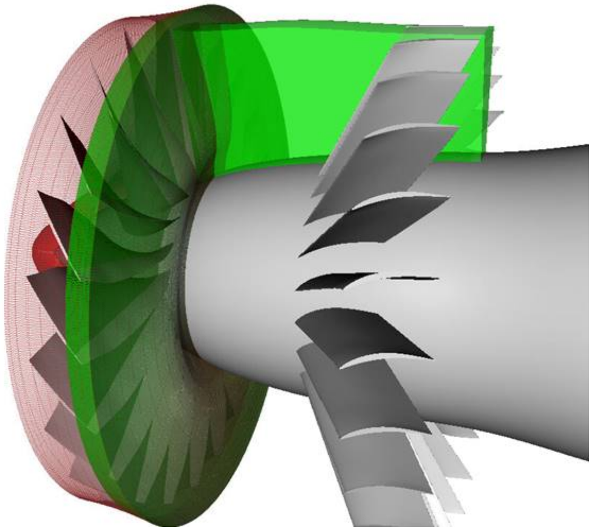
Obtained volume file for portion of flow field.

PowerFLOW runs being improved, methods for dealing with saved data being improved

Many iterations

Have settled on good “extraction” methods etc.

Current data from PowerFLOW



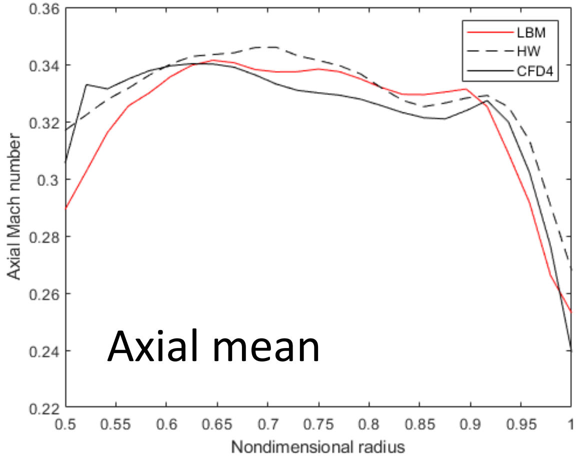
Changed volume in hopes of including some further processing

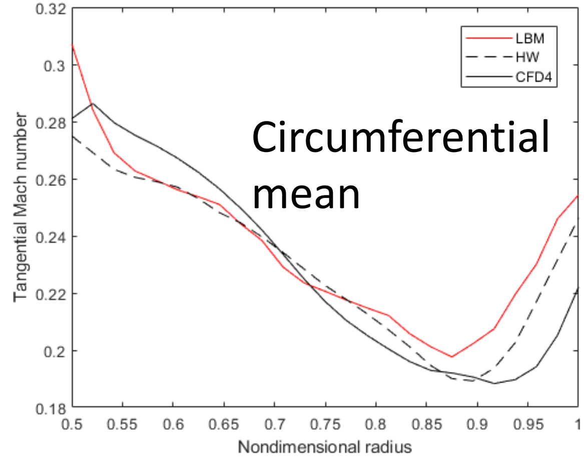
Approach and Takeoff (Sideline) cases now

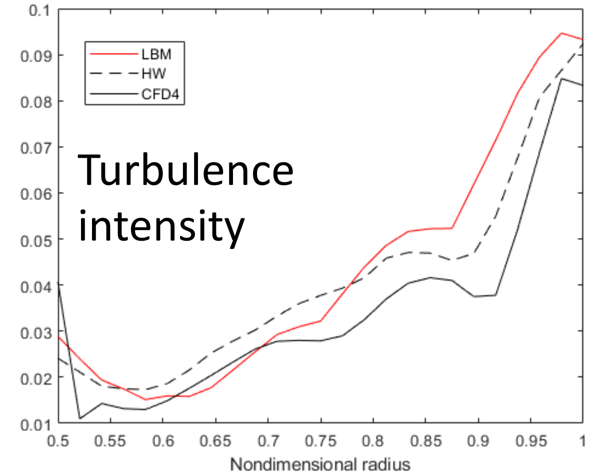
	Design Speed (%)	Tip Mach (-)	Fan Speed (RPM)	Blade Passing Freq. (Hz)
Approach	61.7%	0.669	7809	2863 Hz
Cutback	87.5%	0.949	11075	4060 Hz
Sideline	100%	1.085	12657	4641 Hz

Data analysis still written and run outside of PowerFLOW tools

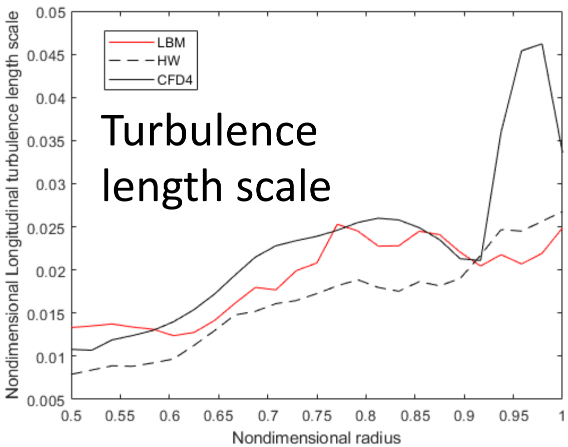
Results from LBM VLES analysis and usage in low-order

