PkQl-like control for ACC6/7 at FLASH

Shin MICHIZONO
KEK

- Current Pk-Ql @ ACC6/7
- Gradient tilt expected at ACC6/7
- Proposal of Ql control for evaluation of PkQl control
- Expected cavity gradient

Default PkQl configuration

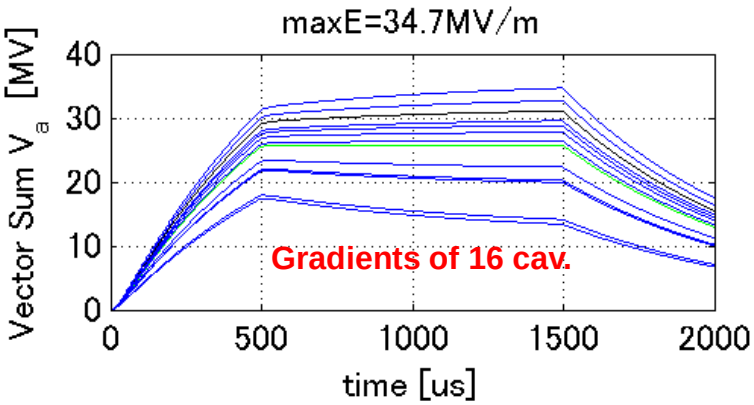
Waveguide Distribution for ACC6 and ACC7

