



Austrian Electrotechnical Association

A background graphic on the left side of the slide shows a globe with a grid of latitude and longitude lines. The globe is rendered in a light, semi-transparent style. Behind the globe, there are faint, stylized representations of circuit boards and electronic components, suggesting a technical or electrical theme. The overall background is a light, hazy gradient.

LIGHTNING Parameters

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- How can we measure lightning parameters?
- Lightning current measurement at Gaisberg tower
- Lightning current parameters inferred from LLS



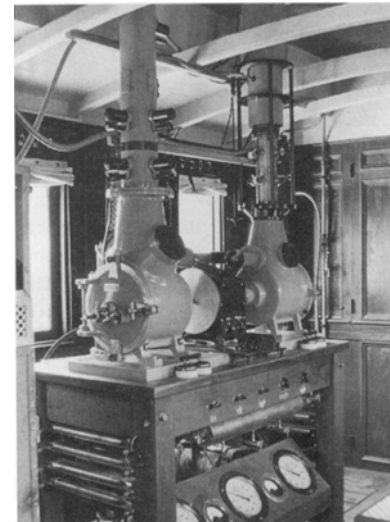
Available Sources for Lightning Parameters



METHOD	TOWER MEASUREMENTS	TRIGGERED LIGHTNING	LIGHTNING LOCATION
PLUS	direct current measurement on natural lightning	direct current measurement correlated measurements of currents, fields, optical properties etc. relatively easy	huge amount of data large scale coverage of lightning activity
MINUS	only few events per year tower effects majority of discharges upward initiated local parameters	NO First Stroke similarity of natural subsequent strokes and triggered strokes is questionable local parameters	peak current is inferred from peak fields measured peak fields are affected by ground conductivity, V_{RS} , sensor bandwidth, etc. peak I versus peak E correlation is unknown for pos. lightning



**Two instrumented towers
1943 – 1972 (29 years !!!)
101 neg. CG first strokes
135 neg. subsequent strokes**

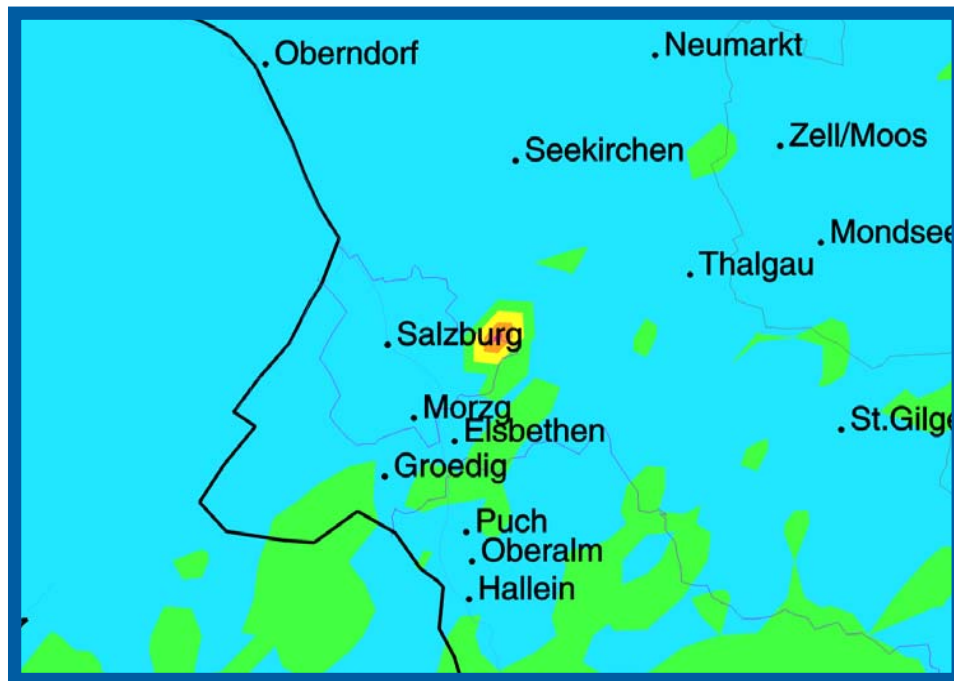


Number of events	Parameters	Unit	Percentage of cases exceeding tabulated value		
			95 %	50 %	5 %
Peak current (>2 kA)					
101	Negative first strokes	kA	14	30	80
135	Negative subsequent strokes	kA	4,6	12	30
26	Positive first strokes	kA	4,6	35	250
Charge					
93	Negative first strokes	C	1,3	7,5	40
122	Negative subsequent strokes	C	0,2	1,4	11
26	Positive flashes	C	20	80	350
Front duration (2 kA tp peak)					
89	Negative first strokes	μ s	1,8	5,5	18
118	Negative subsequent strokes	μ s	0,22	1,1	4,5
19	Positive first strokes	μ s	3,5	22	200
Integral ($i^2 \cdot dt$)					
91	Negative first strokes	A ² s	6.000	55.000	550.000
88	Negative subsequent strokes	A ² s	550	6.000	52.000
26	Positive first strokes	A ² s	25.000	650.000	15*10 ⁶
Maximum di/dt					
92	Negative first strokes	kA/ μ s	5,5	12	32
122	Negative subsequent strokes	kA/ μ s	12	40	120
21	Positive first strokes	kA/ μ s	0,2	2,4	32

Adapted from Berger et al. (1975)

First short stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	200	150	100	
Short stroke charge	Q_{short}	C	100	75	50	
Specific energy	W/R	MJ/ Ω	10	5,6	2,5	
Time parameters	T_1/T_2	$\mu s/\mu s$	10 / 350			
Subsequent short stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	50	37,5	25	
Average steepness	di/dt	kA/ μs	200	150	100	
Time parameters	T_1/T_2	$\mu s/\mu s$	0,25 / 100			
Long stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Long stroke charge	Q_{long}	C	200	150	100	
Time parameter	T_{long}	s	0,5			
Flash			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Flash charge	Q_{flash}	C	300	225	150	

