



# Initial study on 36 GHz linearizing structure and waveguide network

Xiaowei Wu (CERN)



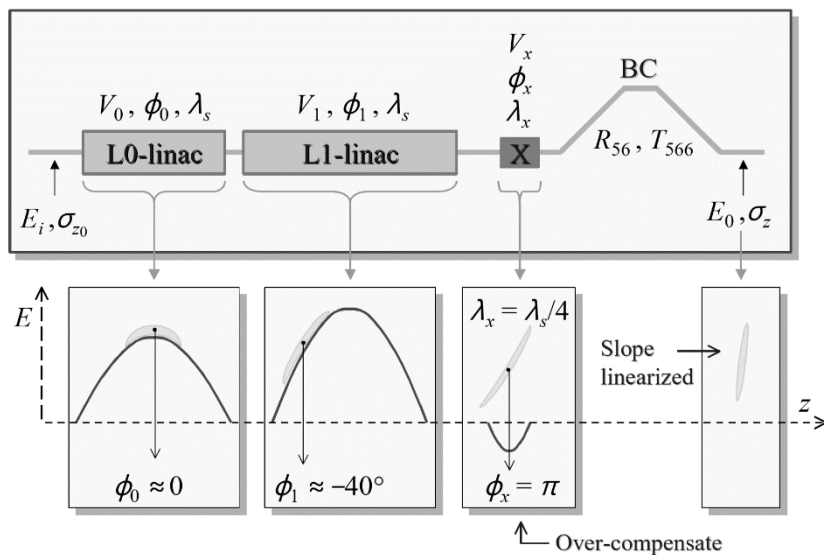
## Global view of Linearizer system

Detailed work to be done in collaboration with Lancaster University (Graeme Burt, Alejandro Castilla) in WorkPackage3

Early validation of the Gyroklystron parameters

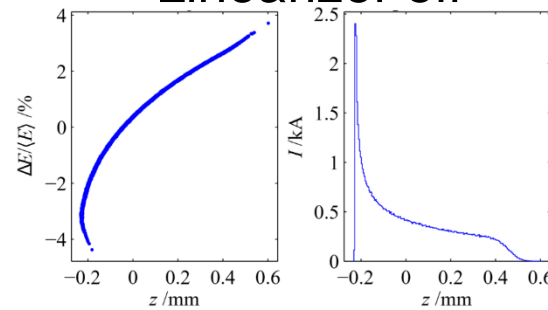
# Background of Linearizer

- Linearize the bunch compression process in XFEL by RF harmonic compensation
  - correct the longitudinal phase space non-linearity from harmonic RF
  - higher harmonics are more efficient for second-order compensation, decelerating the beam less

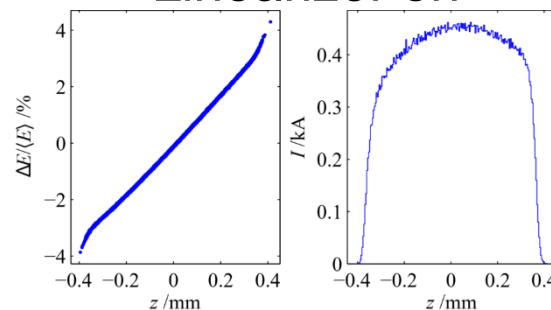


Emma, Paul. No. SLAC-TN-05-004. SLAC, Menlo Park, CA, 2005.

Linearizer off



Linearizer on



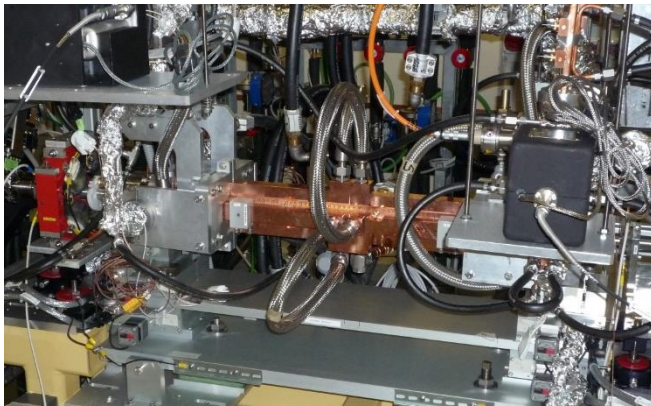
$$V \propto \left( \frac{f_a}{f_L} \right)^2$$