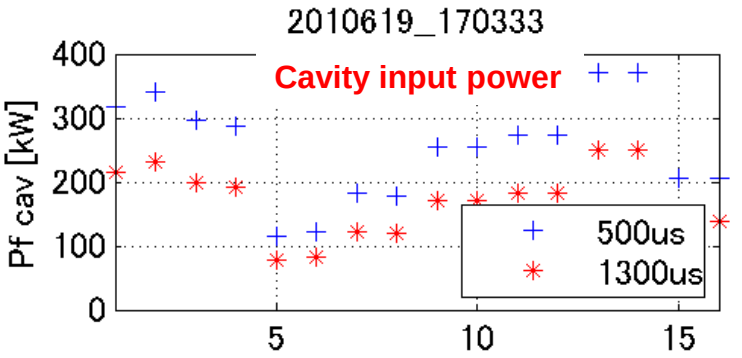
Klystron 4

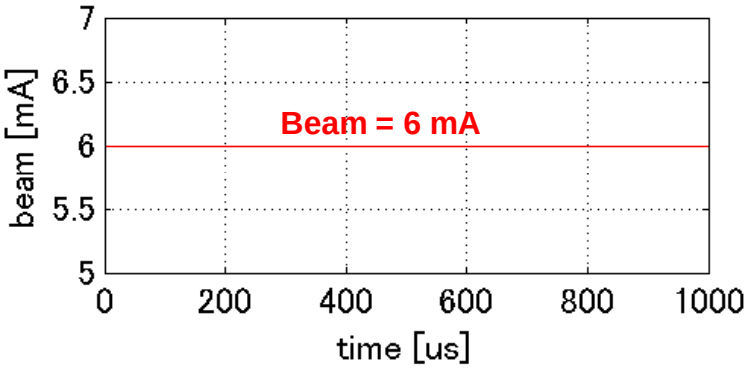
2010/2/5 V.Katalev

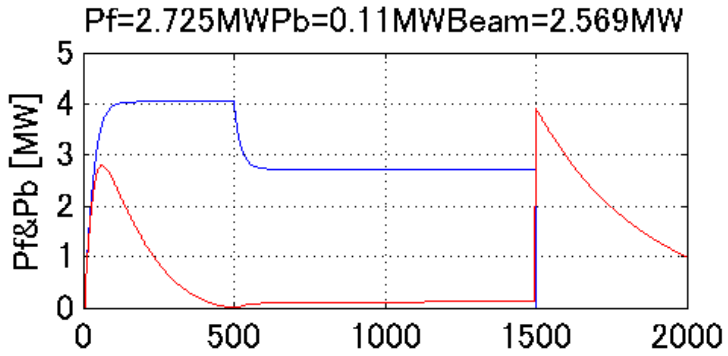
Eacc, MeV	434		Pkly_4	5.1	MW		without beam		Elinac	1347	Mev	
			15% waveguide losses + 10% circulator									
								Hybrid	(power divider)			
tinj, mks				P_ACC6, MW		P_ACC7, MW		S41, dB	S31, dB	S41*S41	S31*S31	
500				1.9		2.2		3.30	2.74	0.468	0.532	
		there are the editing data in green cells						Pcirc_max	370	Lcav =	1,038 m	
ACC6	24.8 MV/m			206 MeV			Max	238	Mev	?	32	
Pin, MW	1.91		RF power	OK								
Qext	2.95	2.97	3.00	2.98	3.00	2.98	2.99	2.98	2007/11/21			
A, dB	7.85	7.54	8.16	8.31	12.27	12.03	10.28	10.37	measured			
Pcav, kW	313.1	336.2	291.5	281.6	113.2	119.6	178.9	175.3		1809.4	99	
Ecav, MV/m	29.77	30.81	28.63	28.18	17.84	18.36	22.45	22.23		24.8	MV/m	
Ecav, max	34	32	34	32	21	21	29	26		28.6		
ΔE	4.2	1.2	5.4	3.8	3.2	2.6	6.6	3.8		Ecav max - Ecav		
	Cav 1	Cav 2	Cav 3	Cav 4	Cav 5	Cav 6	Cav 7	Cav 8				
ACC7	27.5 MV/m			228 MeV			Max	261	Mev	?	32	
Pin, MW	2.17		RF power	OK								
Qext	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00				
A, dB	9.38	9.38	9.08	9.08	7.74	7.74	10.32	10.32				
Pcav, kW	250.7	250.7	268.3	268.3	365.2	365.2	201.5	201.5		2171.6	0	
Ecav, MV/m	26.56	26.56	27.47	27.47	32.05	32.05	23.81	23.81		27.5	MV/m	
Ecav, max	29	31	34	30	35	39	27	26		31.4		
ΔE	2.4	4.4	6.5	2.5	3.0	7.0	3.2	2.2		Ecav max - Ecav		
	Cav 1	Cav 2	Cav 3	Cav 4	Cav 5	Cav 6	Cav 7	Cav 8				

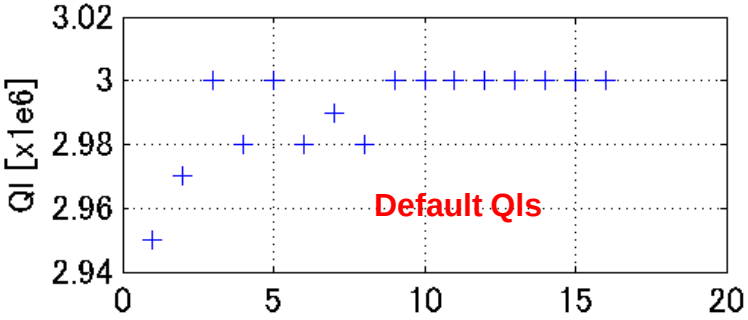
Default PkQl (6 mA beam)

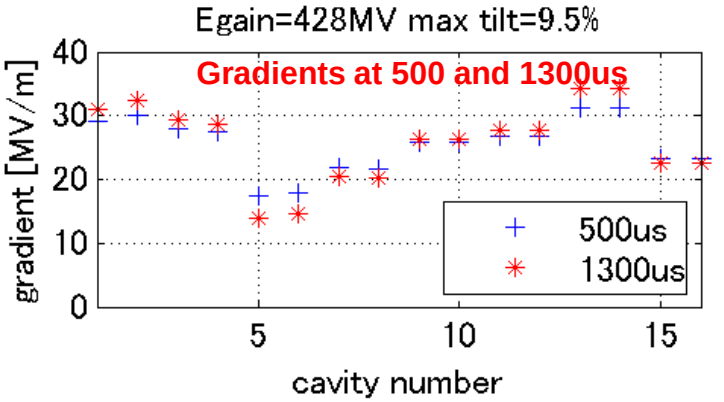












PkQl-like control

- In case of the Pk-Ql control near the quench limit condition, the values of Pks and Qls are calculated as followings.