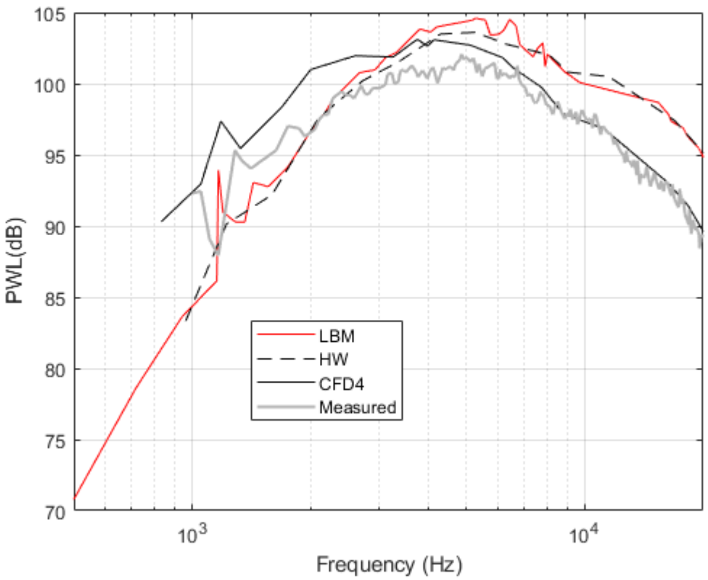




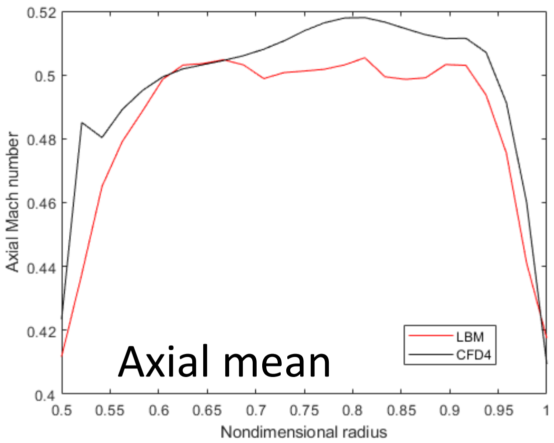


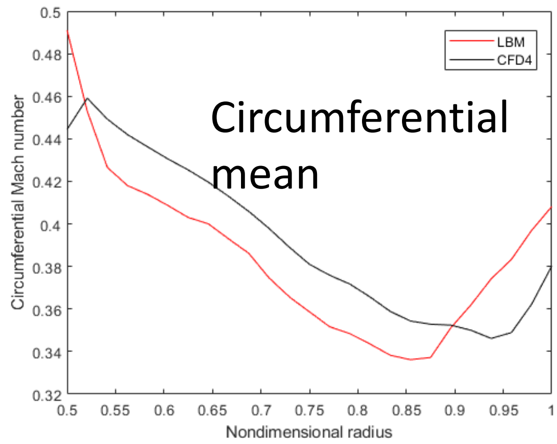
APPROACH

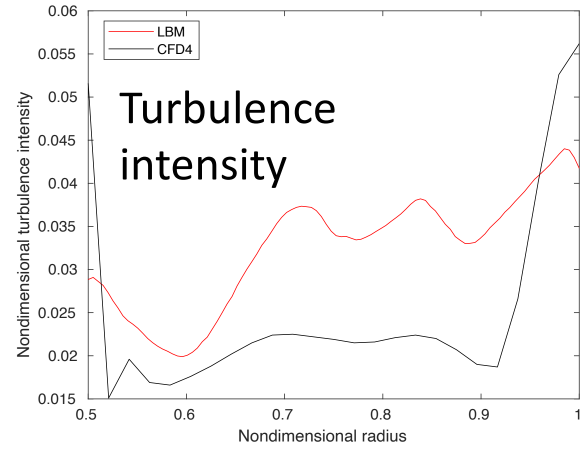




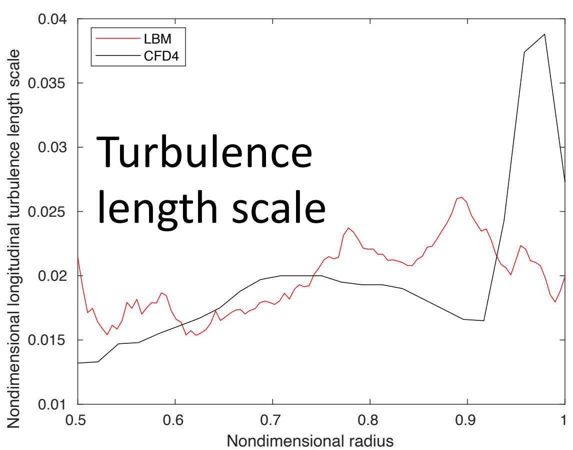
Results from LBM VLES analysis and usage in low-order