$f_a$  : Linac

$f_L$  : Linearizer

# X-band Linearizer has been well applied in XFEL facility

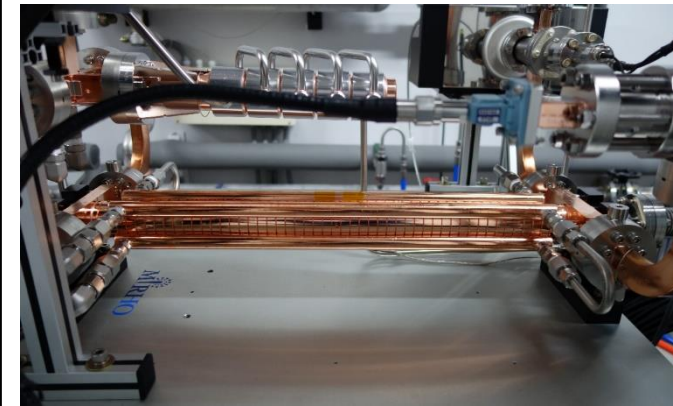
## ***FERMI@Elettra FEL***



## ***SXFEL@SINAP***



## ***PAL-XFEL@PAL***



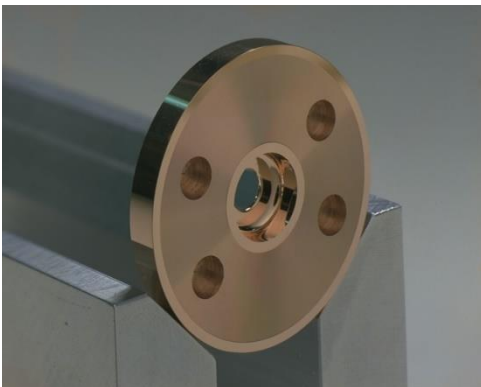
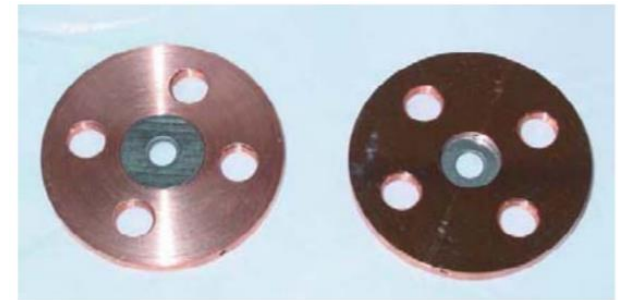
Proceeding of GdA CERN meeting, 2012.

Proceeding of 8th RADSYNCH, 2015.

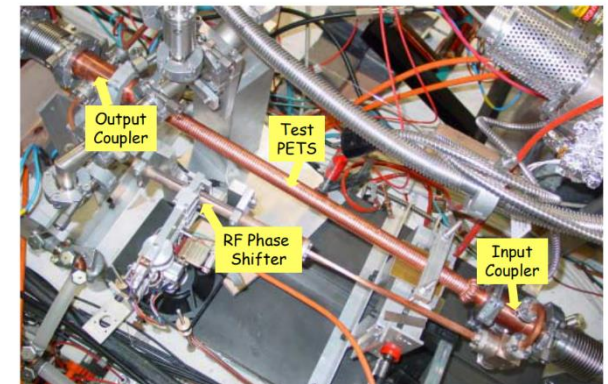


## Motivation of Ka-band Linearizer study at CERN

- Take advantage of extensive experience in CLIC with 30 GHz in the years preceding 2007
- 30 GHz CLIC accelerating structure
- 30 GHz PETS in CTF3
- SLEDII pulse compressor
- Over-moded transmission line
- Experience on many 30 GHz RF components....

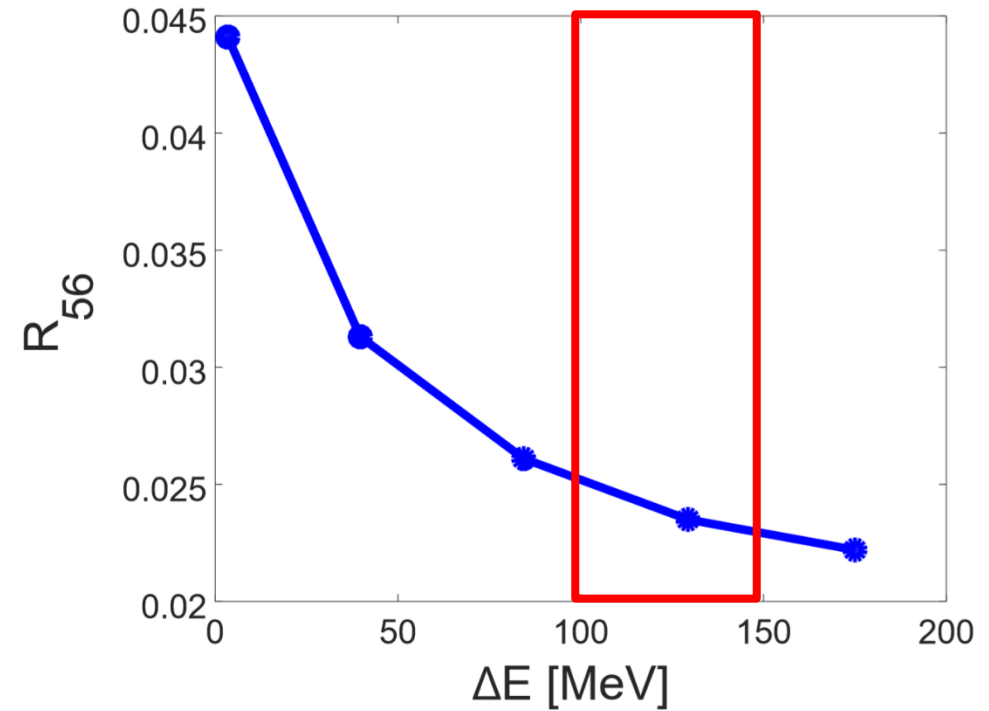
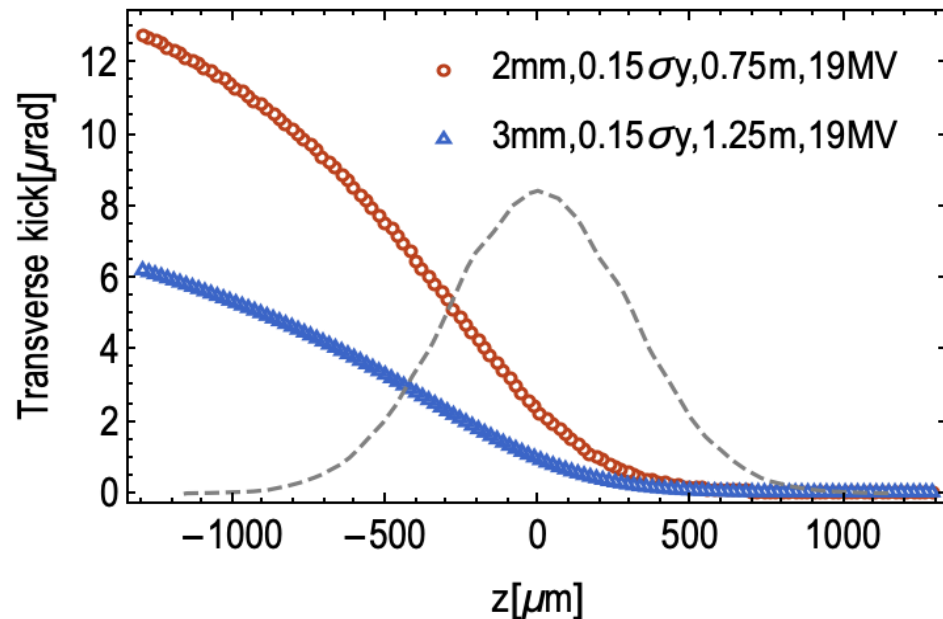


