Space debris measurements with EISCAT radars
The first 1000 (+) hours

J Markkanen and A van Eyken
EISCAT

ESA CONTRACT 1
2000-2001

MEASUREMENTS OF SMALL-SIZE DEBRIS WITH BACKSCATTER OF RADIO WAVES

J Markkanen, M Lehtinen, A Huuskonen, A Väänänen

Is feasible

Sodankylä Geophysical Observatory

CONTRACT 2
2003-2004

REAL-TIME SMALL-SIZE SPACE DEBRIS DETECTION WITH EISCAT RADAR FACILITIES

J Markkanen and M Postila

Is practical

EISCAT Scientific Association

CONTRACT 3
2005

small-size space debris data collection with EISCAT radar facilities

J Markkanen M Postila A van Eyken

700 h 8000 events

+ 5850 meteor events

EISCAT Scientific Association

2006

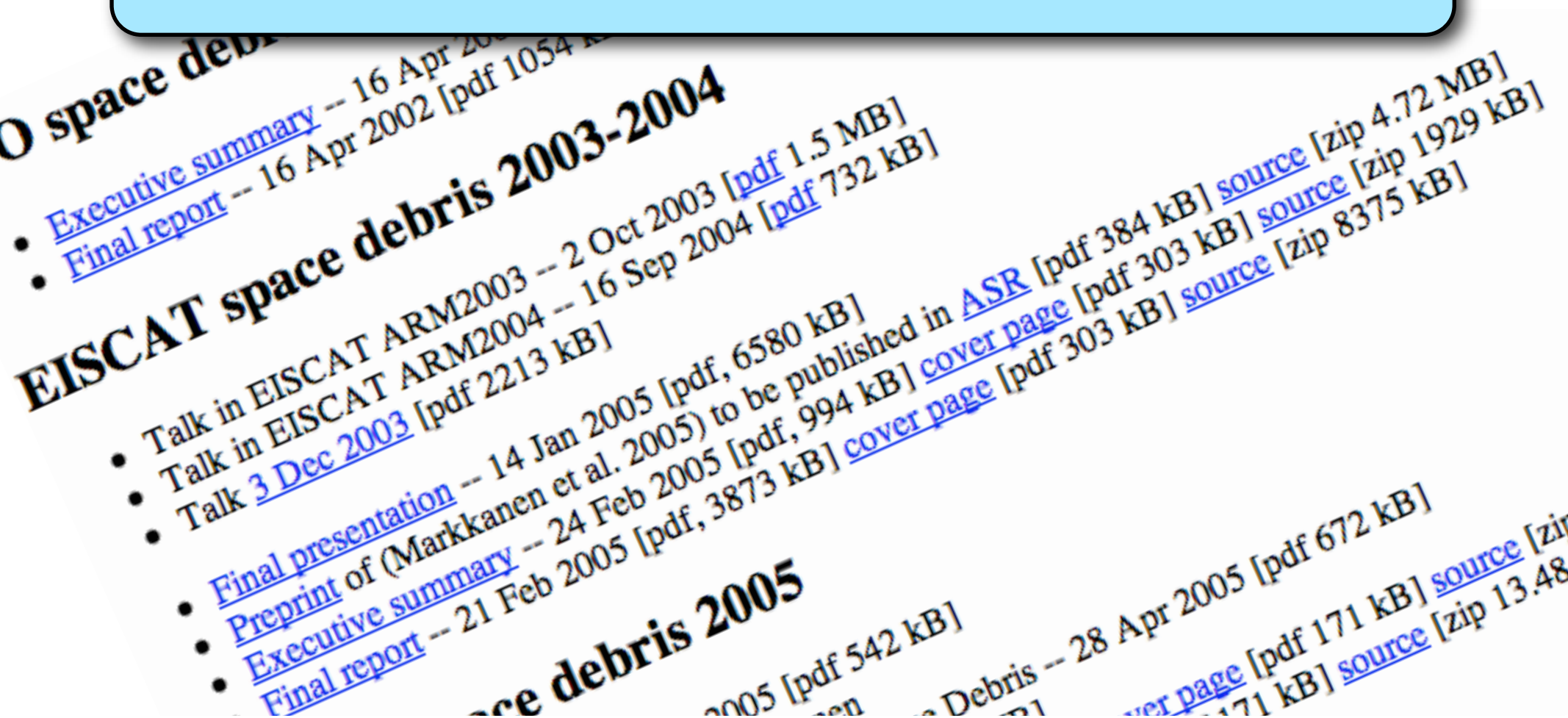
550 h 13700 events

Measurements 2004-2006

experiment	date	hours	events
Tau2 FA	9-13 Nov 04	100	1520
Manda FA	11-13 Aug 05	51	800
Tau2 4-park	7-29 Sep 05	545	5150
Tau0 42m	10 Nov 05	24	650
Manda FA	17-20 Nov 05	79	1350
Tau2 FA	13 Mar-6 Apr 06	387	6820
Steffe 42m	17-23 Mar 06	138	5240
Steffeleo 32m	8-9 Jul 06	24	1660
	Total	1296	23190

EISCAT SD on the WEB

- www.sgo.fi/~jussi/spade/
  Documents, and some of the results.



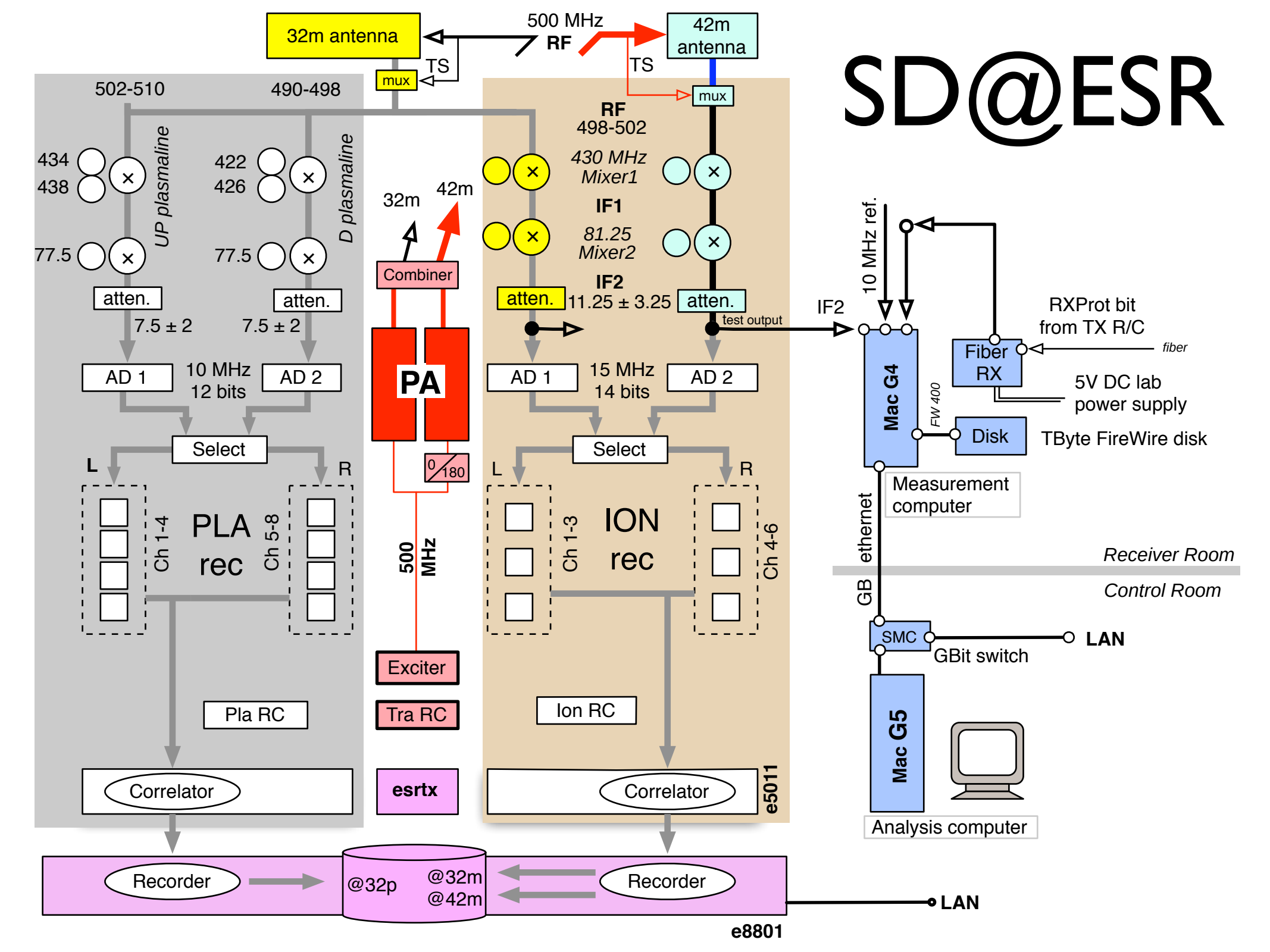
Measurement strategy

- Piggy-packed measurements
- Dedicated receiver back-end
- Coherent integration in data processing

HARDWARE

Tromso 930 MHz

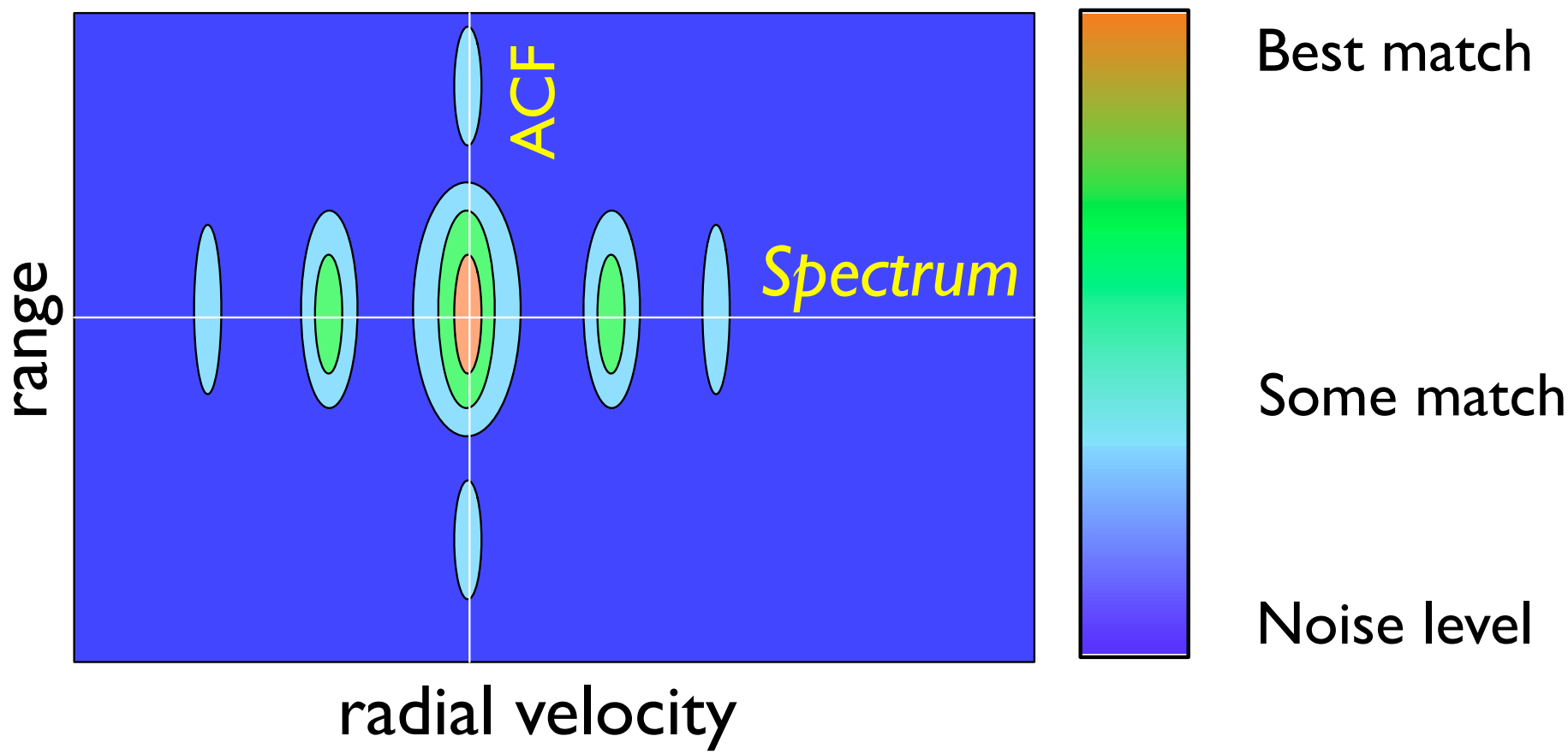
Svalbard 500 MHz


SD@ESR
32m antenna
500 MHz
RF
42m antenna
TS
mux
502-510
490-498
434
438
422
426
UP plasmaline
D plasmaline
77.5
77.5
atten.
atten.
7.5 ± 2
7.5 ± 2
AD 1
10 MHz
12 bits
AD 2
Select
L
R
PLA
rec
Ch 1-4
Ch 5-8
Pla RC
Correlator
32m
42m
Combiner
PA
0/180
500 MHz
Exciter
Tra RC
esrtx
RF
498-502
430 MHz
Mixer1
IF1
81.25
Mixer2
IF2
11.25 ± 3.25
atten.
atten.
test output
AD 1
15 MHz
14 bits
AD 2
Select
L
R
ION
rec
Ch 1-3
Ch 4-6
Ion RC
Correlator
e5011
Recorder
@32p
@32m
@42m
Recorder
LAN
e8801
IF2
10 MHz ref.
Mac G4
FW 400
Fiber
RX
fiber
RXProt bit
from TX R/C
5V DC lab
power supply
Disk
TByte FireWire disk
Measurement
computer
ethernet
GB
Receiver Room
Control Room
SMC
GBit switch
LAN
Mac G5
Analysis computer