1. Select operational gradient of each cavity (Vcav)
2. Find out the Pk and Ql of each cavity under the specific beam current (Ibeam) and injection timing (Tinj).

$$Igen - Ibeam \cdot \exp\left(\frac{T_{inj}}{\tau}\right)$$

$$V_{cav} = 2\frac{r}{Q} Q_L Igen \cdot \left(1 - \exp\left(-\frac{T_{inj}}{\tau}\right)\right)$$

$$\rightarrow \quad Pk = \frac{1}{4}\frac{r}{Q} Q_L (Igen)^2$$

- In case of FLASH, the Pks are not 'knob' (these are fixed.). Thus the Ql is the only free parameter. The selection of the cavity Ql is as followings.

1. Select the operational cavity input power (Pk)
2. Find out the Ql of each cavity under Ibeam and Tinj.
3. Check that the calculated cavity gradient is under the quench limit.

$$Pk = \frac{1}{4}\frac{r}{Q} Q_L (Igen)^2$$

$$Igen = Ibeam \cdot \exp\left(\frac{T_{inj}}{\tau}\right)$$

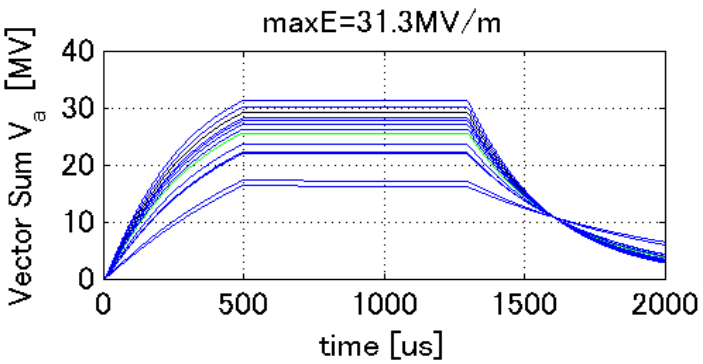
$$\rightarrow \quad V_{cav} = 2\frac{r}{Q} Q_L Igen \cdot \left(1 - \exp\left(-\frac{T_{inj}}{\tau}\right)\right)$$

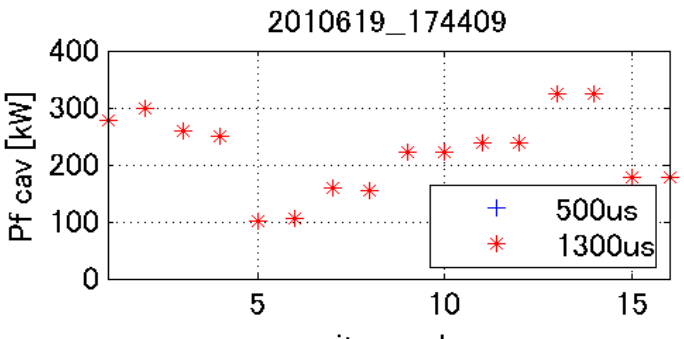
Optimization of Ql @ 6 mA

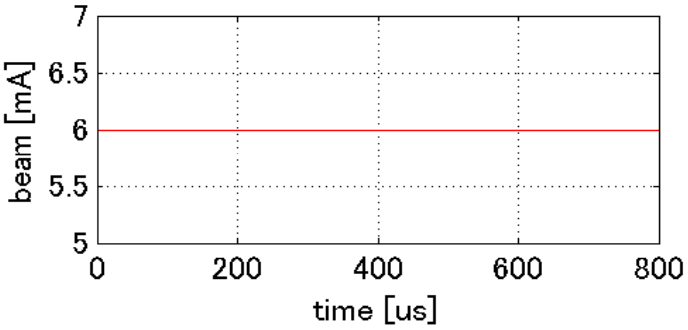
- Only Qls are optimized and Pks are unchanged.
- Qls are 1.1e6~2.75e6
- The rf output power is decreased 5% in order to decrease the operational gradient of ACC6 Cavity#2.