- Introduction
- Instrumentation
- Data analysis
- Measured data versus LLS data



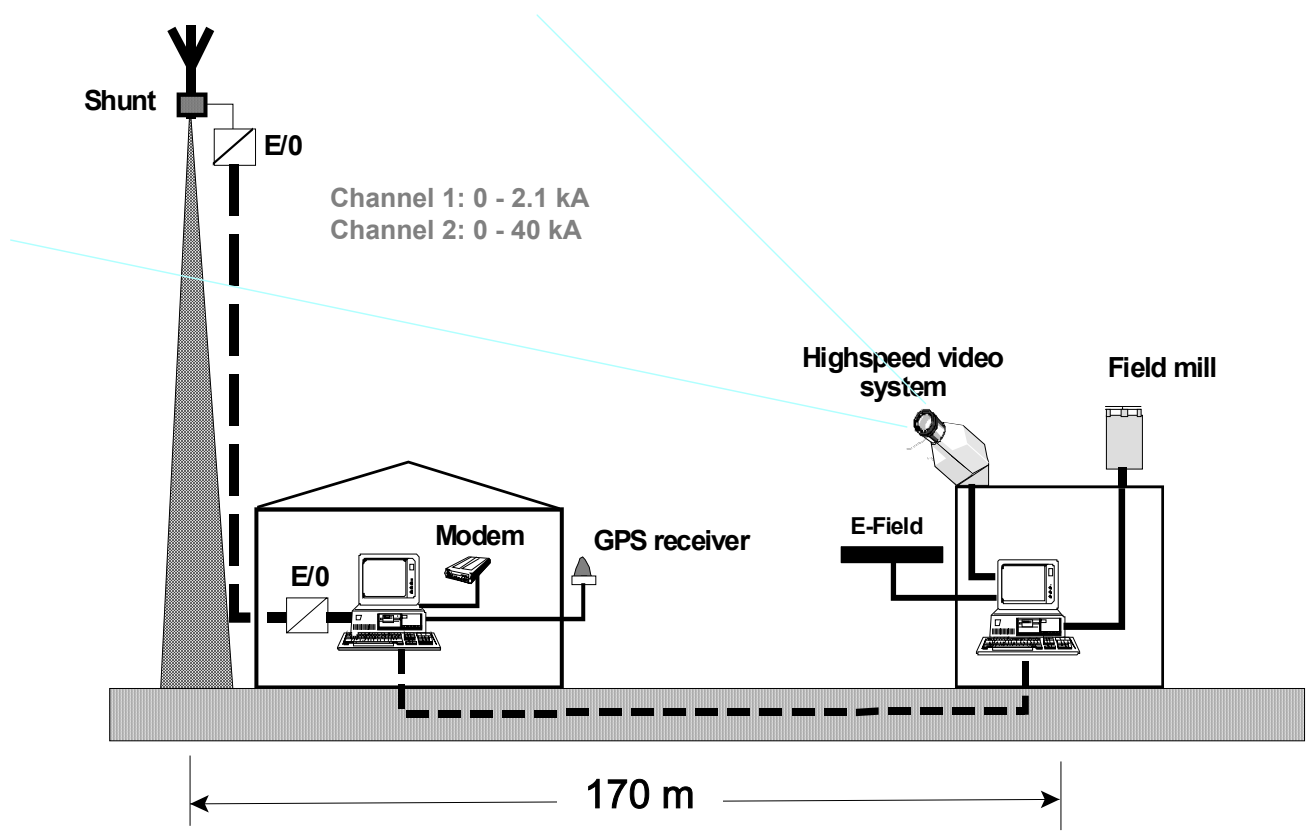
**Flashes/km².year
1992-2001**











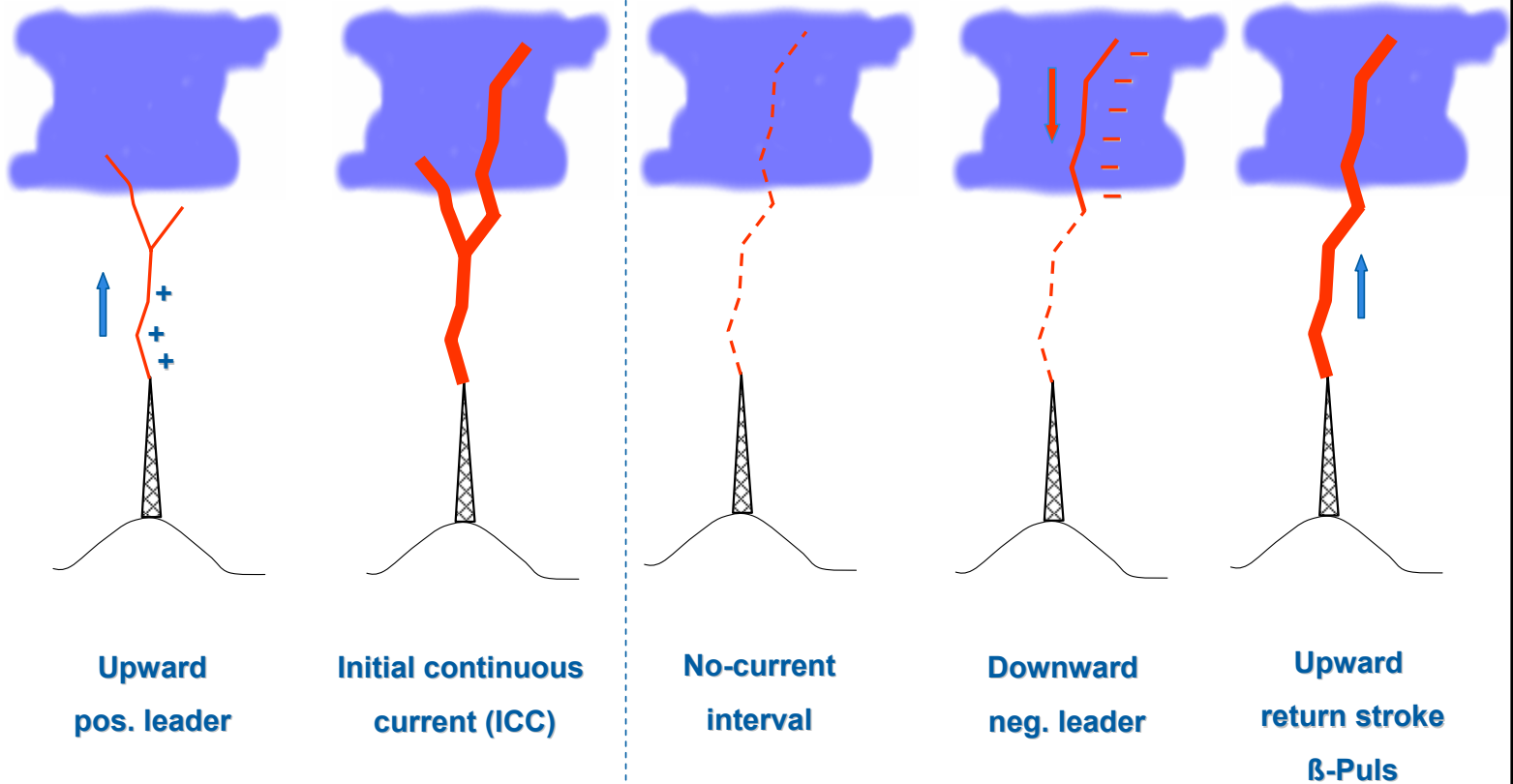
- 0,25 mΩ Shunt
- 2 Channel 8 bit digitizer
 - CH 0: 0 kA 2 kA
 - CH 1: 0 kA ... 40 kA
- Sampling Rate 20 MS/s (50ns Time resolution)
- Total record length 800 milliseconds
- Pretrigger Period 15 milliseconds
- Trigger Threshold 200 A

- Offset Correction for proper measurement of total charge (based on pre-trigger record)
- 250 kHz filter (Butterworth 2nd order) for Noise Reduction
- Q_{tot} , W/R of flash
- I_p , Q_{stroke} of each stroke
- Search for correlated ALDIS data (flash, stroke, sensor data)