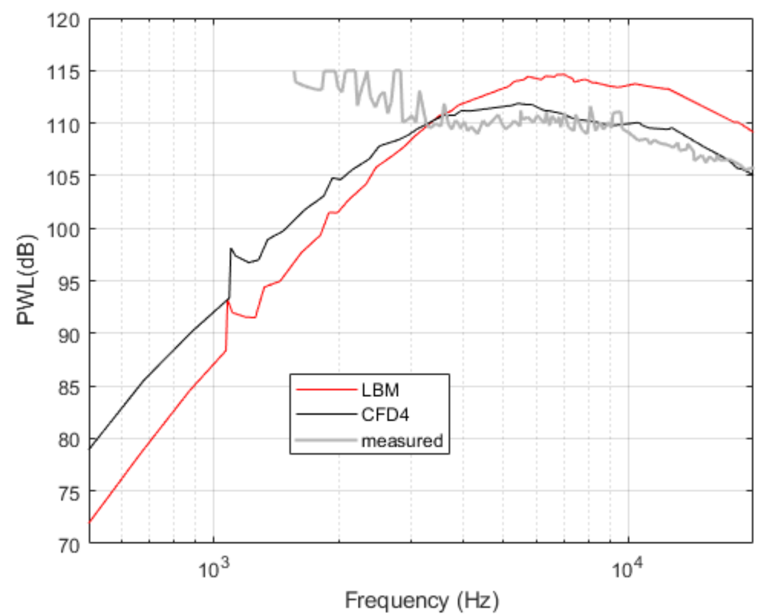




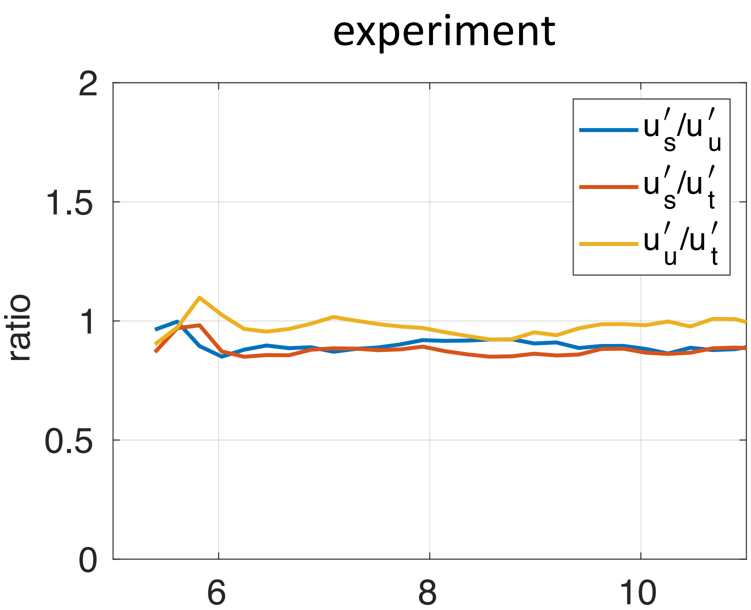


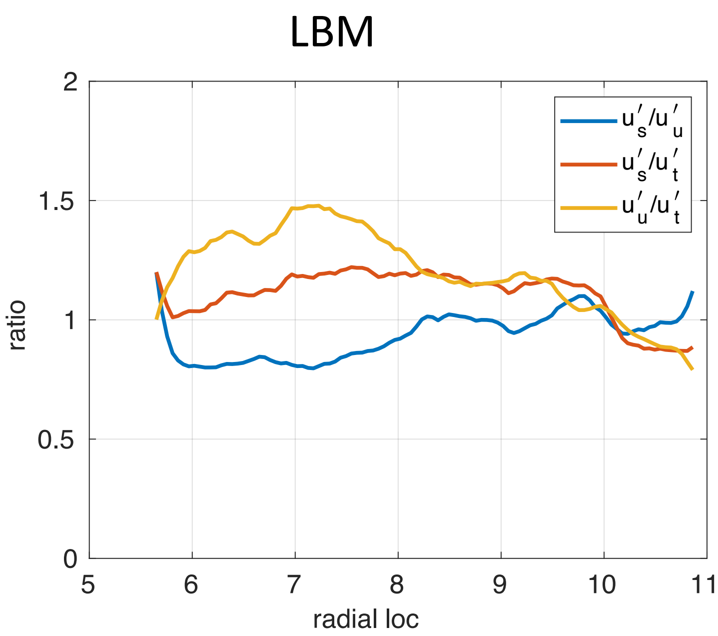
TAKEOFF

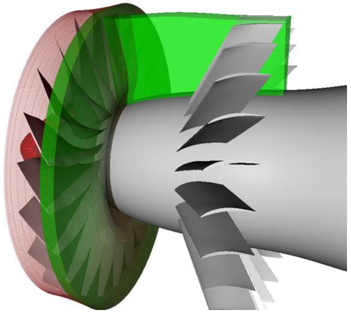




Determination of turbulence isotropy



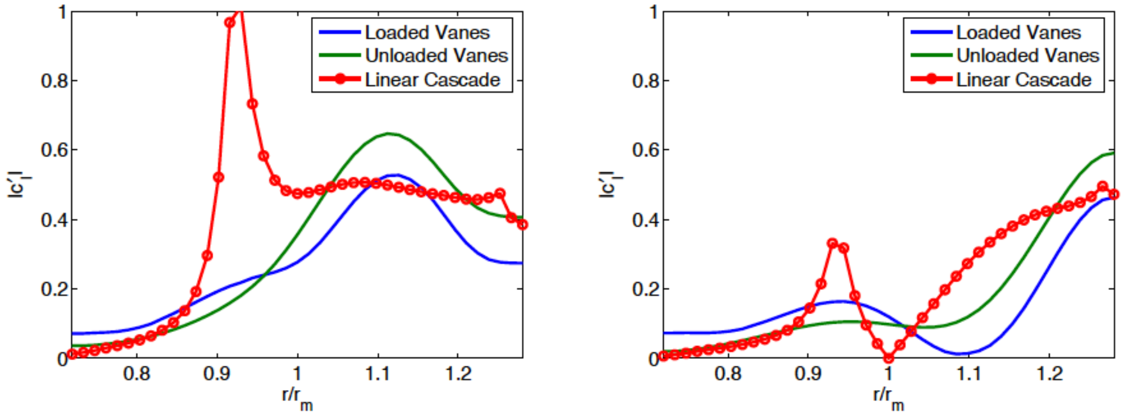




Stator data analysis

Original goal was to use LBM VLES data to check stator response

Logue/Atassi had developed 3D cascade response and shown response based on mode



(a) $n_g = 0$ (b) $n_g = 1$

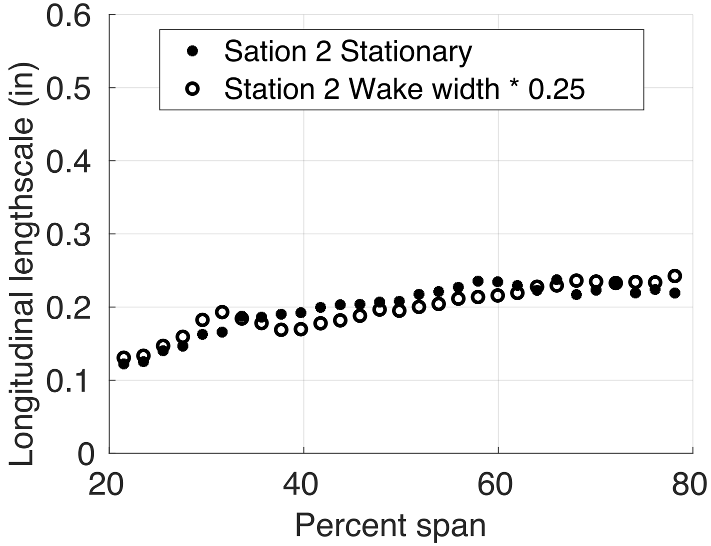
Difficulty is that surface pressure is due to both acoustic and hydrodynamic disturbances