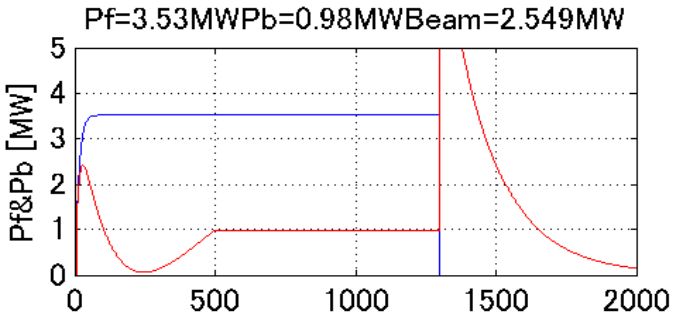
Eacc, MeV	445		Pkly_4	4.8	MW		without beam		Elinac	1358	Mev	
			15% waveguide losses + 10% circulator									
								Hybrid	(power divider)			
tinj, mks				P_ACC6, MW		P_ACC7, MW		S41, dB	S31, dB	S41*S41	S31*S31	
500				1.8		2.1		3.30	2.74	0.468	0.532	
		there are the editing data in green cells						Pcirc_max	370	Lcav =	1,038 m	
ACC6	25.3 MV/m			210 MeV			Max	238	Mev	?	28	
Pin, MW	1.81		RF power	OK								
Qext	1.27	1.23	1.31	1.33	3.13	2.73	1.74	1.74	2007/11/21			
A, dB	7.85	7.54	8.16	8.31	12.27	12.03	10.28	10.37	measured			
Pcav, kW	297.4	319.4	276.9	267.5	107.5	113.6	170.0	166.5		1718.9	94	
Ecav, MV/r	30.47	31.47	29.50	29.03	17.24	18.19	23.30	23.06		25.3	MV/m	
Ecav, max	34	32	34	32	21	21	29	26		28.6		
ΔE	3.5	0.5	4.5	3.0	3.8	2.8	5.7	2.9		Ecav max - Ecav		
	Cav 1	Cav 2	Cav 3	Cav 4	Cav 5	Cav 6	Cav 7	Cav 8				
ACC7	28.3 MV/m			235 MeV			Max	261	Mev	?	25	
Pin, MW	2.06		RF power	OK								
Qext	1.41	1.41	1.36	1.36	1.18	1.18	1.60	1.60				
A, dB	9.38	9.38	9.08	9.08	7.74	7.74	10.32	10.32				
Pcav, kW	238.2	238.2	254.9	254.9	347.0	347.0	191.5	191.5		2063.1	0	
Ecav, MV/r	27.50	27.50	28.38	28.38	32.65	32.65	24.75	24.75		28.3	MV/m	
Ecav, max	29	31	34	30	35	39	27	26		31.4		
ΔE	1.5	3.5	5.6	1.6	2.3	6.3	2.3	1.3		Ecav max - Ecav		
	Cav 1	Cav 2	Cav 3	Cav 4	Cav 5	Cav 6	Cav 7	Cav 8				

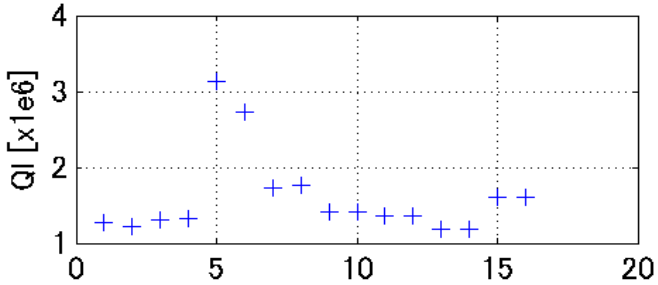
PkQl like (6 mA optimization)

