



## Hızlandırıcı ve Algıç Fiziği Çalıştayı

from 31 May 2016 to 3 June 2016  
Marmara & Boğaziçi Üniversiteleri  
Turkey timezone

***Tümüyle yerli, SANAEM/TAEK RFQ proton hızlandırıcısının projelendirilmesi, tasarım ve üretim evreleri ile sanayi ilişkileri***



Ali ALAÇAKIR  
SANAEM/TAEK  
02.06.2016

# Proje: 1-5 MeV RF Kovuklu Proton Hızlandırıcısı Yapımı.



## Amaç:



- Genç arařtırcılar yetiřtirmek ve projede yük' alarak tasarım, imalat, kurulum ve çalıřtırma sa fhasında aktif görev almalarını sa ğlamak.
- Üretime katkı sa ğlayacak ve/veya bu teknolojiden faydalanacak yerli firmaları belirlemek ve bu iři süresiz olarak uygulamada tutmak.
- Yetiřtirilecek genç arařtırcılar bahsedilen firmalarla bir araya getirerek bu teknolojiyi benimseyen, sindiren hızlandırıcı toplumu ortaya çıkarmak.

**Bütçe : 2.100.000 TL (TAEK)**

**Proje Süresi: 3.5 yıl (Temmuz 2012) -> 4.5 yıl**

# Proje Ekibi (an itibarı ile) ve lab'a gelip elini işe bulaştıranlar...

● Eski ve Yeni Koordinatörlerimiz

● Proje Ekibi



TAEK



CERN & COCKROFT



OGÜ



TAEK



BÜ



AÜ



IYTE



TOBB-ETU



IÜ



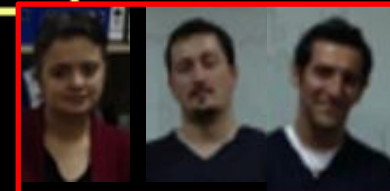
IYTE



GÜ



Mekanik, Cam, Ahsap (SANAEM)

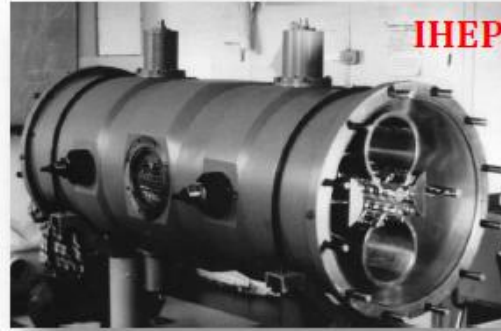


# RFQ tarihçesi ?



**Prof. Mikhailovich  
Kapchinski**

## Tarihçe



**Prof. Vladimir  
Teplyakov**

### o 1970 - RFQ Fikri

o I. M. Kapchinski and V. A. Teplyakov, , Prib.Tekh. . Eksp. No. 2, 19

### o 1974 - İlk deneysel üretim (IHEP, Rusya, Protvino).

o 148.5 MHz'de protonlar 100 keV'den 620 keV'e çıkarıldı (53% verim).

### o 1977 - Yayınlandıktan sonra LANL'ın ilgisini çekti. Benzetim programları yazıldı.

### o 1980 - Rusya dışındaki ilk RFQ (LANL, ABD)

o 425 MHz'de protonlar 100 keV'den 640 keV'e çıkarıldı (87% verim).



# Star Wars !!!

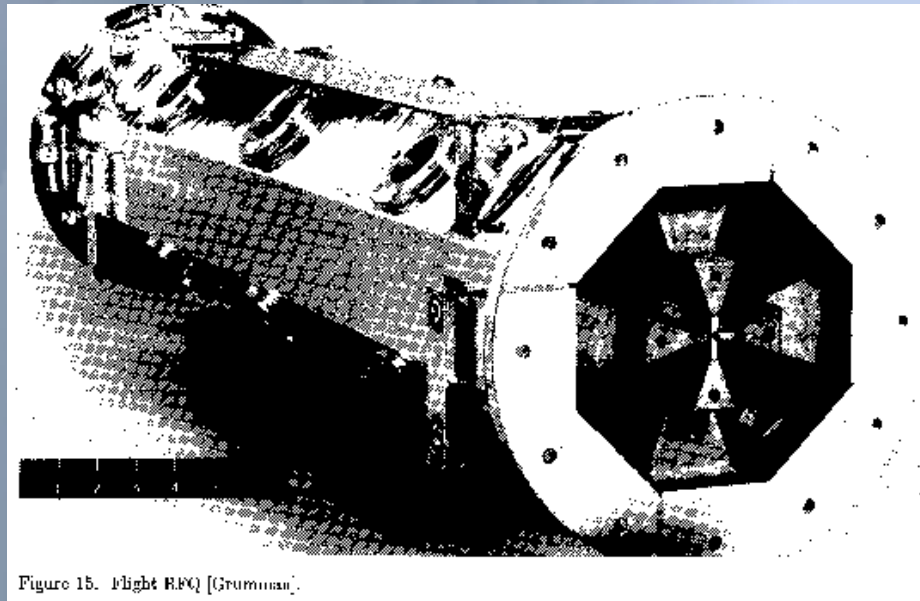
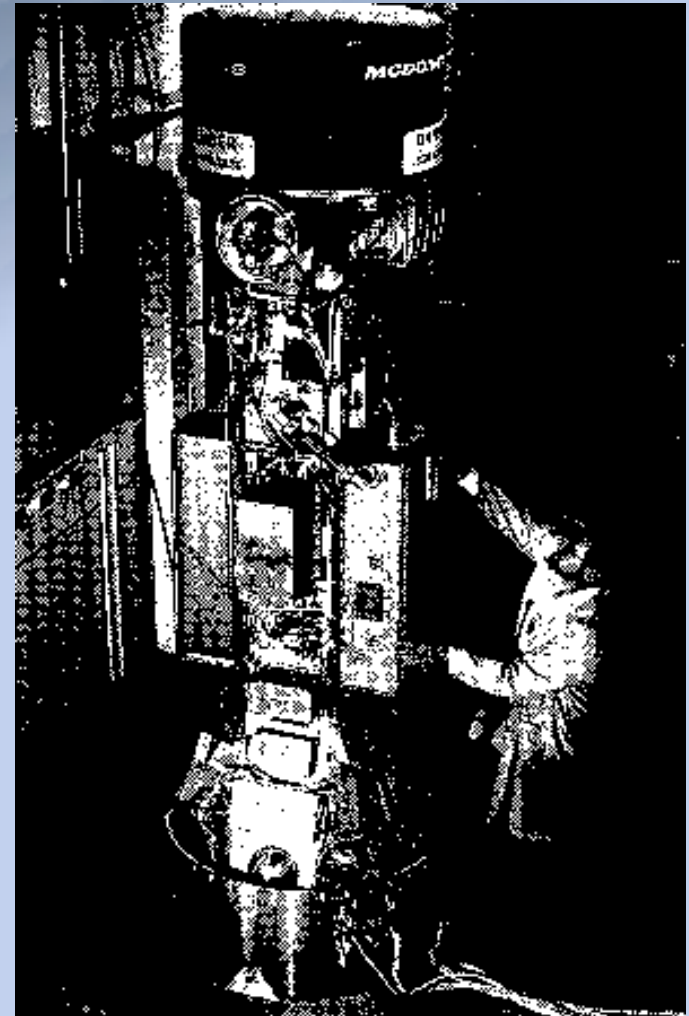
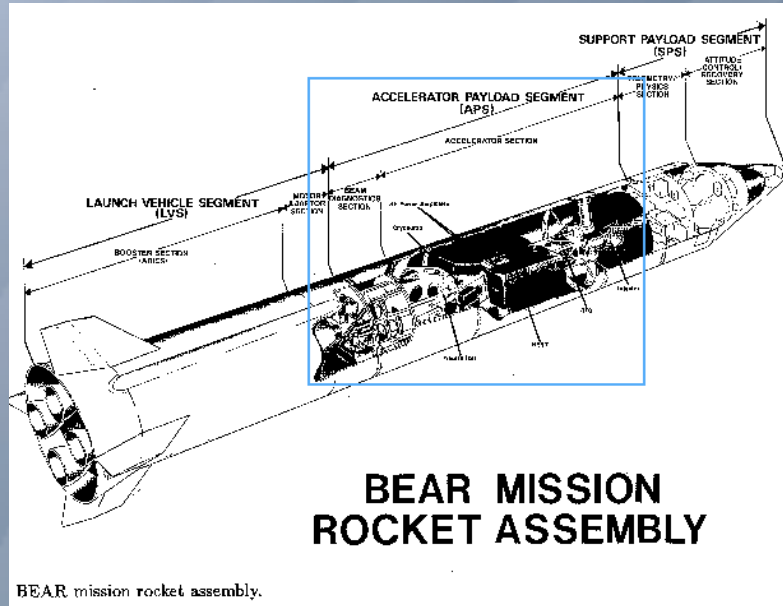