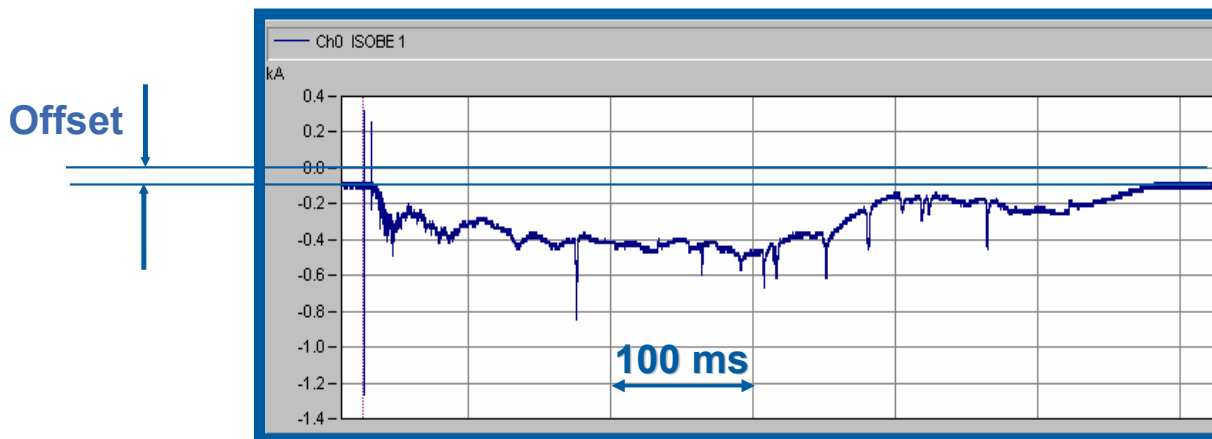
OVE

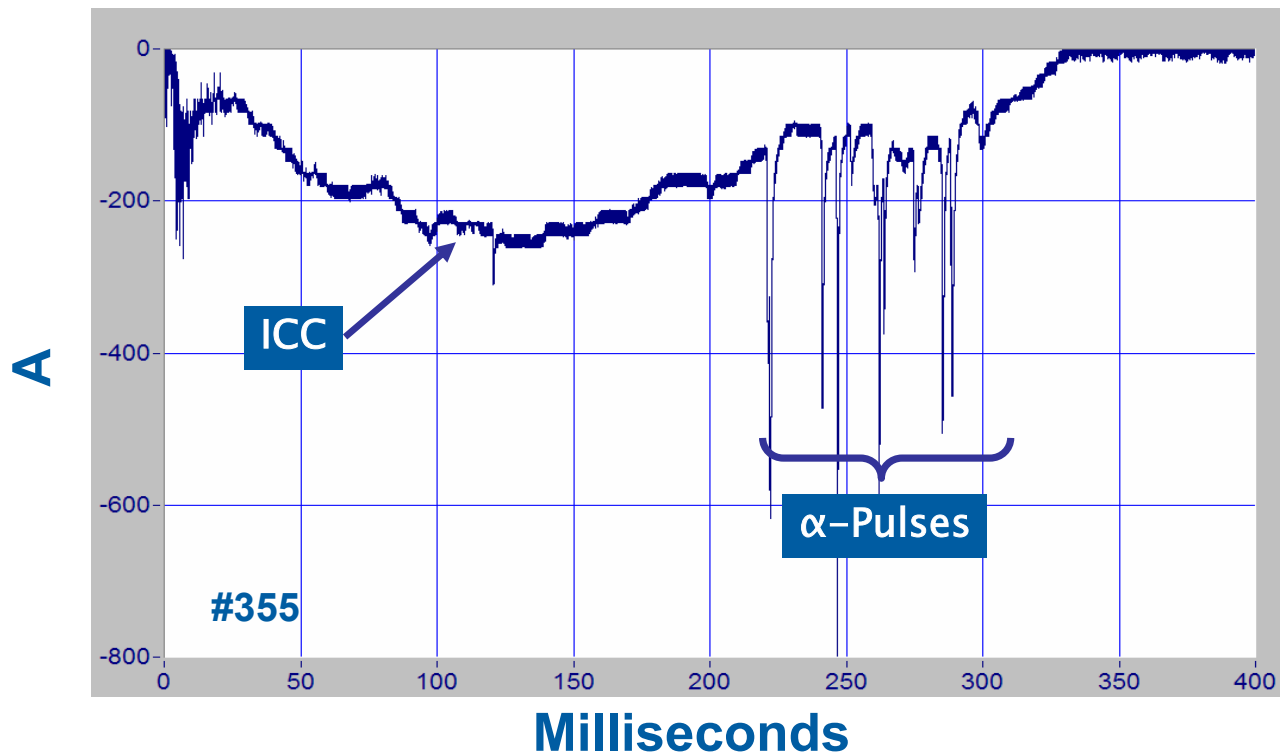
Tower triggered lightning

ALDIS

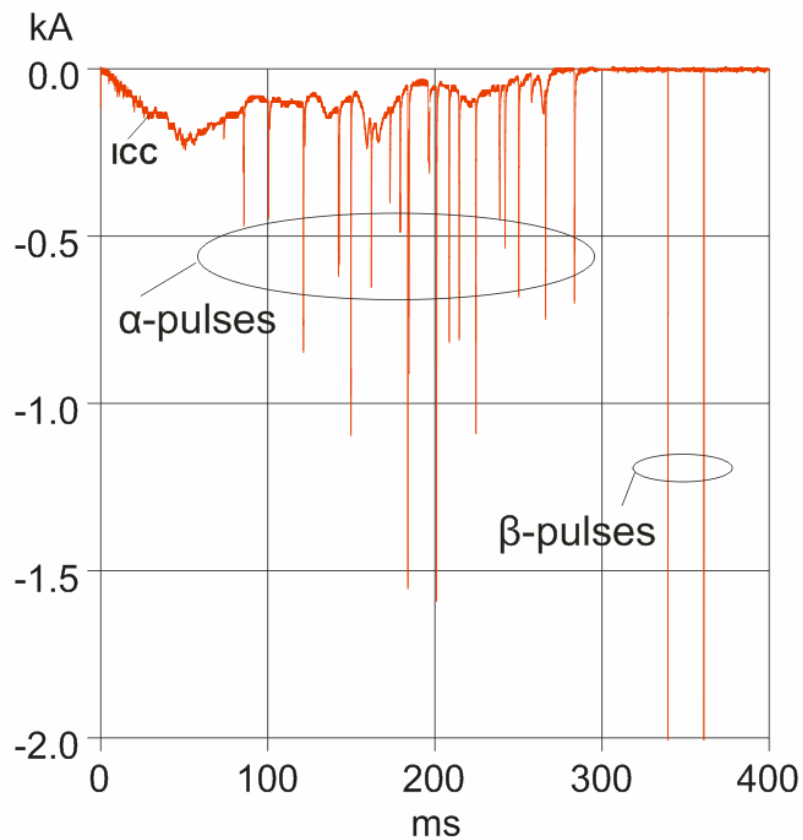


- Initial Continuing Current (ICC) without any pronounced pulses superimposed on the ICC or following the ICC (before offset correction)