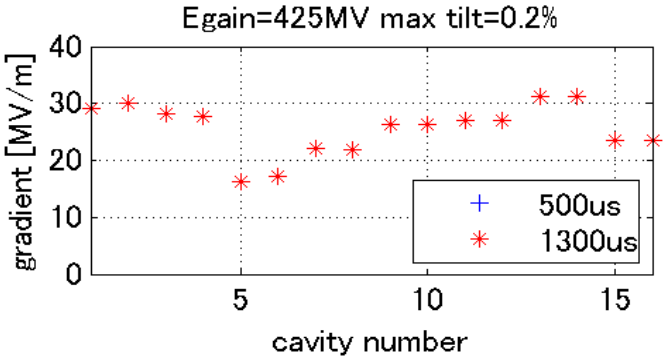




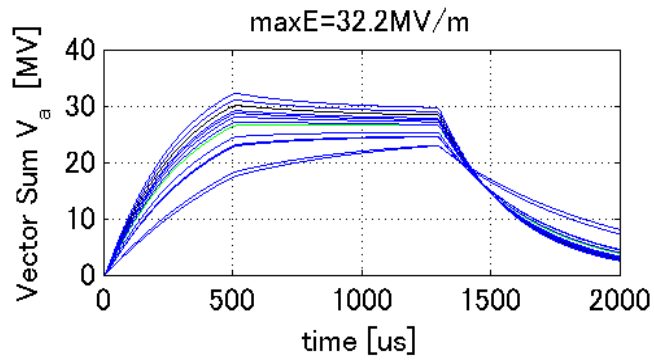


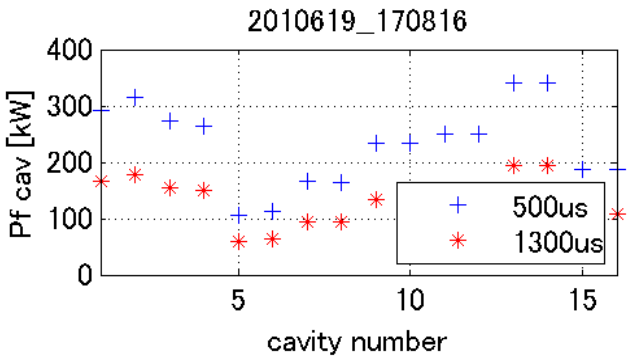


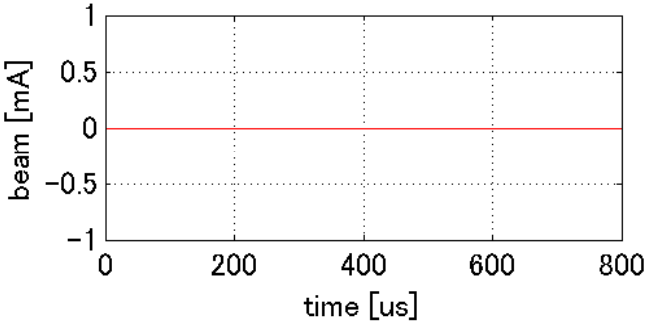


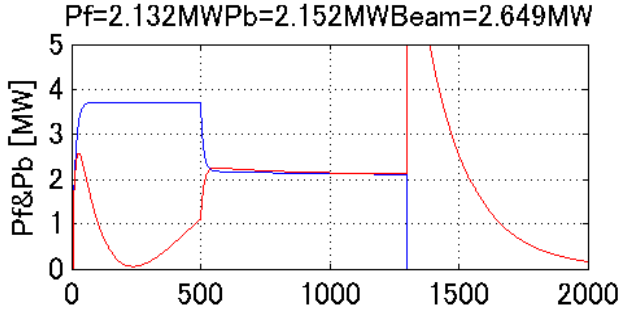


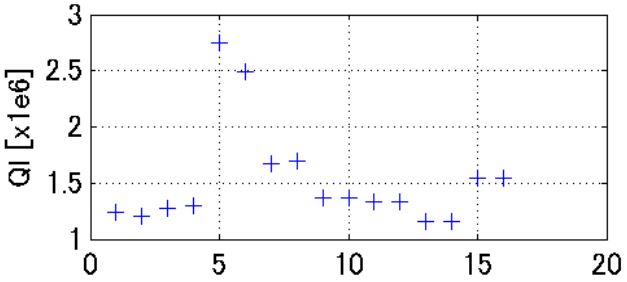
No beam (6 mA optimization)