I. Syrathev, proceeding of LC2002.



Kuzikov, S. V., et al. Vol. 807. No. 1. AIP, 2006.

## Beam dynamic requirement



From WorkPackage6:

Suggested minimum aperture ~ 2mm

Maximum harmonic voltage ~ 20 MV

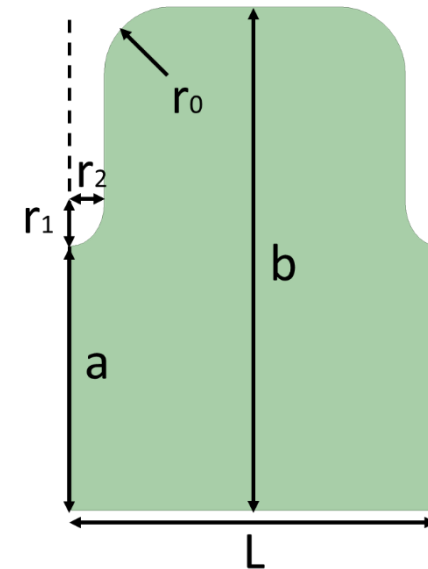
$$CSR \propto R_{56}^{\frac{3}{2}}$$

$$\frac{\Delta E}{(36/12)^2} \sim 20 \text{ MV}$$

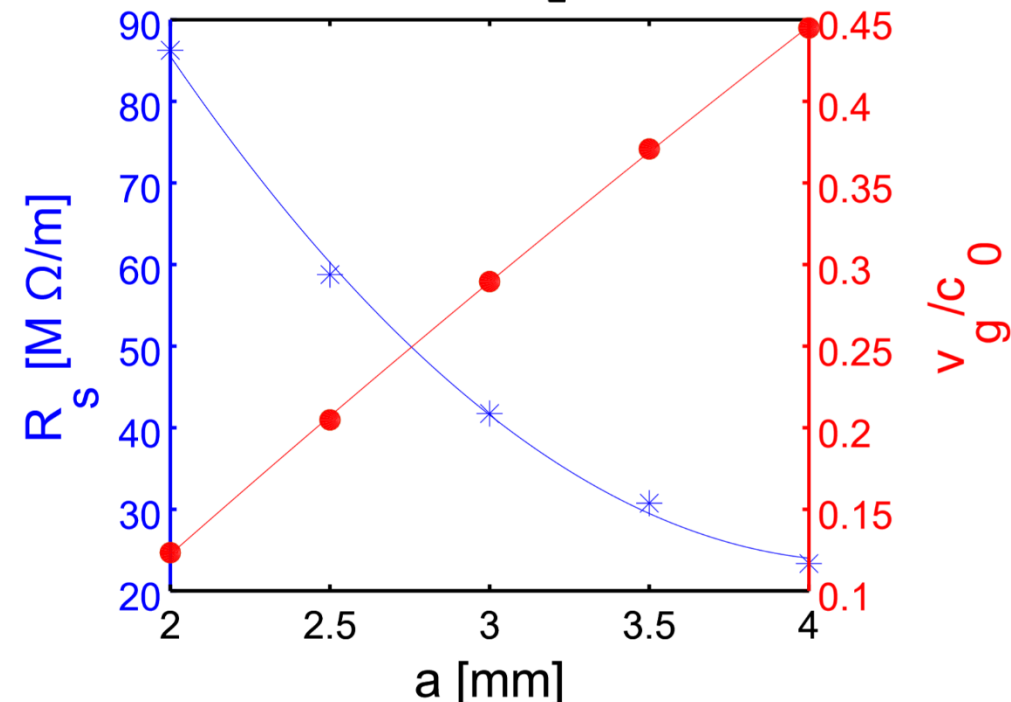
See it in Xingguang's presentation

# Structure analytical optimization

- Working at 36 GHz,  $2\pi/3$  mode
- Constant impedance structure
- Consistent with Lancaster's results