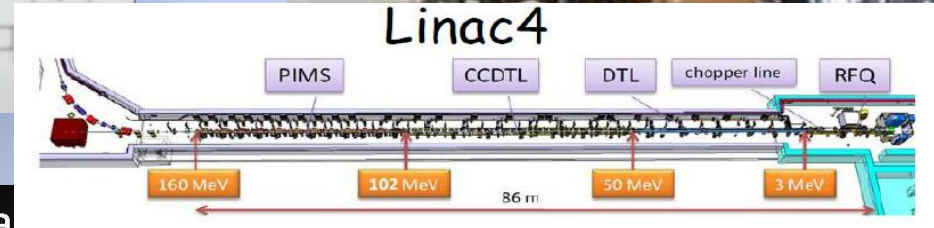
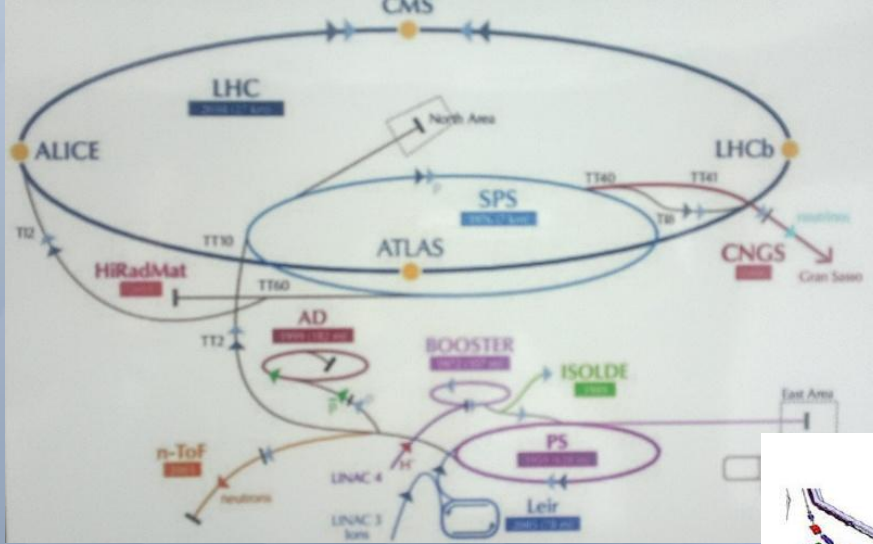
Figure 15. Flight REFQ [Grumman].

# Neden RFQ ?

RFQ -> 3 MeV, 352.2 MHz (LINAC4, CERN)

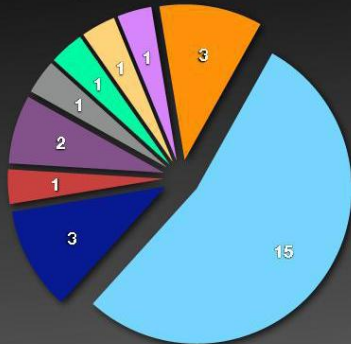
TAEK PHT -> 30 MeV ????

TAEK PHT

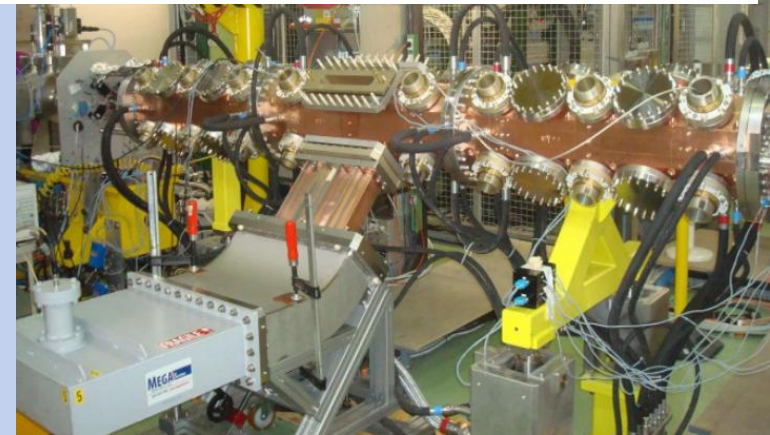


## 1972'den bu yana kanatlı RFQlar

Tüm Dünyada Kanatlı RFQ Üretebilen 9 Ülke

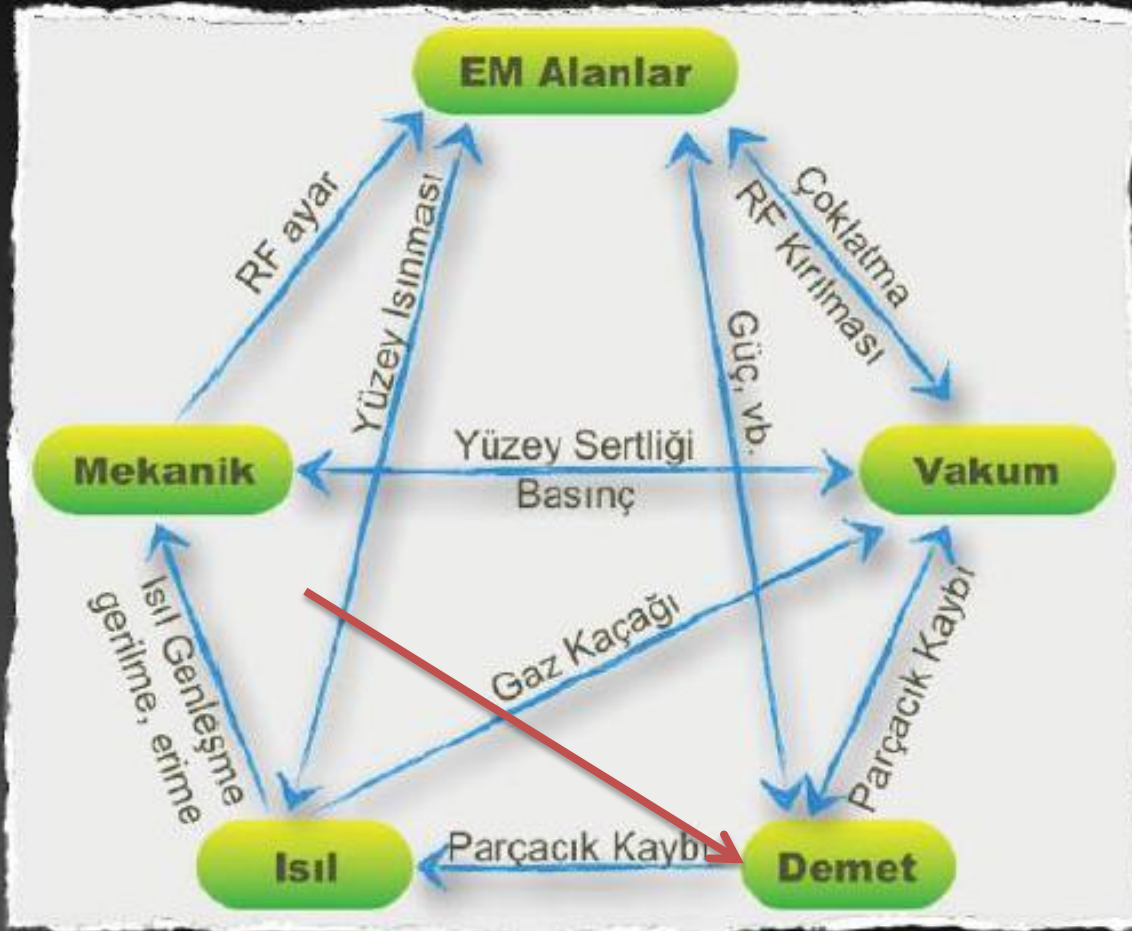


- Rusya
- ABD
- CERN
- Almanya
- Fransa
- Japonya
- İtalya
- Çin
- Kore



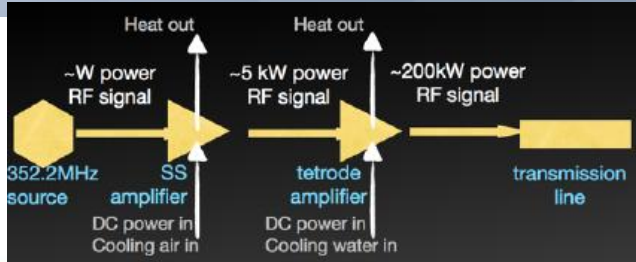
*Ne biliyoruz, neler öğrenmeliyiz ... !*

# RFQ yapmak için bilinmesi gerekenler

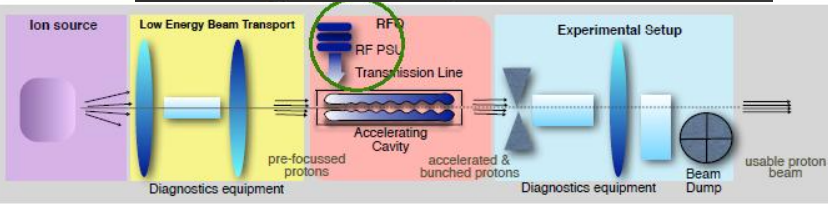




# 2012 tasarım çalışmalarını başlattık.



ID	component	task
1	Ion source	proton source
2	Low energy beam transport	bring "good" protons to RFQ
3	KeV diagnostics	measure keV protons
4*	RF power supply	150 kW pulsed power supply
5	RF transmission line	bring RF power to the RFQ
6	Radio frequency quadrupole	accelerate protons
7*	MeV diagnostics	spectrometer & dump



Ort. Serbest Yol (azot)

$10^{-4}$	65 cm
$10^{-5}$	6.5 m
$10^{-6}$	65 m
$10^{-9}$	65,000 m



## ***İlk altı ay çalışmaları:***

Literatür, LIDOS, bol miktarda görüntülü toplantı (toplamı>60), tasarıma giriş.