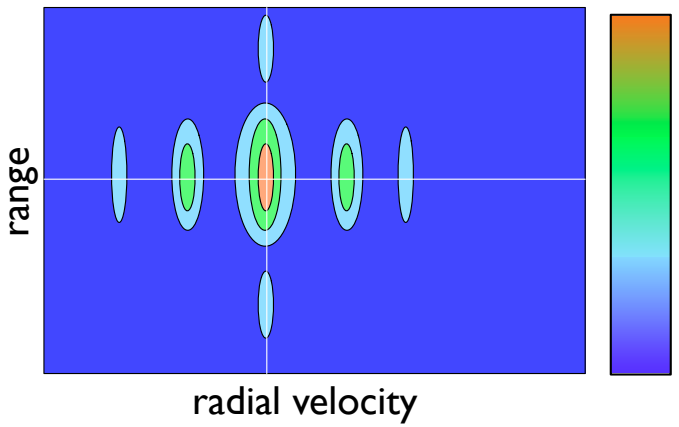
COHERENT INTEGRATION

Coherent integration via "match function" MF(v,R)

$$v_r \;\; R \;\; \frac{E_s}{kT}$$



The match function defined



signal model

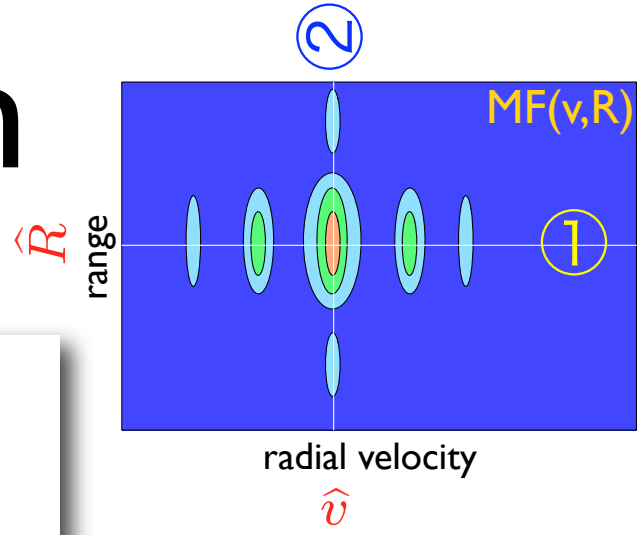
measured transmission

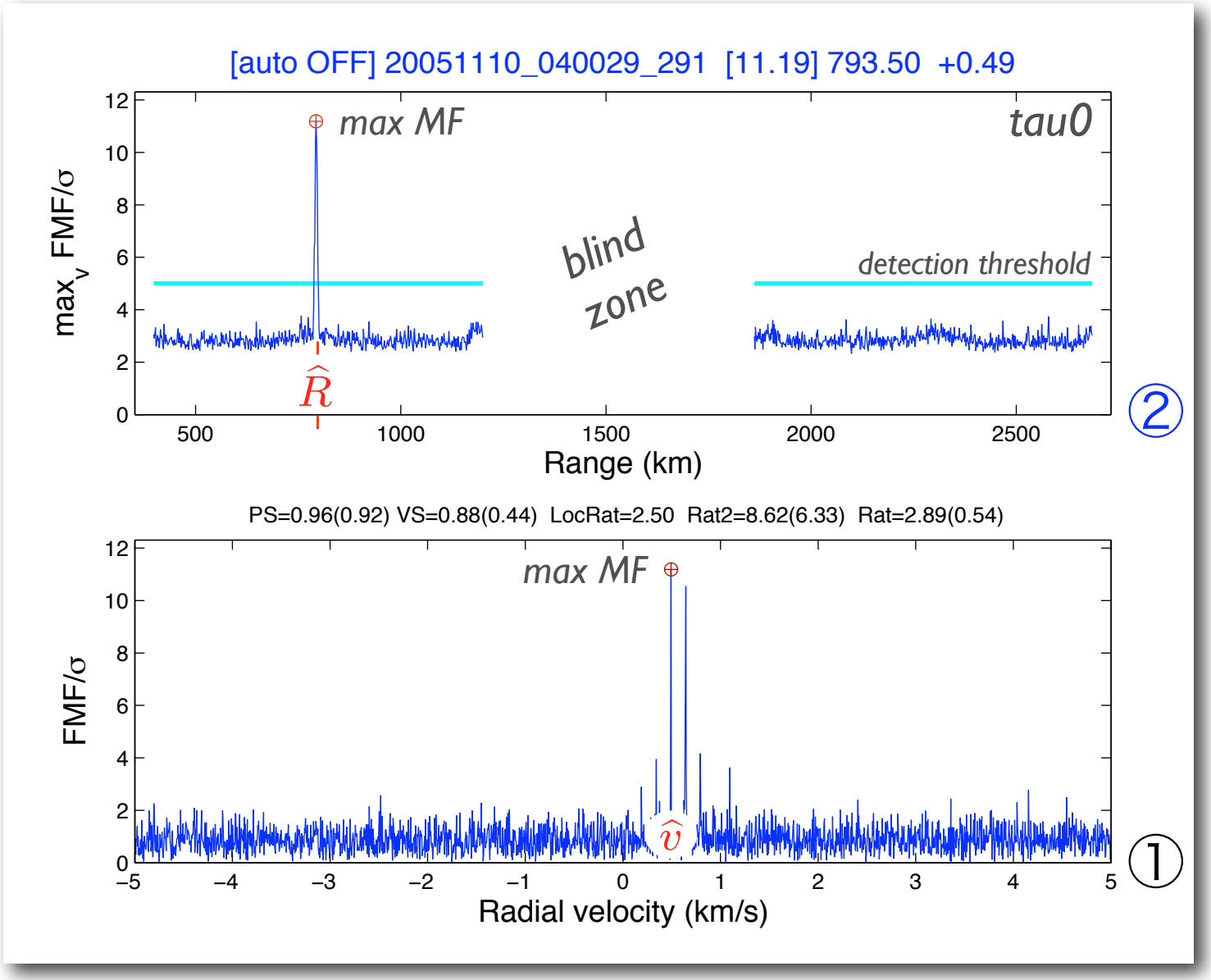
$$\chi_{v,R}(t) = x(t - \frac{2R}{c}) \cdot \mathrm{e}^{-i2\pi\frac{v}{\lambda/2}t}$$

$$\mathrm{MF}(v,R) = \frac{|\langle \mathbf{s} + \gamma, \chi_{v,R} \rangle|}{\|\chi_{v,R}\|}$$

The match function

in detection





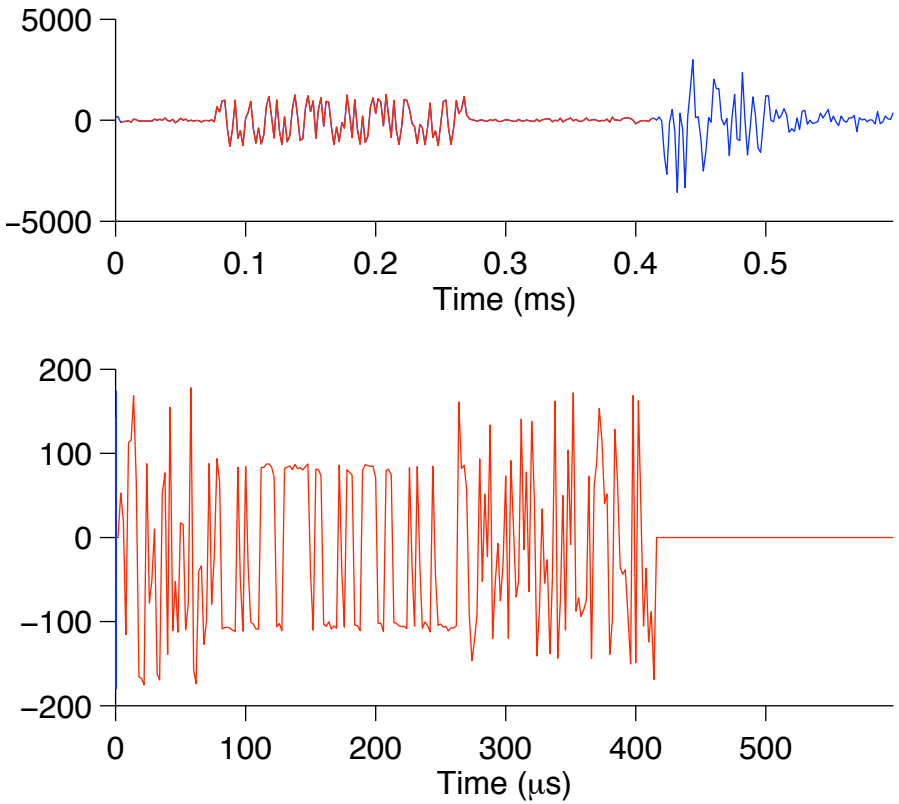
SPECIAL FEATURES

EISCAT SD

- Two latitudes (70 and 78 N)
- Two wavelengths (0.60 m and 0.32 m)
- Three antennas
- Beam-multipark modes (4 positions in CP2)
- Long time series (~month [more to come])
- Only statistical info on RCS
- Gaps in altitude coverage

Various transmission schemes

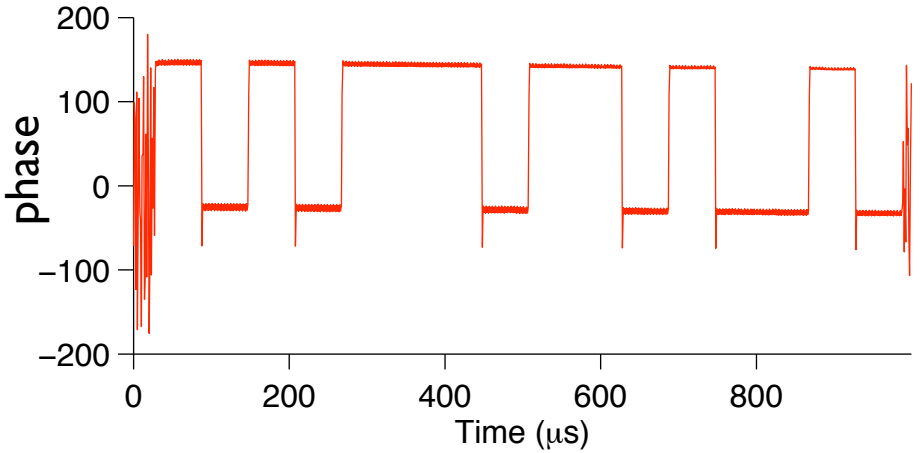
Manda (Tromso UHF)



IPP = 1875 μs

Duty cycle = 10.2%

Tau0 (ESR)

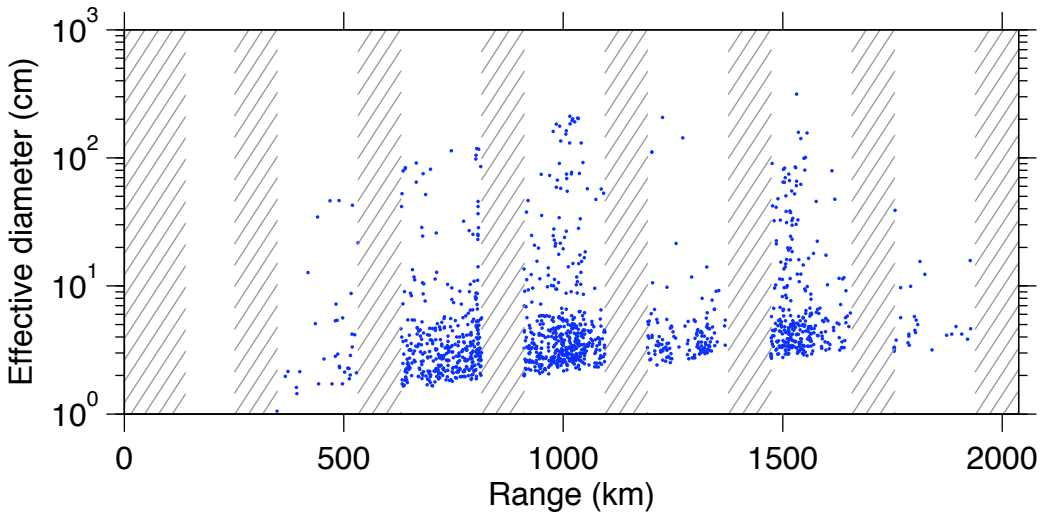


IPP = 10000 μs

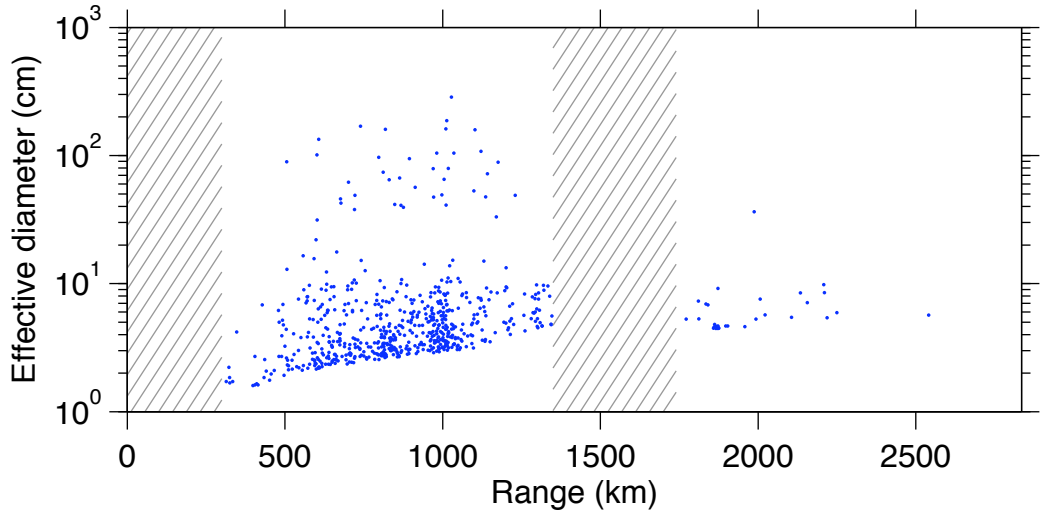
Duty cycle = 19.2%

Gaps in reception windows

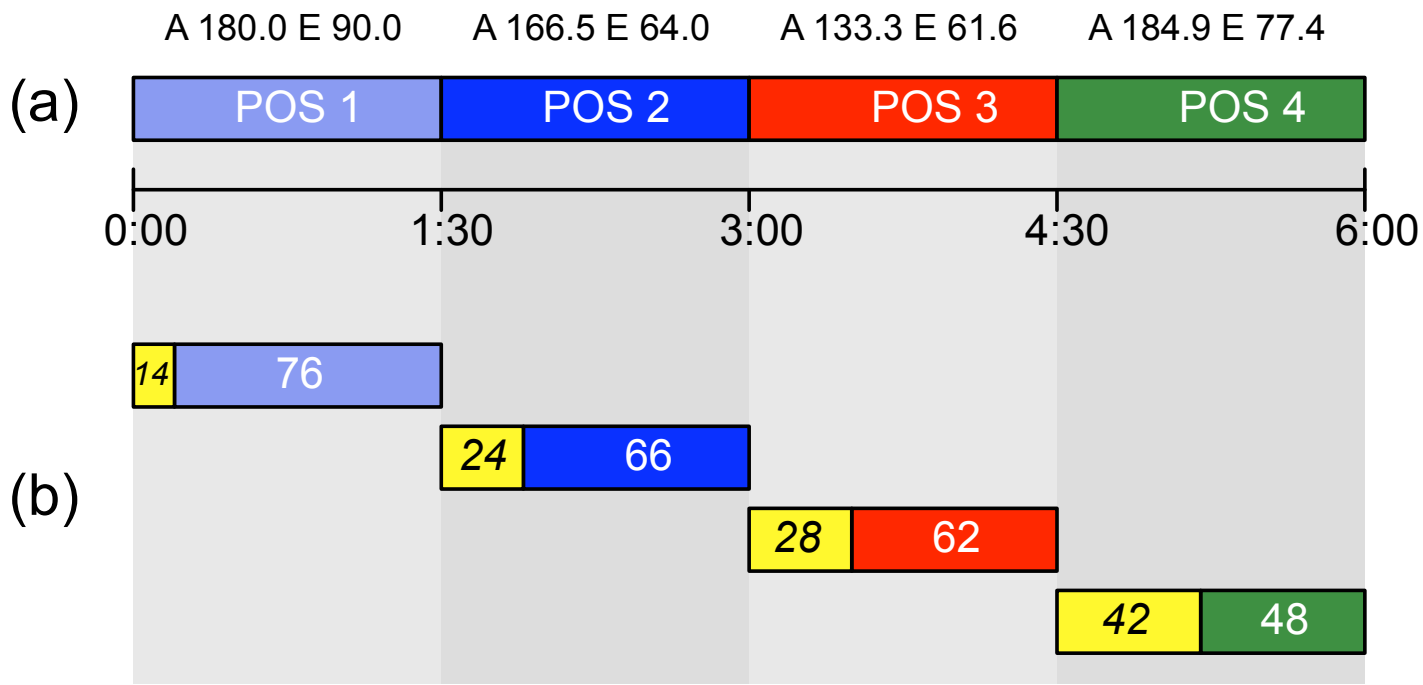
Manda (A 181 E 77)