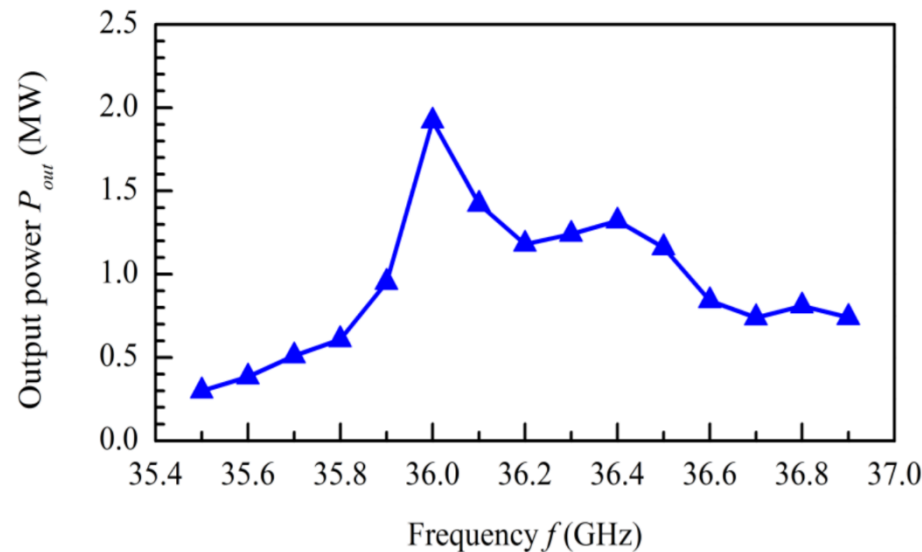


Geometrical parameters	
a [mm]	$\geq 2$
b [mm]	$\geq 3.8869$
L [mm]	2.778 ( $2\pi/3$ mode)
$r_0$ [mm]	0.8
t [mm]	0.6

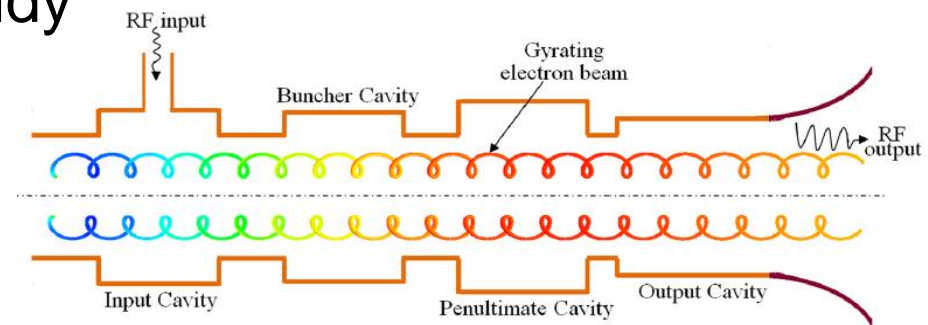


## Power source being developed by University of Strathclyde

- 36 GHz Gyroklystron model verified
  - over 2MW, pulse width 2  $\mu$ s, repetition rate 100 Hz
  - 260 kW output in the medium-power demonstration version
- 48 GHz Gyroklystron is under study
  - aim at 1.5MW output power