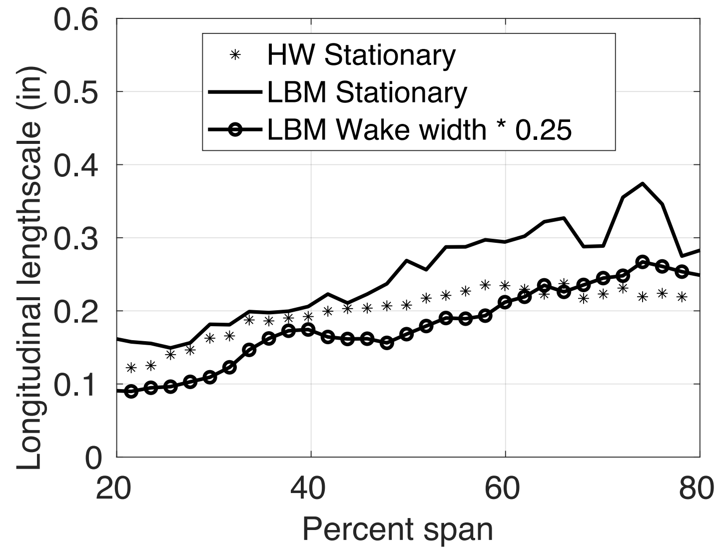
Method to separate cannot be used on a point-by-point basis

Brian Tester is helping with some analysis and we can do more than is possible with HW but…

Lengthscale from half depth wake width

Approach case





Factor is not known across rotors

Using same factor determined by experiment does not give same agreement in LBM

In all cases, determine "half depth wake width" is murky and not easily automated

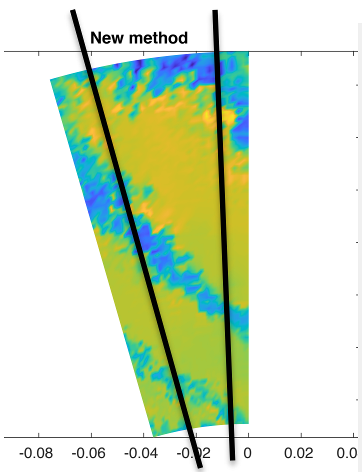
Wake evolution and length scale using separation distance

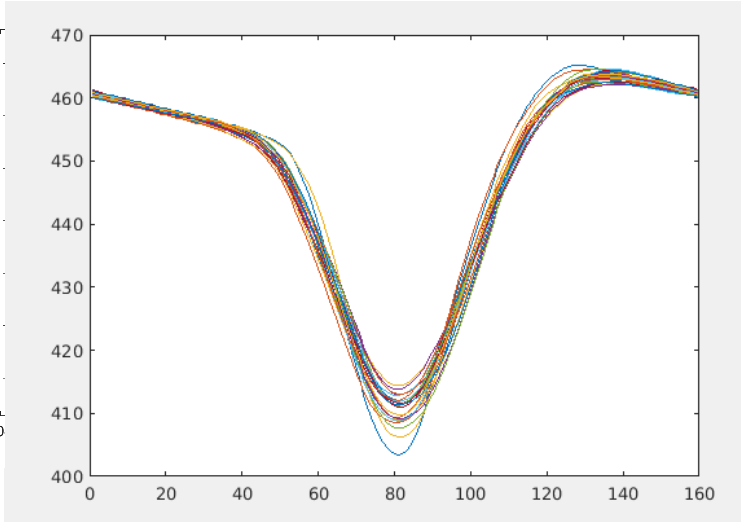
Originally we planned to consider both of these things using the LBM VLES data

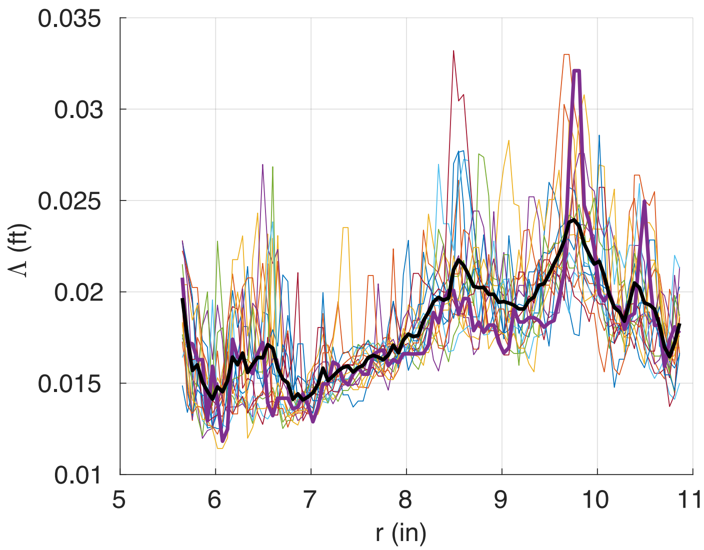
Proven difficult

We believe because of required averaging, saving, then extracting the data again

For instance: If one just considers different "linecuts" extracted from the volume file







As you follow a wake or place probes in a streamwise direction or even axial direction, the method doesn't work well. Demonstrated this previously and don't have work around