Dec 2012, missing  
S. Erhan.



*Başladık çalışmaya ve geldik bir yerlere...!*

## 2 project reviews

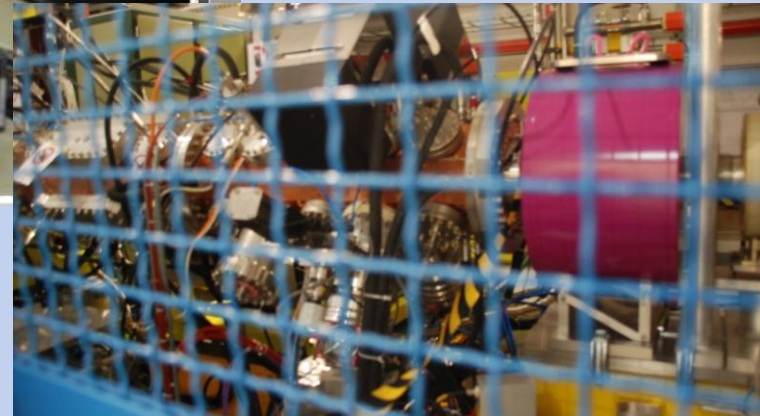
May 2013  
SANAEM



Nov 2013  
CERN



LINAC4 RFQ



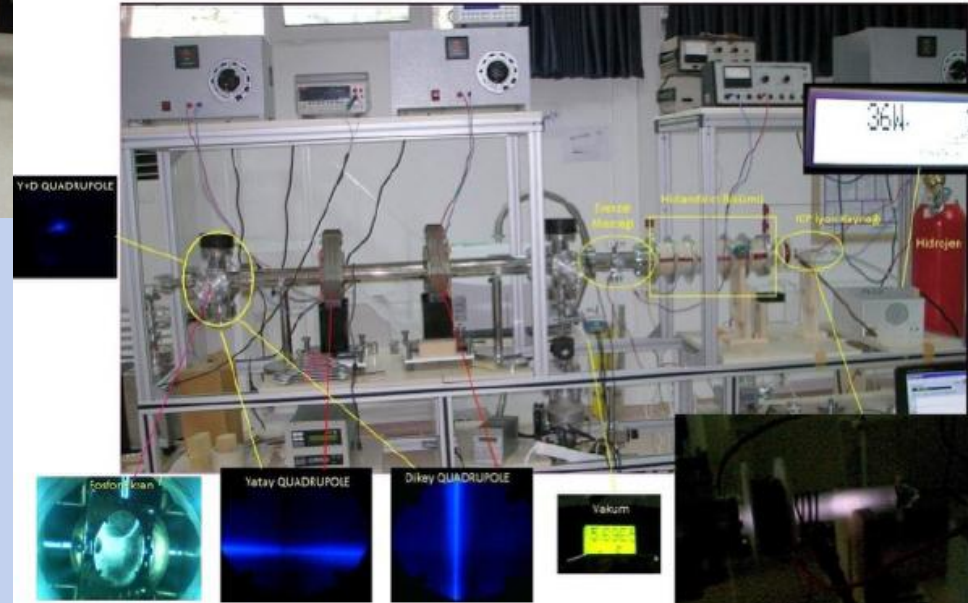


# SANAEM, HTB Laboratuvar'ının kuruluşu (2010)



2012

SANAEM 100 KeV DC DOĞRUSAL PROTON HIZLANDIRICISI

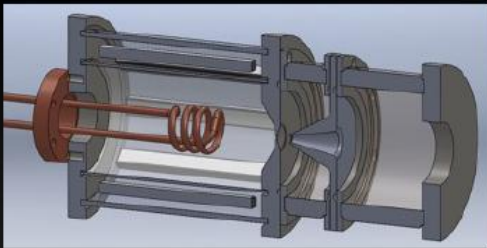


2013

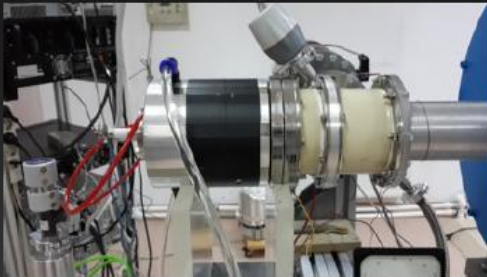


# iyon (Proton) Kaynağı, ICP (Inductively Coupled Plasma)

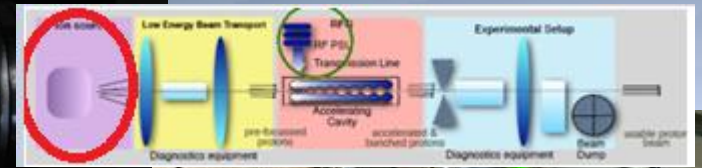
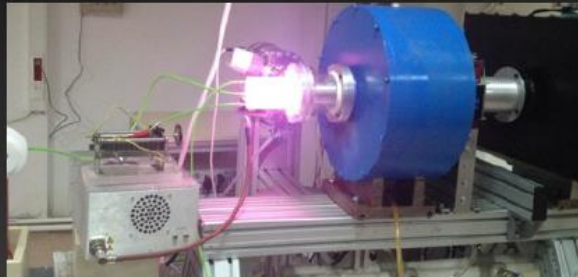
v1



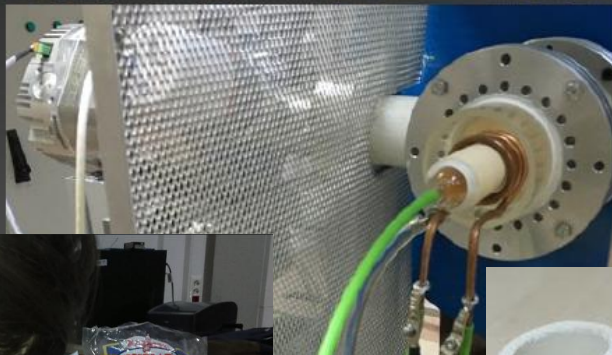
v2



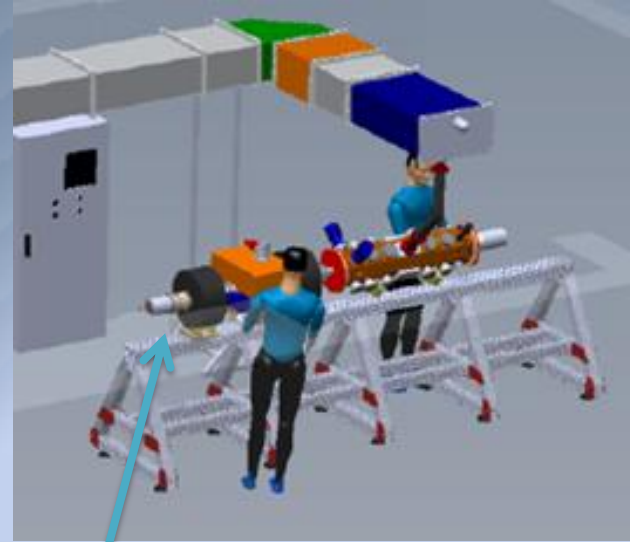
v3



v4

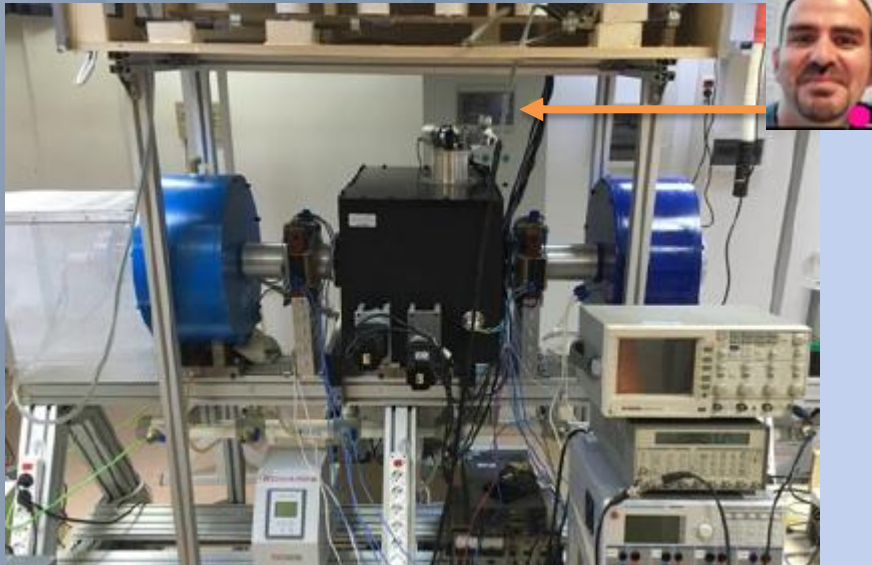
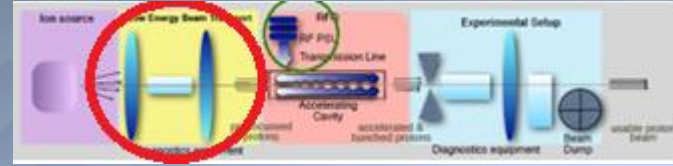


# *Silindirik bobin tasarımı, imalat, kurulum ve ölçümleri..*





# Demet özellikleri ölçüm kutusu.





# Hızlandırıcı, RFQ gövde, imalatı ...

Malzeme: OFC, OFE ...