A. W. Cross, Proceeding of the first Midterm Review Meeting of CompactLight, 2018.



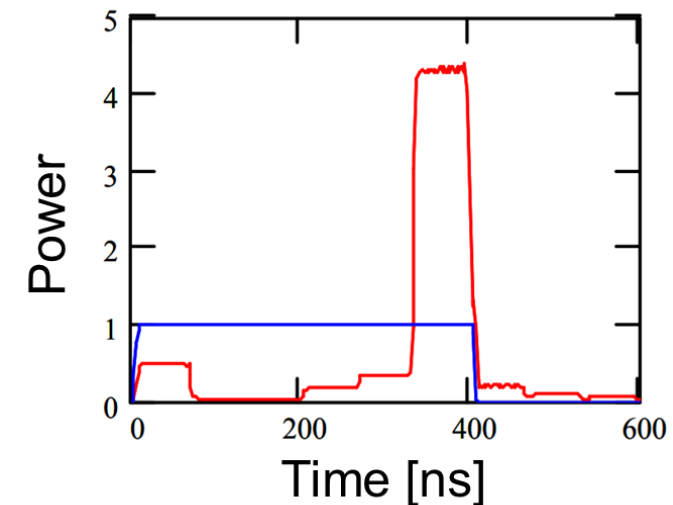
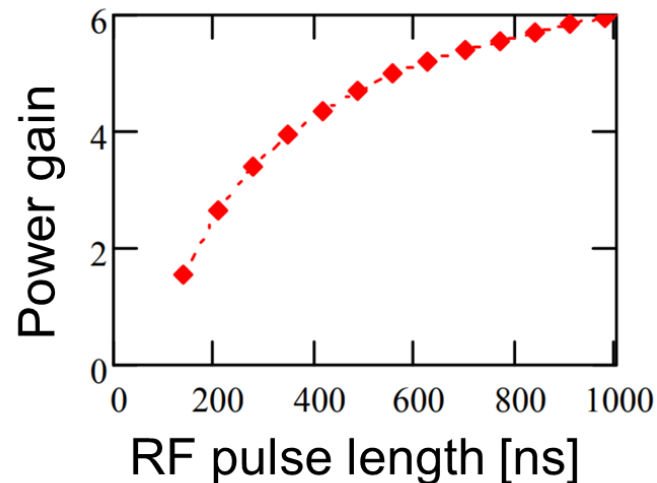
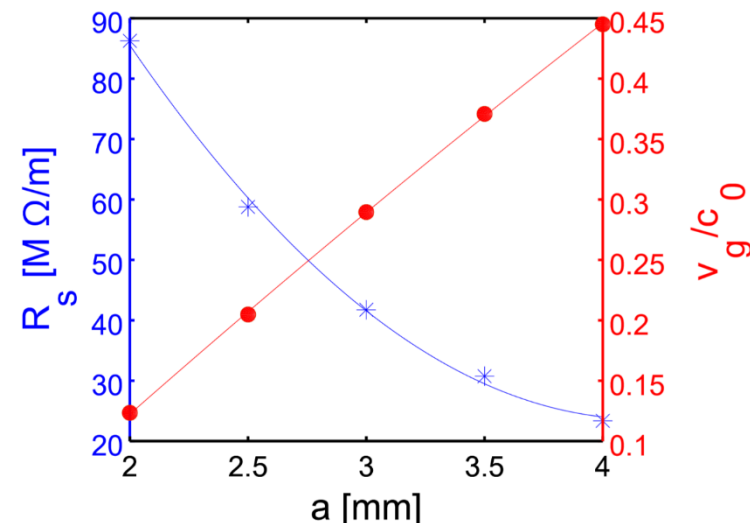
See it in Liang's presentation



# Pulse compression system

- SLEDII type
- Length  $\leq 5$  m for 1 meter Linearizer with  $v_g/c_0$  over 10%
- Power gain over 4
  - 8 MW input power is approximately available for the Linearizer
- More compact with multi-mode delay line
- BOC type/Sphere type?

SLED II at CTF3  
two 50 mm diameter TE01 delay lines



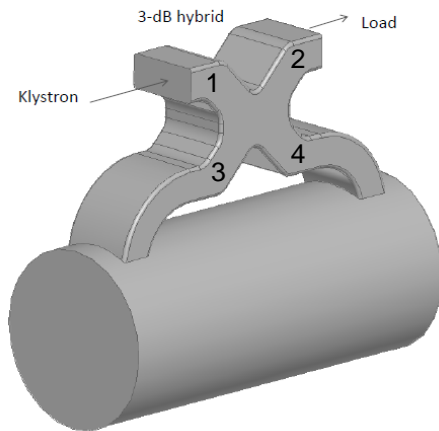
I, Syratcev. Proceeding of EPAC2006.

## Power Re-circulation Option

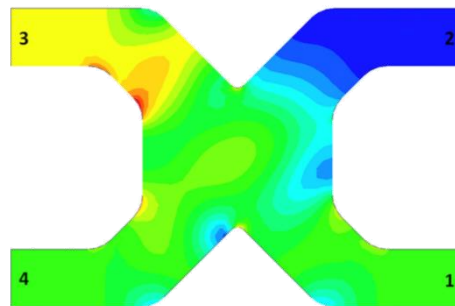
- Using hybrids to recirculate the RF power:
  - Relaxes the requirements on the load
  - Could effectively raise the structure's filling time.
  - Reduction of the input power needs is in function of the total power attenuation along the structure, i.e. it may be difficult in our case (see bottom right figure)

Recirculation has been proposed in the past

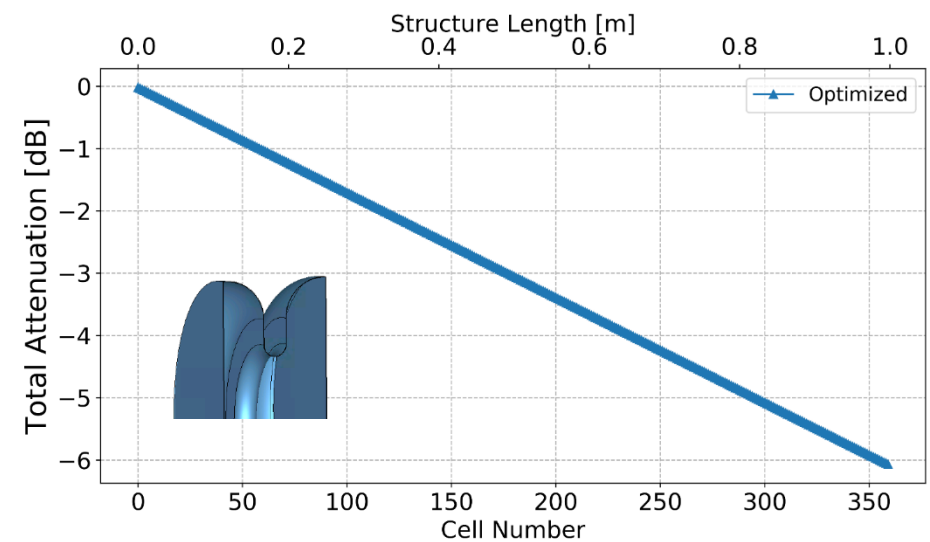
Accelerating structure with re-circulation network (for illustration only)