ACAT1 analysis

Sketch of AneCom Aerotest (ACAT) Universal Fan Facility For Acoustics (UFFA) Rig

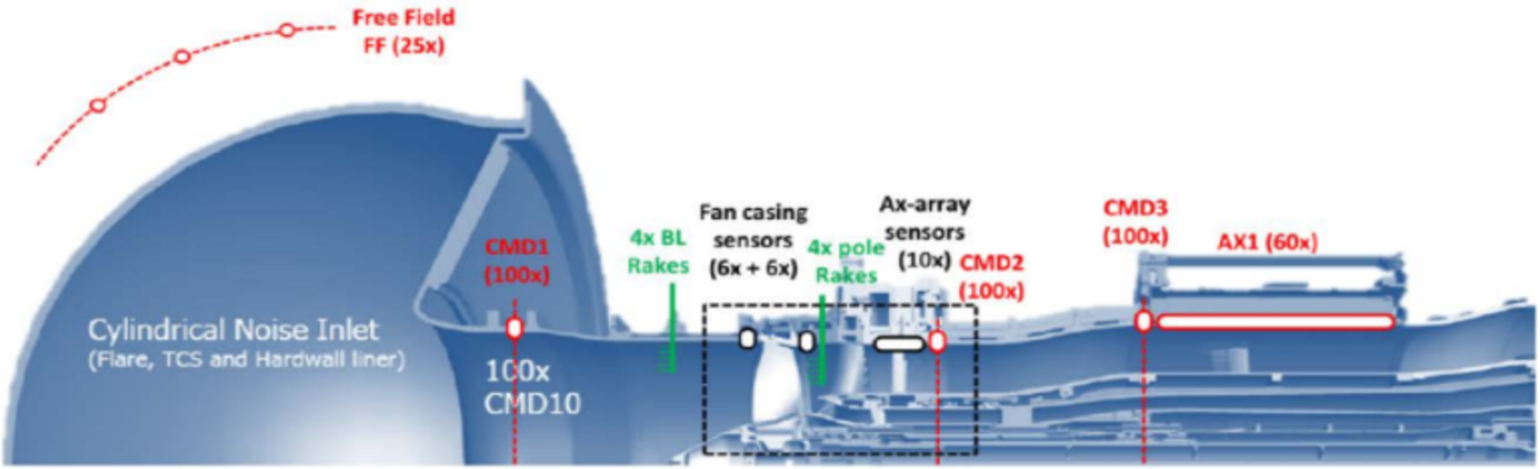


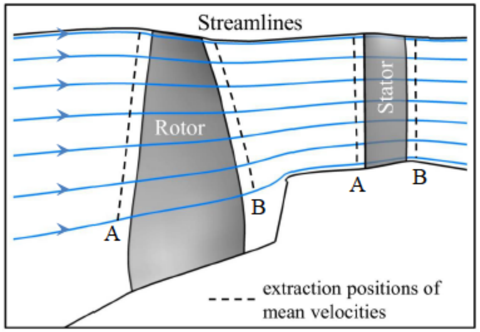
Figure 1. **Sketch of AneCom Aerotest's Universal Fan Facility For Acoustics (UFFA) Rig used for the tests performed by TurboNoiseBB consortium. Red: acoustic probes, green: aerodynamic probes.**

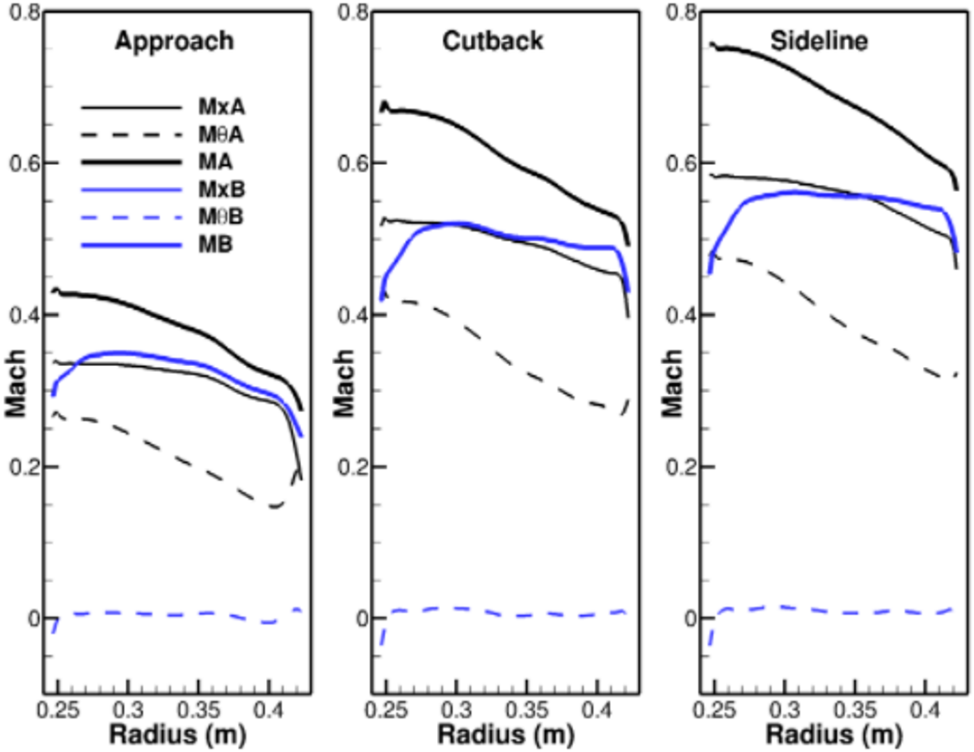
Short Gap	Approach (AP)	Cutback (CB)	Sideline (SL)
rpm	3856.1 (50%)	6175.1 (80%)	6945.7 (90%)
massflow (kg/s)	54.85	88.80	101.32
corr. rpm	3797.9	6077.3	6836.5
corr. massflow (kg/s)	56.48	91.61	104.53

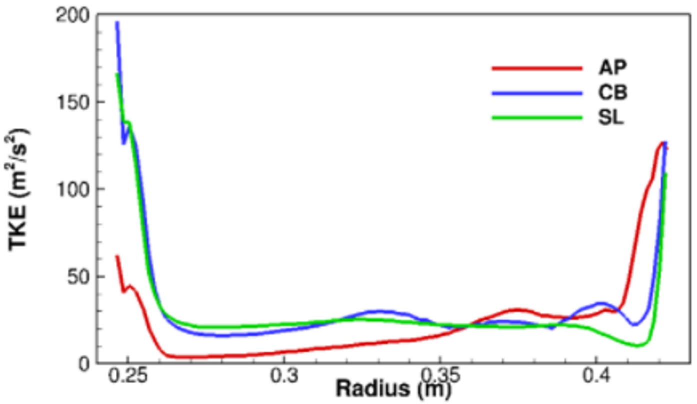
Figure from Ricardo Blázquez(2019)