Tau0 (A 182 E 82)

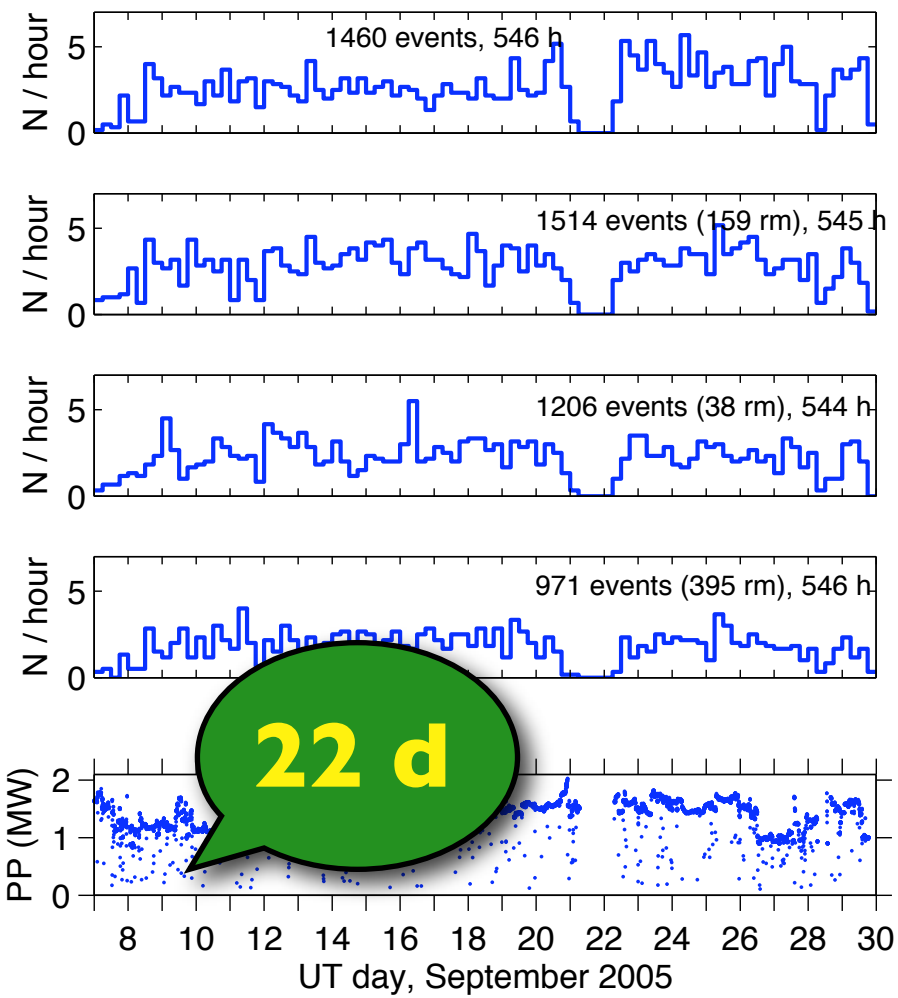


Beam multipark measurements

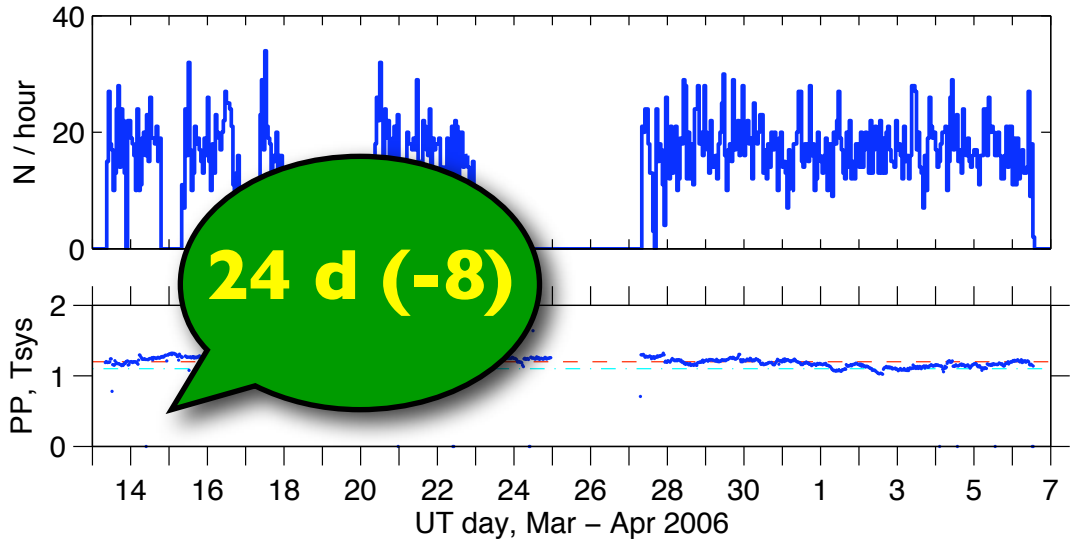


Long measurements

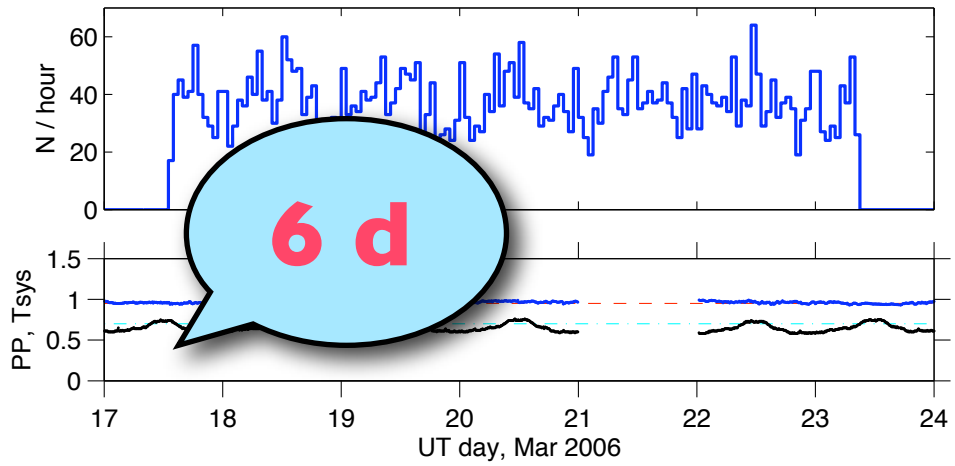
Tromso Sep 2005 4-Pos



Tromso Mar 2006 FA



ESR 42m Mar 2006 FA



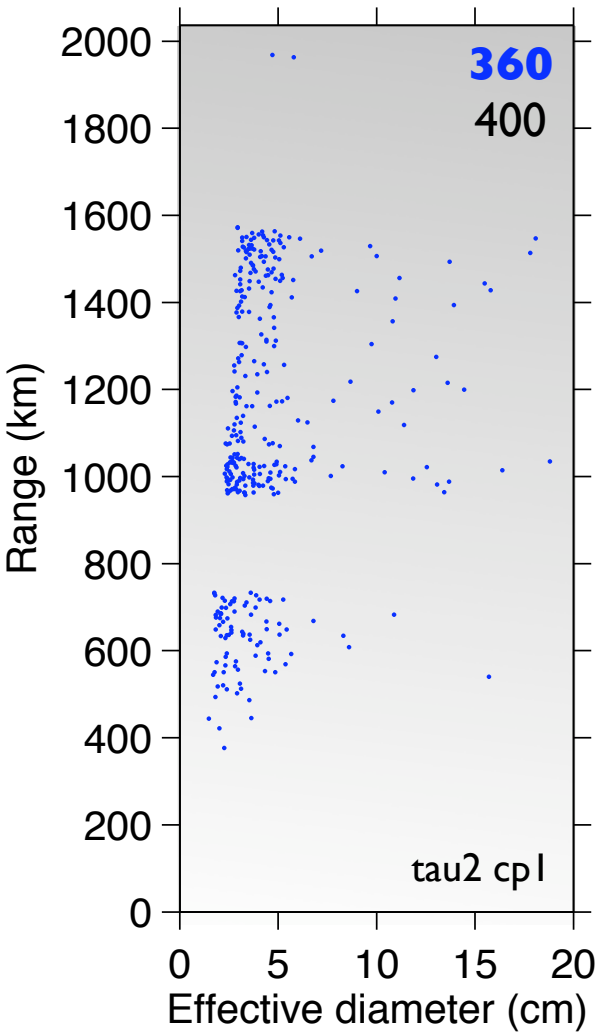
EXAMPLES

Sensitivity (Beam park, 24h)

Tromso

$W = 0.6°$ $\lambda = 32$ cm

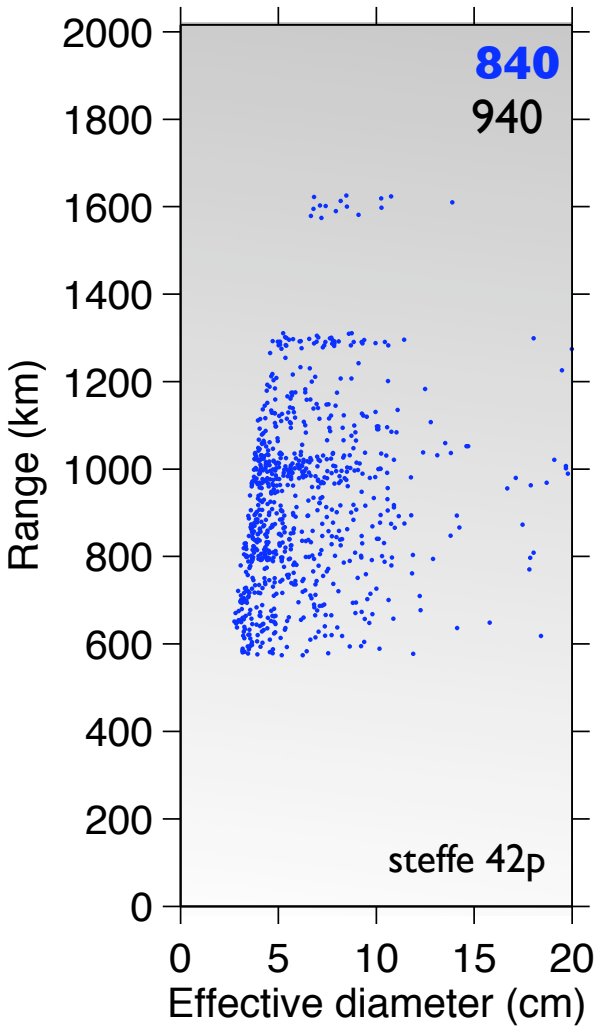
2006 Apr 1



ESR 42m

$W = 0.8°$ $\lambda = 60$ cm

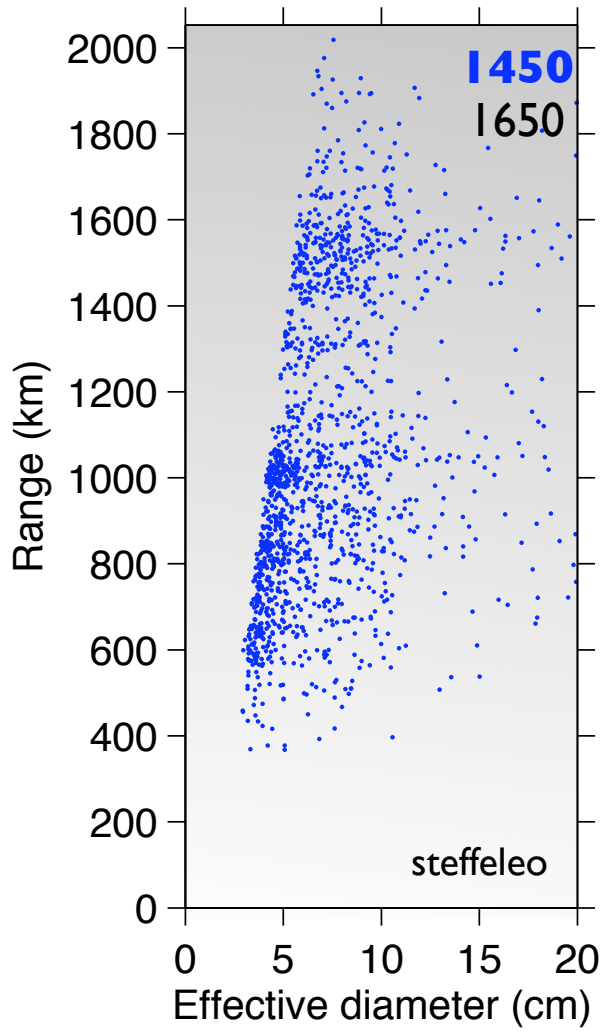
2006 Mar 18



ESR 32m

$W = 1.1°$ $\lambda = 60$ cm

2006 Jul 8

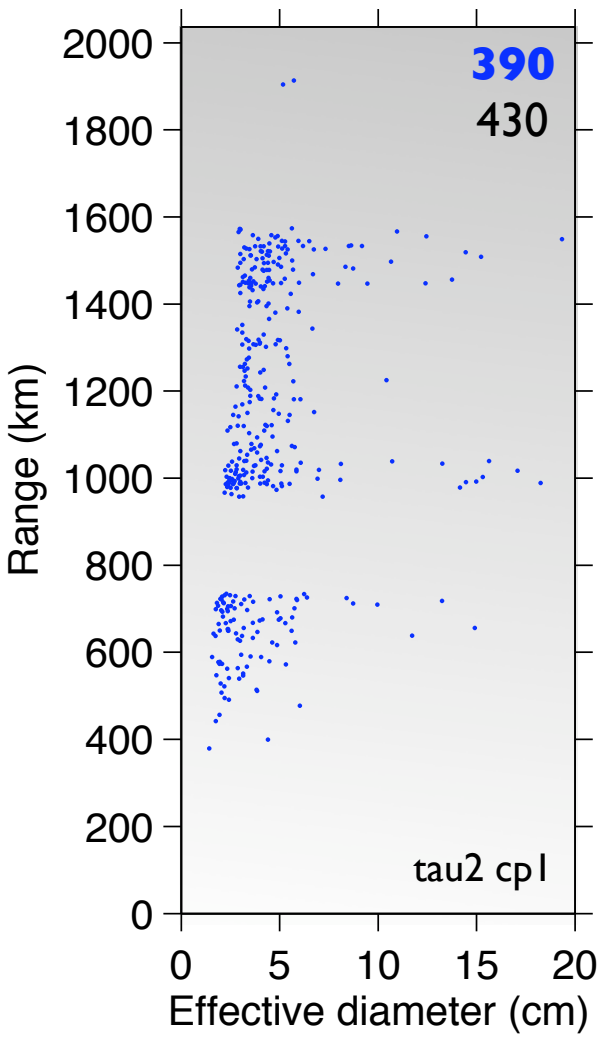


Sensitivity (day 2)