I. Syrathev - CERN



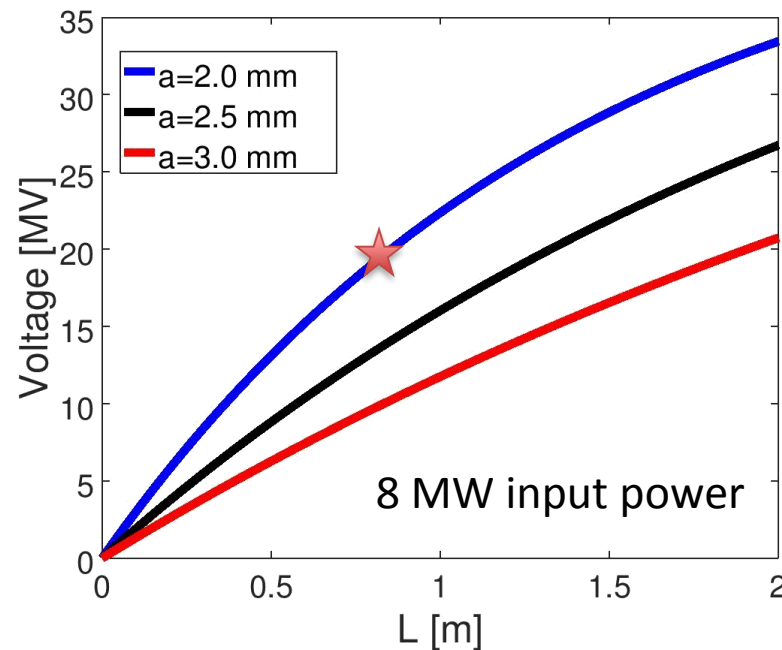
A. Grudiev - CERN



A. Castilla - ULANC

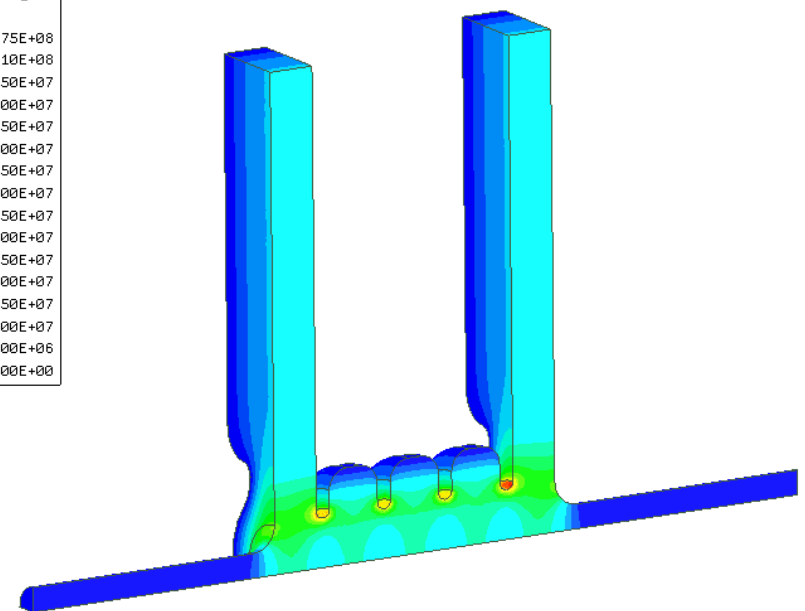
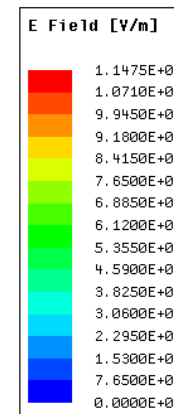
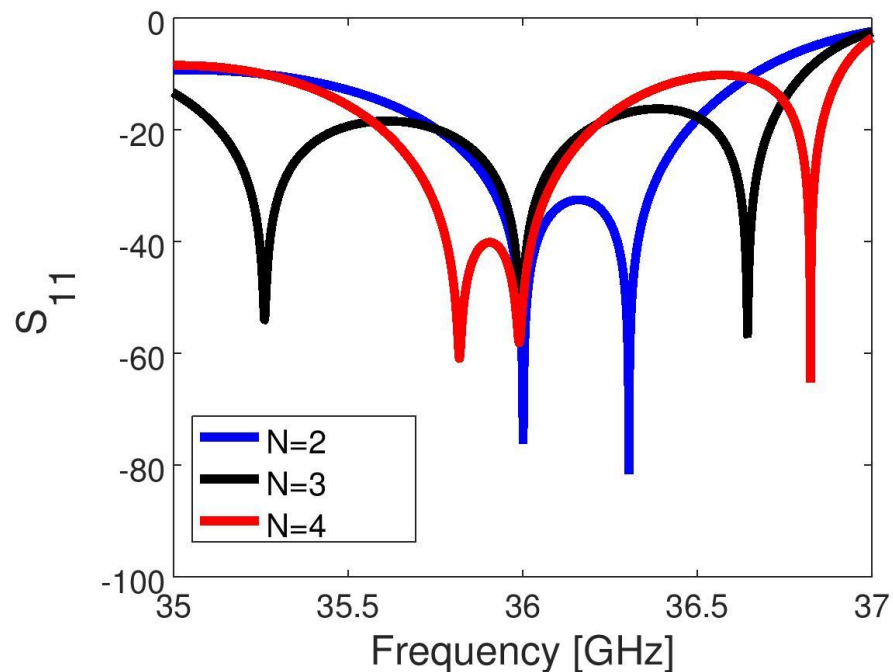
## Baseline solution