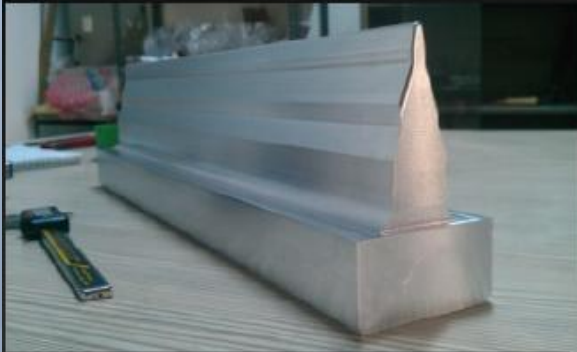
Conductivity and Resistivity Values for Copper & Alloys

Material	Conductivity		Resistivity	Reference	Notes
	(% IACS)	(Siemens/m)	(Ohm-m)	(See End Note)	
<b>Copper and Copper Alloys by Copper Alloy Number</b>					
Pure (annealed)	100.00	5.800E+07	1.724E-08	ECTM	
C10100, C10200	101.00		1.710E-08	MHASM2	
C10300-O61	99.00		1.740E-08	MHASM2	
C10400, C10500, C10700 (O61 temper)	100.00		1.720E-08	MHASM2	
C10800-O61	92.00		1.870E-08	MHASM2	
C11000-O60	100-101.5		1.700E-8--1.724E-8	MHASM2	
C11000-H14	97.00		1.780E-08	MHASM2	
C11100	100.00		1.720E-08	MHASM2	
C11300, C11400, C11500, C11600	100.00		1.720E-08	MHASM2	
C12500, C12700, C12800, C12900, C13000 (annealed)	98.00		1.760E-08	MHASM2	
C14300	96.00		1.800E-08	MHASM2	
C14310	85.00		2.030E-08	MHASM2	
C14500	83.00		1.860E-08	MHASM2	

- **C10100** - also known as Oxygen-Free Electronic (OFE). This is a 99.99% pure copper with 0.0005% oxygen content. It achieves a minimum 101% IACS conductivity rating. This copper is finished to a final form in a carefully regulated, oxygen-free environment. Silver (Ag) is considered an impurity in the OFE chemical specification. This is also the most expensive of the three grades listed here.
- **C10200** - also known as Oxygen-Free (OF). While OF is considered oxygen-free, its conductivity rating is no better than the more common ETP grade below. It has a 0.001% oxygen content, 99.95% purity and minimum 100% IACS conductivity. For the purposes of purity percentage, silver (Ag) content is counted as copper (Cu).
- **C11000** - also known as Electrolytic-Tough-Pitch (ETP). This is the most common copper. It is universal for electrical applications. ETP has a minimum conductivity rating of 100% IACS and is required to be 99.9% pure. It has 0.02% to 0.04% oxygen content (typical). Most ETP sold today will meet or exceed the 101% IACS specification. As with OF copper, silver (Ag) content is counted as copper (Cu) for purity purposes.

# RFQ imalat testleri...

a minor vane  
no modulation

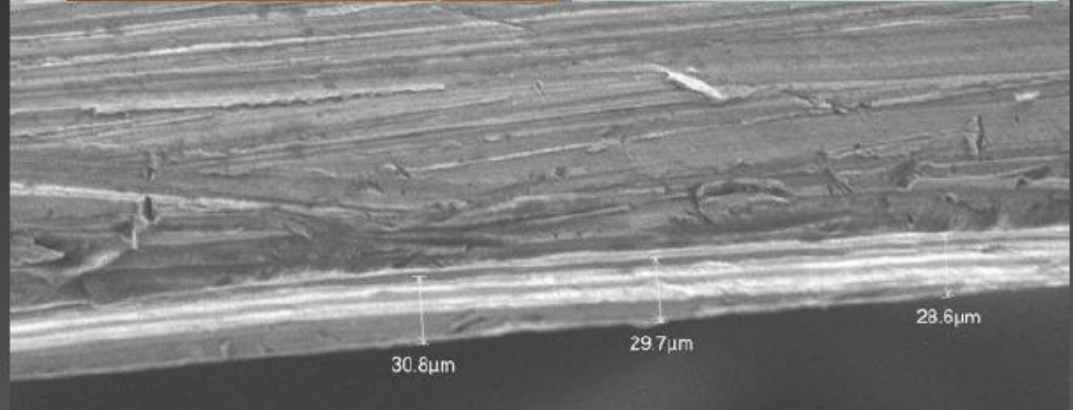


modulation example



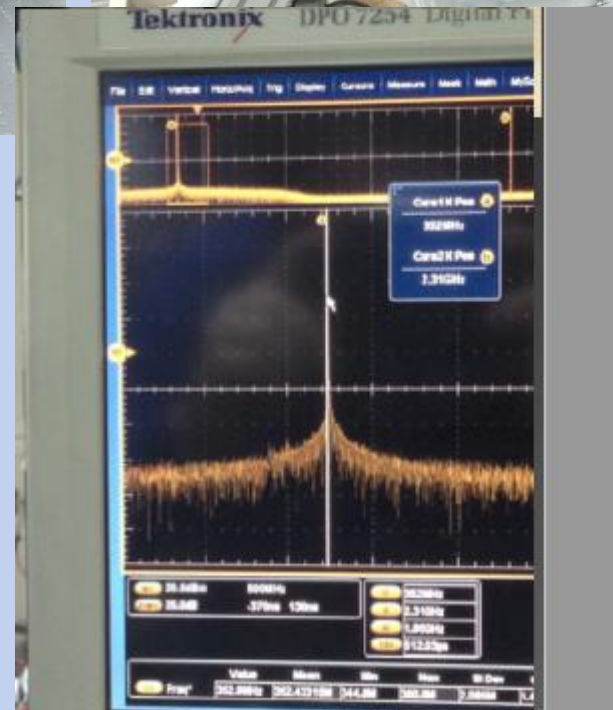
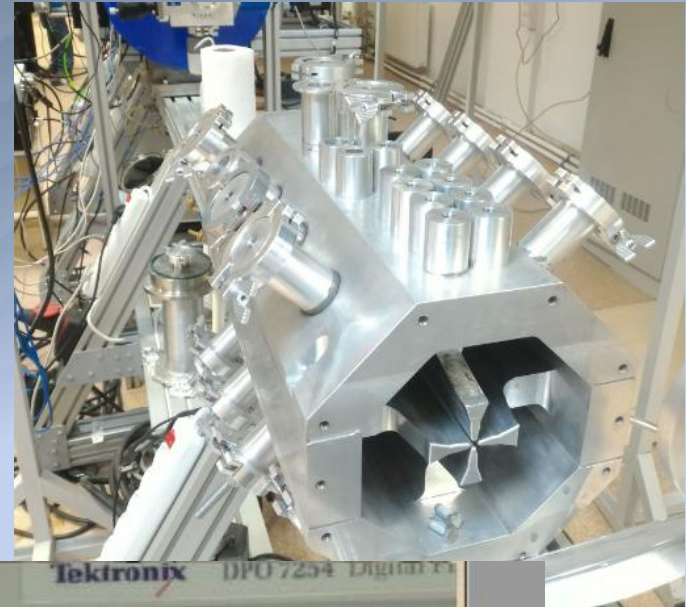
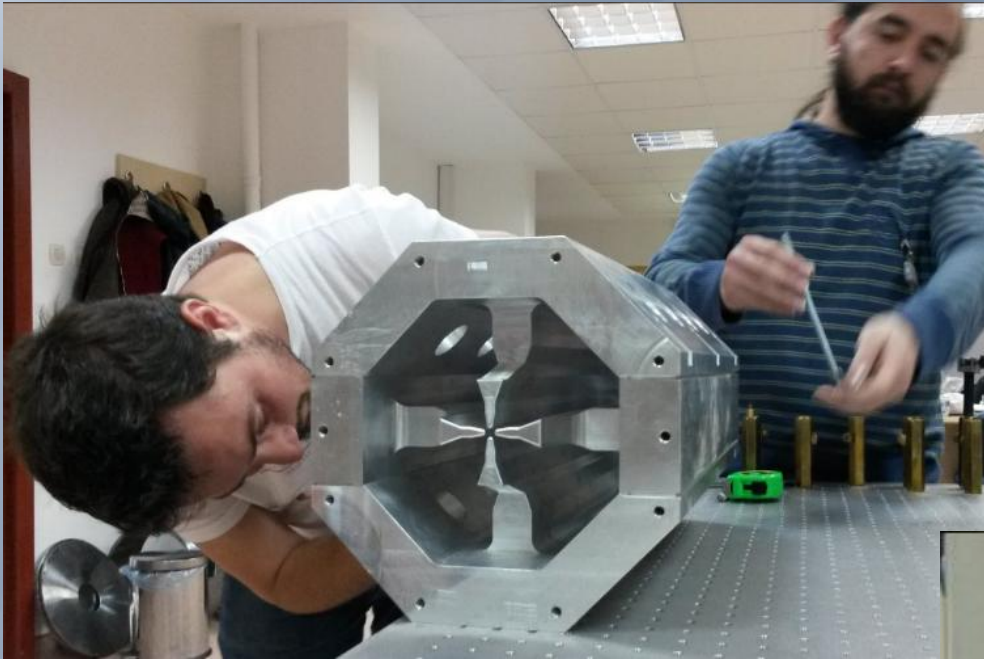
copper coating  
example