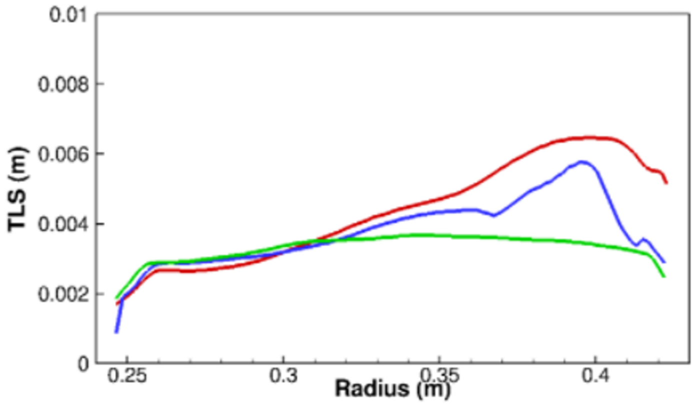
ACAT1 analysis

Inputs taken from Guérin (2020)

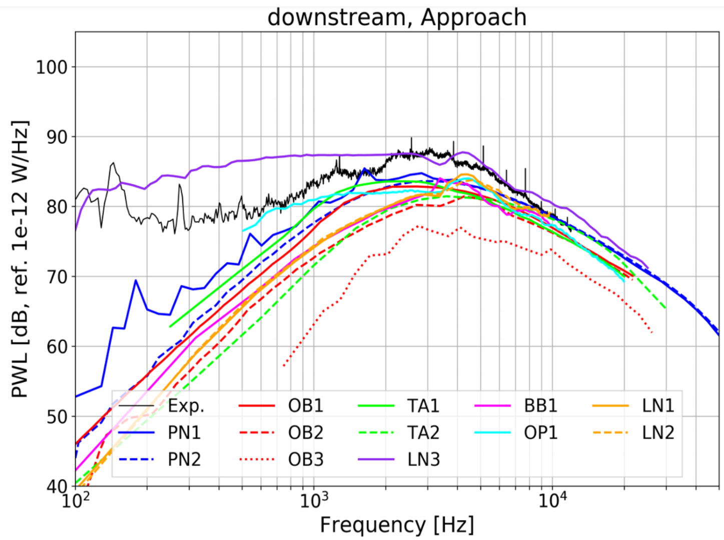


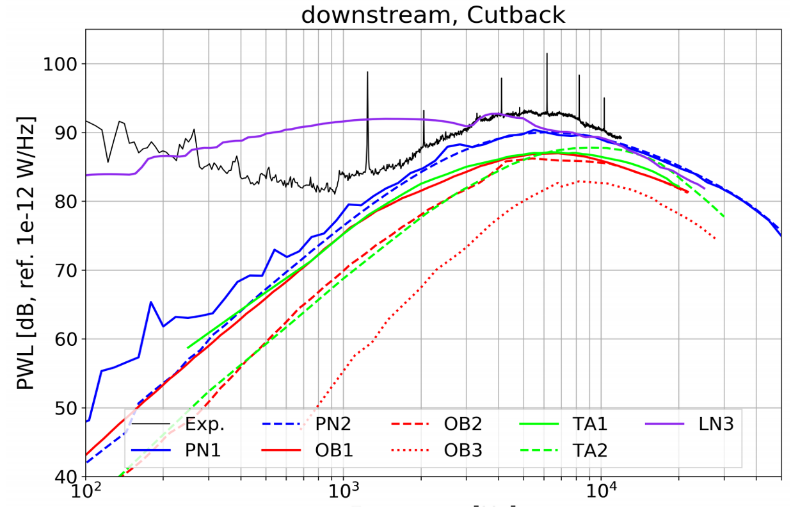


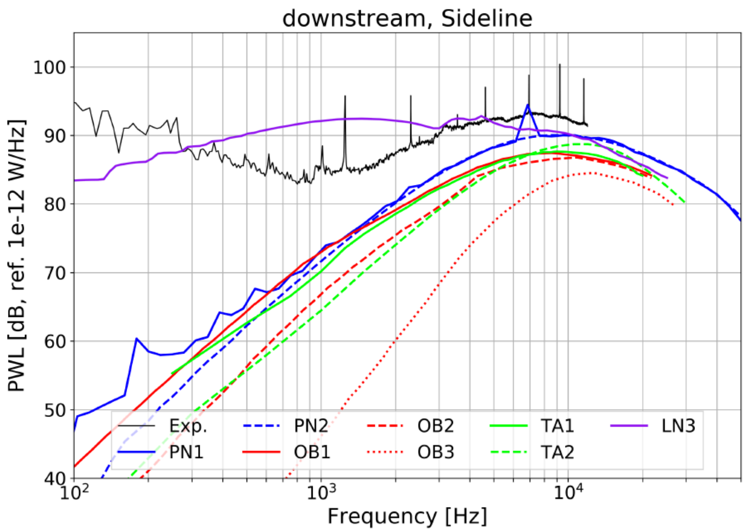