- 2.0 MW, 2  $\mu$ s power from Gyroklystron
- Power gain of 4 from 5 meter SLEDII pulse compressor
- 22.4 MV @ 8 MW input power for 1 meter Ka-band structure

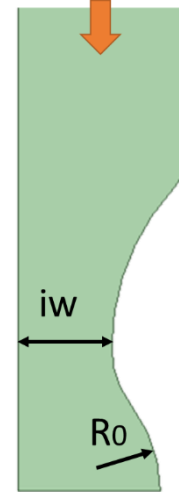


## Coupler design

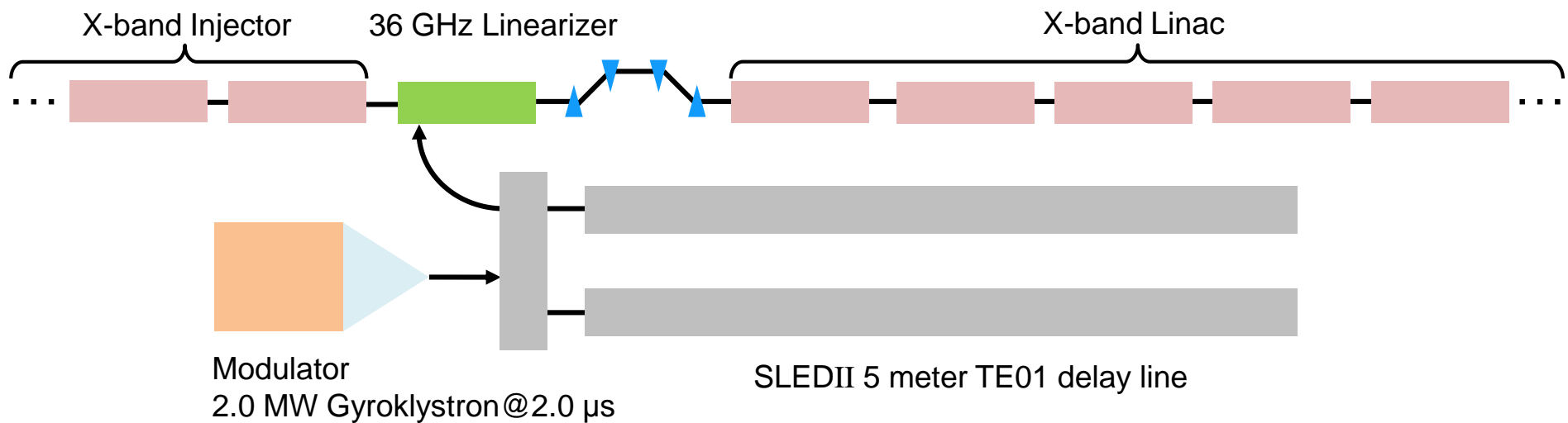
- Preliminary study of waveguide power coupler
- Double rectangular WR28 power port
- Mode converter components are needed to reduce the loss



Input power



## 36 GHz Linearizer system for full X-band XLS module layout

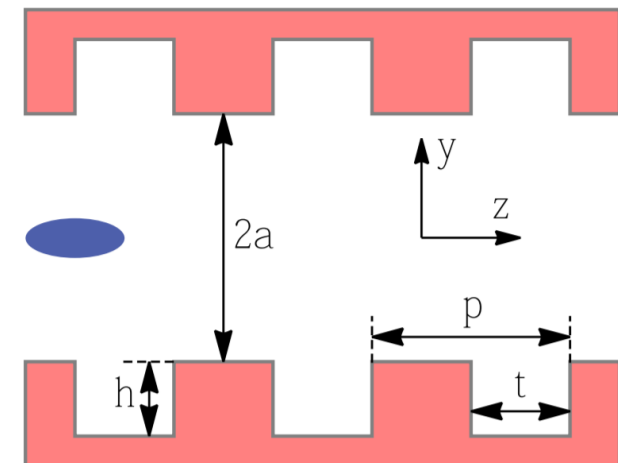
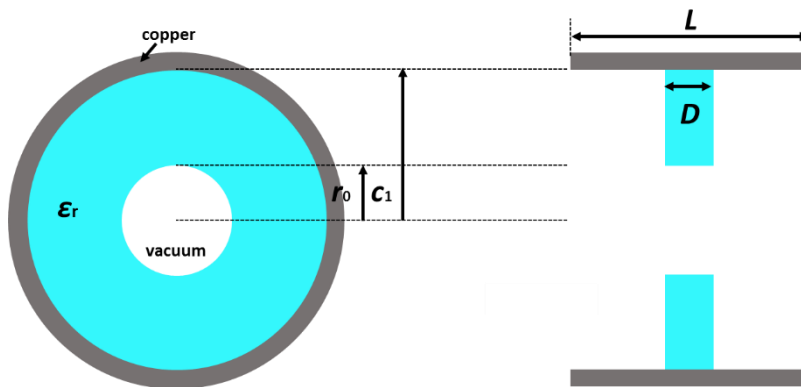