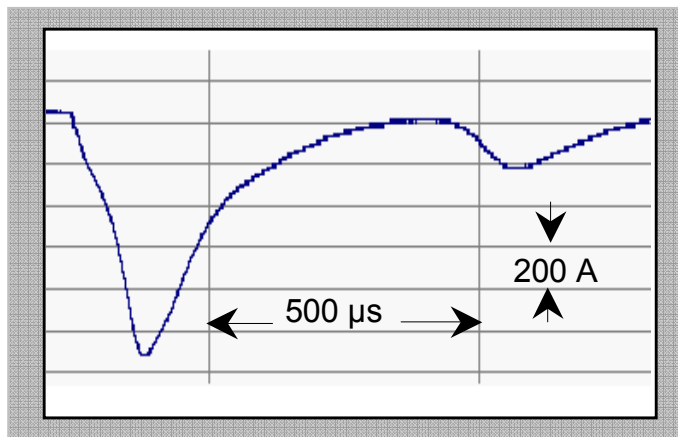




Initial Continuing Current (ICC)
with α -Pulses and followed by β -Pulses



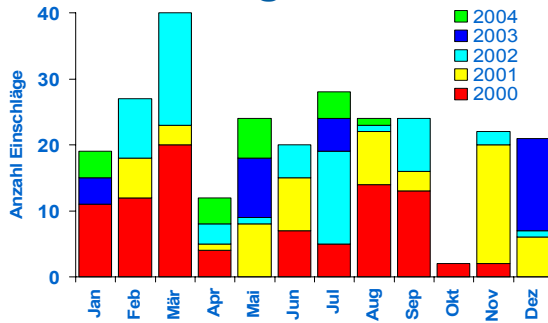
α -Pulse



β -Pulse
(similar to subsequent strokes)

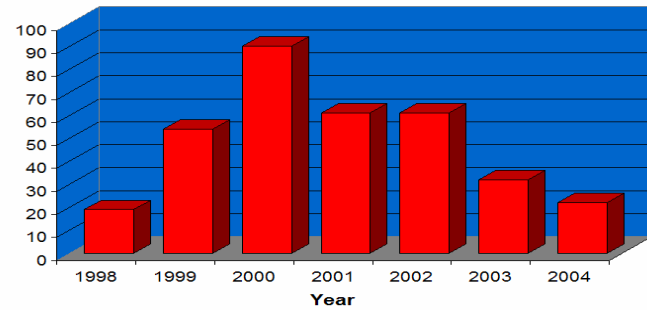


Gaisberg

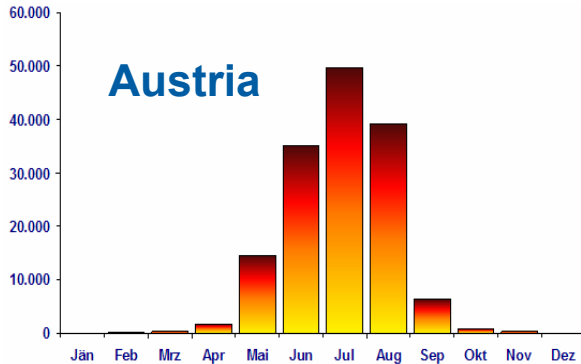


Gaisberg

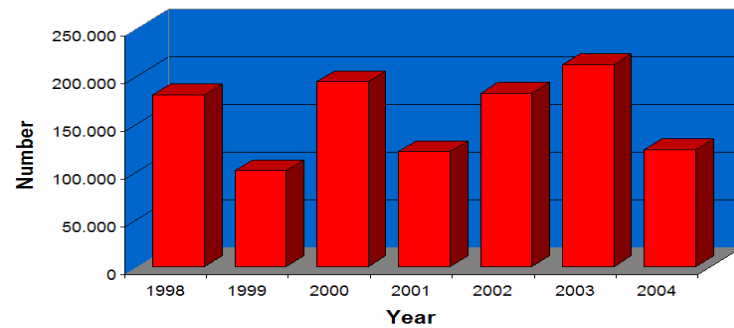
Number of recorded flashes per year



Austria



Austria Flashes in Austria

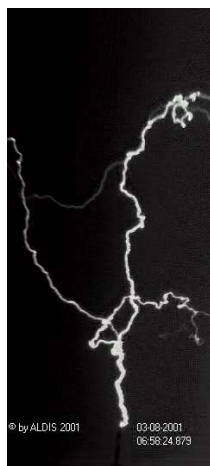
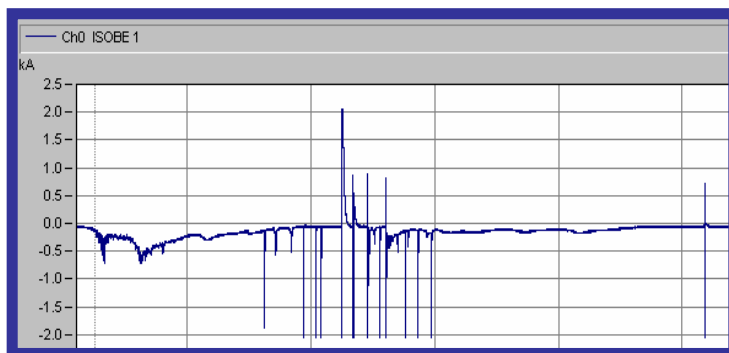




High Speed Video System

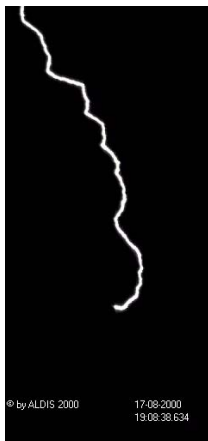
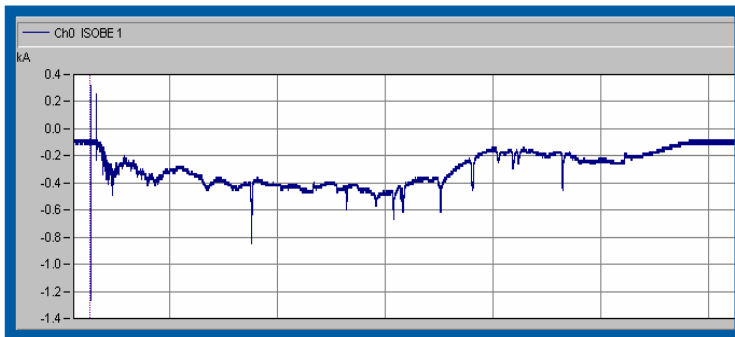


- **UP TO 1000 FRAMES/SEC (BMP FORMAT)**
 - OPERATED IN 500 fps MODE
- **RESOLUTION: 512 x 240 PIXEL**
- **8 BIT GRAY VALUES (0 ... BLACK, 255 ... WHITE)**
- **CAMERA IS TRIGGERED BY THE TOWER CURRENT SIGNAL**