ACAT1 analysis

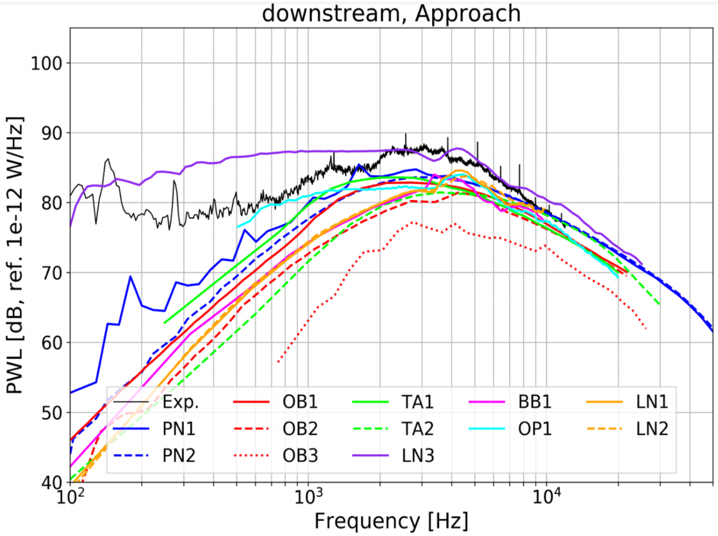


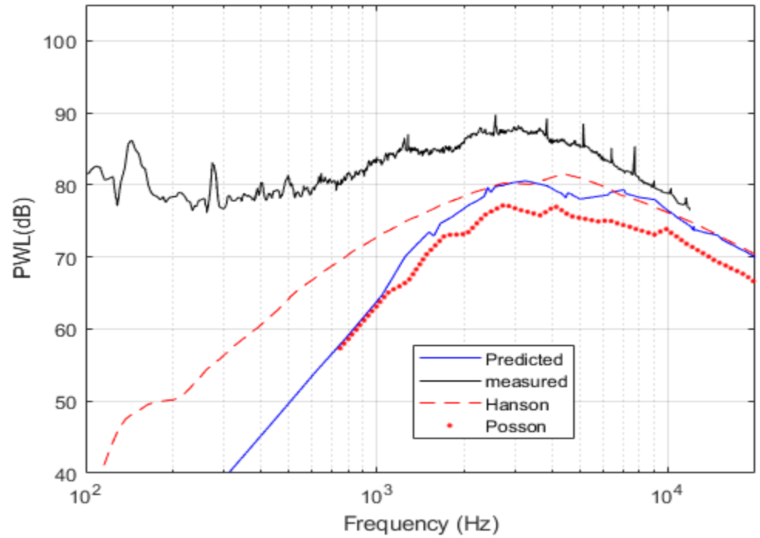


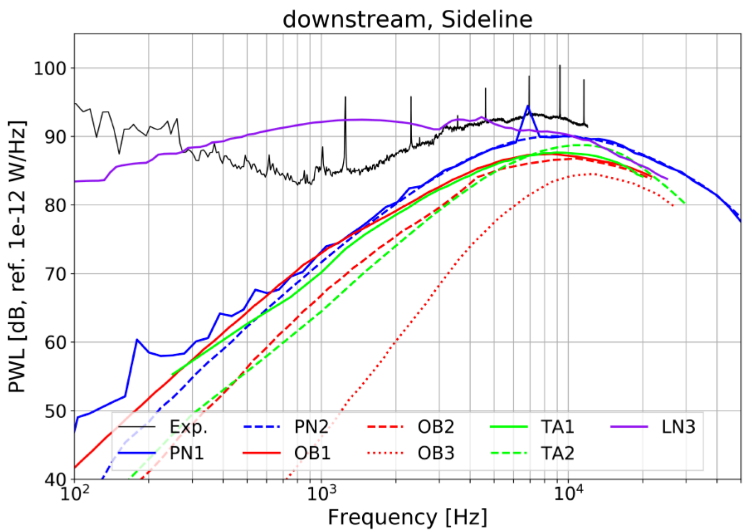


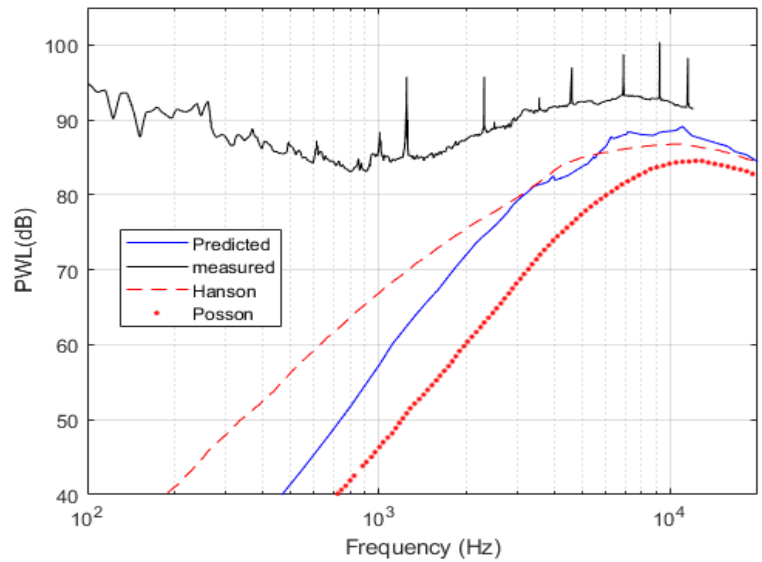
Guérin (2020)