Tromso

$W = 0.6°$ $\lambda = 32$ cm

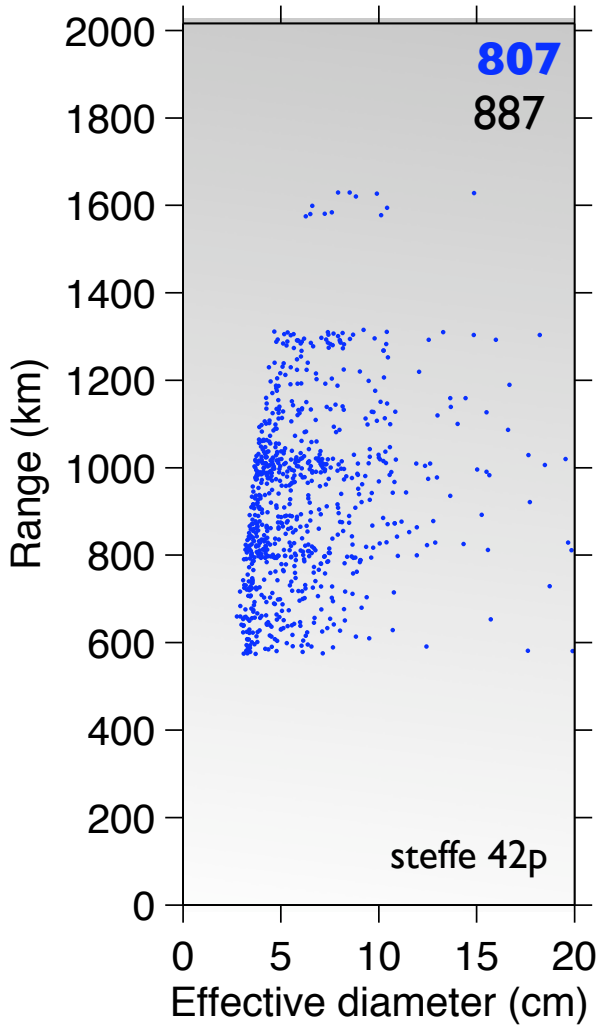
2006 Apr 2



ESR 42m

$W = 0.8°$ $\lambda = 60$ cm

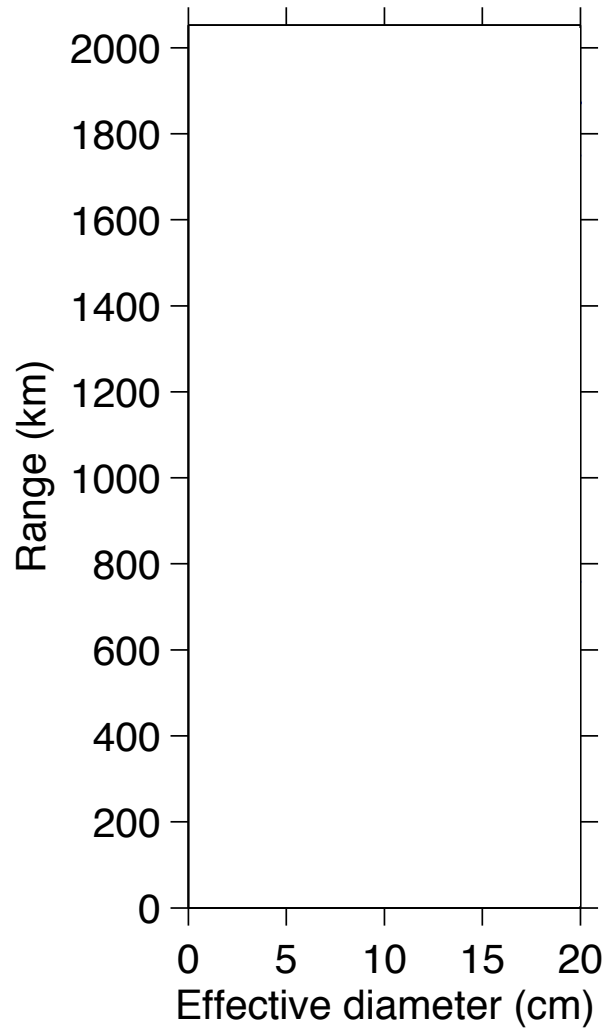
2006 Mar 19



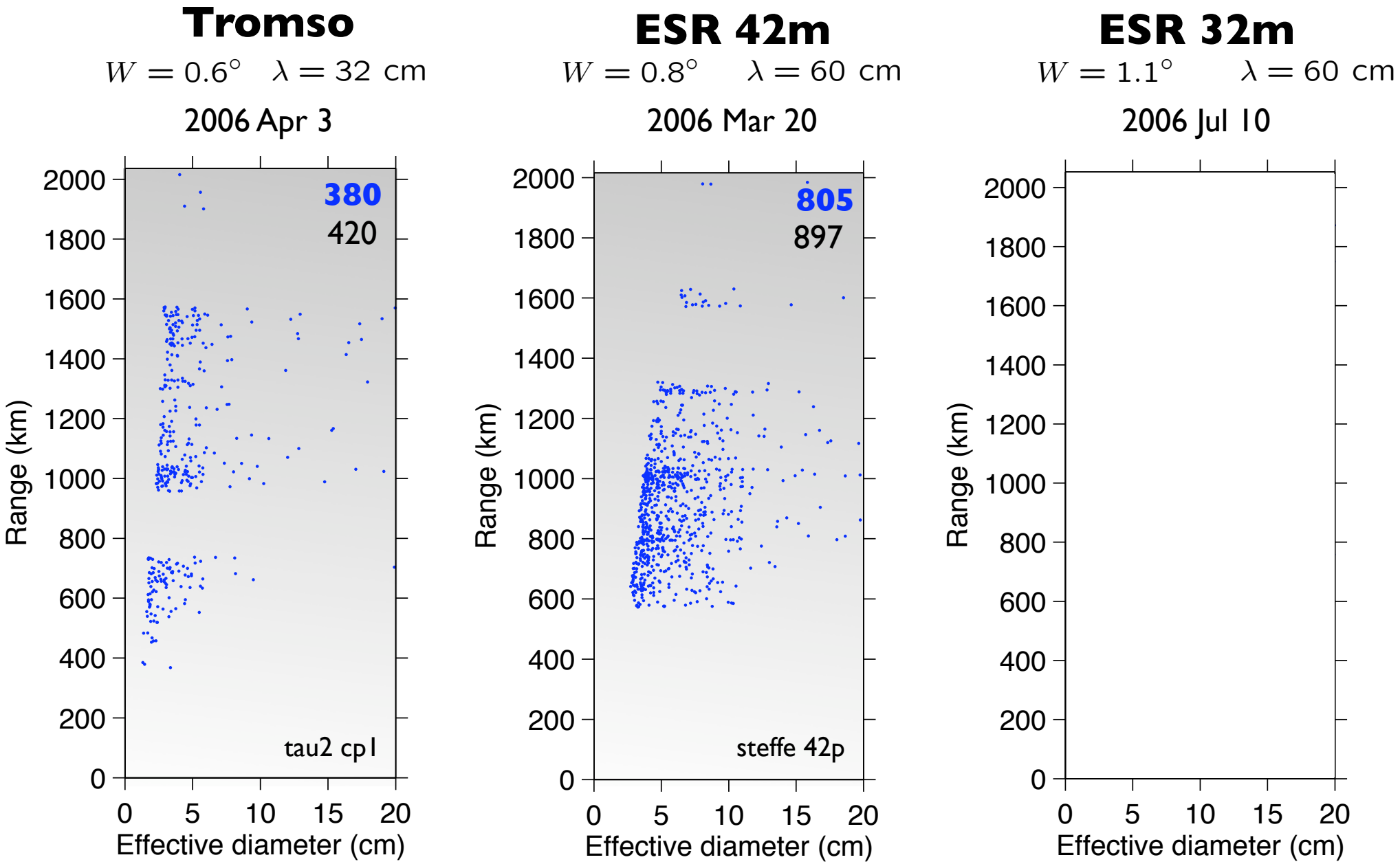
ESR 32m

$W = 1.1°$ $\lambda = 60$ cm

2006 Jul 9



Sensitivity (day 3)

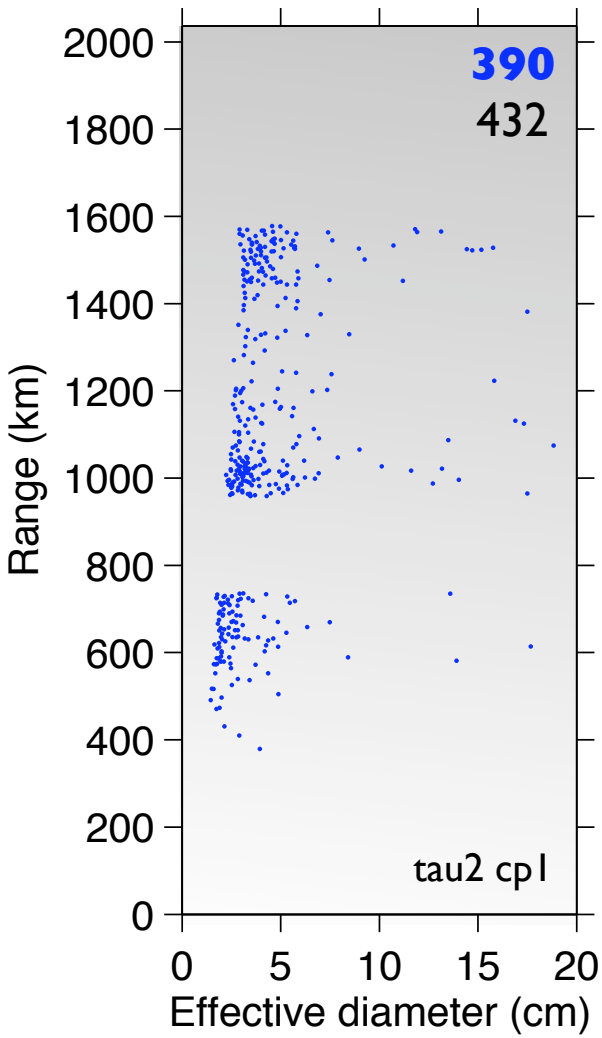


Sensitivity (day 4)