coating uniformity:  
 $\pm 1.5\mu\text{m}$  at  $30\mu\text{m}$





# Deneme ve alıştırma modelinin üretimi (Cold Model)...





# Neden Alüminyum 7075 T6 ?

## 7075-T6

T6 temper 7075 has an ultimate tensile strength of 510–540 MPa (74,000–78,000 psi) and yield strength of at least 430–480 MPa (63,000–69,000 psi). It has a failure elongation of 5–11%.

The T6 temper is usually achieved by homogenizing the cast 7075 at 450 °C for several hours, quenching, and then aging at 120 °C for 24 hours. This yields the peak strength of the 7075 alloy. The strength is derived mainly from finely dispersed eta and eta' precipitates both within grains and along grain boundaries.

www.aircraftmaterials.com/data/aluminium/7075.html



T: + 44 (0) 1494 484844 F: + 44 (0) 1494 482155  
 USA T: + 1 714 735 4413  
 E: sales@aircraftmaterials.com



## Aluminium Alloy 7075

### Chemical Composition Limits

Weight%	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other Each	Others Total
7075 min	Rem	-	-	1.2	-	2.1	0.18	5.1	-	-	-
7075 max	Rem	0.40	0.50	2.0	0.30	2.9	0.28	6.1	0.20	0.05	0.15

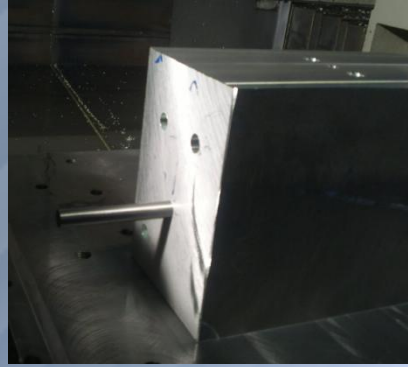
Aluminium Alloy 7075 offers the highest strength of the common screw machine alloys. The superior stress corrosion resistance of the T173 and T7351 tempers makes alloy 7075 a logical replacement for 2024, 2014 and 2017 in many of the most critical applications. The T6 and T651 tempers have fair machinability. Alloy 7075 is heavily utilized by the aircraft and ordnance industries because of its superior strength.

CTE, linear 68°F	23.6 µm/m-°C
CTE, linear 250°C	25.2 µm/m-°C
Specific Heat Capacity	0.96 J/g-°C
Thermal Conductivity	130 W/m-K

Coefficient of thermal expansion α [10 <sup>-6</sup> ·°C <sup>-1</sup> ] between 20°C and				
100 °C	200 °C	300 °C	400 °C	500 °C
17.0	17.3	17.7		
Density (lb / cu. in.)		0.323		
Electrical Resistivity (microhm-cm (at 68 Deg F))		10.3		
Melting Point (Deg F)		1981		
Thermal Conductivity		226		
Mean Coeff Thermal Expansion		9.4		
Modulus of Elasticity Tension		17000		

C10100

# RFQ üretim...



Tel: 0 (312) 395 71 33 Fax: 0 (312) 395 71 34 | info@maksamak.com

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 [Anasayfa](#) [Hakkımızda](#) [CNC Tornalar](#) [CNC İşleme Merkezleri](#) [Kalite Kontrol](#) [Üretimlerimiz](#) [İletişim](#)

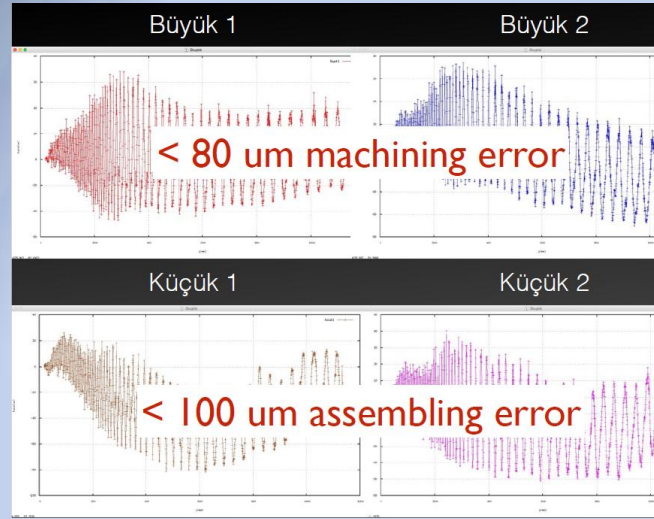
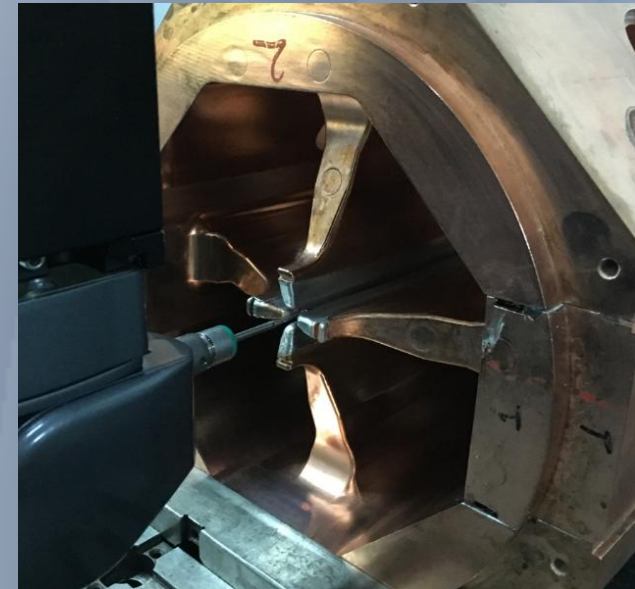
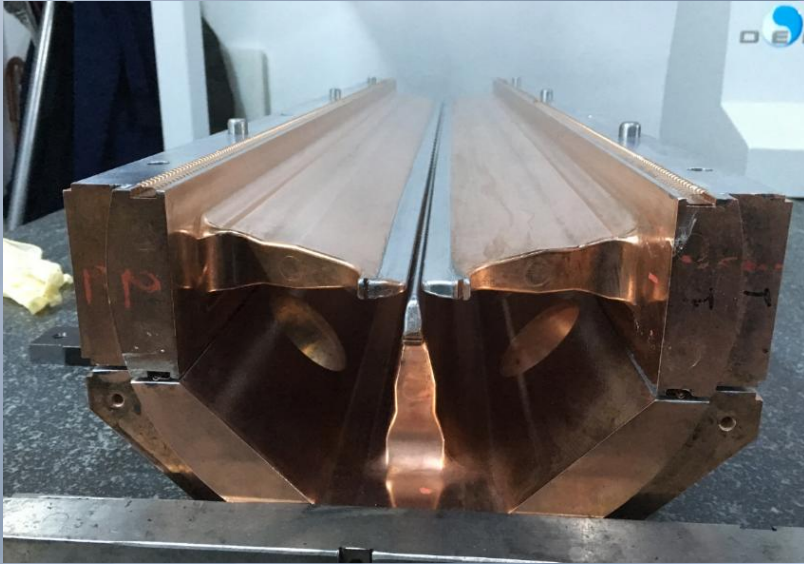