ACAT1 analysis : our results : compared to Hanson & Posson

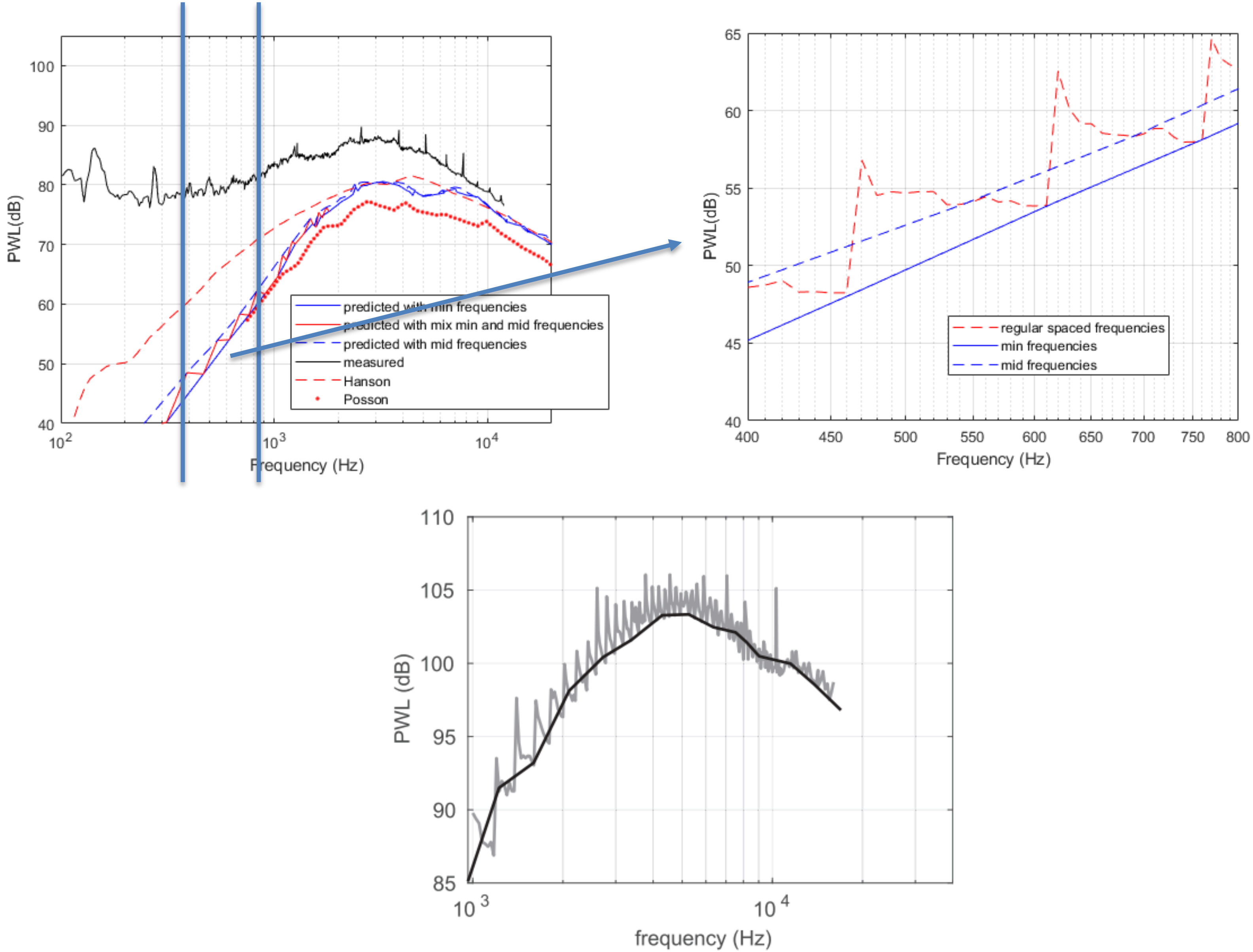








ACAT1 analysis : our results : issue of singular frequencies



Summary

LBM VLES seems to give no advantage for finding the input data for low-order

Advantage is in more direct calculation

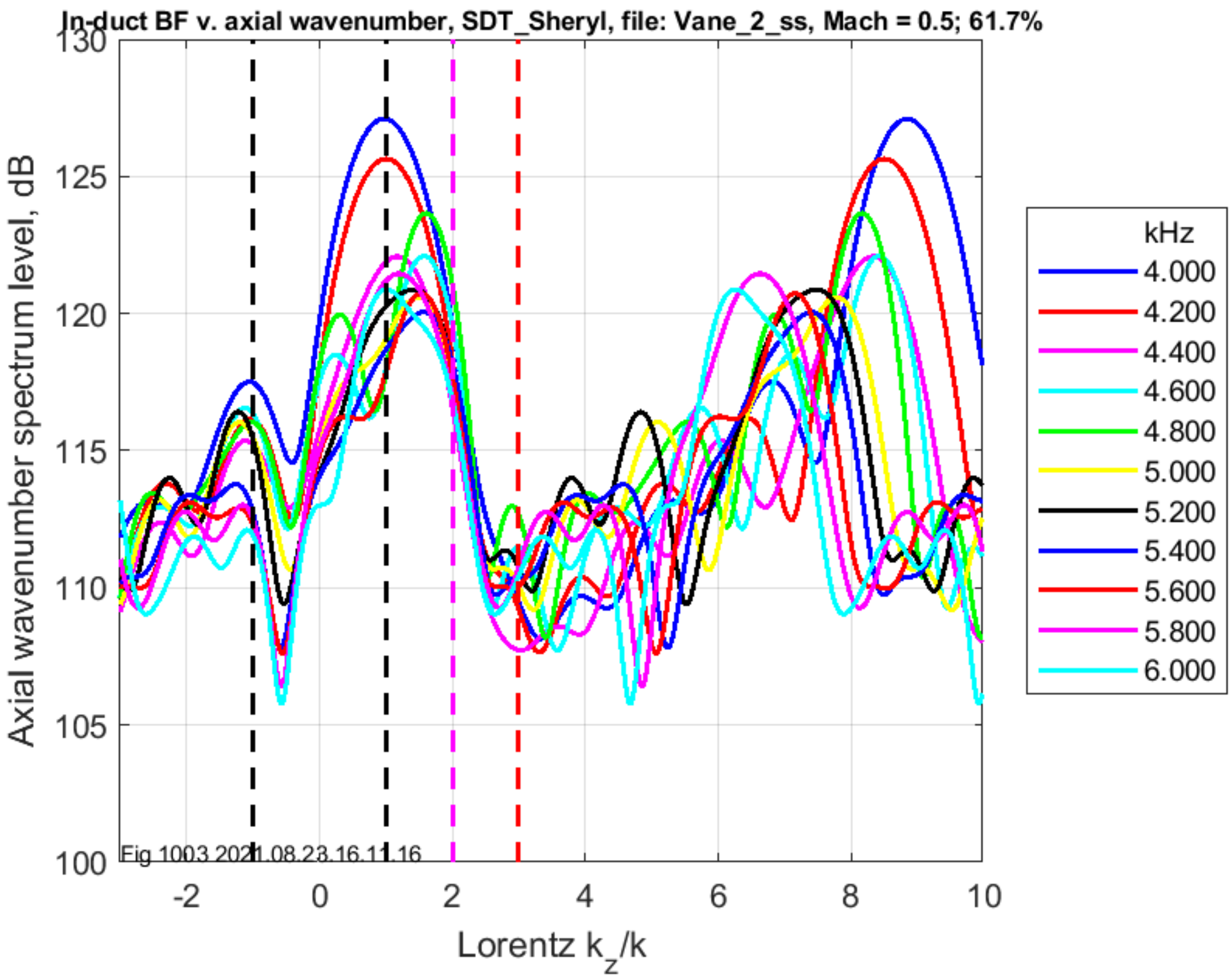
Length scale still not nailed down

Validating these calculations is tough

Low-order method still gives reasonable trends

ML showing promise for getting input quickly, much to be done still

If Brian wants to jump in



Acoustic k_z/k range -
'k' dashed vertical lines at Lorentz = ±1

Non-acoustic k_z/k indicated 'm' & 'r' - convection at $1/M_z$ and $1/(0.67*M_z)$