Tromso

$W = 0.6°$ $\lambda = 32$ cm

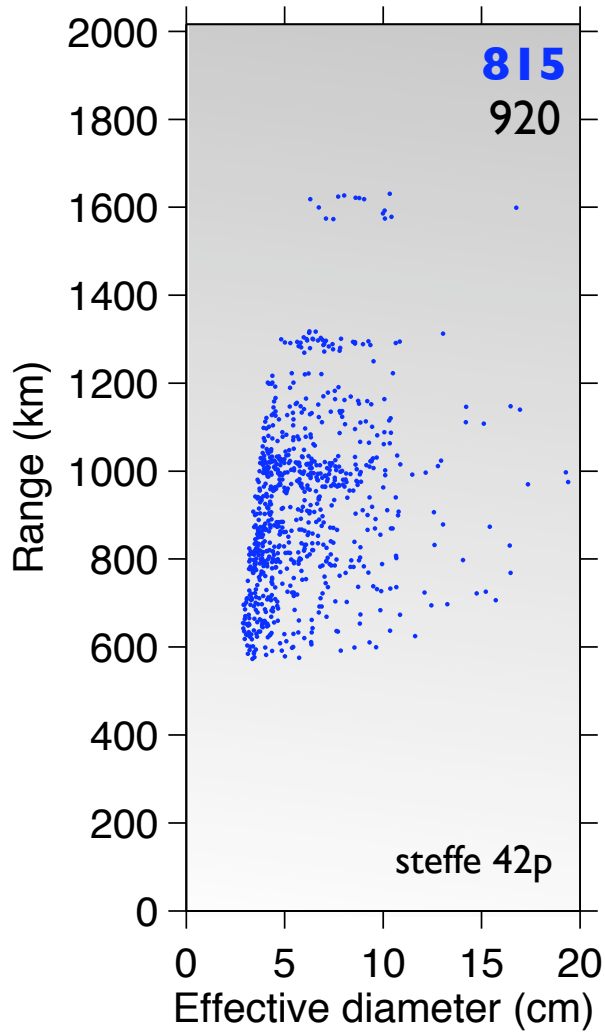
2006 Apr 4



ESR 42m

$W = 0.8°$ $\lambda = 60$ cm

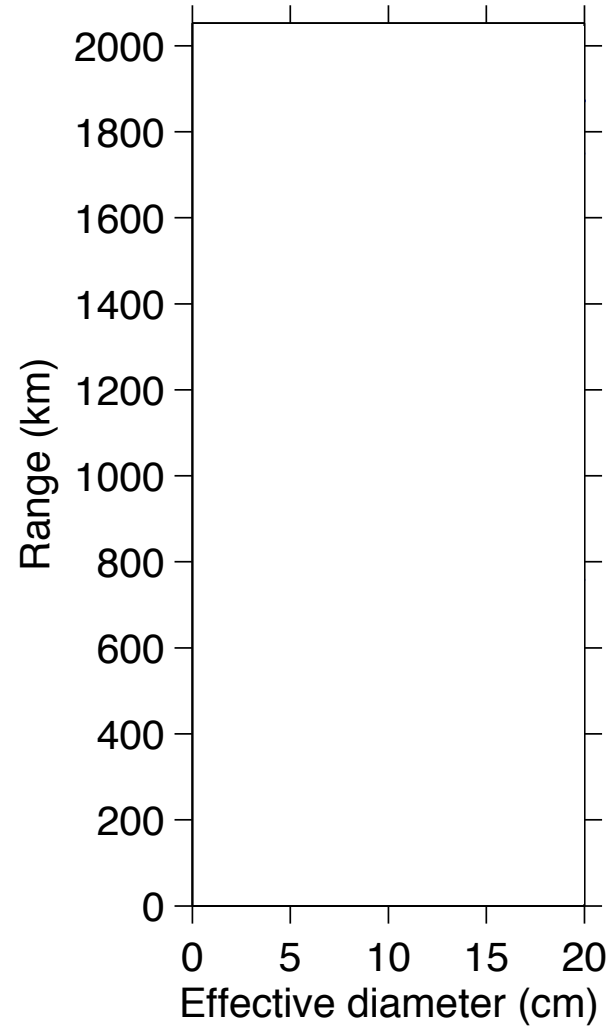
2006 Mar 21



ESR 32m

$W = 1.1°$ $\lambda = 60$ cm

2006 Jul 12

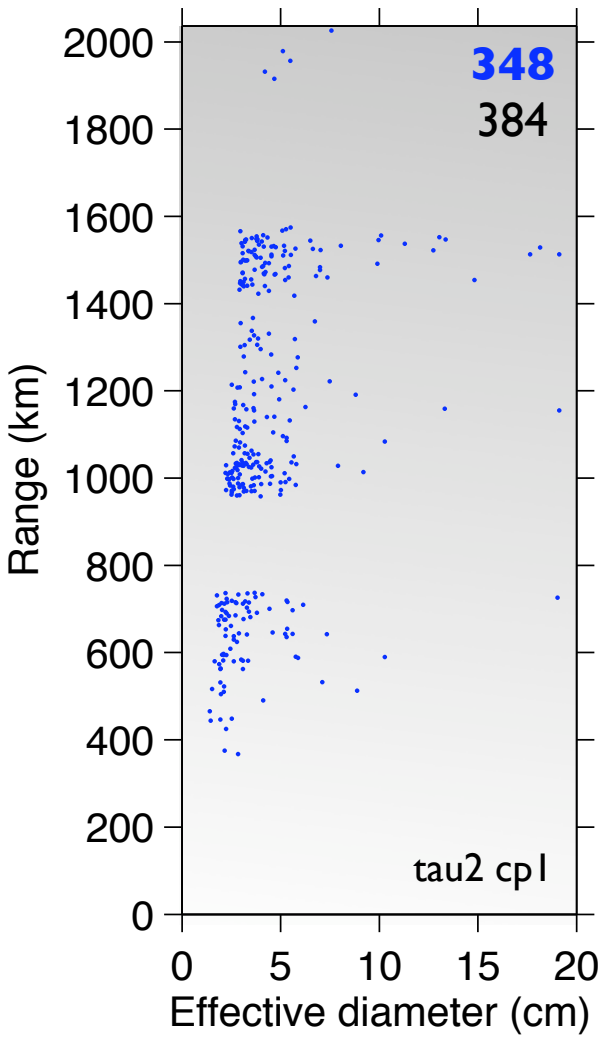


Sensitivity (day 5)

Tromso

$W = 0.6°$ $\lambda = 32$ cm

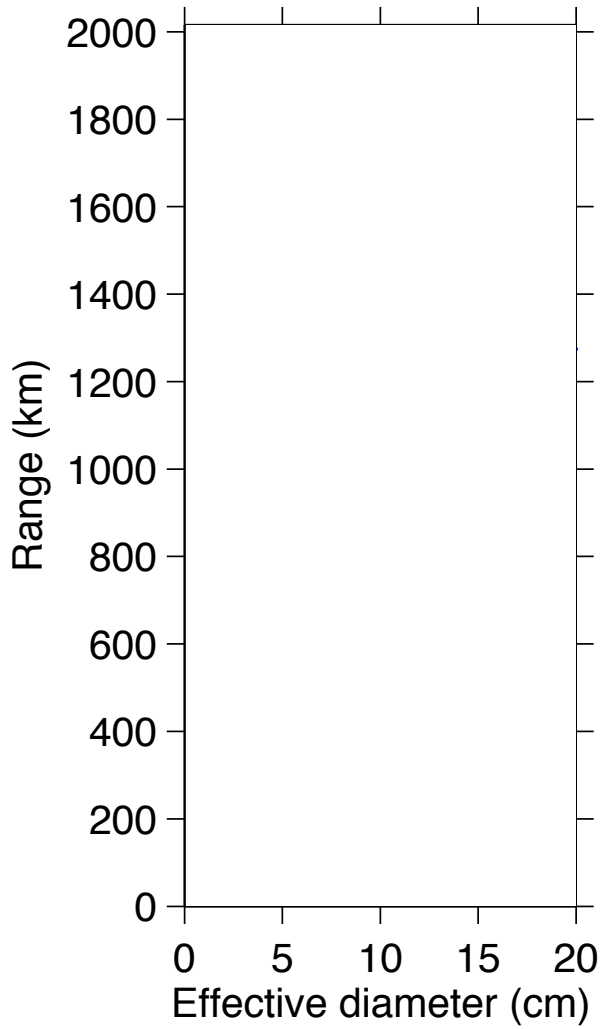
2006 Apr 5



ESR 42m

$W = 0.8°$ $\lambda = 60$ cm

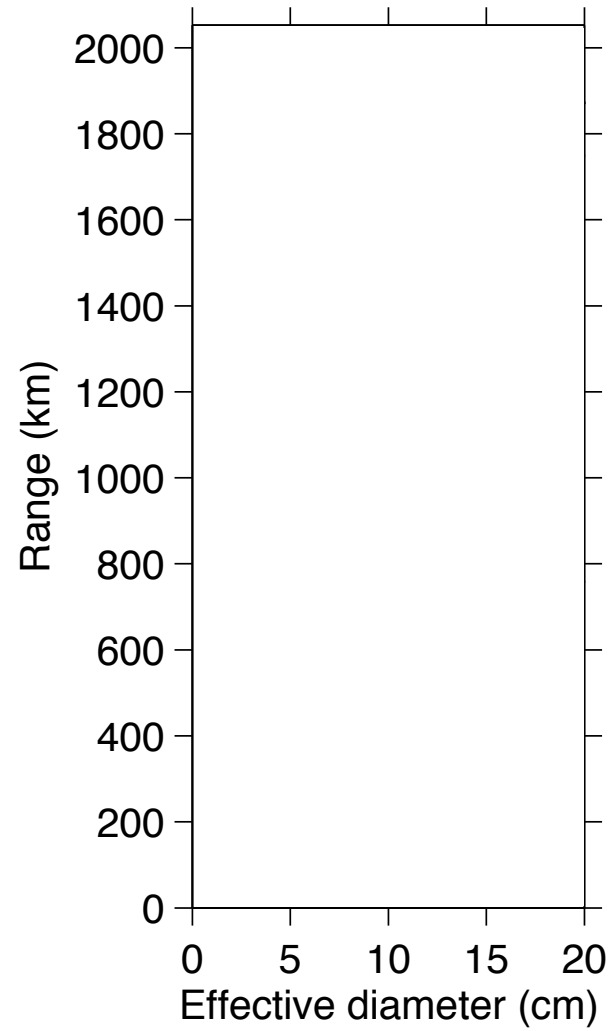
2006 Mar 18



ESR 32m

$W = 1.1°$ $\lambda = 60$ cm

2006 Jul 13

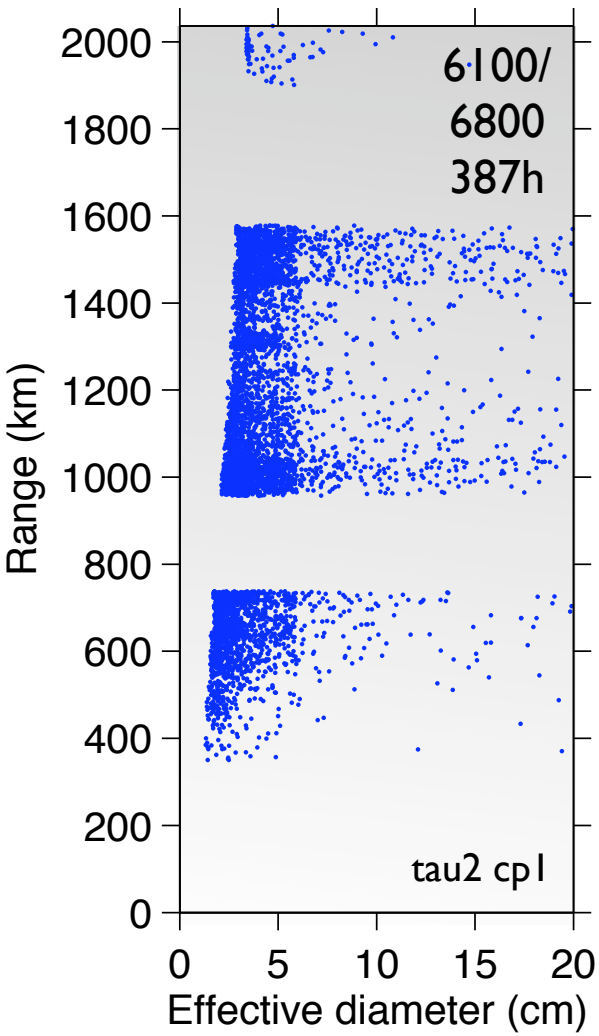


Sensitivity (all days)