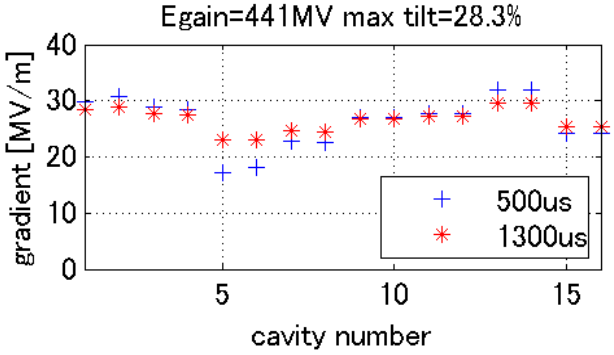












Summary

		Optimization	Beam	Cavity tilt
1	Default Ql,Pk	---	0 mA	3.5%*
2			3 mA	6.5%
3			6 mA	9.5%
4	PkQl like	3mA	3 mA	0%
5			0 mA	6.6%
6		6mA	6 mA	0%
7			0 mA	28.3%

*due to the variation of Qls at default Ql configuration.

Thank you for your attention.

Backup: 3 mA optimization

Waveguide Distribution for ACC6 and ACC7

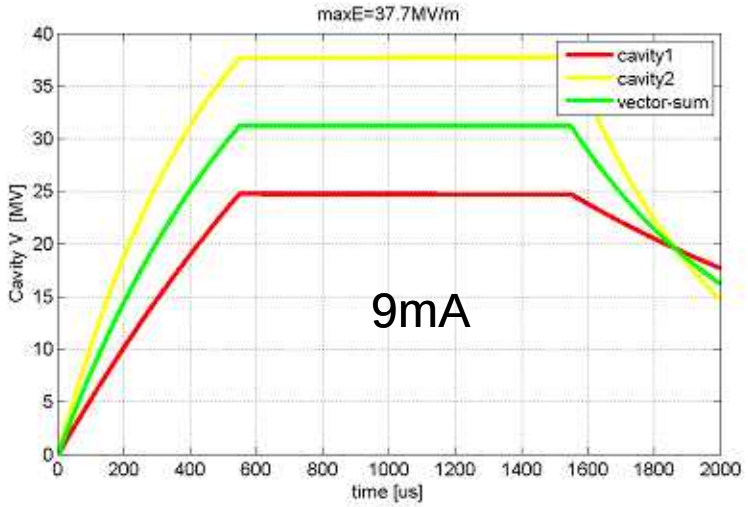
Klystron 4

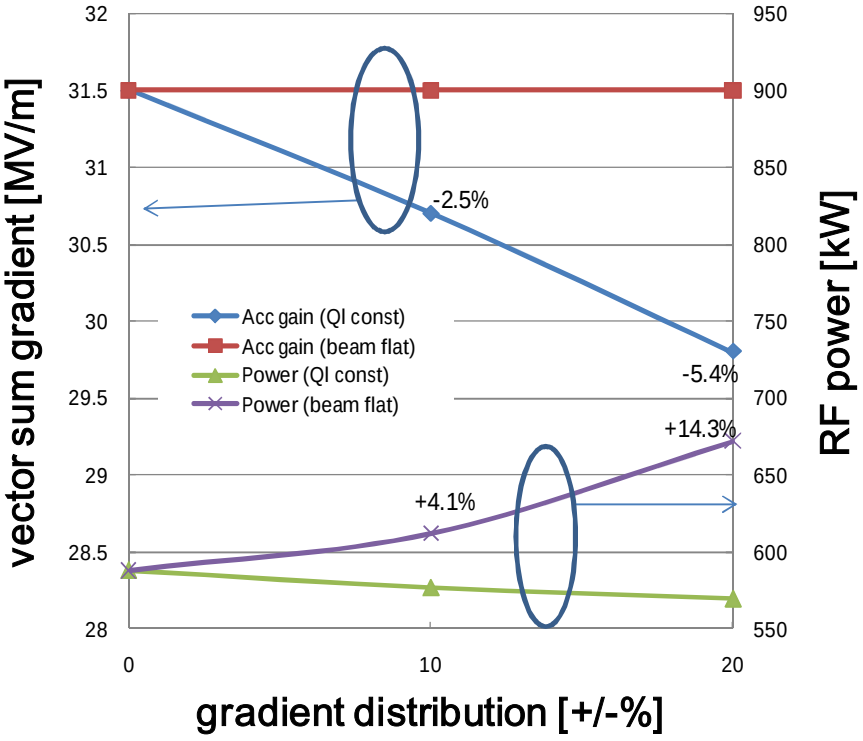
2010/2/5 *V.Kataley*

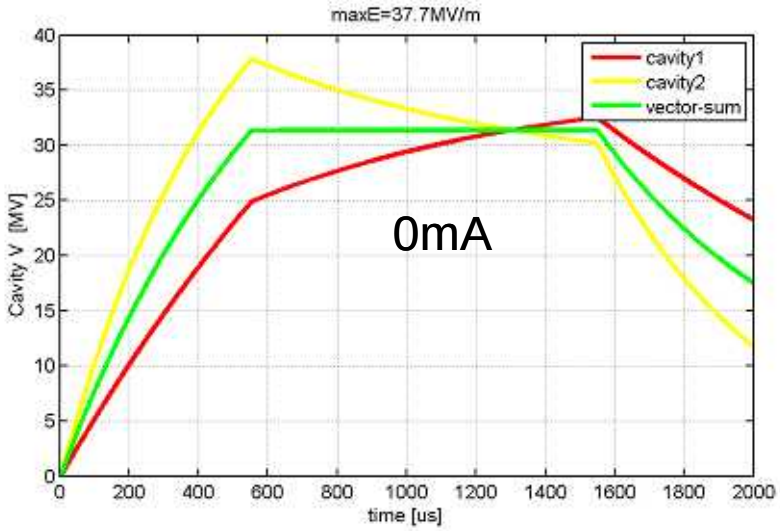
Eacc, MeV	**424**		Pkly_4	**5.1**	MW		without beam		E*linac*	**1337**	*Mev*
			15% waveguide losses + 10% circulator								
								Hybrid	(power divider)		
tinj, mks				P_ACC6, MW		P_ACC7, MW		S41, dB	S31, dB	S41*S41	S31*S31
500				**1.9**		**2.2**		**3.30**	2.74	0.468	0.532
		there are the editing data in green cells						Pcirc_max	370	Lcav =	1,038 m

ACC6	**24.4** MV/m			**202** MeV			Max	238	Mev	?	35
Pin, MW	**1.91**		RF power	OK							
Qext	0.80	0.78	0.81	0.82	1.07	1.05	0.92	0.93	2007/11/21		