$I_{\max} = 20 \text{ kA}$
 $Q_{\text{tot}} = 129 \text{ As}$
 14 Pulses

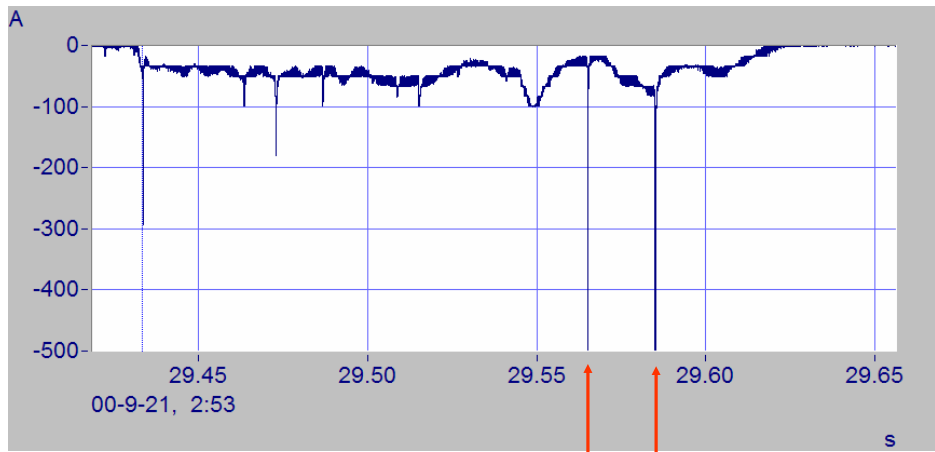




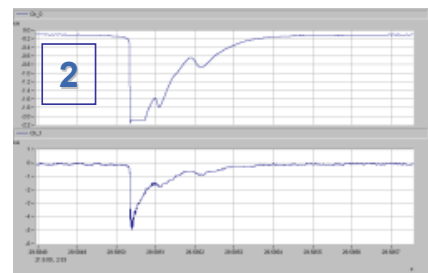
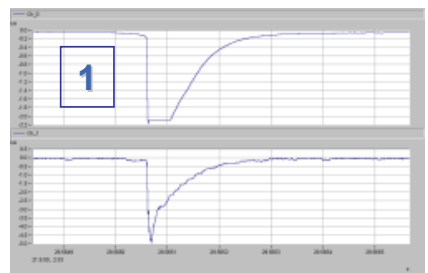
$$I_{\max} = 0,5 \text{ kA}$$

$$Q_{\text{ges}} = 118 \text{ As}$$





1 2



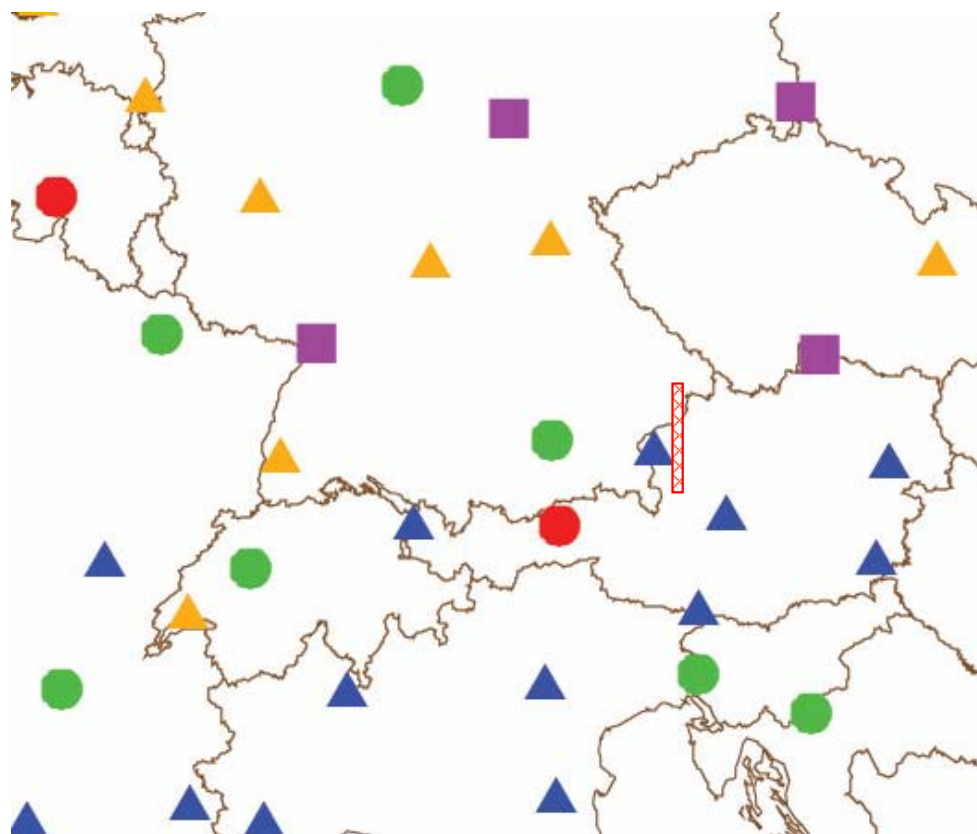




123 Sensors (Dec 2005)

- IMPACT 181T
- IMPACT ES
- IMPACT ESP
- LPATS III
- LPATS IV
- LS 7000

www.euclid.at



Type of sensor:

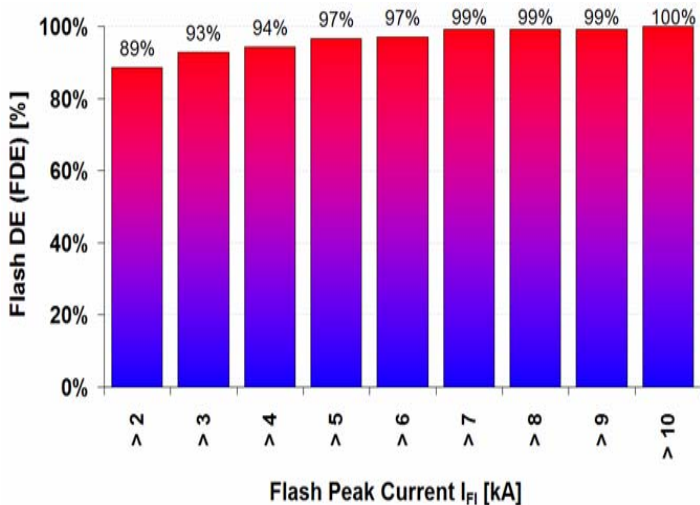
- ▲ IMPACT
- IMPACT ES
- IMPACT ESP
- LPATS 3
- ▲ LPATS 4

- Flash Detection Efficiency
 - Only a fraction of flashes to the tower include a downward leader – return stroke sequence (β -pulse)

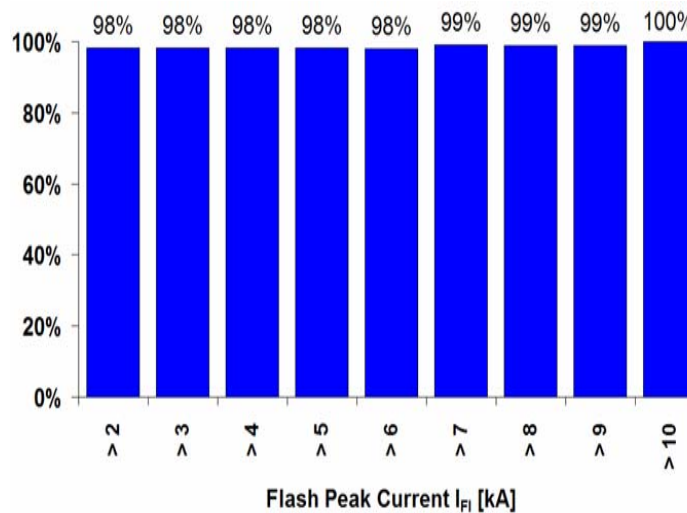
- Total of 343 lightning events were recorded 2000-2005
 - 110 discharges with α pulses and at least one β pulse
 - 109 discharges with one or more α pulses $> 2\text{kA}$