Tromso

$W = 0.6°$ $\lambda = 32$ cm

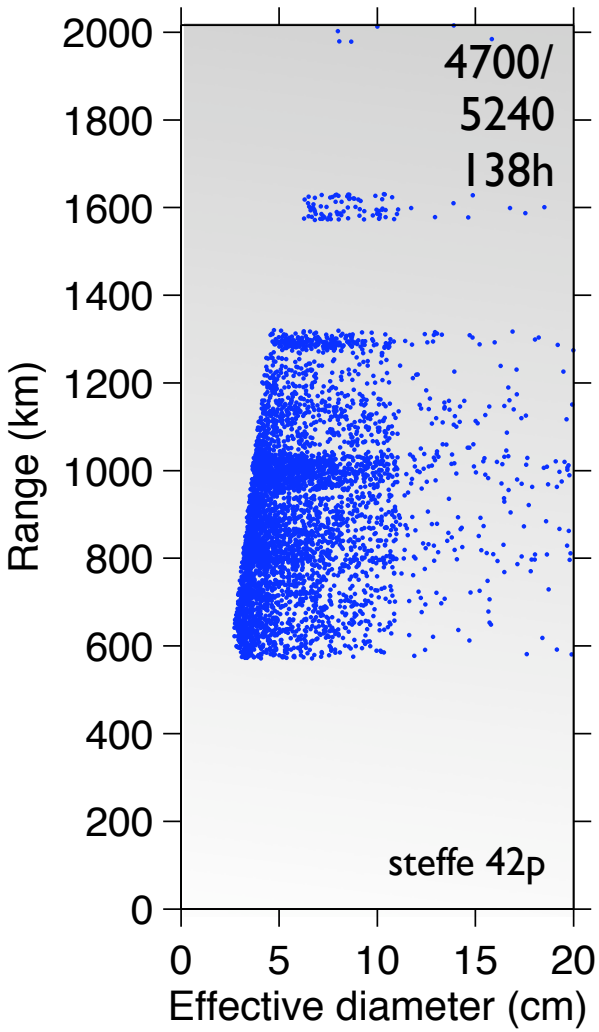
2006 Mar 14 - Apr 5



ESR 42m

$W = 0.8°$ $\lambda = 60$ cm

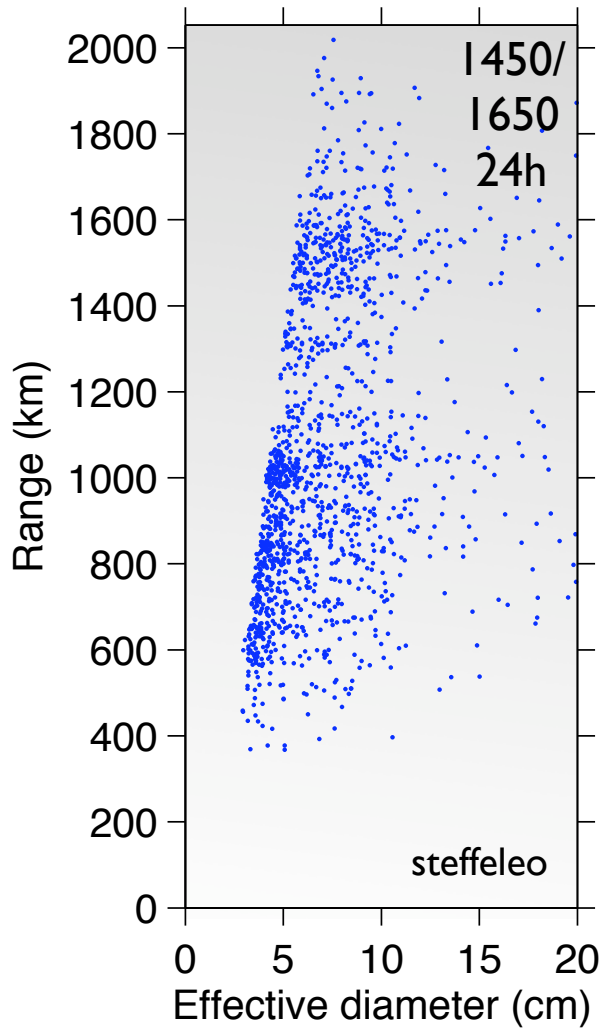
2006 Mar 17-23



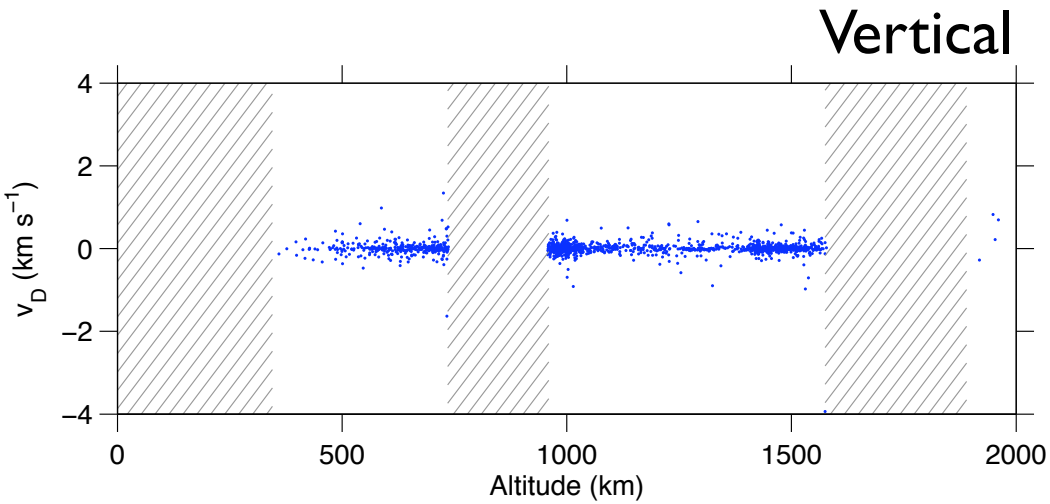
ESR 32m

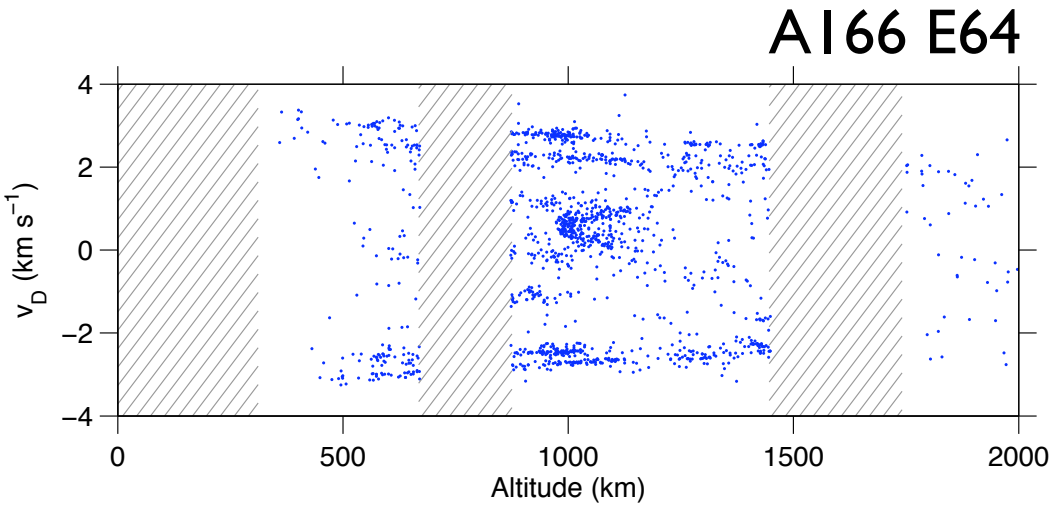
$W = 1.1°$ $\lambda = 60$ cm

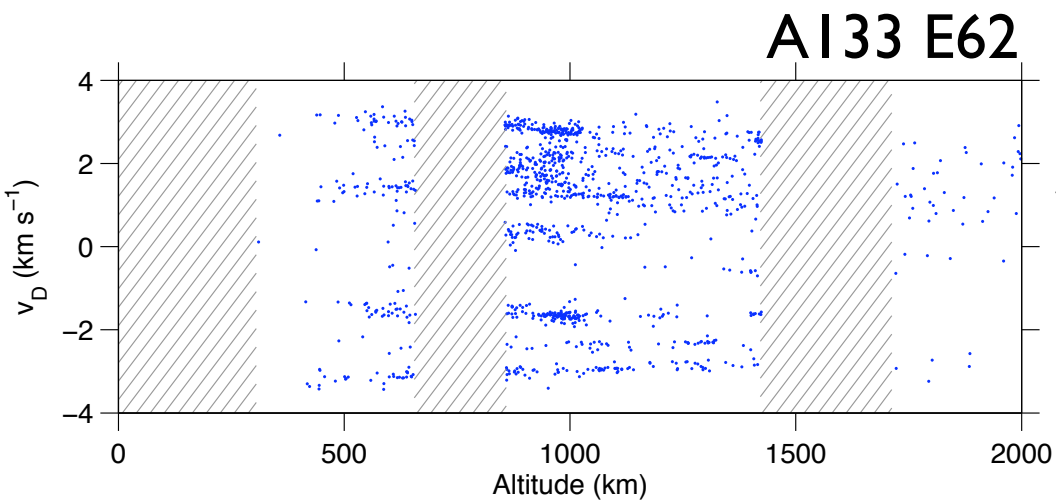
2006 Jul 8

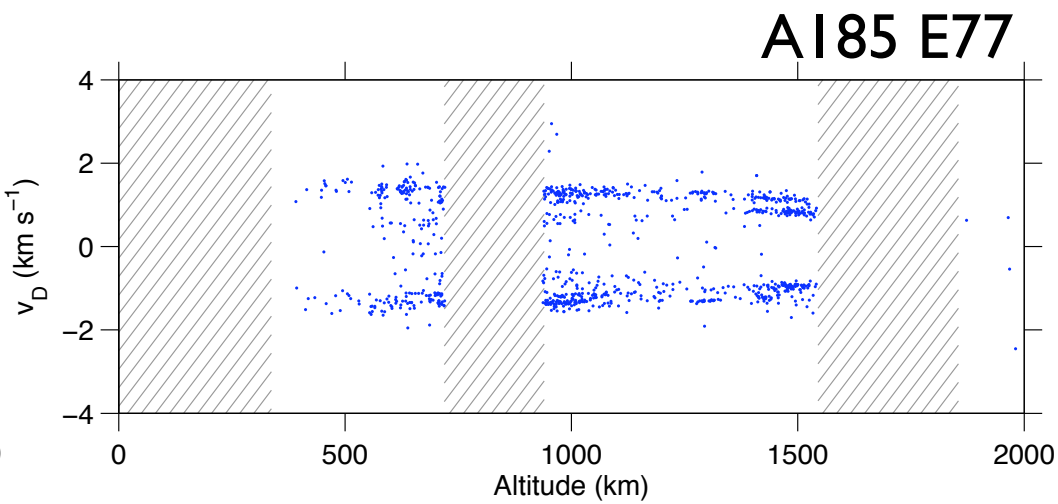


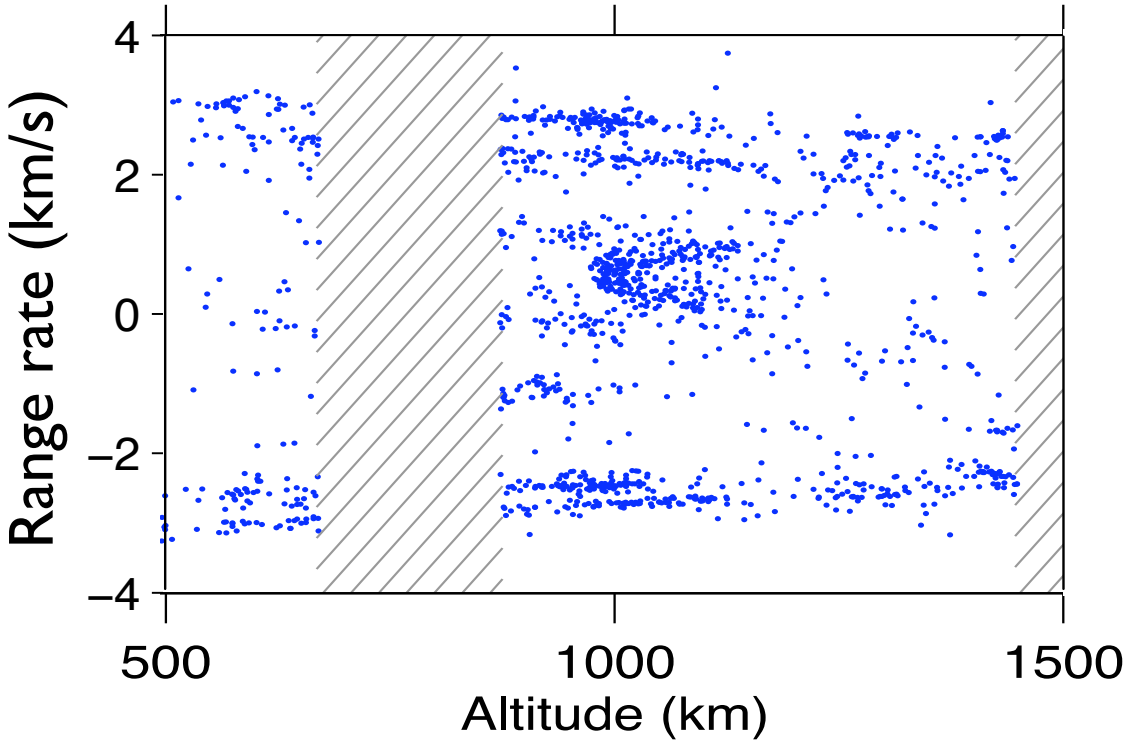
Tromso 4-park Sep 2005: Range rate









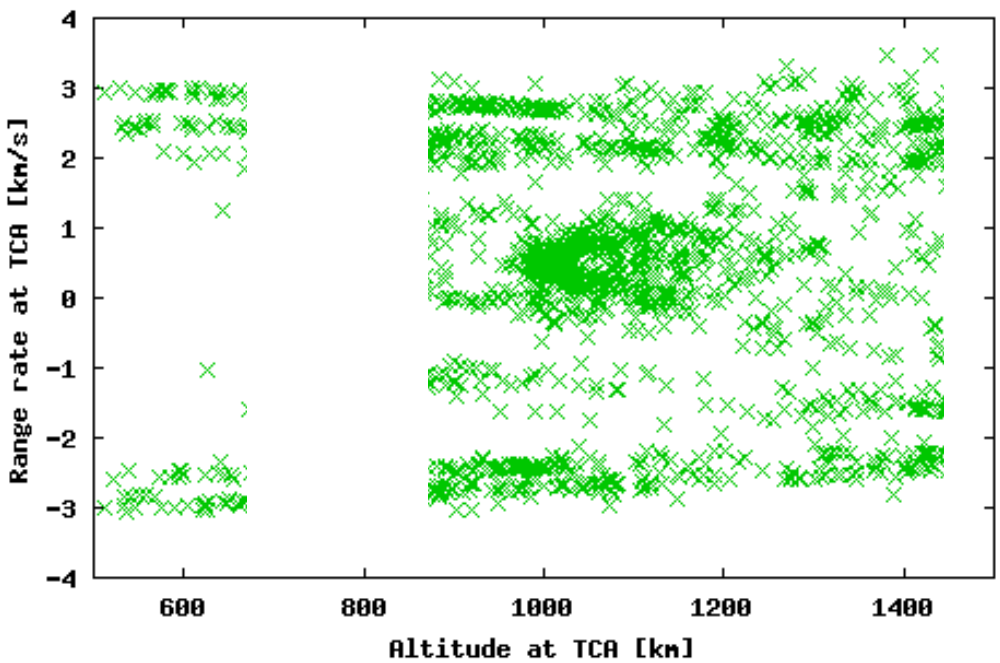


EISCAT

Tromso UHF

2005 Sep 7-29 (98 h)

1500 obj



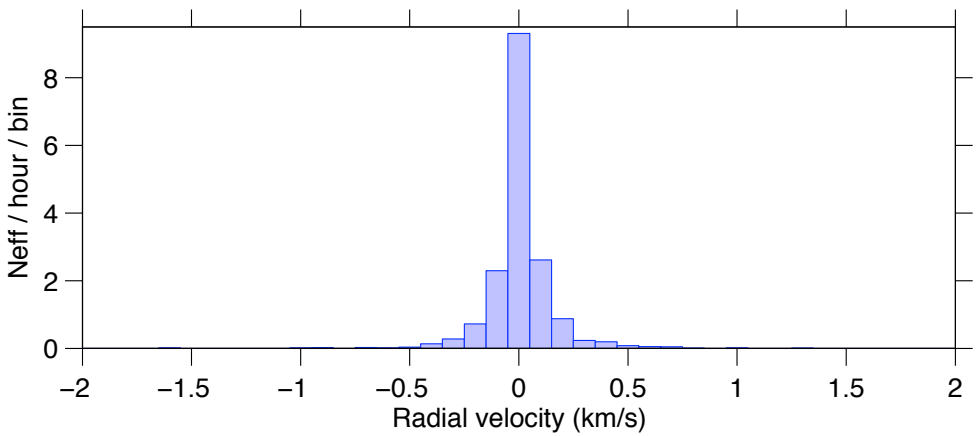
PROOF 2005

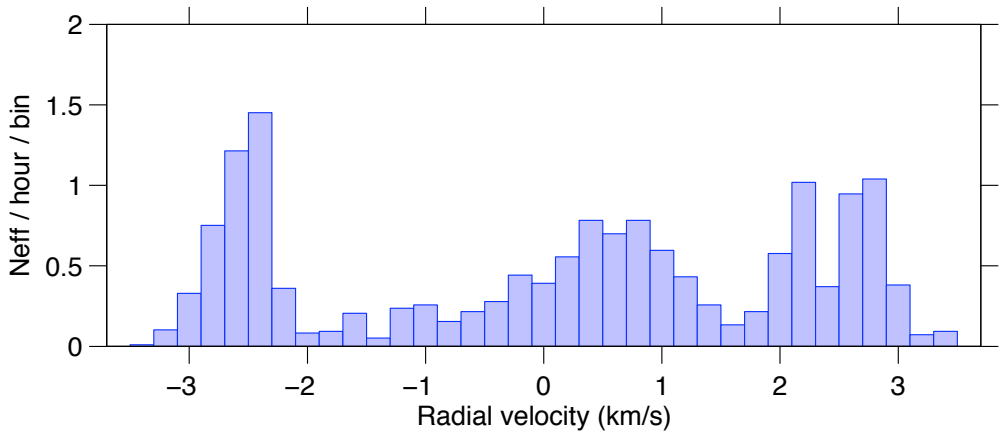
2005 Sep 23-27 (120h)