## *RFQ parçalarının kaplanması ve toplanması.*

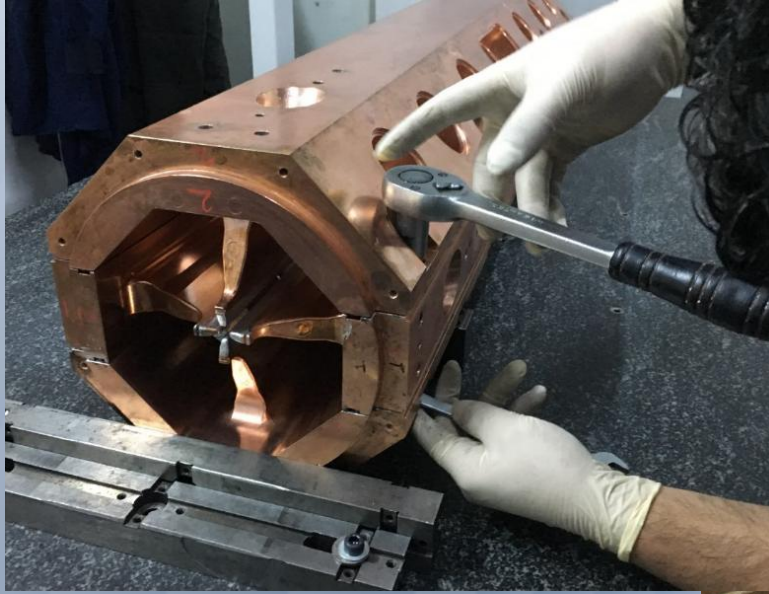


# Kanatların toplanması...





# Civatala ve yapıştır (bizim modelimiz)...



25 Ara 2015



## PELCO® High Performance Silver Paste

Silver flakes in an inorganic silicate aqueous solution, specially formulated a

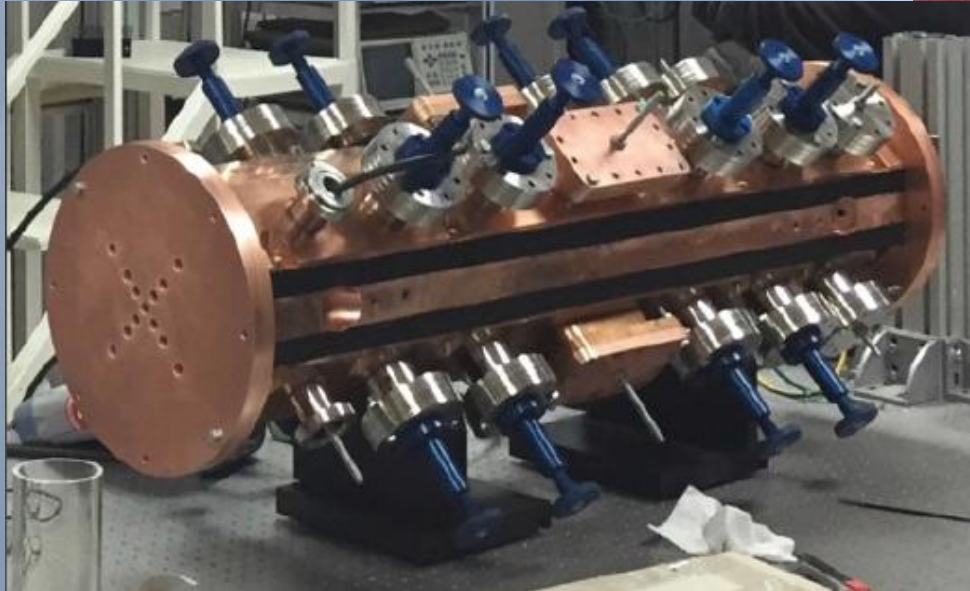
- High temperature up to 927°C (1700°F)
- Ultra high vacuum - no hydrocarbon, no VOC's
- Cryogenic temperatures (suitability depends on matching properties)

## *Eve geliř....*

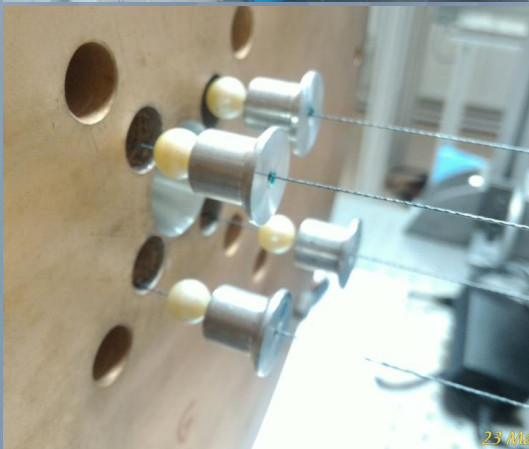
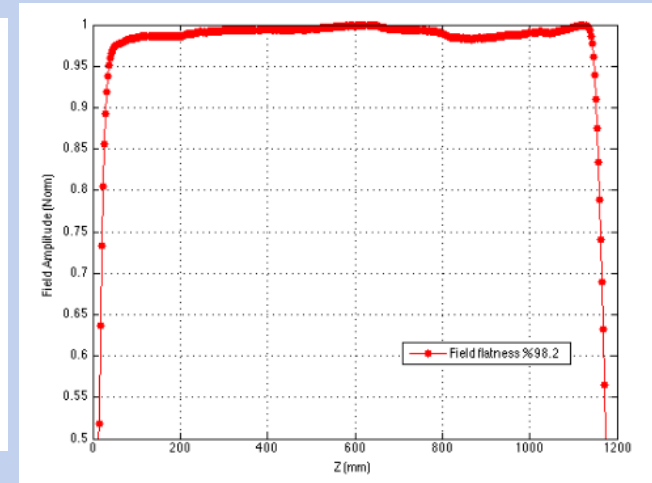
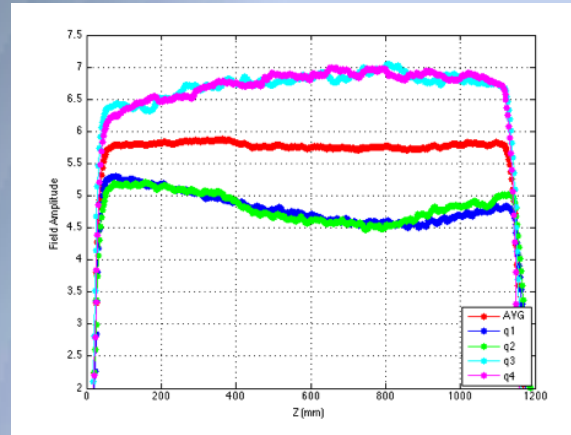
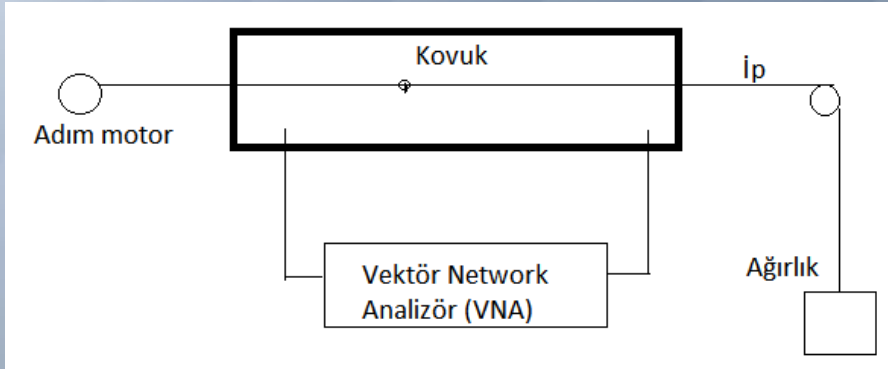




# Hızlandırıcı gövde bileşenlerinin takılması...



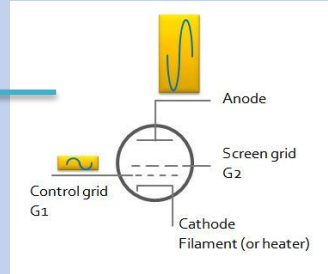
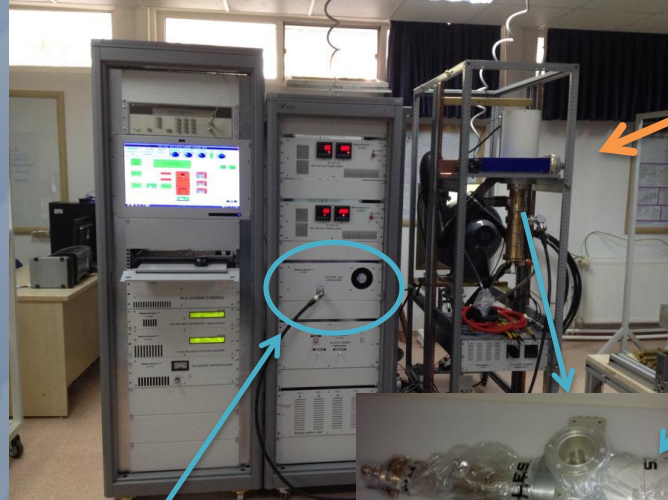
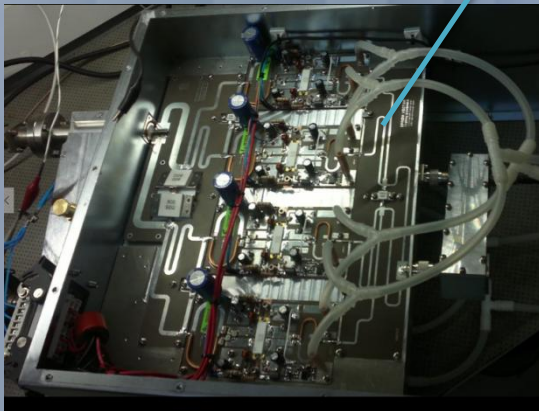
# Bead-pull inceleme ve ayar çalışmaları