A, dB	7.85	7.54	8.16	8.31	12.27	12.03	10.28	10.37	*measured*		
Pcav, kW	313.1	336.2	291.5	281.6	113.2	119.6	178.9	175.3		1809.4	99
Ecav, MV/m	28.58	29.47	27.72	27.31	18.38	18.83	22.45	22.25		24.4	MV/m
Ecav, max	34	32	34	32	21	21	29	26		28.6	
ΔE	5.4	2.5	6.3	4.7	2.6	2.2	6.6	3.8		*Ecav max - Ecav*	
	Cav 1	*Cav 2*	*Cav 3*	*Cav 4*	*Cav 5*	*Cav 6*	*Cav 7*	*Cav 8*			

ACC7	**26.7** MV/m			**222** MeV			Max	261	Mev	?	39
Pin, MW	**2.17**		RF power	OK							
Qext	0.84	0.84	0.83	0.83	0.77	0.77	0.89	0.89			
A, dB	9.38	9.38	9.08	9.08	7.74	7.74	10.32	10.32			
Pcav, kW	250.7	250.7	268.3	268.3	365.2	365.2	201.5	201.5		2171.6	0
Ecav, MV/m	25.96	25.98	26.75	26.75	30.54	30.54	23.64	23.64		26.7	MV/m
Ecav, max	29	31	34	30	35	39	27	26		31.4	
ΔE	3.0	5.0	7.3	3.3	4.5	8.5	3.4	2.4		*Ecav max - Ecav*	
	Cav 1	*Cav 2*	*Cav 3*	*Cav 4*	*Cav 5*	*Cav 6*	*Cav 7*	*Cav 8*			







- If different gradient cavities are driven by a klystron, we need more power to operate them (~14% if operate 25&38MV/m cav.)
- In addition, flatness is only guaranteed when operated the certain beam current.