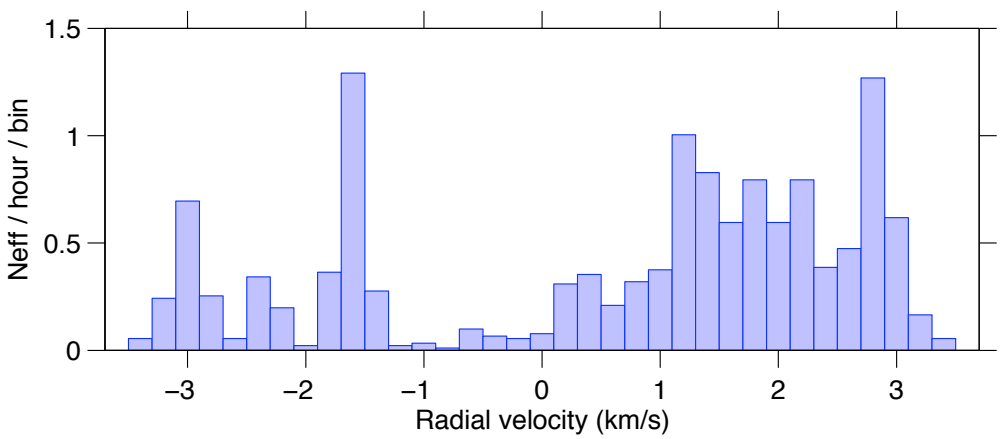
3900 obj

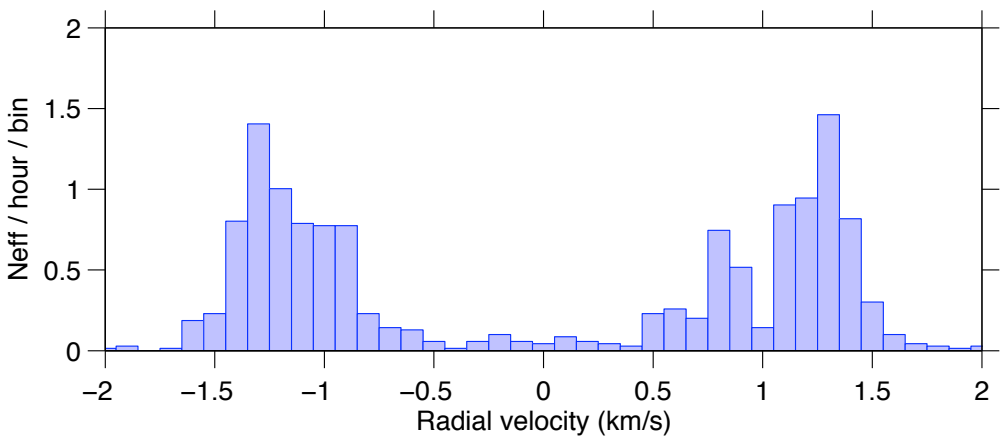
Azim 166, Elev 64

4-park: Rate rate distribution

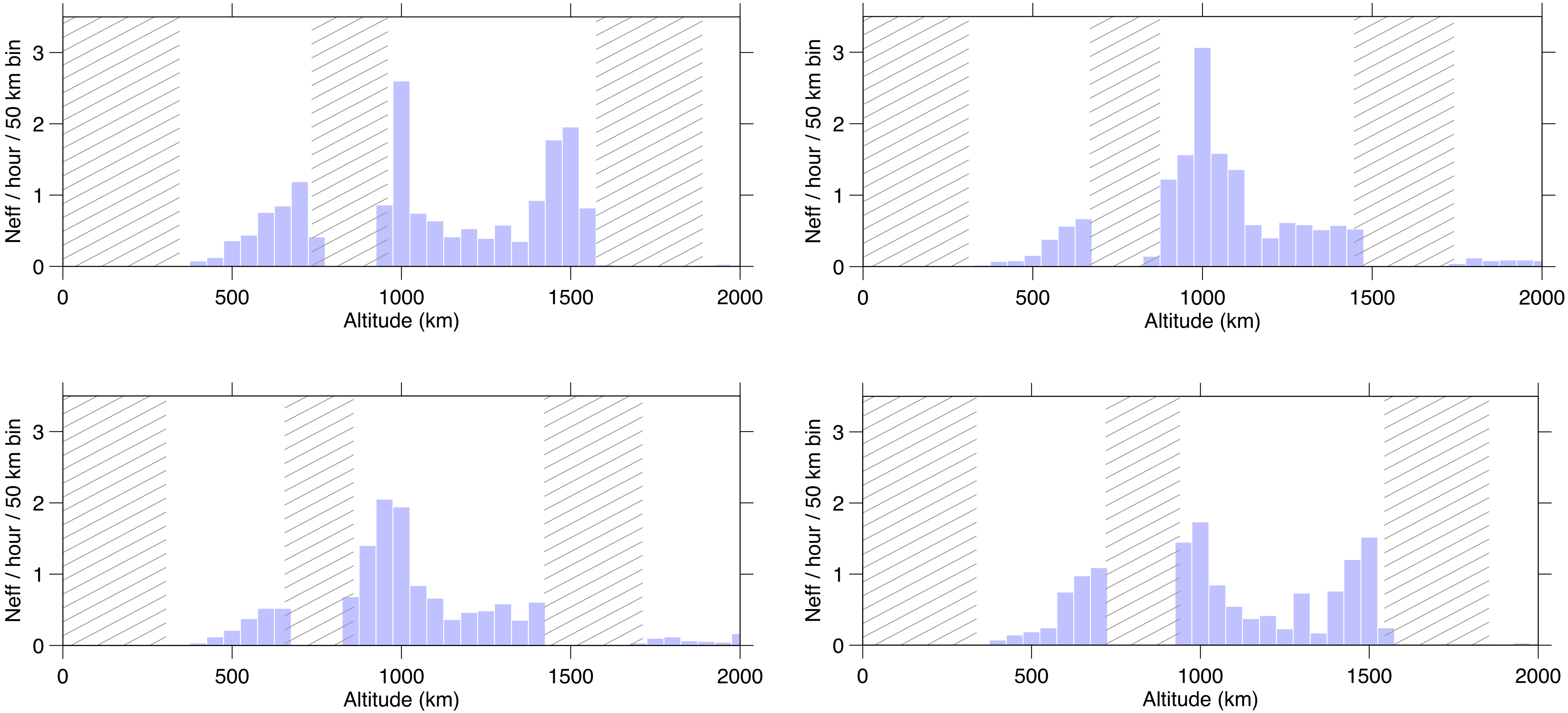






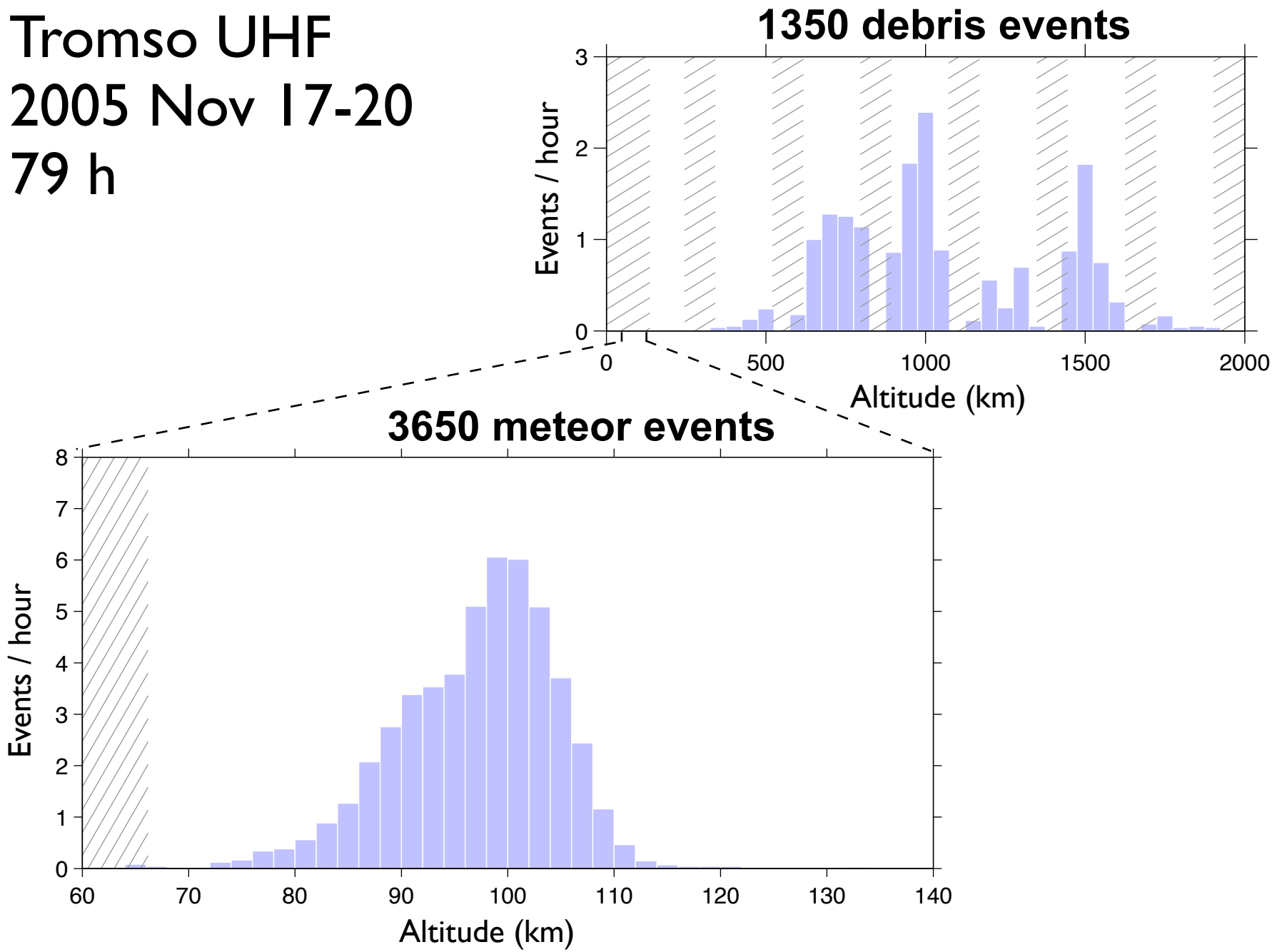


4-park: Eff. event rate v altitude

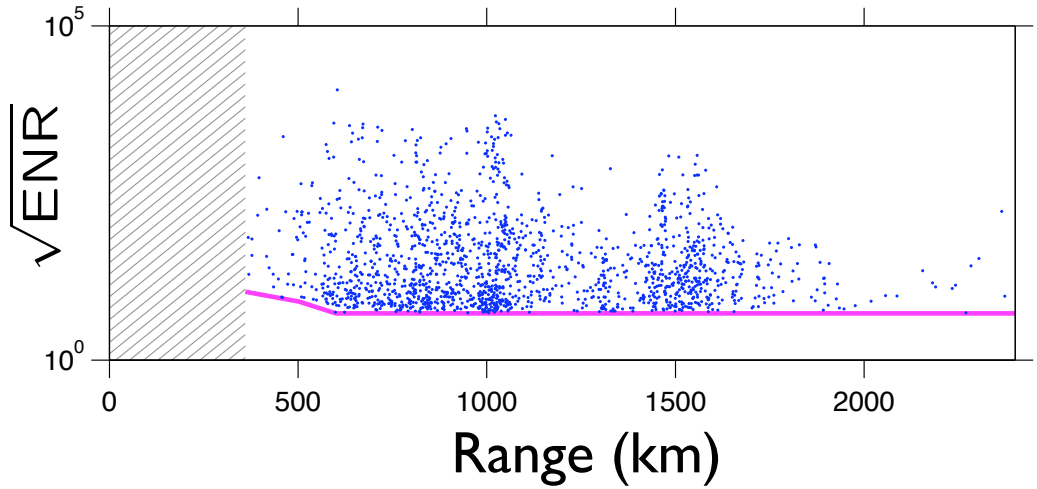


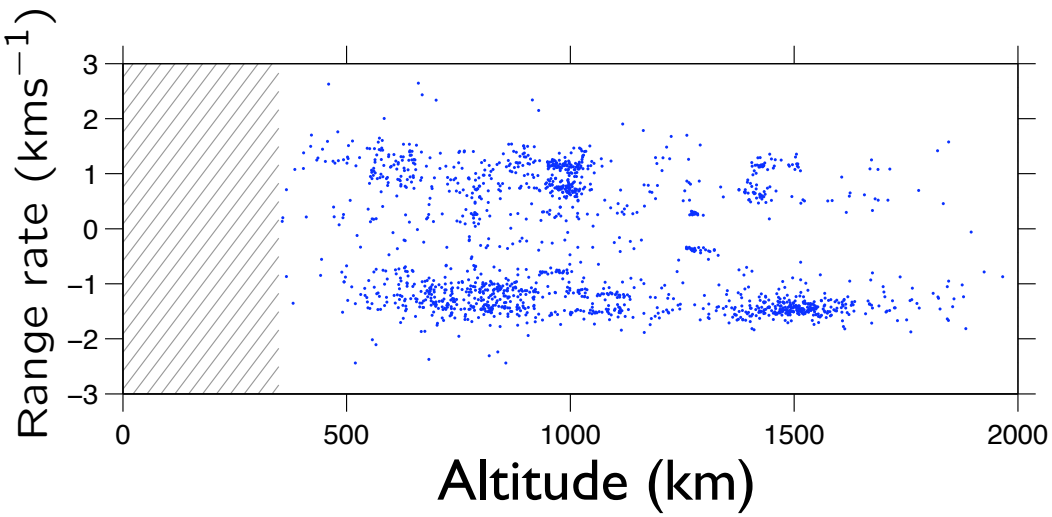
Manda - event rate v altitude

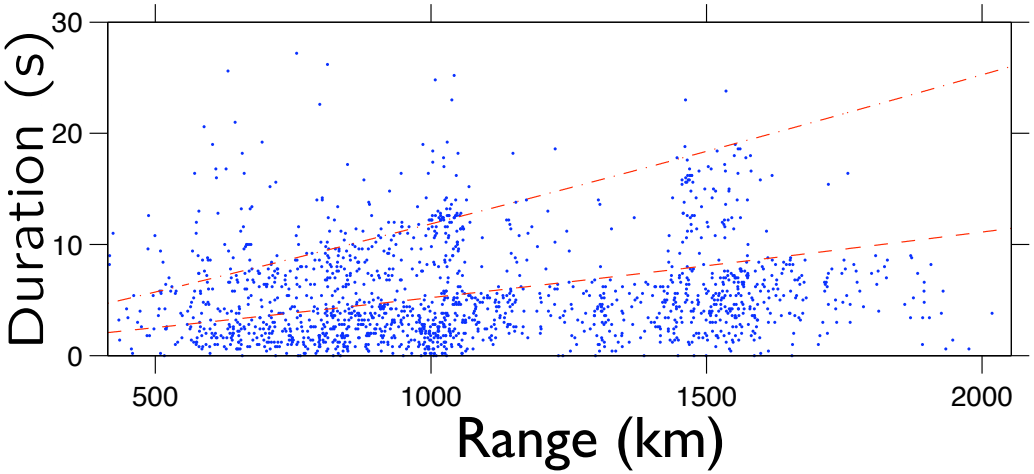
Tromso UHF
2005 Nov 17-20
79 h

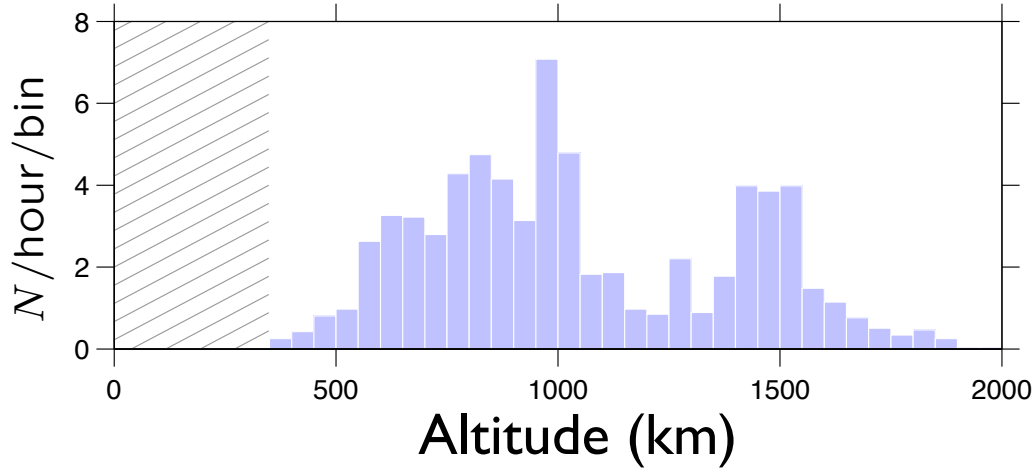


Beam Park 8-July-2006 (24h)
ESR 32m

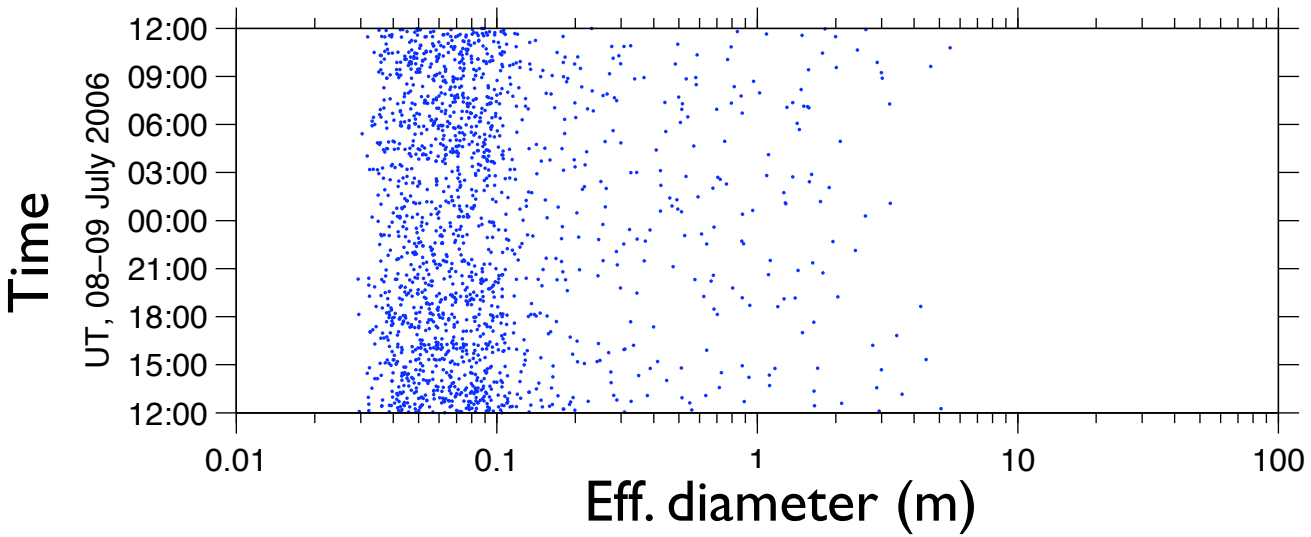






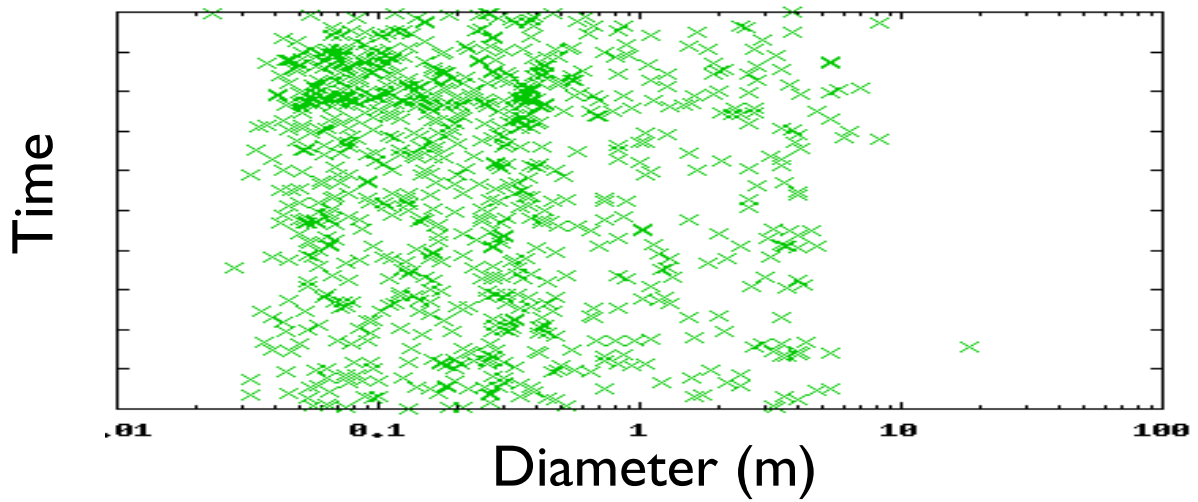


Beam Park 8-July-2006
ESR 32m