Power transfer system needs to be further studied



## Alternative solutions

- Many further ideas to be explored...
  - Dielectric accelerating structure
  - Standing-wave structure
  - 48 GHz Linearizer
  - Passive Linearizer





## Summary

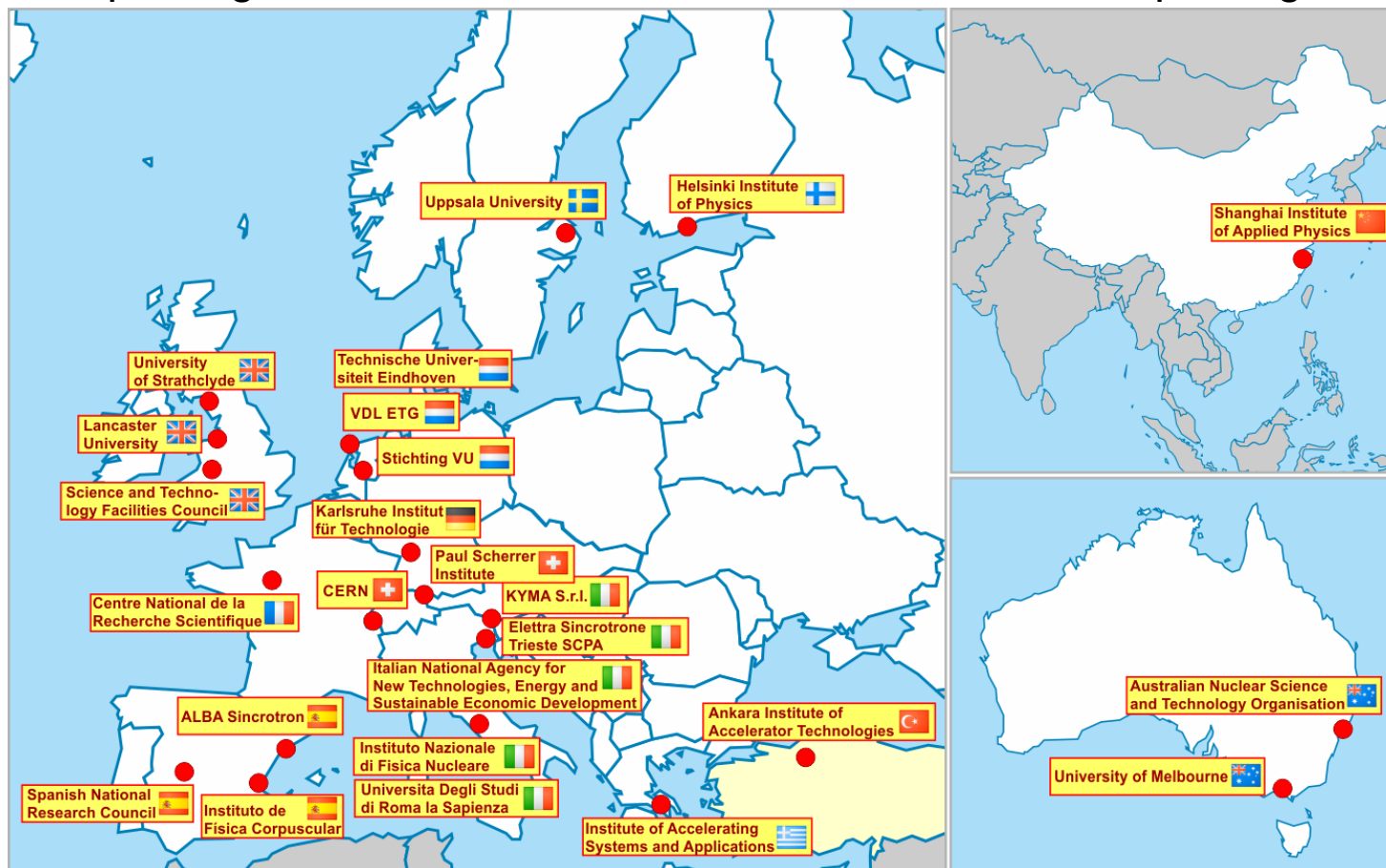
- Initial Ka-band study indicates that 36 GHz TW Linearizer system with 2 MW Gyroklystron and pulse compressor is feasible based on CLIC 30 GHz experience
- Much more details work will be done by the collaboration of Compact Light



# Thank you!

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