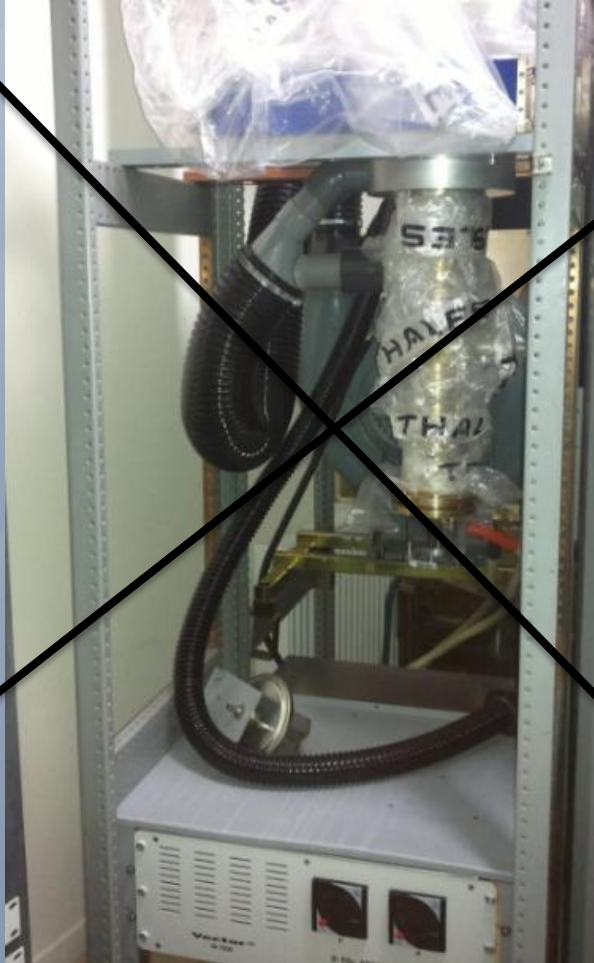
# Güç Kaynakları...

CERN SSA





# DC- 2.5 GHz güç kaynağına hazır mıyız ?

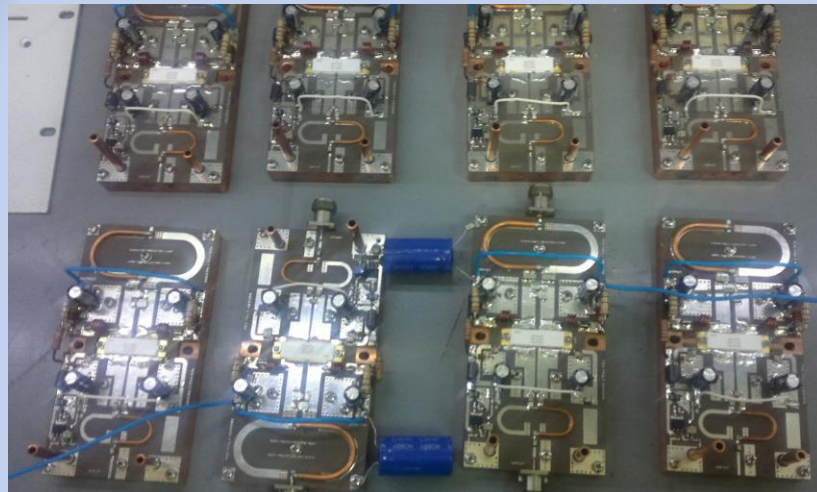


**SOLEIL**  
SYNCHROTRON

## 200 kW Amplifier Design

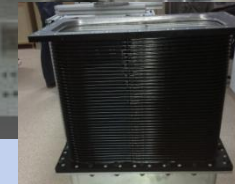
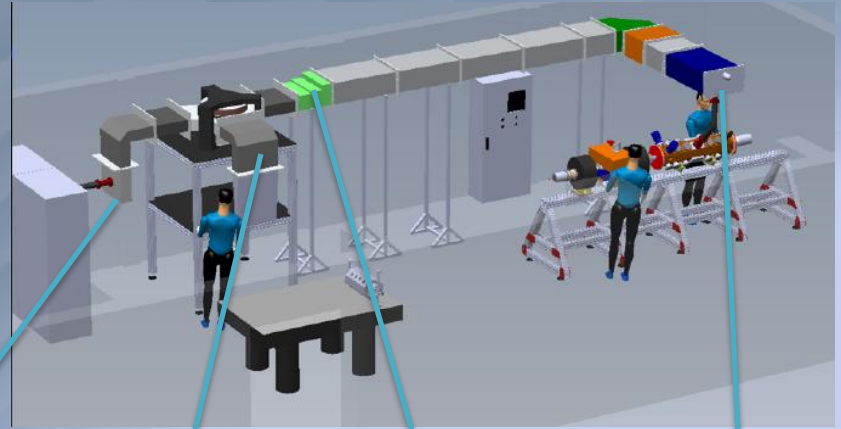
**Symmetrical Configuration: Short RF Connection, Same RF Phase**  
**No Cabinet (No High Voltage): Easy Maintenance**  
**Modules and DC/DC Converters fixed on Cooling Bar**

**Dimension:**  
4.7 x 4.7 x 2.3 m (without waveguide)  
4.7 x 4.7 x 3.6 m (with waveguide)

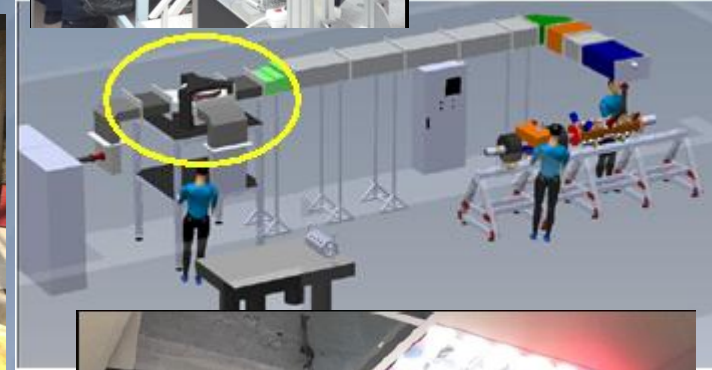
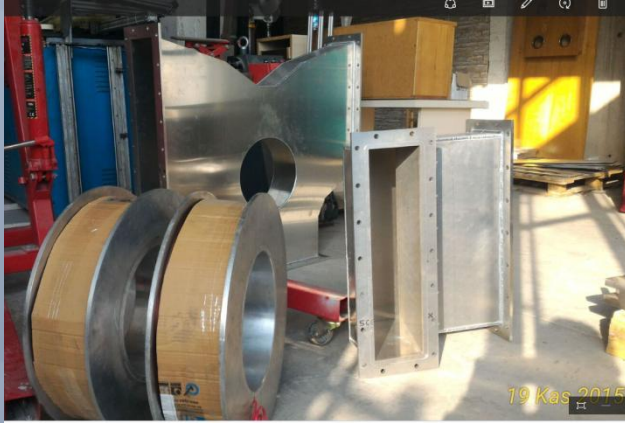




# iletim hattı...

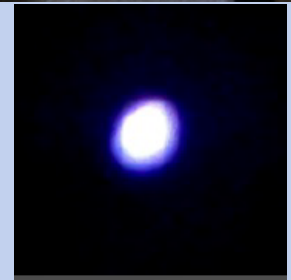
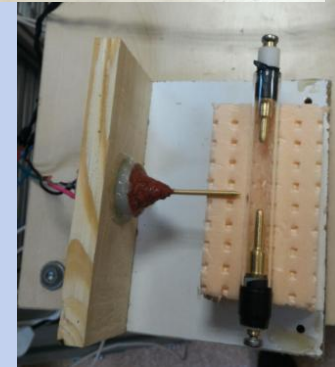
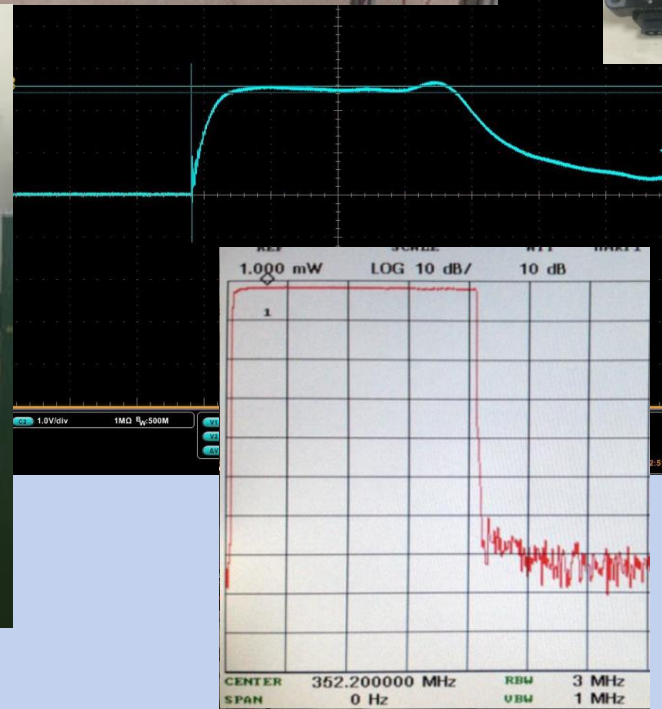
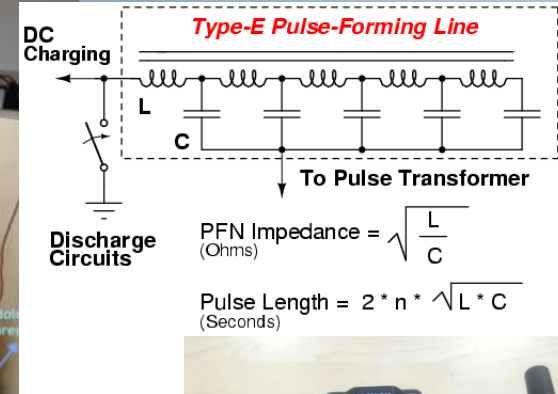
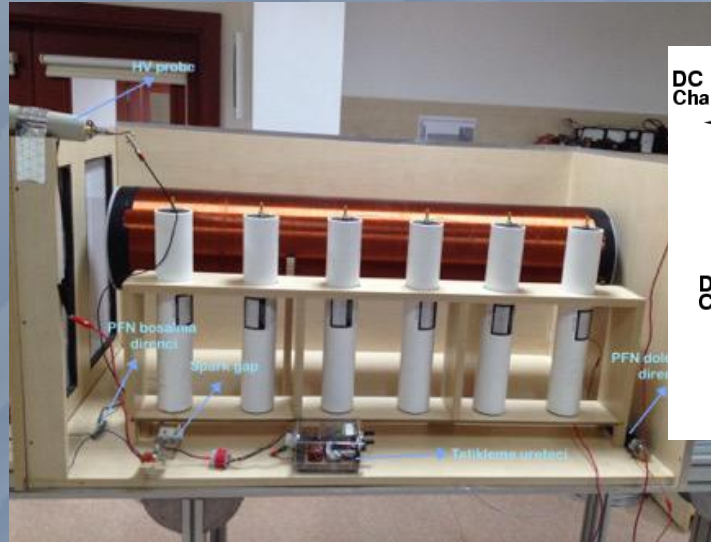