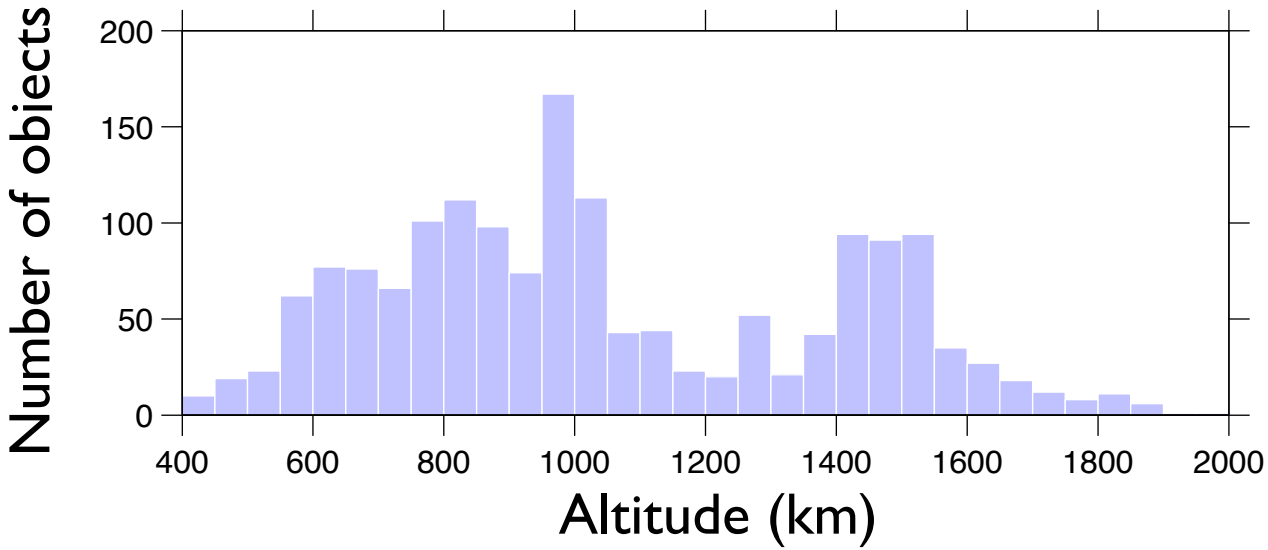
Az 90, El 75

EISCAT
(1600 obj)

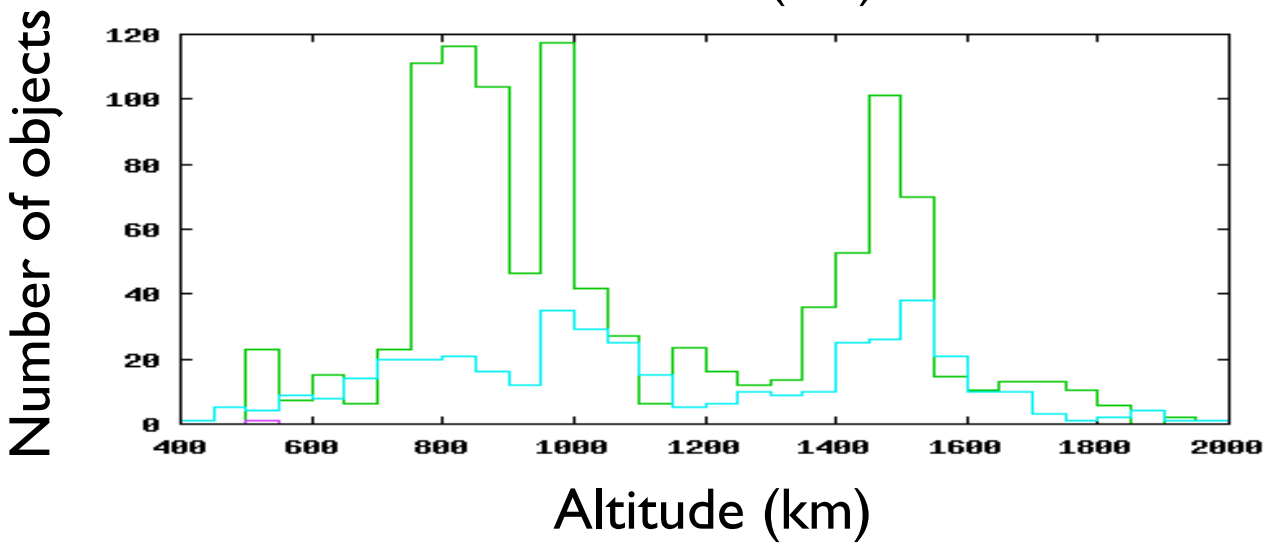


PROOF 2005
(1500 obj)

Beam Park 8-July-2006
ESR 32m

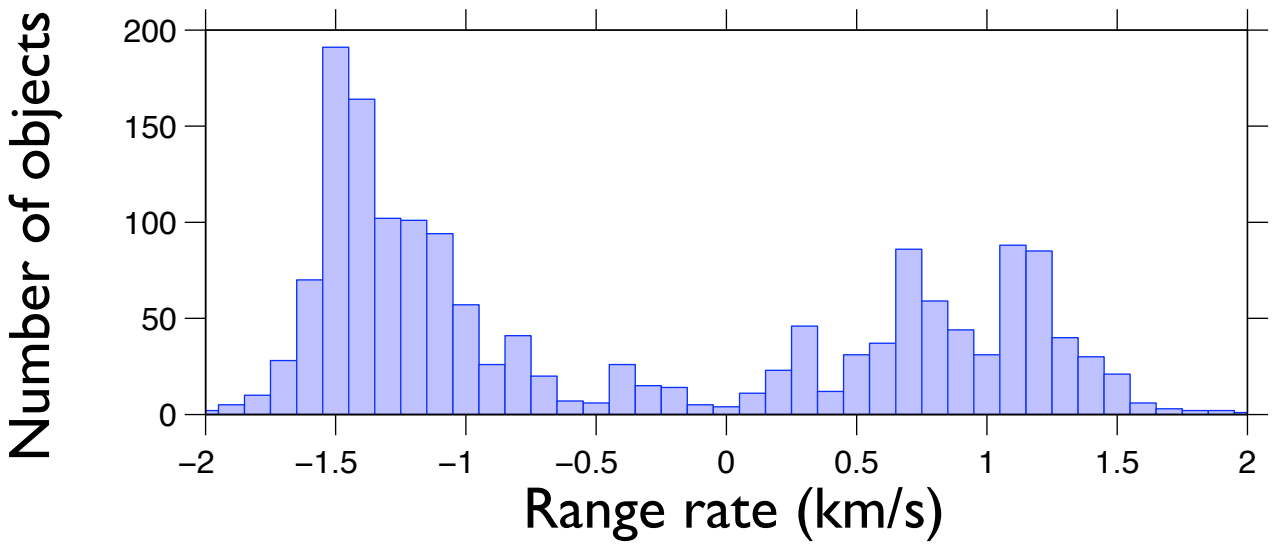


EISCAT



PROOF 2005

Beam Park 8-July-2006
ESR 32m



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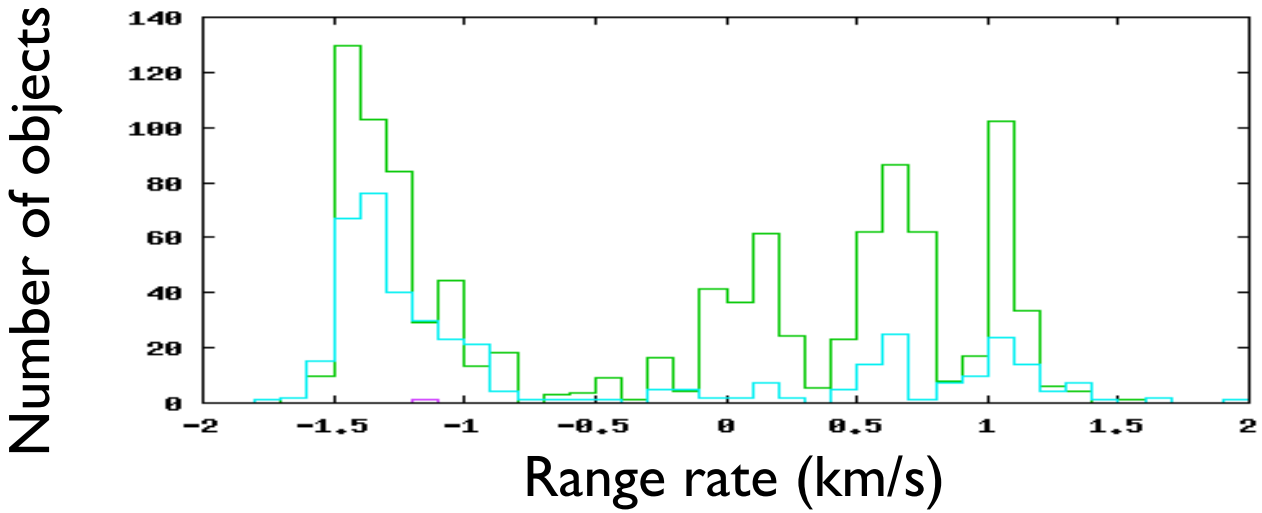

PROOF 2005

FUTURE

Measuring SD with EISCAT

Does it make enough sense ?

- Problem: Cannot, in practice, differentiate between main-lobe and side-lobe detections.
- Problem: Cannot get quantitative hold of integration loss. Data not readily PROOF-able.

Measuring SD with EISCAT

IPY 2007-2008