- About 40% of all tower discharges did not exhibit any pronounced current pulses (ICC only) and therefore were not detected by the LLS

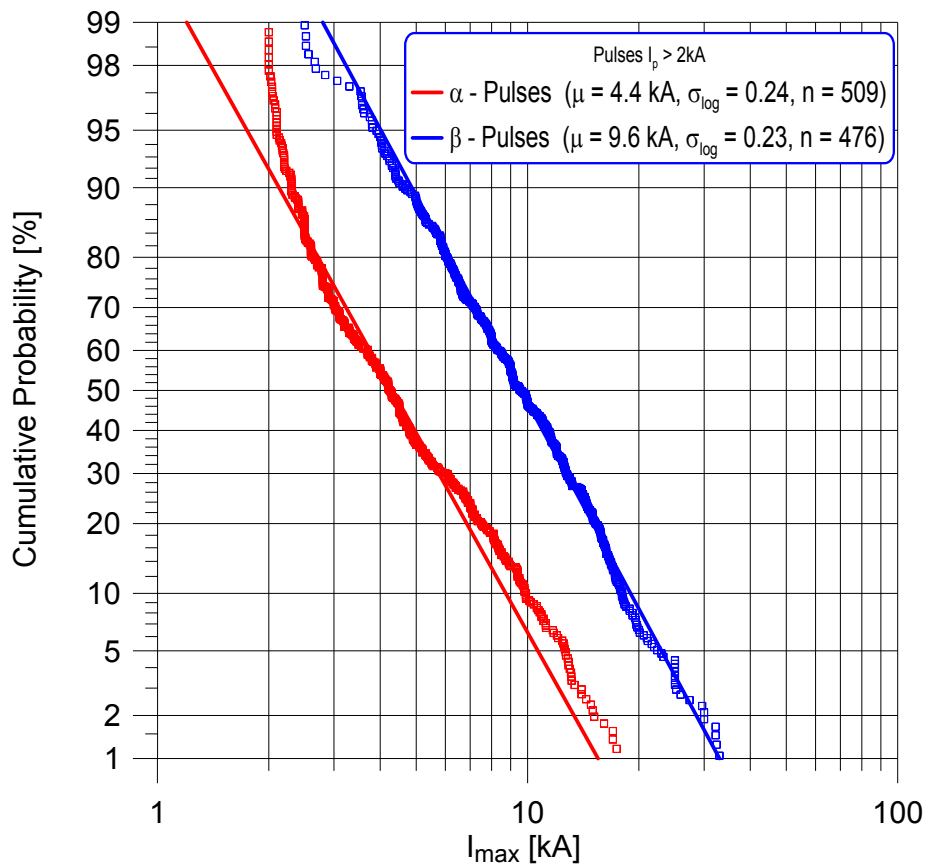
All Flashes to the Tower with $I_p > 2\text{kA}$



DE of Flashes with at least one β pulse

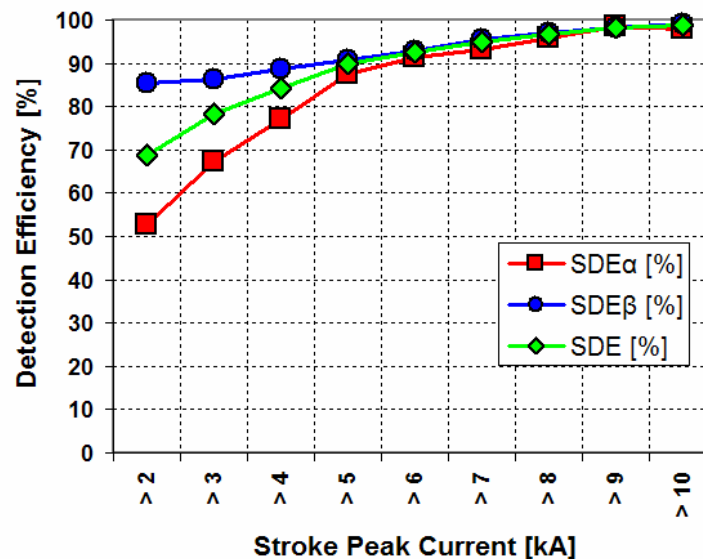


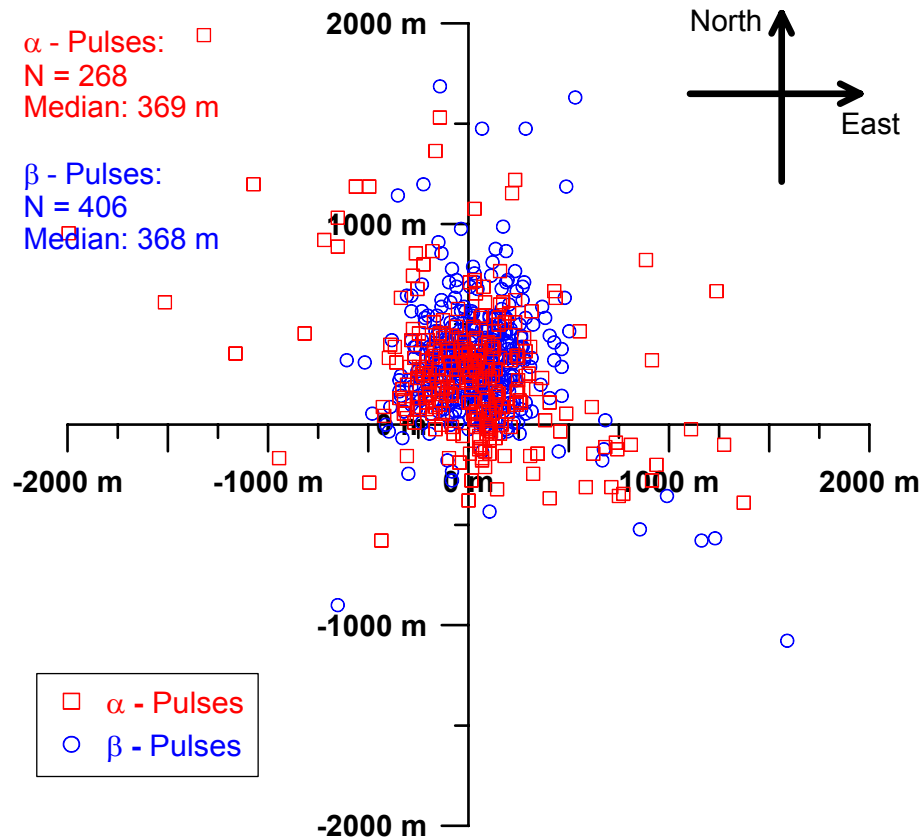
Note: Missing 2 flashes are probably a result of failure in GPS timing of tower records