# Circulator (Dolařtırıcı, Yönlendirici...) imalat ve kurulması...





# Atmalı proton demeti için (150 mikroSan.) PFN (PFL) yapımı.



# Bu işi bitirmek (!) için gereklikler...

- Atölye (ler) ve iyi ustalar
- Yedek parça
- Elektronik, malzeme, kimya, vs diğer bölümler



**Gerçek proje süresi= Tahmini Proje Süresi x  $\pi$**



## Satın alma, tasarım ve üretim sayıları:

Satın alma (Malzeme&cihaz seçimi, teknik şartname, diğer kağıtlar, kabul vb...) >30

Toplam harcamalar : 2.055.000 TL (Bu yıl: 260.000 Sarf)



Atölyeler	Tasarlanan	Üretilen
Mekanik A.	121	318
Cam A.	45	110
Ahşap A.	56	90
<b>TOPLAM</b>	<b>222</b>	<b>518</b>

Yurt içi Satın Alma (Adet)	Tasarımlanarak yaptırılan (Adet)
122 (519)	81 (366)

Yurt dışı : Rf tüp ve kavite (THALES)  
Ferrite plaka (TCI Ceramics)

## • Üreticilerle ilişkiler !

*(Aracını tamirciye götürülenler hayal etmeye başlayabilir...)*

*Çok gezilmeli (Bizim örneğimizde: TEI, TAI, Küçük Pazarlılar, vb....)*

> Üretim çizimleri ve tolerans değerleriniz ?

> En kolay nasıl imal edilir, üretim tezgahları hakkındaki bilgileriniz ?

> Malzeme bilginiz !

> İlgili malzeme ile ilgili üretim süreçleri konusunda bilginiz ?

> Kim nerede ne satıyor ?

> Firmayı iyi tanıyın: İş'te uzmanlığı, sosyal durumu ...

> Firma ile statünüzü iyi belirleyin.

> İstenilen üretim hatalı ise zaman ve zararınızı nasıl telafi edersiniz ? Üretim kabul edilemez olarak gerçekleşirse zaman olarak sizden götüreceklerini en baştan biliyor musunuz ?

> Standartlar hakkında bilginiz !. Bilinen standartlara göre üretim isteyebilirsiniz (bunu test etme imkanınız var mı ?).

> Üreticinin ticari sırlarına saygılı olunmalı (...)

> Üretici kollanmalı.

> Yapılacak işin fiyatı ??? !!!



## ***Çalıştığımız başlıca firmalar:***

***Güç kaynakları : EPROM Elektronik***

[www.eprromvector.com](http://www.eprromvector.com)

***RFQ : MaksaMAK***

[www.maksamak.com](http://www.maksamak.com)

***Dalga kılavuzları ve diğer: KALİTEK Makine ve Kalıp***

[www.kalitek.net](http://www.kalitek.net)

***Kaplama işleri: Ankor Metal Kaplama***

[www.ankormetalkoruma.com](http://www.ankormetalkoruma.com)

***Bobin ve bakır sarım işleri : OMSAN Trafo***

[www.omsantrafo.com.tr](http://www.omsantrafo.com.tr)

# Bazı yayınlar...

**Design Studies with DEMIRCI for SPP RFQ**  
B. Yasaukci\*, G. Tureman, Ankara University, Ankara, Turkey  
A. Alacakir, TAEK-SANAEM, Ankara, Turkey  
G. Unel, UCI, Irvine, California, USA

**Project PROMETHEUS:  
Design and Construction of a Radio Frequency Quadrupole at TAEK**  
G. Tureman\*, B. Yasaukcin  
Ankara University, Department of Physics, Ankara, Turkey

**Current Status of the SANAEM RFQ Accelerator Beamline**  
G. Tureman\*, B. Yasaukcin, Ankara University, Ankara, Turkey.  
S. Ogar, V. Yildiz, Bogazici University, Istanbul, Turkey.  
O. Mene, Cockcroft Institute and University of Manchester, UK  
S. Oz, A. Orbey, H. Yildiz, Istanbul University, Istanbul, Turkey.

**Design and Manufacture of the RF Power Supply and RF Transmission Line for SANAEM Project Prometheus**  
G. Tureman\*, S. Ogar,<sup>2</sup> G. Unel,<sup>3</sup> and A. Alacakir<sup>4</sup>  
<sup>1</sup>Ankara University, Department of Physics, Graduate School of Natural and Applied Sciences, Ankara, TURKEY;  
<sup>2</sup>Bogazici University, Department of Physics, Istanbul, TURKEY;  
<sup>3</sup>University of California at Irvine, Department of Physics and Astronomy, Irvine, USA.  
<sup>4</sup>TAEK, Strontium Isotope Research and Training Center, Ankara, TURKEY.

**SPP Beamline Design and Beam Dynamics**  
G. Tureman\*, Z. Sofli, B. Yasaukcin, Ankara University, Ankara, Turkey  
V. Yildiz, Bogazici University, Istanbul, Turkey  
M. Celik, Gazi University, Ankara, Turkey  
A. Alacakir, TAEK-SANAEM, Ankara, Turkey  
G. Unel, UCI, Irvine, California, USA  
O. Mene, UMAN, Manchester, UK

**Status of the SPP RFQ project**  
G. Tureman\*, B. Yasaukcin, Ankara University, Ankara, Turkey  
H. Yildiz, Istanbul University, Istanbul, Turkey  
A. Alacakir, TAEK-SANAEM, Ankara, Turkey  
G. Unel, UCI, Irvine, California, USA

**Computer Physics Communications**  
Journal homepage: www.elsevier.com/locate/cpc

**A graphical approach to radio frequency quadrupole design**  
G. Tureman<sup>1</sup>, G. Unel<sup>2</sup>, B. Yasaukcin<sup>3\*</sup>

**SPP BEAMLINE**  
The Radio Frequency Quadrupole of SANAEM Project Prometheus will be a three-section and acceleration module where will accelerate protons from 30 keV to 1.5 MeV. The project is funded by Turkish Atomic Energy Authority and it will be located at Strontium Nuclear Research and Training Center in Ankara. The SPP beamline consists of a multi-coop  $H^+$  ion source, a Low Energy Beam Transport line and a four-runs RFQ operating at 352.2 MHz. The design studies for the multi-coop ion source (SP or DC) were performed with IBS-90a and SIMION software packages. The source has already been produced and currently undergoes extensive testing. There is also a preliminary design for the solenoid based LEBT. POSSON and PATSI were used in parallel for the preliminary design. Two solenoid magnets are produced following this design. The RFQ design was made using LEBT-3RFQ Designer and it was validated with the beam dynamics simulation and the pedestal supporting the ion source and two solenoid magnets are installed in the experimental area.

**Ion Source, LEBT and Diagnostic Stations**  
The ion source and LEBT design was discussed extensively elsewhere [1]. Here we mostly report on the ongoing construction and commissioning processes. The ion source, as well as the first (Sol-1) of the two LEBT solenoids (Sol-1 and Sol-2) are installed together with the vacuum and cooling connections as it can be seen in Fig. 1. While waiting the delivery of the "transmission line", LEBT and Sol-2 delivery runs are performed with a simple Faraday cup (FC) for the RFQ and the source connections (RFQ and source).

**Bitti, TEŞEKKÜRLER...**