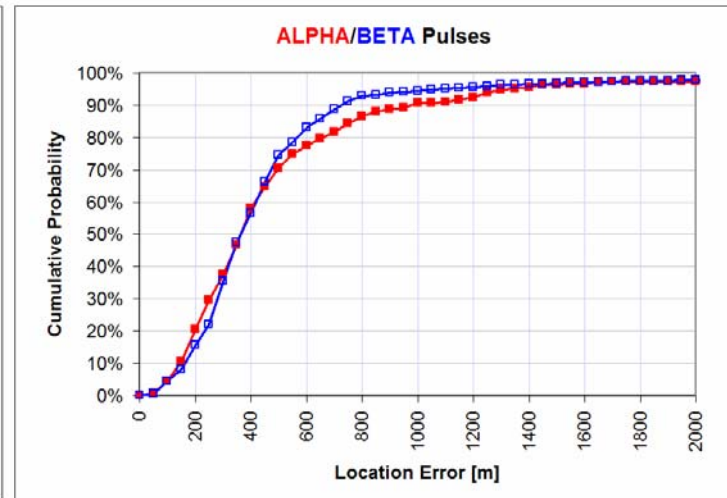
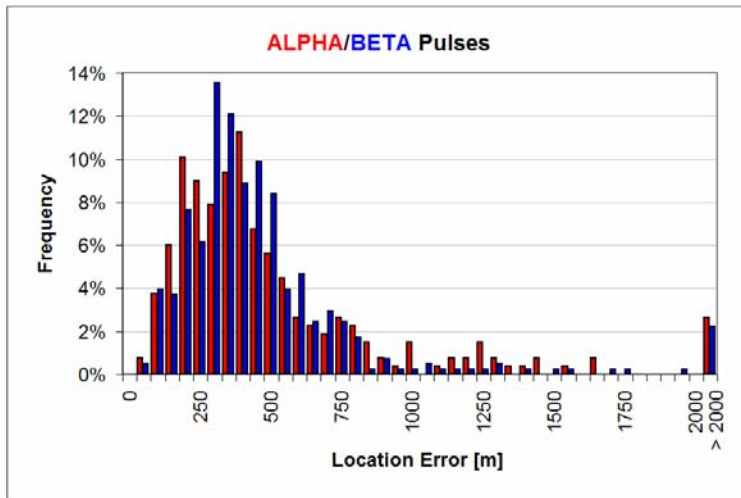


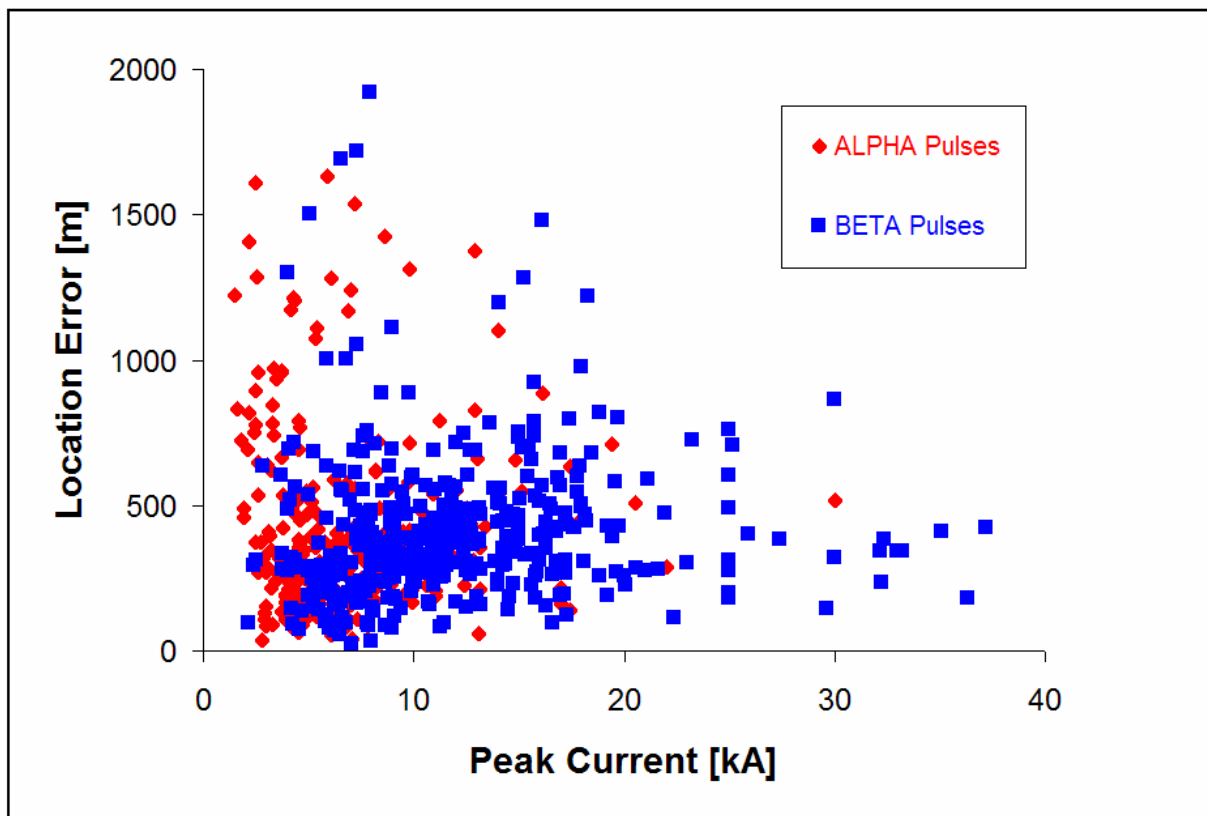
β –Pulses in tower lightning are the best representation of subsequent strokes in natural lightning !!!

I [kA]	GAISBERG			Lightning Location System (LLS)				
	N	N _α	N _β	N _α	N _β	SDE _α [%]	SDE _β [%]	SDE [%]
> 2	974	498	476	263	406	53	85	69
> 3	824	359	465	242	402	67	86	78
> 4	726	276	450	213	399	77	89	84
> 5	607	186	421	163	382	88	91	90
> 6	535	153	382	140	355	92	93	93
> 7	456	117	339	109	324	93	96	95
> 8	390	94	296	90	287	96	97	97
> 9	329	68	261	67	256	99	98	98
> 10	269	48	221	47	219	98	99	99

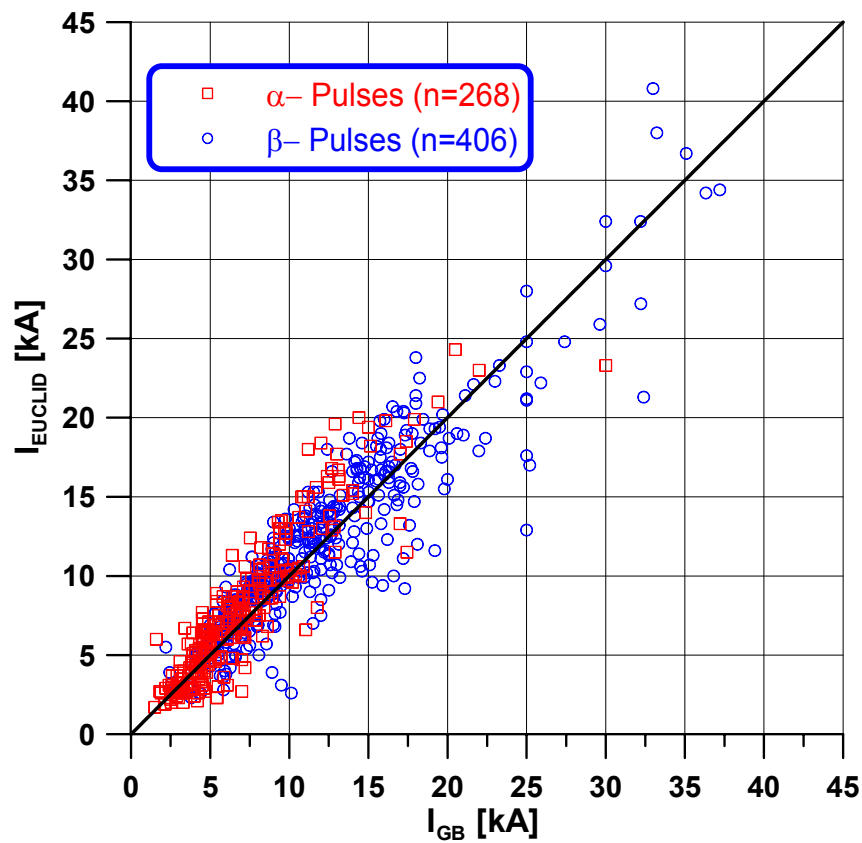


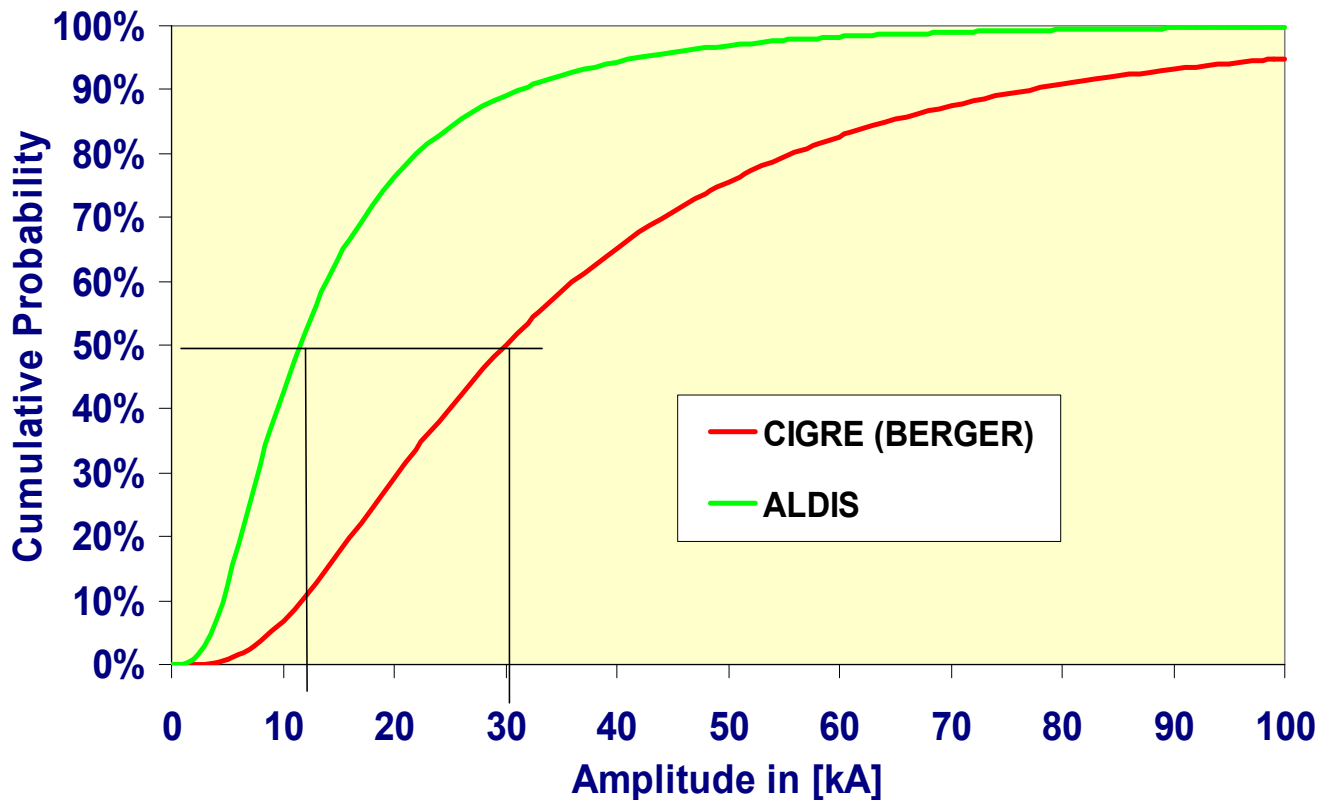




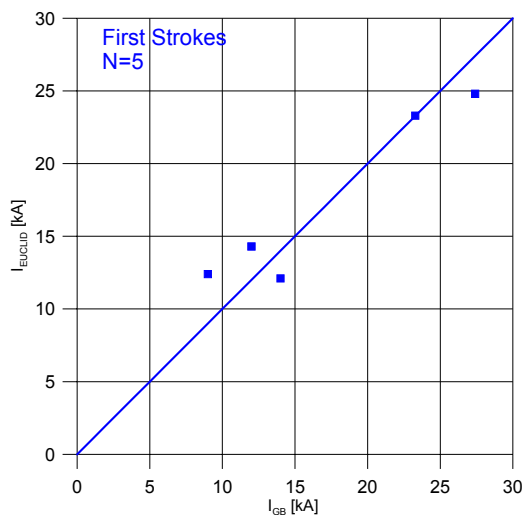


Measured Peak Current versus LLS Inferred Peak Current (2000 – 2005)

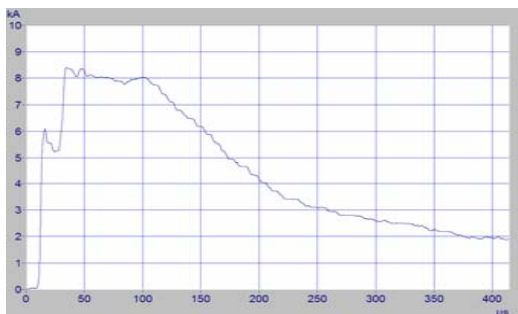




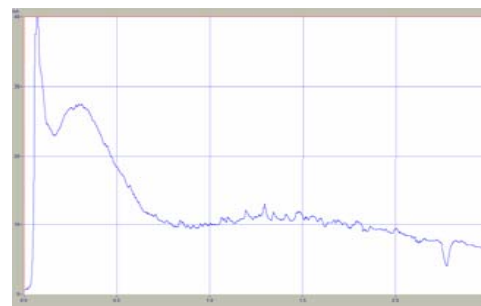
- Only very few cases could be classified as downward discharges to the tower
 - Classification is done based on absence of ICC current
 - images showing branching direction are not available



- Peak amplitudes of pos. lightning is inferred using the same relation as for neg. strokes.
- Only very few ground truth data exists



$$I_{LLS} = 8.4 \text{ kA}$$



$$I_{LLS} = 33.8 \text{ kA}$$

- Tower effect on LLS inferred peak currents
- Field-to-current relation for pos. lightning
 - RS speed of pos. lightning ???
- Regional Differences in Lightning Parameters
- etc.

A night photograph of a city skyline with a prominent lightning bolt striking a tall tower. The sky is dark with several other lightning bolts visible. The city lights are visible in the foreground and middle ground.

THANK YOU!!
QUESTIONS ??????